Needham Board of Health

REVISED AGENDA

Friday July 19, 2019
7:00 – 9:00 a.m.

Charles River Room
Public Services Administration Building
500 Dedham Avenue, Needham MA 02492

- **7:00 to 7:05 – Welcome & Review of Minutes (June 10th)**
- **7:05 to 7:40 – Staff Reports (June)**
  - **FDA Risk Factor Survey: Summary Report**
  - **Nourishing Needham Program**
  - **Needham Farmers Market Food Safety Pocket Guide**
- **7:40 to 7:50 – Preliminary Discussion of 57 Walker Lane Septic System Enforceable Agreement**
- **7:50 to 8:00 – Discussion of Verizon 5G Small Cell Sites & Community Impact**

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Board of Health Public Hearing

- **8:00 to 8:15 – Underage Sale of Tobacco Products by 7-Eleven at 845 Highland Ave**

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- **8:15 to 8:45 – Public Health Nursing Presentation**
- **8:45 to 8:50 – Discussion of Accessory Dwelling Units and Fall 2019 Town Meeting**

178 Rosemary Street, Needham, MA 02494
E-mail: healthdepartment@needhamma.gov
781-455-7940 (tel); 781-455-7922 (fax)
Web: www.needhamma.gov/health

- **8:50 to 8:55 – Ongoing Pest and Trash Management Challenges**
  - **Arlington, MA Board of Health Dumpster Regulation**

- **8:55 to 9:00 – Needham Survey about Electronic Vaping Products**

- **Other Items**

- **Next Meetings**
  - **Friday** **September 13th** **9:00 to 11:00 a.m.**
  - **Friday** **October 11th** **9:00 to 11:00 a.m.**
  - **Friday** **November 8th** **9:00 to 11:00 a.m.**
  - **Tuesday** **December 10th** **TBD p.m.**

- **Adjournment**

(Please note that all times are approximate)

Needham Board of Health Minutes

June 14, 2019

Board: Edward Cosgrove, PhD, Chair
Stephen Epstein, MD, MPP, Member
Kathleen Ward Brown, ScD, Vice Chair
Christina S. Mathews, MPH, Member
Robert A. Partridge, MD, MPH, Member (absent)

Convene: Rosemary Recreation Complex, 178 Rosemary Street, Multi-purpose Room

Staff Present: Tara Gurge, Assistant Director, Maryanne Dinell, Tiffney Zike, Diane Acosta, Catherine Delano, Carol Read, Dawn Stiller

Dr. Cosgrove Chair of the Board called the meeting to order at 7:02 a.m.

Ms. Gurge and the Board discussed Board organization. Dr. Cosgrove made a motion to reorganize the Board. Dr. Epstein made a motion to have Dr. Cosgrove become the Chair of the Board for 2019-2010 and Dr. Cosgrove seconded. Dr. Brown will remain Vice Chair. **The Board voted unanimously to have Dr. Cosgrove become Board Chair for 2019-2020.**

A discussion ensued on fall meeting times. Tuesday December, 10 was selected for the evening meeting. The time for the Friday meetings on September 13, October 11, and November 8, will be 9:00 to 11:00 a.m.

Dr. Brown made two changes to previous minutes. For April, in paragraph 4 of the section on the Warrant for Town Meeting, the job title should be "Public Information Officer" rather than "Director of Health and Human Services." For May, in the second paragraph on page 4, the job title should be "Director of Health and Human Services" rather than "Director of Public Health." **Dr. Brown then made a motion to approve both sets of minutes April 12 and May 10 as amended. Dr. Cosgrove seconded the motion. Upon motion duly made and seconded the vote was unanimous. The April and May 2019 minutes were accepted as amended.**

Public Health Nursing Report—Ms. Tiffney Zike

Ms. Zike provided the communicable diseases report. There were four influenza cases, all influenza B. There were five cases of Lyme disease (Ms. Zike said it was normal to have an increase occur over the summer months.) There were two Human Granulocytic Anaplasmosis (HGA) cases, one in an older male and one in a child. There was one case of babesiosis. There was one case of salmonella in an elderly resident who left chicken out on the counter for a long time. Ms. Zike provided education to the resident on causes and proper food handling. There was one case of giardia with a college student who had symptoms for two months before going to a doctor.

Environmental Health Report—Ms. Tara Gurge and Ms. Diana Acosta

Ms. Acosta said it has been a busy month with many temporary food event permit applications. Ms. Acosta is still working on the rodent control issue with the Hearth Pizza and Farmhouse Restaurant dumpsters. The Planning Board has approved moving their dumpster.

Ms. Acosta spoke about a resident who has made several complaints regarding serious environmental issues including toxic air on his property and nuclear materials on another property. Ms. Acosta plans to visit the property after she speaks with the resident. If a meeting is arranged, Mr. Jack Priest and a public health nurse will accompany Ms. Acosta. Dr. Epstein and Dr. Cosgrove recommended that a social worker accompany them as well.

Ms. Acosta reported that she had inspected all town public and semi-public swimming pools and they have passed inspection.

Dr. Cosgrove noted a rodent siting was identified in the report on Cottage Street. Ms. Acosta visited the area which was an unkempt grass section behind Webster Green. The owner on Cottage Street said the patch of land is owned by Webster Green but it was not noticed by Webster Green management as it is located behind a fence. Webster Green is hiring a landscaper and will also bait for pest control.

In response to a question from Dr. Cosgrove, Ms. Acosta said that Servante is going in where Acorns Bakery was. The permit has been delayed by the requirement for an accessible bathroom. In response to a question from Dr. Brown, Ms. Acosta said that Farmers Market permit inspections take place each Sunday, along with temperature checks for the vendors with refrigeration. Stephanie McCulloch, the new intern, performs the checks most Sundays with Ms. Acosta doing them on days when Ms. McCulloch is unavailable. Ms. Gurge noted that Corrie Locke-Hardy, the new market manager, and Tom Gehman the part-time manager, are working to make sure vendors are abiding by the regulations.

Dr. Cosgrove asked about the sewer extension on Walker Lane. Ms. Gurge had worked with the homeowner 18 months ago who had a cesspool pipe failure and repair. After two years, a sewer tie-in is required. The extension proposal has not yet been submitted and the owner was informed that he had only 6 months left in the two year extension from the pipe repair date. Ms. Gurge said that, although the pipe is still operational, the owner needs to bring a plan to the Public Health Division which will also be shared with the Town Engineering, Conservation, and Water & Sewer departments. Dr. Cosgrove remarked that the property owner appears to be making a good faith effort and Ms. Gurge agreed. She noted that the four neighbors are on board and want to find the right price and the right contractor. Ms. Gurge said that the owner may ask for an extension. Ms. Gurge will provide a status update at the July board meeting.

Ms. Brown questioned the circumstance of Cookies by Design, cited twice for not wearing gloves. Ms. Acosta said that the owner claims he cannot decorate the cookies with gloves but he has been reminded that it is the regulation and that other bakery sites comply without issue.

Traveling Meals Program Report—Ms. Mary Anne Dinell

Ms. Dinell reported that six hundred ninety-nine meals were delivered in May and that the summer program begins June 20 and four people were hired to deliver meals for the summer months. Ms. Dinell noted a case where the Traveling Meals Program, for the first time, has suspended delivery to one of the Springwell consumers due to unsafe delivery conditions. Volunteers have reported hazards, unsafe conditions, and have refused to deliver to this house. The client has been referred back to Springwell and to Ms. Gurge. Ms. Gurge will follow up with the consumer on Monday with the expectations of

arranging for a wellness visit that includes a town social worker, our public health nurse, and the Springwell case manager.

Substance Abuse Coordinator Report—Ms. Catherine Delano

Ms. Delano reported that she distributed the parent survey, which compliments with the MetroWest Adolescent Health survey, four weeks ago. The survey will close at the end of June.

Ms. Delano reported that the new summer intern from the Boston University School of Public Health is working with the MetroWest survey data and will be providing comparisons with previous years. Ms. Delano said that this level of statistical analysis, not previously enjoyed by the Public Health Division before, will help with programming decisions and will provide strong data for future grant applications. Ms. Delano is working with Ms. Read, Ms. Gurge and Ms. Acosta on researching marijuana regulations in the US and in Canada. Ms. Delano is also working with Ms. Mathews on creating a vaping task team.

Ms. Delano is also working on developing a vaping youth cessation program. Youth vaping is such a new issue that programs do not exist yet but a strong one is needed. Ms. Christina Matthews asked if the School Health curriculum covers vaping in the schools health curriculum. Ms. Delano said, while it is not now on the curriculum, the new Director of Youth and Family Services has discussed this with school administration.

Regional Substance Abuse Prevention Collaborative (SAPC) Coordinator Report—Ms. Carol Read

Ms. Read is working with Chief Schlittler, Lieutenant Baker, and a consultant to prepare the Jail/Arrest Diversion Grant Program grant application. The scope of the grant focuses on the social worker and law enforcement co-response model. If awarded, the grant will provide funding to hire a social worker to work in the police department. The social worker will co-respond with police officers on emergency calls that involve residents who are experiencing chronic substance use disorders or mental health conditions. The social worker will also work as a liaison with the Needham Department of Health and Human Services social work team to provide resources and support to residents with chronic mental health and substance use disorders and their families.

Currently, Ms. Read and the core team of the Community Crisis Intervention Team (CCIT) (Public Health nurses, police, and social workers) is working with the Riverside Emergency Services team to develop an in-home crisis support as an alternative to residents seeking mental health care at local Emergency Departments. Chris Lauzon, the Director of Emergency Services at Riverside, attends Needham CCIT meetings and is working to expand Riverside's community-based support program. Dr. Epstein said that not all the stakeholders at BID Needham are familiar with the CCIT model. The Emergency Department frequently has late night mental health related emergencies. A discussion ensued concerning challenges in the Beth Israel Deaconess Needham ED due to limited space and limited overnight counselor availability. Ms. Read said these challenges are discussed with BID Needham leaders who attend the quarterly CCIT Community Partners meetings. Newton-Wellesley Hospital is developing protocols for police and EMS transports of people with mental health and substance including assessment and referral to treatment. These protocols will be shared with BID Needham.

Ms. Read said the state SAPC regional prevention grants funded through the Federal Substance Abuse Prevention and Treatment Block Grant program are contracted through June 2020. The Massachusetts Department of Public Health- Bureau of Substance Addiction Services is creating a new procurement for

substance use prevention funding which is expected to be released in January 2020. Information on the structure and goals of the procurement is not yet available.

To prevent underage access to alcohol the SAPC region police chiefs conduct bi-annual alcohol licensee compliance checks. All four SAPC towns have identified violations in sales to minora during each round of compliance checks. Dr. Epstein recommended a joint meeting with the Select Board soon to discuss violations, jurisdiction, and the need for defined penalties. A Board discussion ensued on revisiting the issue of defining penalty violations and on publicizing any repeat violations.

The SAPC regional grant has funded nine TIPS alcohol licensee trainings in which over 265 staff from Dedham, Needham, Norwood and Westwood have participated. To sustain the TIPs training program, police and public health staff attended the TIPs Train the Trainer program which will allow them to become certified TIPs trainers.

Ms. Read attended the Mass Health Council Vaping forum at Bentley University. Ms. Read provided copies of presentations from the forum.

Vaping and Tobacco Regulations

At the May Board of Health meeting, Mr. Robert Partridge asked whether copies of these model letters could be sent to Massachusetts Association of Health Boards (MAHB) so they could share them with other boards of health. Ms. Gurge said that she had heard from DJ Wilson who said that he would forward the request to Cheryl Sbarra since she is with MAHB and she can determine her group's distribution of this letter. Ms. Gurge also reminded the Board that Mr. Wilson asked whether he can forward the letters to the lobbyists at Cancer, Heart, Lung, and Campaign for Tobacco Free Kids organizations. The Board said it was fine for the model letters to be shared with MAHB and the lobbyists for the other organizations.

Ms. Gurge reported that Mr. Wilson had no updates as of June 13 for any flavor bans elsewhere in the State. The Somerville proposed mint elimination hearing at Middlesex Superior Court is July 1. He will provide an updated list of latest flavor bans by town after that date.

A discussion ensued on national movement to move all e cigarette sales to adult only shops. Needham has no adult only shops. The Board will look at convenience stores sales and the effect of the flavor ban in Needham 6 months after the ban goes into effect July 1. There may be more data from the schools and the MetroWest survey at this point to further inform the Board's discussion.

Pest and Trash Management

The Town has agreed to take on the pest contract by hiring EHS Pest Control to conduct two, 3-consecutive day, Rat Ice treatments on the town and church properties. Rat Ice pellets can eliminate the population by 90-95%. After putting the dry Rat Ice in the rat holes, the EHS Pest Control team can take care of the entire colony at the same time. The eradication will take place the end of June. The Town DPW will have to remove the heavily brushed island areas in the parking lot and also the brushed area next to the shared Hearth Pizza and Farmhouse dumpsters after the eradication. The dumpster move discussion will take place on site the week of June 17th or the following week.

A discussion ensued on adding to the waste hauler regulations that more strict regular collections must occur in certain circumstances. Suggestions included a period of six hours from the restaurant closing. Another suggestion was a 24-hour time period. Set fines may need to be part of the new hauler regulations. Ms. Gurge is working on an assessment of what other towns, including Boston, do with these types of issues.

Dr. Cosgrove asked about how Wellesley manages the problem. Ms. Gurge said demolition pest control protocols, similar to Needham, are in place there. Ms. Lynn Schoeff will be looking at the pest protocols at planning level in Waltham and Boston and will report back for the July meeting. She will also include violation fees in her report.

The Board will examine the current hauler regulations in light of the above information and adjust as needed.

Accessory Dwelling Units (ADU's)

Ms. Gurge conveyed that Mr. McDonald has a request of the Board. If Mr. McDonald writes a statement to the press in support of accessory dwelling units, would the board would be willing to review the draft? Dr. Cosgrove responded that the Board would be happy to review the draft statement prior to their July meeting and vote at the July meeting on whether or not to support the statement. If supported the statement would be posted on the website, and sent to the Needham Times and the Hometown Weekly.

Needham's 10 Essential Health Services

Ms. Gurge included Lynn Schoeff's latest document from 2017 in the Board Packet, and said that Needham is keeping up with most of the ten essential services. The document is provided as a review. Dr. Cosgrove noted we have been ahead of the curve for a while but the Board should review regularly.

Other Business

Ms. Zike said the CPR tourniquet Stop the Bleed kits have been received for all town buildings except the schools. Ms. Zike also said that she, Ms. Carmichael, and all the fire department staff are trained in Stop the Bleed. Narcan training occurred in May at the Library. Ms. Zike will be doing training as requested. Dr. Epstein said that the Surgeon General is pushing all health care providers to carry Narcan with them. A discussion ensued on having Narcan available in all Town buildings. Because Narcan expires, it would need to be rotated out and should be kept with the AEDs so it can be checked every six months. Dr. Epstein said he is willing to meet with Ms. Kate Fitzpatrick, the Town Manager, to further explain the usefulness of Narcan in all Town buildings.

Ms. Zike stated that a future discussion of camp licensing protocols should happen to make sure they match the town concussion regulations. A discussion occurred regarding the goals for the nursing department, specifically regarding prevention with youth.

A discussion of HPV vaccinations and vaccinations also occurred. Dr. Epstein recommended talking to pediatricians locally re: HPV rates.

Dr. Cosgrove suggested working with the schools and Youth and Family Services division on across the board prevention issues.

The new Town website is scheduled to be available in early July. The concussion protocol will be a priority to avoid having to use paper forms for part of the process. The regulations note that the protocol will go into effect in the fall.

Ms. Zike has taken on the public health emergency preparedness role. As of July 1, Emergency Management is in the Fire Department budget. If the Fire Department does not appoint someone to the emergency management position, and if they require Ms. Zike's services, then Fire will have to pay for her overtime by Fire. The board is happy to discuss with the Fire Chief over the summer.

Ms. Gurge and Ms. Brown attended the workshop at the Center at the Heights on healthy and sustainable eating as it also relates to climate change. Ms. Brown is working with other researchers at the Harvard School of Public Health on a study about reducing food waste by 50% and sugar consumption by 50%. The study includes getting more people to cook at home. Ms. Gurge noted that the Farmer's Market has handouts on healthy eating and that healthy eating will be part of the restaurant week. Ms. Mathews and Dr. Cosgrove asked if the healthy eating information could be highlighted on the new Town website either in a separate section or a special place within the Public Health Division

Dr. Cosgrove said that the Special Commission on Local and Regional Health will finalize its report at the end of June meeting. Dr. Cosgrove said he has been nominated to the Board of Directors for the National Association of Local Boards of Health.

A motion was made by Dr. Epstein to adjourn the meeting. The motion was seconded. Upon motion duly made and seconded the vote was unanimous. The meeting was adjourned at 9 am.

The next meeting is Friday July 19 7-9 am.

Minutes Respectfully Submitted,

Faith Crisley

Accreditation Update
June 2019

July 10, 2019
Lynn Schoeff

Activity	Notes
Policies and procedures	Following are policies that were begun in June 2019 - Pest control (during construction) - Media policy The following policies are still in the works: - New staff orientation - After-action report - Duty to warn - Professional staff licensure - Mandated reporting - Blood pressure clinics The following policies for the Aging Services Division are still awaiting approval: - Transportation policy - Lyft Ridesharing Program - Volunteer Management
Accreditation	The orientation packet and checklist for new staff members are complete and have been posted on the shared drive.

Other work:

Lynn developed tips for Public Health staff when writing for the public.

Lynn and Rachael Cain are developing a grant-writing workshop for Health and Human Services staff.

Date: June 2019

Staff: Rachael Cain (Greenberg)

Activities and Accomplishments

Safety at Home Program

Activity	Notes
Presentations and Promotion	• Ongoing promotion at CATH
Program roll-out	• Full program roll-out continued • **30 program visits (including five pilots) completed to date** • **Work specified under the MetroWest Health Foundation grant is complete as of June 30, 2019, with all funds spent and deliverables met** • Home visits and education **will continue** on a slightly more limited basis while they are integrated into the services offered by Aging Services' Social Workers and the Public Health Nurses
Quality Improvement	• Continued improvement on program protocol and forms based on feedback from Safety at Home team members
Evaluation	• Program outcomes evaluated • **Highlights of the evaluation**: o 11 of 30 participants had fallen in the year prior to the visit o No participant had a fear of falling (based on the Tinetti Falls Efficacy Scale) but not all were confident they had the resources to avoid falls and continue living independently (average answer 3.81, with 1 being most confident and 10 not at all confident) o 14 of 30 participants completed a mailed satisfaction survey and stated they agreed or strongly agreed that the information was easy to understand, they will use what they learned, and are satisfied with the program, among other items. ▪ 13 participants said they would recommend the program to a friend (one participant did not respond)
Team Meetings	• Regular team meetings continued
Sustainability	• Matter of Balance to be offered year-round by partnership with Newton-Wellesley Hospital and trained Needham Public Health Nurse. • Working with local physical therapists to offer fall screenings at CATH regularly

Housing Authority Assessment

Activity	Notes
Survey Dissemination	• **Total of 119 surveys completed** (38% response rate), which is sufficient for analysis • Quantitative analysis by consultant is complete • Final report to be written in the coming months

Accreditation Support

Activity	Notes
Community Health Assessment	• Attended BID-Needham Community Benefits meeting

Climate Change Project

Awarded $26,089 grant from the Metropolitan Area Planning Council to implement a one-year climate resiliency project for older adults. Activities will include creating and holding three workshops for older adults about extreme weather and how to prepare for it, as well as a related communications campaign.

Activity	Notes
Planning Activities	• Reached out to program partners • Met with internal team and MAPC to plan next steps • Held interviews and identified strong candidate for Program Coordinator position – finalizing hiring process • Promoted program on Needham Cable
Conduct Workshops	• Held first workshop on June 26th o 30 older adults attended o Presented on extreme heat and how to protect self and loved ones o Conducted interactive activity o Disseminated emergency kits o Signed interested participants (two) up for RAVE alerts
Create Brochure	• Completed and printed educational brochure

NACCHO Million Hearts project

- Awarded $9,912 grant from the National Association of County and City Health Officials to implement a five month Million Hearts project focused on tobacco cessation. Activities will include a communications campaign and tobacco cessation course.

Activity	Notes
Overall Activities	• **Completed project and submitted final report** • Worked with graphic designer to create an infographic and program flyer o Both were translated into Mandarin and Russian • Eight-week Freedom From Smoking course began in early May with three participants and concluded on June 24th (with varying levels of attendance) • Promoted course: o Ongoing social media promotion o Ads in two local papers o In addition to prior promotions (cable, flyers, Town TV, press releases, and emails) • Discussing how to continue course and develop cessation course for youth

Other Public Health Division activities this month:

- Attended meeting with UMASS Amherst Mount Ida campus to identify potential areas for partnership
- Created Healthy Aging tweets, with team, for dissemination

Needham Public Health Division

June, 2019 Monthly Report

Maryanne Dinell- Traveling Meals Program Coordinator

Monthly

Description	*Reason*	*Notes/Follow-Up (ongoing, completed, etc.)*
Residents needing the Traveling Meals June, 2019	Unable to shop or prepare their own meal.	39 clients on the Traveling Meals Program for month of June 31 Springwell Elder Services of Waltham clients 8 private pay clients - Needham residents
20 delivery days in May 39 consumers enrolled in the Traveling Meals Program	26 Clients receive meals 5 days per week 12 Clients receive meals 3 days a week 1 Client receives meals for 7 days	709 meals delivered @ 5.62 per meal =cost of $3984.58 547 meals delivered to Springwell Clients 162 meals delivered to private pay residents
6 Clients no longer need Program	2 Private Pay 4 Springwell	5 Clients -now able to care for self 1 Client in nursing home
3 new clients On Program	2- 1st time on Program 1-re-enrollment	3-Dementia, Anxiety, depression 1- Age and health declining 1- Foot injury under Springwell at risk

Category		*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*FY '18 Total*	*FY '19 Total*	
Meal Delivery		560	660	540	644	536	528	535	541	649	654	603	709	7759	6859	
General Telephone Calls-received		29	62	22	38	65	77	26	32	50	41	52		494	442	
Assistance Calls-to Springwell		4	2	2	2	3	3	6	4	3	7	7		51	43	
Not at home at delivery		4	3	6	5	4	2	4	2	2	5	3		38	40	
911		1	0	0	0	0	0	0	0	0	0	0		0	1	

Category		*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*FY '18 Total*	*FY '19 Total*	

Meetings, Events, and Trainings

BI	*Type*	*Description/Highlights/Votes/Etc.*	*Attendance*
Board of Health Meeting		Monthly Board meeting held at Rosemary Complex	Staff and Board Members
Town		Harassment Training	40 Plus

Donations, Grants, and Other Funding [List any donations received, grants funded, etc. over the past month.]

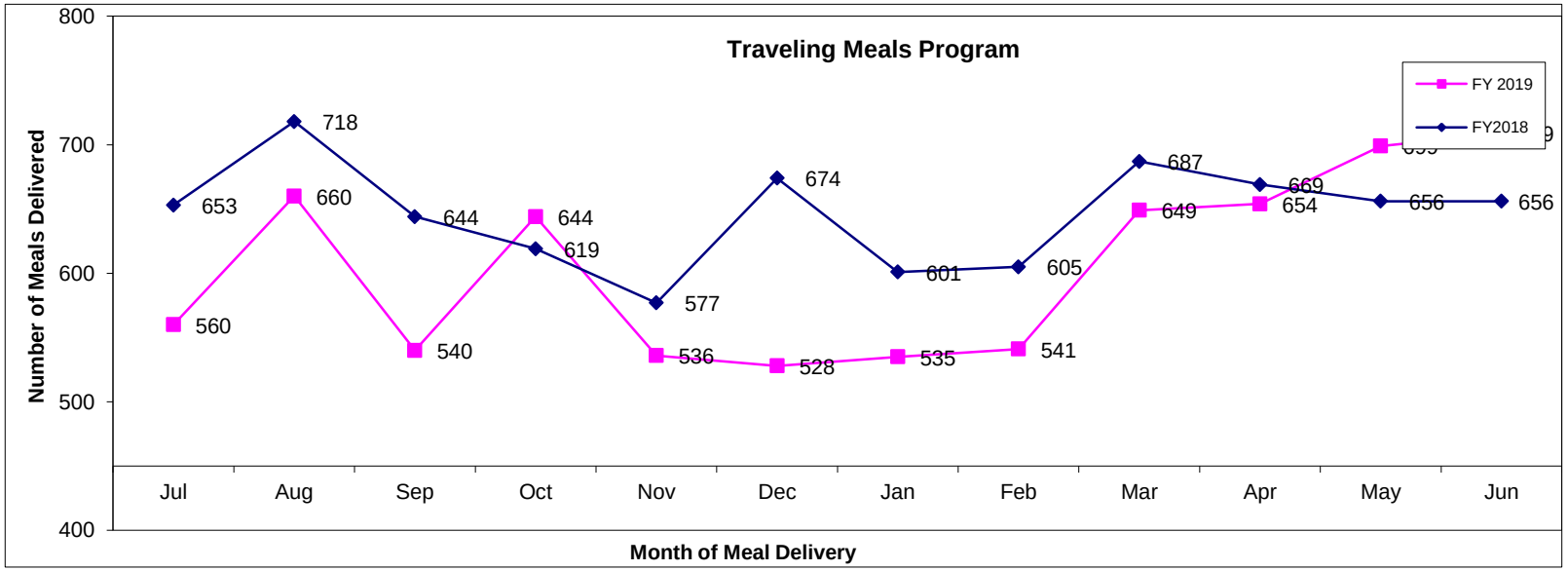
Description	*Type (D,G,O)*	*Amount Given*	*Source*	*Notes*

Traveling Meals Program

June, 2019

	Projected-12 Mo.
$	40,233.58
#	7,255.00

Month	# Meals FY2018	# Meals FY2019	FY19 Cost	% Change # Meals
Jul	653	560	$3,147.20	-14%
Aug	718	660	$3,709.20	-8%
Sep	644	540	$3,034.80	-16%
Oct	619	644	$3,619.28	4%
Nov	577	536	$3,012.32	-7%
Dec	674	528	$2,967.36	-22%
Jan	601	535	$3,006.70	-11%
Feb	605	541	$3,040.42	-11%
Mar	687	649	$3,647.38	-6%
Apr	669	654	$3,675.48	-2%
May	656	699	$3,928.38	7%
Jun	656	709	$3,445.06	8%
Totals:	7,759	7,255	40,233.58	



Needham Public Health Division

Unit: Substance Use Prevention

Date: June 2019

Staff: Catherine Delano, Karen Shannon, Karen Mullen, and Monica DeWinter

Summary:

Activities and Accomplishments

Activity	Notes
Parent Survey 2019	**700** surveys completed. Survey distributed via social media channels, listserv emails from schools, SPAN action team volunteers, and a print ad in the Needham Times.
Madeleine Arthur, graduate intern from BU School of Public Health, begins work with Prevention Team.	Maddie joined the Prevention Team for her summer practicum, having completed her first year of BU MPH program. Maddie will focus on data analysis of the new MWAHS 2018 data, which will include creation of an info graphic summary to present at SPAN meeting in fall 2019.
SPAN parent action team (Needham Parent Care)	End of the year breakfast meeting for NPC volunteers hosted by Alyssa Kence; planning discussion for Family Dinner Project program for fall 2019.
Prevention Team meeting	SPAN Parent Survey final campaign push, vaping task force, fund raising for NHS initiatives, SPAN presentation, Youth Action Team leader.
Alcohol toolkits for Needham alcohol licensees	Karen S., Catherine and Maureen met to discuss procedures for distribution of new alcohol Toolkits to alcohol licensees, both on- and off-premise businesses.
Meeting with Marian Slavin	5th Quarter PTC Funding Request
Youth vaping survey	Completed – Results in Packet
Finished with SAAP clients for summer	
Attended required Town Hall meeting	Topic: Sexual harassment in the workplace
Continued work on marijuana regulations	Working with Tara, Diana, and Karen Shannon
Continued work on ADU project	Set-up meetings with residents to discuss the benefits of ADU's in Needham. Worked with Lynn on a letter to the editor.

Carol Read, M.Ed., CAGS, CPS **June 2019**

Substance Use Prevention and Education ~ Initiative Highlights

Needham NPHD, Needham SPAN and Substance Abuse Prevention Collaborative (SAPC) grant* collaboration with the towns of Dedham, Needham, Norwood and Westwood**.**

SAPC grant
Town coalition meetings:
Dedham coalition: June 4th 10:00am and 6:00pm Dedham Town Hall *Conflict TIPS*
Impact Norwood coalition: June 13th 3:00pm Norwood High School
Westwood Cares coalition: *No meeting scheduled*
Needham SPAN coalition: *No meeting scheduled*

SAPC program, capacity building and strategy implementation preparation:
(1) BSAS- SAPC grant program quarterly programmatic report (Q3) online submission, June 14th **(2)** Training for Intervention ProcedureS (TIPs) alcohol responsible sales and service trainings: American Legion, Dedham. Final registration confirmations, email/phone to 45/9:30am-25/3:00pm, logistics for two trainings (food- hall set-up and welcome speakers) Monday, June 3rd Section 12 and Section 15 licensees (9:30am-2:30pm **40 attendees final** | 3:00pm-8:00pm **24 attendees final**) **(3)** TIPs *Train the Trainer* program, June 17th and 18th Norwood Police Department: Final registration confirmations, nine (9) SAPC stakeholders registered for outreach for trainer fee per town funding, $499.00 per person. **(4)** SAPC FY19 budget line item adjustment to fund one TIPs session and one Train the Trainer fee, request approval Amal Marks, BSAS **(5)** SAPC Regional Alcohol Compliance Check (CC) completions: Dedham (April 11th) Norwood (April 25th) Westwood (May 18th) Needham *(June 4th)* ABCC outreach, notification parameters, operative purchase protocols. Consultation Ralph and Ted Mahoney and D.J. Wilson, MMA. **(6)** Impact Norwood, Social Host liability resources, M.G.L. parameters, speaker resource Marianne LeBlanc, JD, Westwood parent- Sugarman Associates **(7)** Westwood Police Chief Jeff Silva, Alcohol compliance protocols, ABCC notification parameters, second sales to minor violation consequence. **(8)** Mass. Department of Agricultural Resources (MDAR) CBD food and health supplement product sale policy, M.G.L. c. 128 Section 117 (c) email distribution, phone follow-up, support from by D.J. Wilson, MMA.

Training for Intervention Procedures for Servers (TIPs) June 3rd Section 12 and Section 15 Alcohol licensee sales and service training to prevent underage alcohol use and promote road safety. Two sessions (9:30am-2:30pm **40 attendees** | 3:00pm-8:00pm **24 attendees**) Three year certification pending posttest completion. Mike Marcantonio facilitator. Welcome remarks, Chief Mike D'Entremont and Deputy Chief Mike Buckley. American Legion, Dedham.

Marijuana Forum: June 5th Massachusetts Prevention Alliance (MAPA) *Marijuana: Addiction, Mental Health and Policy.* Keynote address: Dr. Nora Volkow, Director of the National Institute on Drug Abuse at the National Institutes of Health. Presentations by: Dr. Bertha Madras, Harvard Medical School, McLean Hospital Substance Use Disorders Division, Alex Berenson, Author *Tell Your Children: The Truth About Marijuana, Mental Illness, and Violence,* science and research between marijuana use and mental illness. Dr. A. Eden Evins, Founding Director of the Massachusetts General Hospital Center for Addiction Medicine and Professor of Psychiatry at Harvard Medical School, Massachusetts clinicians and scientists' research and findings on the link between marijuana and psychosis. Will Jones III, Founder, Two is Enough (TIE DC) and representative of Smart Approaches to Marijuana (SAM) John F. Kennedy Presidential Library and Museum Boston.

TIPs *Train the Trainer* program: June 17th & 18th Responsible service, sale and consumption of alcohol, evidence-based model teaching skills to prevent intoxication, underage drinking and under the influence driving. Facilitated by Mike Marcantonio, TIPs Master Trainer. 8:30am-4:00pm Norwood Police Department. Nine SAPC region staff participants (Dedham 2/ Needham 3/ Norwood 4) Sgt. John McGrath – Officer Chris Poirier, Needham Police Department, Carol Read, NPHD.

SAMHSA- DFC application 2019: June 13th & 20th Conference calls, Amanda Decker. Medfield and King Phillip 2019 DFC grant application review, narrative content guidance, stakeholder engagement agreement options and online submission options and requirements (SAMHSA grants.gov- NIH) Deadline July 8, 2019. DFC Support Program created by the Drug- Free Communities Act of 1997 (public Law 105-20)

Norwood Board of Health meeting: June 19th Public Hearing on Tobacco Regulation. Impact Norwood Coalition education and advocacy, access and availability to e-cigarettes/vaping products. Testimony by D.J. Wilson, JD, Mass. Municipal Association. BOH vote: prohibition of all flavored products in all licensed tobacco stores (including mint, menthol and wintergreen) restriction of sales of nicotine delivery products (e-cigarettes, hookas or vape pens and other smoke accessories) to the two (2) 21 year and older licensed tobacco stores, effective September 15, 2019.

Alcohol Compliance- CBD products: June 19th D.J. Wilson, Mass. Municipal Association- MassTAPP. Review: (1) ABCC alcohol compliance protocols including advance notification content, timeframe and frequency (2) Operative protocols for alcohol compliance purchase attempts (3) Hemp/CBD policy Hemp derived products, food, products with therapeutic /medical claims and dietary supplements released by Mass. Department of Agricultural Resources (MDAR) 4 prohibitions for retail sale outside of licensed registered marijuana dispensaries. Federal 2018 Farm Bill (federal law treats Hemp as an agricultural commodity) and M.G.L. c. 128 Section 118, MDAR licensees Hemp product sales.

AdCare- BSAS training: June 28th *Helping People with Co-Occurring Substance Use & mental Health Disorders from a Clinical Perspective* Identifying substance use disorders, mental health and co-occurring disorders and best practice integrated treatment using ASAM criteria for evaluation. MH-SUD assessment tools cross system collaboration for co-occurring disorder treatment and risk of relapse. Mary E. McCloskey, MS, LMHC, LADC1. 9:00am-4:00pm, Best Western Marlborough.

Needham Public Health Division:
NPHD – SPAN initiatives:

NPHD programs meeting preparation outreach for research and resource gathering: (1)NPHD May monthly report (2) April BOH meeting minutes edit (3) Suicide prevention awareness, support resources, Laurie Hutcheson Coordinator, *Notes for Hope* event, in honor of Christine Crocker June 20th (4) CCIT core team capacity: Riverside Emergency Services resident response protocol parameters for co-response with REST staff, intervention support, assessment and evaluation to circumvent ED transport (1:1/Needham service providers/family) insurance coverage commercial and Medicare.

Town of Needham Emergency Planning: June 10th Local Emergency Planning (LEPC) staff training: *Active Threat Workshop*. Facilitated by Tiffany Zike, MPH, Needham Public Health Division and Needham Emergency Services providers, Chief Schlittler and Congdon. Powers Hall, Needham, 9:00am-1:00pm.

DMH-Law Enforcement Conference: June 11th 9th Annual Department of Mental Health Mental Health and Law Enforcement Conference. Joan Mikula Commissioner, DMH and Chief Jeff Farnsworth, Mass. Chiefs of Police Association. Keynote: Dr. Ruth Potee The Physiology of Addiction: Addiction, the Opioid Epidemic, the Changing Landscape and Treatment Possibilities. The Public health Response to the Overdose Crisis, Brittni Reilly, MSW, DPH- BSAS. Sarah Gaer, MA, Riverside Trauma. Trauma, Suicide Prevention & Self Care. Needham Police presentation: Developing and Implementing CIT (Crisis Intervention Team): CIT is More Than Attending Training, Lt. Chris Baker, Sgt. John McGrath.

Community Crisis Intervention Team (CCIT): June 12th Collaboration to support residents navigating acute and chronic substance use disorders and/or mental health conditions.
Core Team: Lt. Chris Baker, Sgt. John McGrath and Katie McCullough, Needham Police Department, Tiffany Zike, RN, MPH, Donald Anastasi, Deputy Fire Chief, Ed Sullivan, EMS Supervisor, Jessica Moss, LICSW, Kristen Lindley, LICSW and Kerrie Cusack, LICSW Senior Services, Sara Shine, Director, Needham Youth & Family Services, Catherine Delano, MPH, NPHD, Chris Lauzon, Director, Riverside Emergency Services and Evan Marcus, Riverside Mobile Crisis Supervisor.
Core Team, Confidentiality Agreement signing and overview of Riverside Emergency Community Based Program, home based intervention and assessment model (insurance reimbursable) diversion from Emergency Departments. *Attendance medical conflict.*

Town of Needham staff training: June 12th *Preventing and Addressing Harassment in the Workplace.* Learning objectives (1) Educating employees about unlawful workplace harassment (2) Understanding state and federal discrimination laws (3) Employee obligations and responsibilities regarding workplace harassment (4) Off- premise behavior/individual liability (5) Definitions of unlawful harassment and hostile environment. Strategies to recognize report and support. Sexual Harassment and Harassment Prevention, Susan Mitchell, JD, Mirick, O'Connell, DeMallie & Lougee, LLP.

Needham Public Health Division- strategic planning: June 19th Marijuana health regulation, *commercial/recreational* draft. Create *commercial/recreational* sale health regulations and protocols, comparisons with Needham BOH (medical regulations) Massachusetts CCC, Washington State, Colorado, California and Oregon *commercial/ recreational.* Primary focus: product safety standards, THC packaging labels, product safety (cultivation and testing) preventing underage access and minimizing exposure to advertising, promotions and delivery. Diana Acosta and Tara Gurge, Environmental Health and Catherine Delano, MPH SPAN Prevention. Main category areas: youth access, community marketing exposure, THC potency and other components.

Town Accountant: June 11th Conference call. Processing of SAPC grant expense reimbursement May 2019. Michelle Vaillancourt, Town Accountant, Dawn Stiller, NPHD Office Manager. Virtual Gateway EIM system.

Needham Board of Health meeting: June 14th Directors Report, staff reports of public health and prevention initiatives, resident education and support programs. Agenda review and discussion: Vaping, Youth Use, and Tobacco Regulations, Pest and Trash Management Challenges/Dumpster relocation, Accessory Dwelling Unit project, Concussion Protocol update and review of Needham's 10 Essential Services.

Needham Public Health Division office support: June 14th Summer hour coverage 12:00pm-3:00pm.

Needham Public Health- DMH grant: June 20th Conference Call, Jessica Goldberg, consultant. DMH Jail/ Arrest Diversion grant program project. Review draft scope, narrative time line and ongoing communication with Needham Police Department leaders for content, data and supporting document resources. Update on grant structure, FY20 funding time frame and narrative from Karin Orr, LICSW, NE Area Forensic Director, DMH, CIT model. Initial draft week ending July 19th.

SAPC FY19 budget review: Conference call, June 21st Dawn Stiller, NPHD Office Manager. Review SAPC expense tracking sheet, June expenses for reimbursement, final purchase order requests and available FY19 funds by UFR code. NPHD operational budget salary allocation, week ending June 21st and June 28th.

Resident Support: Respond to calls and/or meeting requests related to mental health conditions and/or substance use disorder. Referral to Riverside Emergency Services 24/7 support and counseling, assessment, treatment and recovery resources.

F 62 yrs. Suicide risk, SMI- Alcohol. In home evaluation, Evan Marcus, Riverside Mobile Crisis Services.
M 58 yrs. Acute depression and substance use, in office assessment. Consult with family on risk and intervention for treatment, Evan Marcus, Riverside Mobile Crisis Services.
F 50 yrs. SMI- Alcohol- chronic hospitalizations. DMH application resource and referral for services.

Respectfully submitted by Carol Read July 15, 2019

*SAPC technical assistance calls, coordinator meetings, and compliance related to the SAPC grant program are extensively documented in the BSAS-SAPC online quarterly reports.

Public Health Nurse Report - May FY2019
Donna Carmichael and Tiffany Zike

COMMUNICABLE DISEASES:	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	Apr	MAY	JUN	T19	T18	T17
BABESIOSIS		3									1		4	4	2
Borrelia Miyamota													0	0	0
CAMPYLOBACTER				2	1	1	1		1				6	14	7
CRYPTOSPORIDIUM													0	1	0
Cyclosporiasis													0	1	0
Dengue													0	0	1
E-Coli													0	0	0
EHRLICHIOSIS/ HGA	1	1									2		4	2	2
Enterovirus													0	1	1
GIARDIASIS									1		1		2	1	2
Haemophilus Influenza													0	1	1
HEPATITIS B		1		1		2	2	1			2		9	8	8
HEPATITIS C	1		3	2		3				1	1		11	14	21
Influenza						9	19	30	20	16	4		98	211	108
Legionellosis													0	2	0
Listeriosis													0	0	0
LYME	13	7	2	4	4	2	1	2		3	5	3	46	53	44
MEASLES													0	0	0
MENINGITIS													0	0	0
Meningitis(Aseptic)													0	1	2
Mumps												1	1	0	0
Noro Virus							1	1	3				5	3	2
PERTUSSIS	3												3	1	4
RMSF(Rocky Mt Spotted Fever)						1									
SALMONELLA			1								1	1	3	3	2
SHIGA TOXIN									1				1	0	1
SHIGELLOSIS		1		1								1	3	0	0
STREP Group B													0	1	0
STREP (GAS)										2			2	5	0
STREP PNEUMONIAE				1			1			1			3	3	0
TUBERCULOSIS													0	0	0
TULAREMIA													0	0	1
Latent TB	1												1	0	1
Varicella	2	1	1		1				1				6	12	10
Vibrio			1										1	0	1
West Nile virus													0	0	0
Zika													0	1	1
TOTAL DISEASES	21	14	8	11	6	18	25	34	27	23	17	6	209	343	221
Revoked/Suspect Diseases Investigated			1	3			1						5	6	13
Contact Investigation	4						1						5	5	1

Public Health Nurse Report - May FY2019
Donna Carmichael and Tiffany Zike

ANIMAL TO HUMAN BITES	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	Apr	MAY	JUN	T19	T18	T17
DOG	6	3	4	0	2	1	2		2	3	0	0	23	42	15
CAT													0	0	0
BAT													0	8	5
SKUNK										1			1	0	0
RACOON													0	0	0
other													0	1	1
TOTAL BITES	6	3	4	0	2	1	2	0	2	4	0	0	24	51	22

IMMUNIZATIONS	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	FY19	FY18	FY17
B12	2	2	2	2	2	2	2	2	2	2	2	2	24	24	22
Flu (Seasonal)			284	408	20	0	0	0	0	0	0	0	712	522	674
Hep B						2	0	0	0	0	0	0	2		
Polio		4		0	0	0	0	0	0	0	0	0	4		
TDap		3		1	0	2	0	0	0	0	0	0	6	0	1
Varicella				0	0	0	0	0	0	0	0	0	0	2	0
Consult	49	50	90	72	32	98	34	25	71	65	46	70	702	319	592
Fire/Police	20	7	15	15	16	20	6	5	22	15	10	6	157	59	80
Schools	2	8	30	40	4	35	10	8	14	12	6	3	172	42	106
Town Agencies	25	20	20	15	10	35	15	10	30	25	27	35	267	185	246
Community Agencies	2	15	25	2	2	8	3	2	5	10	3	26	103	32	160

ASSISTANCE PROGRAMS	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	FY19	FY18	FY17
Food Pantry		1	2	0	3	0	1	1	1	1	0	4	14	13	20
Food Stamps			0	0	0	0	1	0	0	0	0	0	1	0	4
Friends			0	0	0	0	0	0	0	0	0	0	0	0	0
Gift of Warmth	1		2	2	1	1	4	1	2	6	0	0	20 ($5817)	20($7250)	11
Good Neighbor			0	0	0	0	0	2	0	0	0	0	2	5 $425/fam	8
Park & Rec			0	0	0	0	0	0	1	0	0	1	2	1	2
Salvation Army			0	0	1	0	0	0	0	0	0	0	1	0	0
Self Help	2	2	1	3	0	2	1	3	4	5	3	0	26	34	46

Gift Cards Distributed - 0

Public Health Nurse Report - May FY2019
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WELLNESS PROGRAMS	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	FY19	FY18	FY17
Office Visits	56	49	34	26	11	18	20	27	29	30	34	34	368	467	481
Safte Visits	0	3	2	1	2	0	0	1	2	0	0	1	12	10	7
Clinics	0	0	0	0	4	2	7	7	11	7	14		52	0	0
Housing Visit	1	1	0	0	2	0	0	1	0	0	0	0	5	15	6
Housing Call	0	3	3	4	7	4	13	5	4	1	0	10	54	110	37
Camps-summer	6	7	0	0	0	0	0	8	1	8	5	7	42	60	50
Tanning Insp	0	0	0	0	0	0	0	0	0	0		0	0	0	0
Articles	1	0	1	0	0	0	1	0	1	2	0	0	6	3	3
Presentations	1	1	6	2	5	2	2	1	1	1	2	3	27	16	0
Cable	0	1	1	1	0	0	1	0	0	1	1	1	7	2	5

EMPLOYEE WELLNESS	July	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	FY19	FY18	*FY17*
BP/WELLNESS - DPW/RTS	0	0	10	13	11	11	13	12	12	12	11	9	114	148	169
CPR/AED INSTRUCTION	0	0	0	0	11	7	0	0	0	0	0	0	18	0	31
Narcan Training											13	0	13		
Police Weights	0	0	0	0	13	0	0	0	0	0	12	6	31		
First Aide	10	8	5	6	3	2	0	3	6	9	5	4	61		
Total People	10	8	15	19	38	20	13	15	18	21	41	19	237		
Community Education Hours															
HEALTH ED Tick Borne	50	20	15	5	3	0	0	0	0	1	0	32	126	132	90
HEALTH ED Mosquito Borne	50	20	15	5	0	0	0	0	0	0	0	32	122	135	80
HEALTH ED FLU	0	0	15	15	10	20	2	2	1	3	0	0	68	289	160
GENERAL HEALTH EDUCATION	20	10	10	10	15	20	5	12	8	3	2	32	147	186	258
HEALTH ED Measles										15	2	7	15		
Total Hours	120	50	55	35	28	40	7	14	9	22	4	103	478	1077	954

Public Health Nurse Report - May FY2019
Donna Carmichael and Tiffany Zike

MEETINGS, EVENTS, TRAININGS

Title	*Description/Highlights/Votes/Etc.*
Emergency Planning	NC8 - Monthly Meeting
	Active Threat Table Top Exercise
	After Action Reviews, LEPC Certification, CEMP planning
	MRPC EDS training and workshop
Emergency Preparedness	Grant writing - EMPG
DVAC	Monthly Meeting - Organizing and Preparing for meeting, meeting minutes, follow up and distribution of information
	Organizing Summer initiatives with Intern
	Book club discussion
Concussions	Working towards Roll-out
Healthy Aging	Home visit x 1
Trainings	Town Hall training on Sexual Harassement
	TIPS
	COCA call- MDR Candida
Summer Camps	Office Visits and paperwork review
	Camp Visits on 7/24 and 7/25
	Managing Packet information
Managing	DVAC Intern and EP Program Coordinator
Narcan Training	Discussion with more library staff about training
MAPC Grant	Lunch and Learn Presentation
Solutions Group	Presentation Preparation with Town Manager
	Presented to Town Leadership on Communication Core Value

Needham Public Health Division

June 2019

Assist. Health Dir. - Tara Gurge

Health Agents - Diana Acosta and Monica Pancare

Activities

Activity	*Notes*
Animal Permits	**19 - Animal Permits Issued.** - All renewals were issued a new permit - 1 permit issued to Needham Golf Club (for 3 goats.)
Beaver Permit	**1 – Issued 10-Day Emergency Beaver Permit to:** - **#292 Forest St. - Dave Volante at Volante Farms requested a permit due to flooding issues in his fields caused by beaver dams. Issued permit. Five beavers were removed.**
Bodyworks	**1 – Bodyworks Establishment Application Received** - Baan Thai Spa **2 – Bodyworks Practitioner Applications Received** - Baan Thai Spa o Both applications pending Doctor's note and CORI/SORI Results
Demo Reviews/ Approvals	**11 - Demolition sign-offs:** • 57 Hawthorne Ave • 116 Woodbine Circle • 77 Wayne Road • 304 Country Way • 21 Utica Road • 24 Bess Road • 53 Edwardel Road • 22 Parker Road • 290 Manning Street • 93 Dawson Drive • 758 Webster St.
Farmer's Market	**41 – Farmers Market inspections conducted:** - Initial inspections conducted by Diana and Stephanie McCulloch (intern). Follow up inspections have been conducted by Stephanie. **1 – Farmers Market Application Received** - Simple Sips
Food – Temporary Food Event Permits	**10 – Temporary Food Permits issued to:** - Charles River YMCA Independence Day 5k - Oath Pizza @ Mitchell - PMC Kids Ride - Sweet Pete Ice Cream - Boston Open Dancesport @ Powers - Parent Talk @ Memorial Field - Flicks on the Field - Sweet Tomatoes Mobile Truck - Needham Community Council @ Rosemary Pool - Charity Lemonade Stand - Firefly BBQ @ Brigham & Women's Physician BBQ

Food – Food Permit Plan Reviews (Updates)/Permits Issued Food – Food Permit Plan Reviews (Updates)/Permits Issued	**5 – Food Establishment looking to start their Pre-operation inspection process:** - Eat Well – Updated plans need to be submitted since they have recently informed us of a proposal to expand their seating area. Will submit a new plan for review. (Pending.) - Servente Bakery & Café – Permit packet and fees received. Awaiting bathroom renovations. Pre-operation insp. pending. - Pancho's Taqueria – Updated kitchen layout plan still pending for review. Additional plan review items received. Pre-operation inspection pending. - Hungry Coyote – Submitted plan review packet. Pre-operation inspection pending. - Mike's Trattoria – Submitted plan review packet. Plan review items still pending. Scheduled initial pre-operation inspection. **1 – Food Establishment Plan Review Received** - Latina Kitchen & Bar – Still in plan review process. (Old L&K location.) **3 – Food establishment seasonal/annual permit issued:** - Forklift Catering – To take over vacant #301 Reservoir St. location. - Tiffany's Brownies & Treats LLC – Residential kitchen. - Wingate at Needham
Food Pre-operation Inspections conducted	**4 – Pre-operation inspections conducted for:** - NEW Suny Williams School (x1) - Pre-operation inspections conducted. (Follow-up pending.) - Forklift Catering (x2)– Pre-operation inspection conducted. Permit issued. - Tiffany's Brownies & Treats LLC (x1)– Pre-operation inspection conducted. Permit issued.
Food - Mobile	**3 – Mobile Truck Inspections conducted:** - Chicken and Rice Guys – back up truck - Sweet Tomatoes Mobile Truck - Sweet Pete's Ice Cream (temporary event)
Food Complaints	**1/1 – Food Complaints/Follow-ups:** - Dragon Chef – Customer reported seeing staff working without gloves in the kitchen while preparing food. Diana followed up with the owners to notify and re teach staff that bare hand contact with ready to eat foods is not allowed.
Housing – Complaints/Follow-ups	**1/1 – Housing Complaints/Follow-ups** - Chambers Street (NHA) – Waiting to hear on status of unit. One inspection of the unit was conducted but will need to conduct a re-inspection of this unit, prior to re-occupancy. (On-going.)
Nuisance – Complaints/ Follow-ups	**5/12 – Nuisance Complaints/Follow-ups conducted for:** - **Dumpsters near CVS/Farmhouse/Hearth/Masala Art (1/4) –UPDATE** – Pest elimination progress being made. Weekly meetings continue to be conducted with Pest Control companies, along with establishment owners, to review progress. Daily dumpster checks are being alternatively conducted by Tara and Diana. EHS pest conducted a major dry ice treatment to eradicate population. Progress to continue to be monitored. (Shared dumpster enclosure to be built, along with rodent landscape exclusion of potential harborage areas, prior to the end of July.) - **Gould Street (0/1) –** Diana informed by radiation control that they tried reaching out to the resident with no answer. Diana was not able to get in contact with the resident and no calls have come in from the resident. They do not have a working voicemail to leave a message. (On going). - **St. Mary Street (0/1)** – Order letter sent out. Tara and Diana to follow up with resident on July 8th (Done.) Will continue to conduct weekly inspections to check on progress. (On-going) - **Hampton Ave (1/1)** – Neighbor's trash has been overflowing again. Diana conducted a site visit and did not witness overflowing trash. The trash barrels on the front of the property were very full. Diana left a business card with a note to reach out. The resident has yet to call in to go over the issue. (On-going) - **Oakcrest Road (0/1)** – Resident with leaf pile called to report it is a compost pile that they actively turn over. - **Canavan Circle (1/1)** – Resident's neighbor had various items in driveway and lawn was overgrown. In the past, the complainant had to replace wires in their A/C units because animals chewed through. Was conc n overgrowth. Diana

Nuisance – Complaints/ Follow-ups (cont.)	conducted a site visit and left a business card with a note. The area had tall grasses and there were also chipmunks sited in the area. The neighbor contacted Diana and explained why the property was in that status as they had been out of state for a while and there was miscommunication with the landscapers and junk removal company. The neighbor was able to resolve the issues with the grass and items in the driveway. Discussed that chipmunks may have been the culprit in the chewed wires. - **Charles River YMCA (1/2)** - Member reported contracting an antibiotic resistant staph infection in February. Suspects the YMCA Pool as the member's primary care doctor told them that it was possible to contract from swimming. Diana reached out and received the pool logs from YMCA for February. The chemical levels were in the appropriate ranges and the pool was not closed during this time period. Diana contacted the member again and shared the info sheet from the Center for Disease Control on Pools and MRSA : https://www.cdc.gov/healthywater/pdf/swimming/resources/mrsa-factsheet.pdf It is not likely that the infection came from the pool. - **Sheraton Needham (1/1)** – Guest called to report he had been bitten by bed bugs. The general manager of Sheraton is bed bug certified. Ecolab was immediately called out before the complaint was reported to the Public Health Division. The presence of bedbugs was confirmed by Ecolab. Ecolab initially treated the rooms above below and to the left of the affected room (the room to the right was occupied by long term guests). Diana followed up with the hotel to confirm the mattress and box spring were removed from the room. The manager also reported the room to the right of the affected room would be inspected while the long term guests were not in the room.
Registered Medical Marijuana Dispensary / Annual Permit Renewal for Needham RMD	**2 – Registered Medical Marijuana routine inspections conducted at:** - Sira Naturals, Inc. - Needham Dispensary - Sira Naturals , Inc. - Milford Grow site inspected by Tara **1 – Registered Medical Marijuana Dispensary Permit issued to:** - Sira Naturals, Inc. (in Needham) **(NOTE: Sira Naturals, Inc. is still interested in having a follow-up discussion with the BOH about the Vet/Senior discount option for their Needham dispensary. Will submit data for the board to review and attend an upcoming meeting.)**
Septic - Abandonment Form	**1 – Septic Abandonment form submitted for:** - **#260 Cartwright Rd.**
Septic - Soil Test Application/Perc Tests conducted	**1 – Soil Test/Perc Test conducted for:** - **#1 Wellesley Ave.** – For septic system upgrade. (Plan submittal pending.)
Septic – Enforceable Agreement Discussion	**1 - Enforceable Agreement Discussion held for:** - **#57 Walker Lane – Met with Town Engineering, Water and Sewer, and Conservation Depts., along with homeowner, to discuss the timeline for the municipal sewer extension project to bring up the sewer line to his property. (PLEASE NOTE: DEP Enforceable Agreement set on this property which is due to expire of Dec. 31, 2019.) Homeowner will work on contacting additional sewer contractors to take on this proposed sewer extension job. Homeowner may ask for an extension from the BOH for this Order once he has exhausted all efforts to connect by the 2-year deadline. UPDATE – Discussion to be held at BOH meeting.**
Tobacco	**10 –** Calls made to remind all tobacco establishments of mint menthol ban going into effect on July 1. Inspections in process to spot check that no flavored items are on shelves.
Tobacco Hearing	**1 – Tobacco Compliance Check Violation Hearing scheduled with:** - **Hiren Patel – Owner of 7-Eleven Highland Ave. (@ BOH Meeting.) See summary in BOH packet.**
Trainings	**1 – MHOA Training** - Mobile Food Vendor Program **1 – AFDO Training** - 123rd Annual Educational Conferenc

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Waste Hauler Permits Issued	**1 - Waste Hauler Inspections conducted:** - Republic **1– Waste Hauler Permits issued to:** - Zaccaria Trucking
Well – Approval to Drill	**1– Approval to Drill letter sent for an irrigation well to be drilled at:** - **#403 Grove St. – By Mr. Thomas Ogden (REG # 552). Ogden Well & Pump Company, Inc.**
Planning Board Plan Reviews	**0 – Plan reviews conducted for Planning Board.**
Zoning Board of Appeals Plan Reviews	**3 - Plan Reviews conducted for Zoning Board of Appeals/Comments sent for:** - **#7 Rolling Lane** – Comments send re: demolition notification requirements. - **#324 Chestnut St.** - Comments sent on the proposed food establishment at the site. New Indian catering/take out restaurant. (Vacant spot next to Sweet Tomatoes.) - **#150 Gould St.** – Comments sent for proposed catering/commissary expansion. (Existing Baker's Best Catering.)

Yearly

Category	*Jul*	*Au*	*S*	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*Ma*	*Ju*	***FY '19***	FY' 18	*FY' 17*	FY' 16	*Notes/Follow-Up*
Biotech	0	0	0	0	1	0	0	0	0	0	0	0	**1**	1	2	2	Biotech registrations
Bodywork	0	0	0	0	0	4	2	8	0	0	0	0	**14**	14	6	11	Bodywork Estab. Insp.
Bodywork	0	2	0	0	0	5	2	0	0	0	0	0	**9**	6	4	3	Bodywork Estab. Permits
Bodywork	0	2	1	0	0	16	2	0	0	0	0	0	**21**	22	13	10	Bodywork Pract. Permits
Bottling	0	0	1	0	0	0	0	0	0	0	0	0	**1**	1	2	1	Bottling Permit insp.
Demo	12	13	9	5	11	5	12	4	7	2	13	11	**104**	105	112	110	Demo reviews
Domestic Animal Permits/Insp.	0	1	1	0	0	0	0	0	0	0	0	19	**21**	19	17	16	Animal permits/
	0	0	20	0	1	0	0	0	0	0	1	0	**22**	3	16		Inspections
Food Service	16	8	23	25	16	13	20	9	22	15	15	18	**200**	225	198	209	Routine insp.
Food Service	3	1	0	1	0	1	1	0	0	1	1	3	**12**	32	37	35	Pre-oper. Insp.
Retail	6	5	7	7	2	2	3	4	4	3	0	3	**46**	60	69	71	Routine insp.
Resid. kitchen	0	1	0	0	1	0	0	1	2	0	1	0	**6**	8	7	11	Routine insp.
Mobile	1	4	0	1	0	0	0	0	1	2	5	3	**17**	13	15	9	Routine insp.
Food Service	1	1	0	3	5	3	4	4	3	2	1	1	**28**	53	51	50	Re-insp.
Food Service/retail	2	1	0	0	1	129	1	0	0	1	2	3	**140**	171	177	176	Annual/Seasonal Permits
Food Service	7	12	19	14	12	2	3	3	3	14	35	10	**134**	163	158	107	Temp. food
	9	1	10	0	0	0	0	0	0	1	16	0	**37**	29	62	54	permits/Inspe
Food Service	1	0	1	0	0	0	0	0	1	5	6	0	**14**	14	7	9	Farmers Market permits
	50	45	41	42	10	0	0	0	0	0	0	41					Farmers insp.

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Category	*Jul*	*Au*	*S*	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*Ma*	*Ju*	***FY '19***	FY' 18	*FY' 17*	FY' 16	*Notes/Follow-Up*
Food Service	0	2	0	2	1	1	1	3	1	4	2	1	**18**	20	13	21	New Compl/
	0	2	0	2	1	1	4	3	1	4	2	1	**21**	21	17	21	Follow-ups
Food Service	0	1	1	3	4	3	2	1	2	1	1	1	**20**	42	33	32	Plan Reviews
Food Service	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	3	Admin. Hearings
Grease/ Septage Haulers	0	0	0	0	0	21	0	0	0	0	0	0	**21**	24	24	29	Grease/ Septage Hauler Permits
Housing (Chap II Housing)	0	0	0	0	0	0	0	0	0	0	0	0	**0**	14	14	7	Annual routine insp./
	0	0	0	0	0	0	0	0	0	0	0	0	**0**	5	4	4	Follow-up insp.
Housing	2	4	1	3	4	1	3	0	2	0	1	1	**22**	22	7	18	New Compl./
	3	5	1	4	4	1	3	3	2	0	1	1	**28**	24	11	37	Follow-ups
Hotel	0	0	0	0	0	3	0	0	0	0	0	0	**3**	3	3	3	Annual insp./
	0	0	0	0	0	0	1	0	0	0	0	0	**0**	0	0	0	Follow-ups
Nuisance	2	5	5	4	4	4	1	4	6	8	7	5	**55**	42	30	44	New Compl./
	2	5	5	4	4	4	1	4	8	8	12	12	**69**	42	45	50	Follow-ups
Pools	1	4	0	0	1	7	0	0	0	0	7	0	**20**	12	13	9	Pool insp./
	1	5	0	0	0	1	1	0	0	0	4	0	**12**	7	8	3	Follow up
Pools	1	2	1	0	0	7	1	0	0	0	7	0	**19**	12	9	9	Pool permits
Pools	2	1	0	0	0	0	0	0	0	0	0	0	**3**	44	19	8	Pool plan reviews
Pools	0	0	0	0	0	4	0	0	0	0	1	0	**5**	7	6	4	Pool variances
Septic	0	0	0	1	2	1	1	1	0	1	1	1	**9**	5	18	8	Septic Abandon
Septic	1	0	0	0	0	1	0	0	0	0	0	0	**2**	2	5	9	Addition to a home on a septic plan rev/approval
Septic	0	0	0	8	9	3	1	0	0	0	0	0	**21**	28	43	23	Install. Insp.
Septic	0	0	0	0	1	0	0	0	0	0	2	0	**3**	1	0	3	COC for repairs

Category	*Jul*	*Au*	*S*	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*Ma*	*Ju*	***FY '19***	FY' 18	*FY' 17*	FY' 16	*Notes/Follow-Up*
Septic	0	0	0	0	2	1	1	0	0	0	0	0	**4**	4	3	3	COC for complete septic system
Septic	6	4	3	5	7	6	5	4	6	5	5	6	**62**	51	62	61	Info. requests
Septic	0	0	0	0	0	0	0	0	0	1	0	0	**1**	2	6	8	Soil/Perc Test.
Septic	0	1	0	1	2	0	0	0	0	2	0	0	**6**	5	8	6	Const. permits
Septic	0	0	1	0	1	3	2	0	0	0	0	1	**8**	9	11	9	Installer permits
Septic	0	0	1	0	1	1	1	0	0	0	0	1	**5**	3	6	6	Installer Tests
Septic	0	0	0	0	1	0	0	0	0	0	0	0	**1**	3	7	3	Deed Restrict.
Septic	1	1	0	1	2	1	0	0	0	1	2	0	**9**	23	14	14	Plan reviews
Sharps permits/Insp.	0	0	0	0	0	7	0	0	0	0	0	0	**7**	9	9	10	Disposal of Sharps permits/
	0	0	0	0	2	5	0	0	0	0	0	0	**7**	7			Inspections
Subdivision	0	0	0	0	0	0	0	0	0	1	0	0	**1**	0	3	3	Plan review-Insp. of lots /
	0	0	0	0	0	0	0	0	0	0	1	0	**1**	0	1	0	Bond Releases
Special Permit/ Zoning memos	1	2	0	2	4	2	7	6	0	3	4	3	**34**	15	12	16	Special Permit/Zoning
Tobacco	0	0	0	0	0	10	0	0	0	0	0	0	**10**	11	12	13	Tobacco permits
Tobacco	4	1	3	2	0	0	1	1	2	0	0	0	**14**	18	25	25	Routine insp./
	1	0	0	0	0	0	0	0	2	0	0	0	**3**	3	6	7	Follow-up
Tobacco	0	0	0	10	0	0	0	10	0	10	0	0	**30**	41	34	48	Compliance checks
Tobacco	0	0	0	0	0	0	0	2	1	0	0	0	**3**	4	2	4	New compl./
	0	0	0	0	0	0	0	2	1	0	0	0	**3**	4	2	4	Compl. follow-ups
Trash Haulers	0	0	0	0	0	0	0	0	3	10	3	1	**17**	14	26	30	Trash Hauler permits
Medical Waste Haulers	0	0	0	0	0	2	0	0	0	0	0	0	**2**	1	2	2	Medical Waste Hauler permits
Wells	0	2	0	0	0	0	2	0	1	0	0	1	**6**	2	7	6	Permission to drill letters/
	0	0	0	0	0	0	0	1	0	0	0	0	**1**	0	3	0	Well Permits

FY 19 Priority FBI Risk Violations Chart (By Date)

Restaurant	Insp. Date	Priority Violation	Description
Comella's	7/16/2018	**28 - 7-206.13 (A) Tracking Powders, Pest Control & Monitoring -** A tracking powder pesticide may not be used in a food establishment.	**Kitchen -**Eliminate mouse infestation
Cookies By Design	9/21/2018	**9-3-301.11 (B) Preventing Contamination from Hands -** Except when washing fruits and vegetables, food employees may not contact exposed, ready-to-eat food with their bare hands and shall use suitable utensils such as deli tissue, spatulas, tongs, single-use gloves or dispensing equip.	**Kitchen -**Need gloves.
Pollard Middle School	9/24/2018	**28-7-204.11 Sanitizers -** Chemical sanitizers, including chemical sanitizing solutions generated onsite, and other chemical antimicrobials applied to food-contact surfaces shall meet the requirements specified in 40 CFR 180.940. Chemical sanitizers shall not exceed manufacture's label instructions.	**Kitchen -**Sanitizer in 3 bay sink was low, ~100 ppm - should be 150-200 ppm.
St. Sebastian's	9/27/2018	**33-3-501.15 (A) Cooling Methods -** Cooling shall be accomplished in accordance with the time and temperature criteria specified under 3-501-14 by using one or more of the following: placing food in shallow pans; separating the food into smaller or thinner portions; using rapid cooling equipment; stirring the food in a container placed in an ice water bath; using containers that facilitate heat transfer; adding ice or other effective methods	**Kitchen -**Tortellini was at 68 F - Should be cold held in walk-in before being placed in the salad bar.
Gari	10/3/2018	**4-501.110 Warewasher Wash Sol. Temp. -** Ensure that low temp dishwash machine operates at a minimum of 120'F wash & rinse. The temperature of the wash solution in spray-type warewashers that use chemicals to sanitize may not be less than 120ºF.	**Kitchen** -110'F in wash cycle
Wingate at Needham	11/6/2018	**5-402.13 Conveying Sewage -** Sewage shall be conveyed to the point of disposal through an approved sanitary sewage system or other system, including use of sewage transport vehicles, waste retention tanks, pumps, pipes, hoses, and connections that are constructed, maintained, and operated according to law.	**Kitchen -** Repair hand wash sink drain in dish room
Beth Israel Deac. Hospital Kitchen	12/15/2018	**4-703.11 Methods-Hot Water and Chemical -** After being cleaned, equipment food-contact surfaces and utensils shall be sanitized in: hot water manual operations for at least 30 seconds; hot water mechanical achieving surface temperature of 160°F as measured by an irreversible registering temperature indicator; or chemical (manual or mechanical) for times specified the EPA-registered label use instructions.	**Kitchen -** Wash Temperature 140-140F.
Residences at Wingate	12/15/2018	**4-602.11 (A) Food-Contact Surfaces and Utensils -** Equipment food-contact surfaces and utensils shall be cleaned: before each use with a different type of raw animal food such as beef, fish, lamb, pork, or poultry; each time there is a change from working with raw foods to working with RTE foods; between uses with raw fruits and vegetables and with TCS food; before using or storing a food temperature measuring device; and any time during the operation when contamination may have occurred.	**Kitchen -** Slicing machine blade has encrusted food debris on rim of blade. Thorough cleaning and sanitizing required.

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Sweet Tomatoes	12/20/2018	**3-501.14 (A) Cooling Cooked Foods -** Cooling cooked TCS foods shall be done within 2 hours from 135ºF to 70ºF and then within 4 hours from 70ºF to 41ºF.	**Kitchen -** A hot holding unit was found unplugged in the back of the kitchen on the shelf which contained tomato sauce and another pan of meatballs. PIC stated she was told to unplug it at 4 o'clock the meatballs and sauce were in the danger zone products discarded tomato sauce was 106°F and meatballs were 110°F.
Briarwood Healthcare Center	1/6/2019	**7-201.11 Storage Separation -** Poisonous or toxic materials shall be stored so they cannot contaminate food, equipment, utensils, linens, and single-service and single use articles.	**Kitchen -** Oven cleaner and other toxic chemicals stored above prep sink and prep table area. Store segregated and away from all food, equipment prep areas.
Mandarin Cuisine	1/19/2019	**3-302.11 (A)(2) Raw Animal Foods Separated from each other** - Except when combined as ingredients, separating types of raw animal foods from each other such as beef, fish, lamb, pork and poultry during storage, preparation, holding, and display by: (a) Using separate equipment for each type, or (b) Arranging each type of food in equipment so that cross contamination of one type with another is prevented and (c) preparing each type of food at different times or in separate areas. **3-501.14 (A) Cooling Cooked Foods -** Cooling cooked TCS foods shall be done within 2 hours from 135ºF to 70ºF and then within 4 hours from 70ºF to 41ºF.	**Kitchen** - Raw chicken stored above RTE foods. This chicken was wrapped in a chef's coat. Removed. Specific discussion w/ PIC on storage segregating product so it is more functional for him. **Kitchen –** Large bulk pans cooked rice cooling improperly Rice was 129°F, 110°F.
Spiga	1/19/2019	**3-501.16 (A)(2) (B) Proper Cold Holding Temps.** - All cold TCS foods shall be held at 41ºF or below. Eggs that have not been treated to destroy all viable Salmonellae shall be stored in refrigerated equipment that maintains an ambient air temperature of 45ºF or less.	**- Kitchen -** Bechamel 54 °F; Fresh fish filets 41 °F; Porcini mushrooms mix 52 °F; Suggest pre-chilling pans in freezer to help in keeping food 41 F or below. Provide a lid or cover for this unit, and the other refrigerator roll top (without the top) in the far corner -COS. Several coddled raw whole shell eggs were observed in a small pan insert in warm water. (This was used for making Carbonara sauce.) The inside is not fully cooked and in the danger zone. Suggest using pasteurized shell eggs.
Masala Art Restaurant	1/19/2019	**3-304.11 Food Contact with Soiled Items 3-302.11 (A)(3) Using clean and sanitized equipment -** Food shall only contact surfaces of: equipment and utensils that are cleaned and sanitized; single-service and single-use articles; or linens, such as cloth napkins that are used to line a container for the service of foods AND are replaced each time the container is refilled for a new consumer.	**Kitchen -**Utensils stored improperly after cleaning and sanitizing above 3-Comp sink.
Tomorrow's Lunch @ WCVB	1/29/2019	**3-501.16 (A)(2) (B) Proper Cold Holding Temps. -** All cold TCS foods shall be held at 41ºF or below. Eggs that have not been treated to destroy all viable Salmonellae shall be stored in refrigerated equipment that maintains an ambient air temperature of 45ºF or less. **3-501.16 (A)(2) (B) Proper Cold Holding Temps. -** All cold TCS foods shall be held at 41ºF or below. Eggs that have not been treated to destroy all viable Salmonellae shall be stored in refrigerated equipment that maintains an ambient air temperature of 45ºF or less.	**Cafeteria -** Fridge is at 46°F. Service is to be done today. Forward receipt of service to Health Div. ASAP. End of service. **Kitchen** - Chickpeas and tuna temps were high. PIC voluntarily discarded.
The James	2/9/2019	**3-301.11 (B) Preventing Contamination from Hands -** Except when washing fruits and vegetables, food employees may not contact exposed, ready-to-eat food with their bare hands and shall use suitable utensils such as deli tissue, spatulas, tongs,	**Kitchen –** Bare hand contact w/ ready to eat food. Product discarded. Train and review with staff.

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		use gloves or dispensing equipment.	
Otrada Adult Day Care	2/16/2019	**3-801.11 (C) Special Requirements (Raw/Partially Cooked RTE) -** - The following foods may not be served or offered for sale in a RTE form: raw animal foods such as raw fish, raw-marinated fish, raw molluscan shellfish, and steak tartare, a partially cooked animal food such as lightly cooked fish, rare meat, soft-cooked eggs that are made from raw eggs, and meringue; and raw seed sprouts. **7-204.11 Sanitizers -** Chemical sanitizers, including chemical sanitizing solutions generated onsite, and other chemical antimicrobials applied to food-contact surfaces shall meet the requirements specified in 40 CFR 180.940. Chemical sanitizers shall not exceed manufacture's label instructions.	**Kitchen -** Cook stated that they provide omelet, sunny side undercooked eggs to adult day care participants. Cease and desist this practice, unless pasteurized shell eggs or pasteurized liquid eggs are used. **Kitchen -** Kitchen chlorine sanitizer in 3 comp sink was in excess of 200 ppm. Discussed w/ chef DeMaris and PIC.
Farmhouse Restaurant	2/16/2019	**3-304.11 Food Contact with Soiled Items -** Food shall only contact surfaces of: equipment and utensils that are cleaned and sanitized; single-service and single-use articles; or linens, such as cloth napkins that are used to line a container for the service of foods AND are replaced each time the container is refilled for a new consumer. **3-501.14 (A) Cooling Cooked Foods -** Cooling cooked TCS foods shall be done within 2 hours from 135ºF to 70ºF and then within 4 hours from 70ºF to 41ºF.	**Kitchen -** Micro greens, towel and other products covered w/ paper towels direct food contact. Discussion with Juan PIC **Kitchen -** Bolognese Sauce 176°F **i**n walk in cooler. COS. Discussion w/ PIC on alternative methods to cool rapidly sautéed mushrooms on service line- cool quickly, keep below rim of food to assist in keeping well chilled.
7-Eleven 36044A (Chestnut Street)	2/21/2019	**3-701.11 Discarding or Reconditioning Unsafe, Adulterated, or Contaminated Food -** A food that is unsafe, adulterated, or not honestly presented as specified shall be discarded or reconditioned. Food that is not from an approved source shall be discarded. RTE food that may have been contaminated by an employee who has been restricted or excluded shall be discarded. Food that is contaminated by food employees, consumers, or other persons through contact with their hands, bodily discharges, such as nasal or oral discharges, or other means shall be discarded.	**Store -** Box of Cinnamon Toast Crunch was ripped into. Discarded by PIC.
Volante Farms	2/22/2019	**3-501.16 (A)(2) (B) Proper Cold Holding Temps. -** All cold TCS foods shall be held at 41ºF or below. Eggs that have not been treated to destroy all viable Salmonellae shall be stored in refrigerated equipment that maintains an ambient air temperature of 45ºF or less. **3-501.15 (A) Cooling Methods -** - Cooling shall be accomplished in accordance with the time and temperature criteria specified under 3-501.14 by	**Store -** "From Our Kitchen" reach-in unit was observed at 46° F. May be on defrost. **Basement -** Employees were not able to report definite time when soups were added into fridge. In ice bath but still above 41°F. Recommend cooling and keeping a log

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		one or more of the following: placing food in shallow pans; separating the food into smaller or thinner portions; using rapid cooling equipment; stirring the food in a container placed in an ice water bath; using containers that facilitate heat transfer; adding ice or other effective methods.	
New Garden	3/2/2019	**3-304.11 Food Contact with Soiled Items -** Food shall only contact surfaces of: equipment and utensils that are cleaned and sanitized; single-service and single-use articles; or linens, such as cloth napkins that are used to line a container for the service of foods AND are replaced each time the container is refilled for a new consumer. **3-302.11 (A)(2) Raw Animal Foods Separated from each other -** Except when combined as ingredients, separating types of raw animal foods from each other such as beef, fish, lamb, pork and poultry during storage, preparation, holding, and display by: (a) Using separate equipment for each type, or (b) Arranging each type of food in equipment so that cross contamination of one type with another is prevented and (c) preparing each type of food at different times or in separate areas.	**Kitchen -** Raw TCS foods fish stored layered with paper towel. Paper towel is not food grade. Use approved food grade **s**torage only. **Kitchen -** TCS foods stored improperly in walk in Cooler. Raw chicken stored above raw pork and large buckets of cabbage/ vegetables were on lower shelf. Smaller prepared TCS animal foods were all stored on the same shelf in the walk-in without segregation. Store all TCS foods separated and segregated to prevent cross contamination-Provide proper and organized food storage plan within 3 days or less.
Sudbury Farms	3/15/2019	**3-202.11 (A)(C)(D) Temperature -** TCS food shall be at a temperature of 41°F or below when received. Raw eggs shall be received in refrigerated equipment that maintains an ambient air temperature of 45°F or less. TCS food that is cooked to a proper temperature and received hot shall be at a temperature of 135°F or above. **4-703.11 Methods-Hot Water and Chemical-** After being cleaned, equipment food-contact surfaces and utensils shall be sanitized in: hot water manual operations for at least 30 seconds; hot water mechanical achieving surface temperature of 160°F as measured by an irreversible registering temperature indicator; or chemical (manual or mechanical) for times specified the EPA-registered label use instructions.	**Kitchen -** Two lobster tails on table at room temp 60F. Product discarded **Kitchen -** The 3 comp sinks in the meat room and prep area in the basement were not set up properly. The middle rinse sink was used as a wash/ soap sink without a clear clean water rinse prior to sanitizing. Sinks were not labeled properly - Wash/ rinse/ sanitize. Provide additional training and proper signage.
Acapulcos	3/23/2019	**3-501.14 (A) Cooling Cooked Foods -** Cooling cooked TCS foods shall be done within 2 hours from 135ºF to 70ºF and then within 4 hours from 70ºF to 41ºF.	**Kitchen -**Bulk Sauces cooling improperly on counter. Cool properly. Enchilada sauce was 185F+ PIC stated they were made 1.5 hours ago.
Cookies by Design	3/27/2019	**3-301.11 (B) Preventing Contamination from Hands -** Except when washing fruits and vegetables, food employees may not contact exposed, ready-to-eat food with their bare hands and shall use suitable utensils such as deli tissue, spatulas, tongs, single-use gloves or dispensing equipment.	**Kitchen -**No gloves on site. Employees observed working with cookies without any gloves. Hand washing was noted.
Fuji Steakhouse	4/6/2019	**3-304.11 Food Contact with Soiled Items -** Food shall only contact surfaces of: equipment and utensils that are cleaned and sanitized; single-service and single-use articles; or linens, such as cloth	**Walk in freezer-** Frozen salmon stored inside a previously used raw chicken box. These are considered single use only and should not be used for food storage. Provide proper storage food grade containers

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		napkins that are used to line a container for the service of foods AND are replaced each time the container is refilled for a new consumer. **3-304.11 Food Contact with Soiled Items** - Food shall only contact surfaces of: equipment and utensils that are cleaned and sanitized; single-service and single-use articles; or linens, such as cloth napkins that are used to line a container for the service of foods AND are replaced each time the container is refilled for a new consumer. **3-302.11 (A)(2) Raw Animal Foods Separated from each other -** Except when combined as ingredients, separating types of raw animal foods from each other such as beef, fish, lamb, pork and poultry during storage, preparation, holding, and display by: (a) Using separate equipment for each type, or (b) Arranging each type of food in equipment so that cross contamination of one type with another is prevented and (c) preparing each type of food at different times or in separate areas.	**Kitchen -** Side towels are used to cover food products and as absorbable cloths for eggrolls Use food grade materials only. Discussed w PIC recommendations. **Kitchen -** Raw cutlets of Pork, salmon, pork and chicken were all stored in the same container on service line. Store all TCS foods separated and segregated to prevent cross contamination
Gyro and Kebab House	4/8/2019	**3-302.11 (A)(1) Raw Animal Foods Separated from RTE -** Food shall be protected from cross-contamination by: (1) Separating raw animal foods during storage preparation, holding and display from: (a) Raw RTE food including other raw animal food such as fish for sushi or molluscan shellfish or other raw RTE food such as fruits and vegetables, and (b) cooked RTE food. **7-201.11 Storage Separation -** - Poisonous or toxic materials shall be stored so they cannot contaminate food, equipment, utensils, linens, and single service and single use articles.	**Kitchen -** **Pr** Raw meat stored above hummus. Corrected on site - **Basement -** Paint and varnish seen next to catering pans. Chemical cleaners stored near food and food equipment. All food must be stored together away from all chemicals. Chemicals should be put on designated shelf.
Gari Restaurant	4/15/2019	**3-304.11 Food Contact with Soiled Items -** Food shall only contact surfaces of: equipment and utensils that are cleaned and sanitized; single-service and single-use articles; or linens, such as cloth napkins that are used to line a container for the service of foods AND are replaced each time the container is refilled for a new consumer. **3-304.11 Food Contact with Soiled Items -** Food shall only contact surfaces of: equipment and utensils that are cleaned and sanitized; single-service and single-use articles; or linens, such as cloth napkins that are used to line a container for the service of foods AND are replaced each time the container is refilled for a new consumer.	**Kitchen -** Raw pork was stored with raw chicken in walk in cooler. The raw chicken was exposed. Product discarded. Store TCS food separated and segregated. Train staff on proper food storage **Kitchen -** Paper towels used for hand drying were used to wrap Raw sushi fish, and other food items. Wrap and store with food grade products only such as pvc film,foil,food grade tissue and similar. Discussion with PIC

Olin College	4/18/2019	**4-602.11 (A) Food-Contact Surfaces and Utensils 4-602.11 (E)(1-3) Food-Contact Surfaces and Utensils -** Equipment food-contact surfaces and utensils shall be cleaned: before each use with a different type of raw animal food such as beef, fish, lamb, pork, or poultry; each time there is a change from working with raw foods to working with RTE foods; between uses with raw fruits and vegetables and with TCS food; before using or storing a food temperature measuring device; and any time during the operation when contamination may have occurred.	**1st Floor Kitchen -** Ice machine to clean out.
Avita of Needham	4/20/2019	**2-301.11 Clean Condition -** Food employees shall keep their hands and exposed portions of their arms clean.	**Kitchen -** Cook observed with uncovered/unprotected burn/ cut on lower forearms. Gloves did not cover. Protect this area.
Baker's Best	4/27/2019	**3-302.11 (A)(2) Raw Animal Foods Separated from each other** Except when combined as ingredients, separating types of raw animal foods from each other such as beef, fish, lamb, pork and poultry during storage, preparation, holding, and display by: (a) Using separate equipment for each type, or (b) Arranging each type of food in equipment so that cross contamination of one type with another is prevented and (c) preparing each type of food at different times or in separate areas.	**Kitchen -** Raw chicken breasts in walk-in were stored above cooked chicken breasts, and above rare beef cubes on sheet pans. COS
Fresco	5/4/2019	**3-501.16 (A)(1) Proper Hot Holding Temps.** All hot TCS foods shall be held at 135ºF or above except roasts cooked to a temperature and time as specified in 3 403.11 (B).	**Kitchen -** Hollandaise sauce made with raw eggs @127F. Was held at room temp on top of service line. PIC stated that it was made at 730am. Product discarded. Discussion with PIC to make batches more frequently to hold less than 4 hours, alternatives to use pasteurized eggs, or hot hold in water bath@135f or higher. Keep out of danger zone 40-135f
The Rice Barn	5/11/19	**4-501.111 Manual Warewashing - Sanitization Water Temp 4-501.112 Mechanical Warewashing - Sanitization Water Temp -** If immersion in hot water is used for sanitizing in a manual operation, the temperature of the water shall be maintained at 171°F or above. **3-501.14 (A) Cooling Cooked Foods -** - Cooling cooked TCS foods shall be done within 2 hours from 135ºF to 70ºF and then within 4 hours from 70ºF to 41ºF. **7-301.11 Separation -** Poisonous or toxic materials shall be stored so they cannot contaminate food, equipment, utensils, linens, and single service and single-use articles by separating these materials by spacing or partitioning, and locating these materials in an area that is not above food, equipment, utensils, linens and single-service/ single-use	**Kitchen -** It was observed that female cook did not sanitize equipment properly in the 3 compartment sink. She rinsed in in water from faucet, did not properly wash rinse or sanitize to prevent contamination. **Kitchen -** Basement -Observed 3 metal containers of sauce/ liquid cooling improperly **Kitchen -** Cleaning chemical spray bottle stored where cooked rice is located Butane torch stored on top of refrigerator next to food equipment storage shelf

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Otrada	6/1/2019	**MA 590.003 (C) FC 3-301.11 (B) - Preventing Contamination from Hands 6-301.11 Hand Cleanser Available** - Except when washing fruits and vegetables, food employees may not contact exposed, RTE food with their bare hands and shall use suitable utensils such as deli tissue, spatulas, tongs, single-use gloves, or dispensing equipment. Single use natural rubber latex gloves are not recommended for food contact in food establishments.	**Kitchen -** Hand soap empty
Wingate at Needham	6/8/19	**3-501.14 (A) Cooling Cooked Foods -** Cooling cooked TCS foods shall be done within 2 hours from 135ºF to 70ºF and then within 4 hours from 70ºF to 41º	**Kitchen -** Rice wrapping and cooling improperly @121f**;** Meatballs wrapped and cooling improperly 157f; Beef Gravy 143; Discussion with PIC on proper cooling
Spiga	6/22/2019	**8-103.12 Conformation with Approved Procedures/HACCP -** - If the RA grants a variance or a HACCP plan is otherwise required, the permit holder shall comply with the HACCP plans and procedures that are submitted and approved as a basis for the modification or waiver **3-501.15 (A) Cooling Methods -** Cooling shall be accomplished in accordance with the time and temperature criteria specified under 3-501-14 by using one or more of the following: placing food in shallow pans; separating the food into smaller or thinner portions; using rapid cooling equipment; stirring the food in a container placed in an ice water bath; using containers that facilitate heat transfer; adding ice or other effective methods.	**Kitchen -** Non-conformance with establish variance for sous vide cooking temperature logs incorrect and missing data hot water bath was required per Board of Health to be 160° but the hot water bath was in actually 145° proper internal temperatures of product was not charted. Datemarking of product in walk in non existent. Provide datemarking. discussion with PIC on adding additional columns of the existing chart to make it easily understood to be in compliance. **Kitchen -** A porcini sauce was cooling improperly at room temp. Temp was 100F. Chef stated it was placed in container at approx 2.5 hours earlier. Product reheated to 165f reconditioned and cooler in ice bath
Sweet Tomatoes	6/27/2019	**3-501.16 (A)(2) (B) Proper Cold Holding Temps. -** All cold TCS foods shall be held at 41ºF or below. Eggs that have not been treated to destroy all viable Salmonellae shall be stored in refrigerated equipment that maintains an ambient air temperature of 45ºF or less.	**Kitchen -** Pizza prep unit in front was at 44° F. Maintenance to be performed later today. Send receipt
Three Squares Restaurant	6/29/2019	**4-703.11 Methods-Hot Water and Chemical 4-501.113 Warewasher - Sanitization Pressure –** The flow pressure of the fresh hot water sanitizing rinse in a warewashing machine, as measured in the water line immediately downstream or upstream from the fresh hot water sanitizing rinse control value, shall be within the range specified on the machine manufacturer's data plate and may not be less than 5 psi or more than 30 psi. **3-501.14 (B) Cooling TCS Ingredients at Ambient Temperature -** TCS foods shall be cooled within 4 hours to 41ºF or less if prepared from ingredients at ambient temperatures, such as reconstituted foods and canned tuna.	**Kitchen -**There was no sanitizer solution for the mechanical dishmachine. The bucket was empty, and Equipment and utensils that had been washed for not being sanitize properly the dish machine operation was seized and in employee went to restaurant depot to purchase a new supply during the inspection equipment and utensils plates and flatware must be washed and sanitize properly to prevent contamination **Kitchen -** Egg wash for French Toast was stored near the hot grill and was 76f. The pan was stored in a double pan insert without ice. Only water remained. Product discarded
Blue on Highland	6/29/2019	**3-302.11 (A)(1) Raw Animal Foods Separated from RTE -** Food shall be protected from cross-contamination by: (1) Separating raw animal foods during storage preparation, holding and display from: (a) Raw RTE food including other raw a	**Kitchen -**Raw chicken breast piccata at sauce prep area stored above RTE. Raw chicken should be stored on lower shelf below all ready to eat foods.

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		food such as fish for sushi or molluscan shellfish or other raw RTE food such as fruits and vegetables, and (b) cooked RTE food.	
		3-403.11 (A)(D) Reheating for Hot Holding Potentially hazardous foods that are being reheated for hot holding shall be reheated so that all parts of the food reach a temperature of at least 165ºF for 15 seconds and shall be done rapidly – within two hours.	**Kitchen -** Sweet mashed potato on service line range 90f-120f. Remove product and reheat and hold at 135f or higher - COS.
		3-501.14 (B) Cooling TCS Ingredients at Ambient Temperature - TCS foods shall be cooled within 4 hours to 41ºF or less if prepared from ingredients at ambient temperatures, such as reconstituted foods and canned tuna.	**Kitchen -** Buttermilk for dredging breaded product at room temp 76F Product discarded. Maintain all TCS food at 41°F or below at all times
		3-501.16 (A)(1) Proper Hot Holding Temps. - All hot TCS foods shall be held at 135ºF or above except roasts cooked to a temperature and time as specified in 3-403.11 (B).	**Kitchen -** Whole muscle intact roast beef was in the alto sham oven hot holding at 130°F. The internal temperature of the rare beef was 115°F registered by digital thermometer. The ambient temperature was 122°F as registered by an infrared thermometer. Hot hold at 135F or higher to reduce bacteria growth.

Town of Needham Food Establishment Risk Factor Study

July 12, 2019

Tara Gurge, *Assistant Director of Public Health*
Diana Acosta, *Environmental Health Agent*
Pamela Ross-King, *Project Consultant*
Stephanie Argetsinger, *2018 Intern*
Michelle Iovino, *2019 Intern*

Background

The duty of public health is to prevent disease and promote the health and well-being of the community. One significant responsibility is to continuously monitor and improve food safety throughout public food establishments. There are over 250 identified foodborne diseases that can contribute to a variety of illnesses, from minor to severe symptoms. It is estimated that 48 million individuals get sick, 128,000 are hospitalized, and 3,000 die each year as a result.[1]There are many ways food can be contaminated or compromised, therefore identifying direct causes and prevention methods is not any easy task. Many factors of potential risk must be evaluated and continuously enhanced in order to stay on top of food safety.

The Town of Needham has a population of over 30,000 and 121 annual food permits. Needham joined the U.S. Food and Drug Administration's (FDA) Voluntary National Retail Food Regulatory Program Standards in 2017. The standards include nine areas of focus to achieve uniformity among state and local governments regarding food safety. Needham subsequently received a grant for assistance in completing Standard 9, Program Assessment, in order to analyze and reduce risk factors that contribute to foodborne illness. The five major risk factors include Poor Personal Hygiene, Contaminated Equipment, Improper Holding Temperatures, Improper Cooking Temperatures, and Unsafe Food Sources.[2]

The FDA designed the five risk factor categories in 1998 as a performance indicator of food safety. At the time, there was no national standard reporting structure since foodborne illnesses often went underreported. The measureable retail food program goal was then to reduce the occurrence of these factors. The project was a three phase, ten year study to determine baseline conditions nationally. Data was collected every five years, in 1998, 2003, and 2008.[3] In 2013, the study was renewed and updated for another cycle, and converted into guidelines for local jurisdictions to conduct their own.[4]

Needham's risk factor survey was conducted by a consultant in 2018 in 85 randomly selected food establishments to determine town baseline conditions. Data was then analyzed, and in 2019, focused interventions began. The ongoing interventions aim to reduce the risk of foodborne illness and increase food safety in both the establishments, and the risk factor areas, that were determined the most out of compliance.

Methods

Data collection tools were designed using assessment criteria based on FDA data collection protocols.[5,6] Four different standardized surveys were used representing types of facilities:

Restaurants, Healthcare Facilities, Schools, and Retail Food Stores. The following steps were implemented to calculate the participating establishments and their category:

1. A list of all food establishment licensees was printed from the town food database with their assigned risk level. All risk level 1's, temporary or mobile licensees, and inapplicable locations, were removed from the list. A total of 93 establishments were then eligible for the study.
2. An additional column was added to the updated list assigning the type of establishment: Retail Deli, Retail Produce, Retail, Seafood, Fast Food Restaurant, Full-Service Restaurant, Hospital, Long-Term Care, or School *(Table 1).*

Food Establishment	**Count**
Retail Deli	4
Fast Food Restaurant	37
Full Service Restaurant	23
Hospital	1
Long-Term Care	11
Retail Produce	3
School	11
Retail Seafood	3
Grand Total	**93**

Table 1. *Eligible Town of Needham establishment list based by type*

3. The minimum sample size for each category was calculated using a 95% confidence interval with a 5% margin of error, estimating a total of 88 establishments needed (Table 2). Some individual sample sizes were not possible to meet because of Needham's existing facilities, including a lack of Healthcare Facilities, Schools, and Retail Produce than suggested.

Food Establishment	**CI 95% 5% ME**
Retail Deli	4
Fast Food Restaurant	30
Full Service Restaurant	21
Long-Term Care	13
Retail Produce	4
Schools	14
Retail Seafood	2
Total	**88**

Table 2. *Calculation for study sample size*

4. In some categories, all establishments were automatically selected for the study. For restaurants, establishments were placed in a spreadsheet with sequential numbers assigned to each. Using an online program to select random numbers,[7] restaurants were then selected for participation in the study.

5. The final sample size for the study was set at 85 establishments *(Table 3).* These categories were then broadened into the four types of surveys *(Table 4).*

Food Establishment	Sample Size
Retail Deli	4
Fast Food Restaurant	33
Full Service Restaurant	22
Hospital	1
Long-Term Care	8
Retail Produce	3
School	11
Retail Seafood	3
Total	**85**

Table 3. *Number of establishments selected from each establishment type*

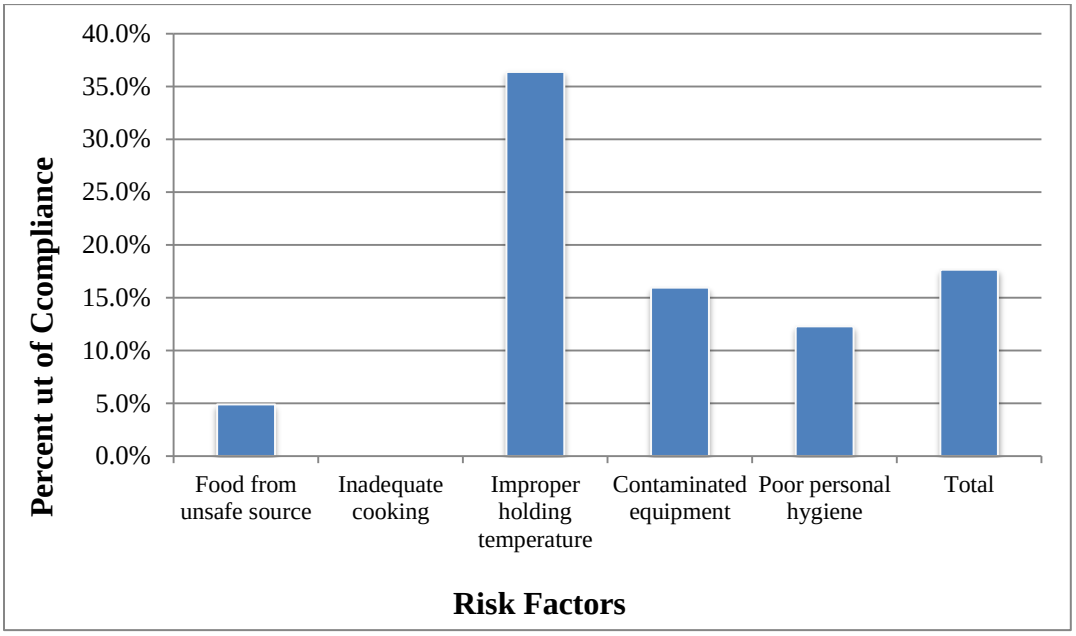
Survey Categories	Number of Establishments
Retail Food Store	10
Restaurant	55
Healthcare Facility	9
School	11
Total	**85**

Table 4. *Number of establishments selected in each survey category*

Selected establishments were sent a letter on April 9, 2018 describing their participation in the risk factor study and alerting them of a future unannounced visit. Visits took place from May 17, 2018 to November 7, 2018, and the data was then analyzed using the FoodSHIELD online system.[8]

Results

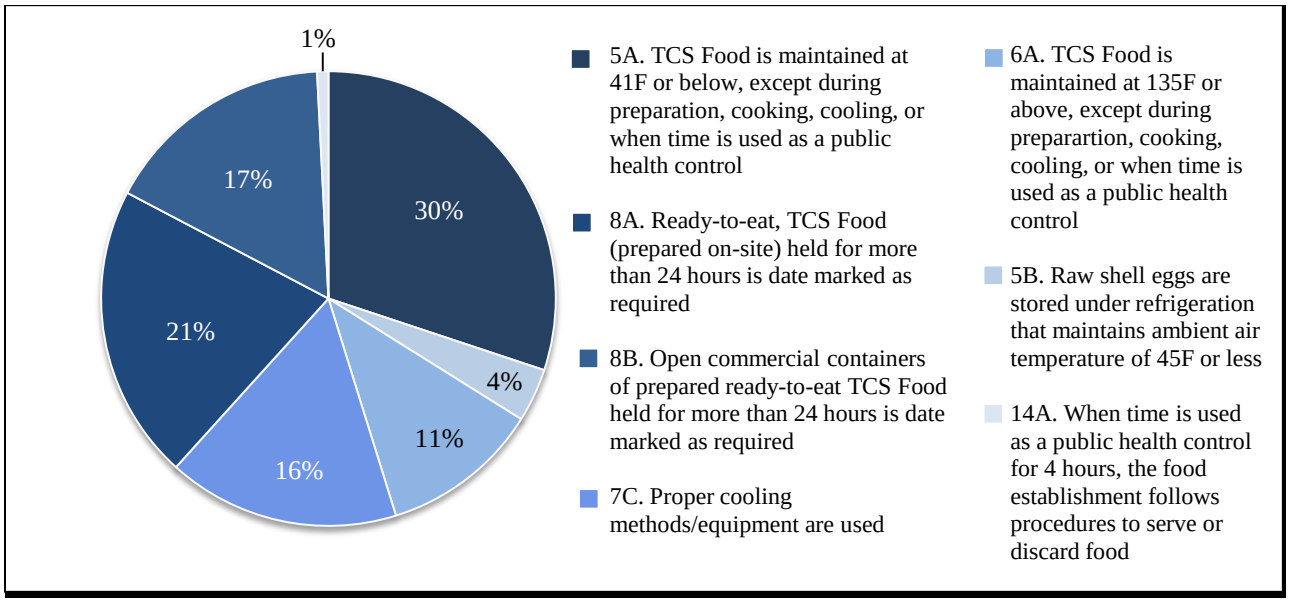
Of the five risk factors, 36.4% of establishments were out of compliance with Improper Holding Temperatures, 12.3% with Poor Personal Hygiene, 15.9% with Contaminated Equipment, and 4.9% with Food from Unsafe Sources. None of the food establishments were out of compliance with Improper Cooking Temperatures *(Graph 1).*



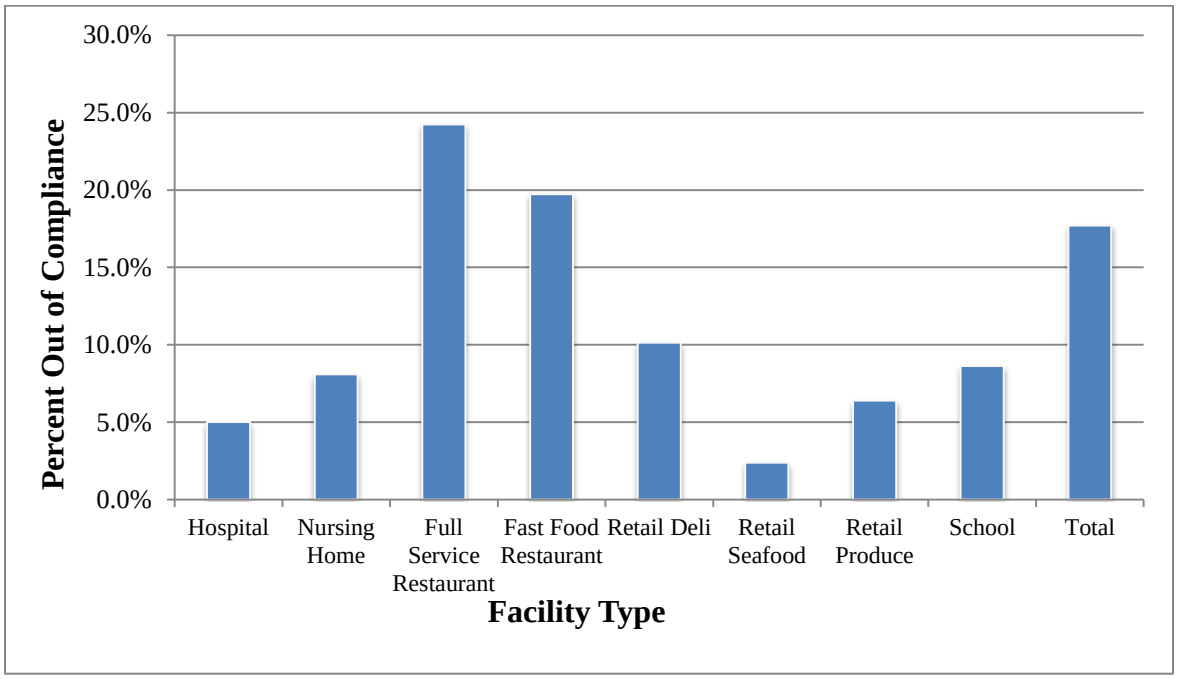
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Graph 1. *Percent out of compliance by risk factor*

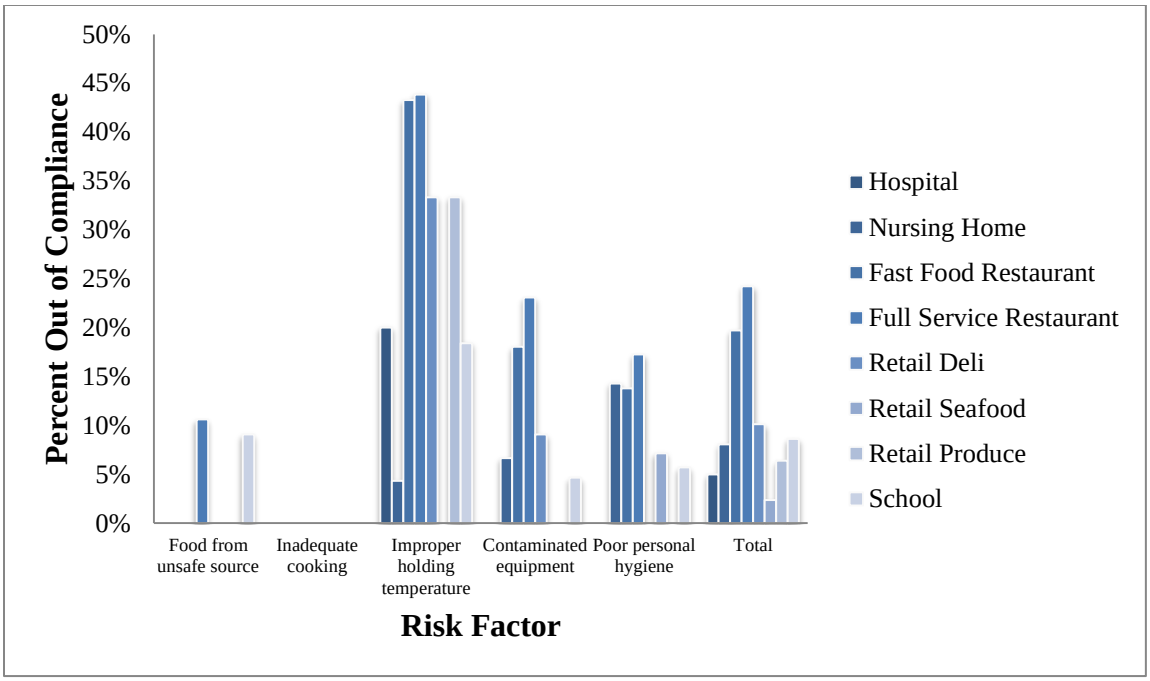
Regarding improper holding temperature, the most common individual survey items that were out of compliance were improper cold holding, date marking, and cooling methods *(Graph 2).* For all food establishments, full service restaurants were out of compliance the most, and retail seafood the least *(Graph 3).*



Graph 2. *Improper Holding Temperature out of compliance composition*



Graph 3. *Percent out of compliance by facility type*



Graph 4. *Percent out of compliance by risk factor and facility type*

Besides the five main areas of focus within the study, additional areas of potential interest were evaluated. These areas include handwashing, advisories, adequate equipment, time as a public health control, and HACCP Plans. The most significant areas of concern are shown in Table 5, with multiple categories containing roughly half of establishments in compliance.

Other Items of Interest	Percent Out of Compliance
13. Consumers are properly advised of risks of consuming raw or undercooked animal foods	**50.0%**
15A. Refrigeration/cold holding units have sufficient capacity to maintain TCS Foods at 41F or below	**14.1%**
15C. Refrigeration and hot storage units are equipped with accurate ambient air temperature measuring device	**5.1%**
15D. Accurate temperature measuring device is provided and accessible for use to measure internal food temperatures	**24.4%**
15E. Accurate temperature measuring devices and/or test kits provided and accessible for use to measure sanitization rinse temperatures and/or sanitization concentrations	**43.6%**
18A. Poisonous or toxic material,	**16.7%**

chemicals, lubricants, pesticides, medicines and other personal care items are properly stored and used	
19A. The person in charge accurately describes foods identified as major food allergens and the symptoms associated with major food allergens	**42.3%**
19B. Food employees are trained in food allergy awareness as it relates to their assigned duties	**32.1%**

Table 5. *Other out of compliance data items of interest*

Intervention

The intervention component of Standard 9 began in 2019. Most interventions focused on the most out of compliance risk factors. The three main areas of intervention include trainings, consulting, and communication strategies.

1. Trainings
    a. Three educational trainings took place in April as a mandatory requirement for establishment representatives. The trainings were conducted by a food consultant to present information from the risk factor data, and go over procedures for increasing food safety. The topics were personalized to Needham's area of concerns.
    b. 101 representatives attended the trainings. In a survey given out at the end, 92% of attendees stated the program met their expectations, 70% said their knowledge of foodborne illness risk factors increased, and 91% said they are more confident to prevent these risk factors in the future.

2. Individual Consulting
    a. 25 out of the original 85 establishments were selected to participate in personalized visits. Establishments encouraged to participate saw more than six violations on their risk factor survey. These visits are scheduled from July to October, focusing on previously out of compliance risk factors and hands-on trainings to improve food safety outcomes.
    b. After each visit, materials are sent to Needham Public Health Division regarding their new procedures and plans to increase food safety. The evaluations from these visits, as well as future inspection reports, are expected to highlight and increase compliance.
    c. So far, 22 establishments are scheduled to participate. Three places have since closed.

3. Communication Strategies
    a. In collaboration with Standard 7, Industry and Community Relations, educational outreach has increased on the topics of food safety specific to Needham. Activities include a food advisory board to be conducted in Fall 2019 that combines industry, consumers, and establishments to meet regularly on food-

related topics. Educational material has also improved, including social media posts, a packet of informational posters, and an increased presence in food-related events. The aim is to be more transparent and accessible to all parts of the community, and engage in more conversations regarding food safety.

Discussion

Overall, Needham saw a total of 17.6% out of compliance across all risk factors. This percentage proves that even if there are some continuous concerns within the town, the majority of food safety practices have been met. The study was limited regarding category sample size, as there are not an equal number of facilities. There are over five times the amounts of restaurants than schools, retail, or healthcare facilities. Restaurants may have seen a larger amount of violations on average as a result of a higher frequencies in exposure.

Compared to FDA's most recent baseline foodborne illness risk factor survey conducted in 2013 and 2014,[9] Needham's out of compliance for both fast food and full-service restaurants were 40% lower on average. Improper holding temperature was the highest out of compliance risk factor in both studies, and inadequate cooking the least. This data demonstrates that Needham is well above the national average regarding food safety; however see similar difficulties across the board.

The highest errors of concern came from other areas of interest, not directly related to the five risk factors. This data is significant for Needham's intervention purposes, as more attention may need to be given to areas not normally focused on. Needham will continue to work directly with individual establishments and their concerns, as well as overall community awareness to the issue of food safety. The goal is to see a reduction in out of compliance risk factors during the next survey cycle, estimated every five years, in 2023.

References

1. Centers for Disease Control and Prevention. *Causes of Food Poisoning.* https://www.cdc.gov/foodsafety/foodborne-germs.html. Updated February 16, 2018.

2. Centers for Disease Control and Prevention. *CDC Surveillance Summaries*, October 25, 1996. MMWR 1996;45(No. SS-5).

3. Food and Drug Administration. *FDA Trend Analysis Report on the Occurrence of Foodborne Illness Risk Factors in Selected Institutional Foodservice, Restaurant, and Retail Food Store Facility Types (1998-2008).* https://wayback.archive-it.org/7993/20170113095247/http://www.fda.gov/downloads/Food/GuidanceRegulation/RetailFoodProtection/FoodborneIllnessRiskFactorReduction/UCM369245.pdf. Published October, 2010.
4. Food and Drug Administration. *Retail Food Risk Factor Study.* https://www.fda.gov/food/retail-food-protection/retail-food-risk-factor-study. Updated December 6, 2017.

5. Food and Drug Administration. *Study on the Occurrence of Foodborne Illness Risk Factors in Selected Retail and Foodservice Facility Types (2013-2024): Protocol for the Data Collection.* https://www.fda.gov/media/98224/download. Updated April 28, 2015.

6. Food and Drug Administration. *Marking Instructions for the Data Collection Form.* https://www.fda.gov/media/98232/download. Published June 6, 2016.

7. Research Randomizer. https://www.randomizer.org. Updated 2015. Accessed 2018.

8. FoodSHEILD. https://www.retailfoodriskfactorstudy.net. Updated 2017. Accessed 2018.

9. Food and Drug Administration. *FDA Report on the Occurrence of Foodborne Illness Risk Factors in Fast Food and Full-Service Restaurants, 2013-2014.* College Park, MD: 2018.

You are invited to be a

Nourishing Needham

restaurant providing healthy menu items.



For questions or additional information please contact:

Stephanie McCulloch
Food Security Intern
smcculloch@needhamma.gov

or

Tara Gurge
Assistant Director
(781) 455-7940 ext. 211
tgurge@needhamma.gov

Needham Public Health
Prevent. Promote. Protect.

Nourishing Needham

Date

Dear Restaurant Owner/Manager,

In an effort to make Needham a healthier community, the Needham Public Health Division is launching the Nourishing Needham healthy eating week in collaboration with local restaurants and food establishments. The initiative's main goal is to raise awareness about healthy eating and to improve access to healthier foods in our community. As more and more people spend their food dollars away from home, it is important for people to have healthier options even when eating out.

Nourishing Needham is a voluntary week-long recognition program taking place **September 21st through the 29th** that offers some impressive benefits. To become a Nourishing Needham partner, a restaurant has to meet the following criteria:

- Provide at least two menu items that meet specific "nutrition" criteria.
- If applicable, provide at least one children's menu item that meet specific "nutrition" criteria. The criteria for recognition are included with this letter.

Nourishing Needham partners will receive publicity highlighting their efforts to provide healthy, great tasting food as well as in-store promotional items. Promotion may include:

- FREE artwork for use in advertising
- FREE link from the Nourishing Needham website to your website
- Advertising opportunities such as television, news print and social media
- Opportunities to be recognized at community and health focused events
- A plaque
- Window clings
- Table tents
- Menu inserts showcasing those items that meet Nourishing Needham criteria

Please let us know if you would like to participate in the Nourishing Needham week. Thank you for helping Needham residents and visitors live healthier lifestyles. Please call 781-455-7940 with any questions or for more information.

Sincerely,

Stephanie McCulloch
Food Security Intern
Needham Public Health Division

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Nourishing Needham Restaurants must serve at least two healthy menu options that meet the following nutrition criteria.

Entrees (or full meals) must include one of the following:

- Lean proteins (i.e. chicken, fish, tofu, beans)
- Small amounts of heart healthy fats/dressings
- 100% whole grains (i.e. breads, brown rice, oats, quinoa)
- Unsweetened or low fat dairy
- At least one serving of fruit or vegetable

None of the food items may be deep fried.









Nourishing Needham Restaurant Application

Please provide the following information:

Name of Establishment: _____

Type of Establishment (e.g., restaurant, fast food, café, etc.):

_____

Type of Food Served (e.g.: Asian, American, Italian, Subs, etc.):

_____

Address: _____

Hours of Operation: _____ Phone _____

Contact Name: _____

Contact E-mail: _____

Website: _____

Healthy Restaurant Criteria
Please check the appropriate box with an "X"

1.	Do all menu items have 0 grams of trans fat per serving?	☐ Yes	☐ No	
2.	Do you offer at least 2 menu items that you think meet the Nourishing Needham criteria?	☐ Yes	☐ No	
3.	Does your establishment currently have nutrition information available to patrons?	☐ Yes	☐ No	
4.	Does your establishment offer smaller portion sizes upon request?	☐ Yes	☐ No	

Please return your completed application with the partnership agreement to:

Needham Public Health Division
Rosemary Recreation Complex
178 Rosemary Street
Needham, MA 02494

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Nourishing Needham

This restaurant offers Nourishing Needham Restaurant menu items.

Menu Item					
Lean Proteins (if applicable)					
Whole grains (if applicable)					
Dairy (if applicable)					
Fruit/vegetable (if applicable)					

Nourishing Needham Restaurant Nutrition Criteria

Entrees (or full meals) must include one of the following:

- Lean proteins (i.e. chicken, fish, tofu, beans)
- Small amounts of heart healthy fats/dressings
- 100% whole grains (i.e. breads, brown rice, oats, quinoa
- Unsweetened or low fat dairy
- At least one serving of fruit or vegetable

None of the food items may be deep fried.



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Nourishing Needham

Nourishing Needham Partnership Agreement

Congratulations on becoming a Nourishing Needham Restaurant: To complete your establishment's enrollment in the program, we are asking for a completed Partnership Agreement. The agreement outlines key provisions of the program and the responsibilities of each party.

I _____, representing _____ agree to thee following statements:

I understand that the Nourishing Needham healthy eating week encourages establishments to take proactive and voluntary measures to promote healthy eating and healthy foods.

As a Nourishing Needham Restaurant, **I agree to:**

- Post Nourishing Needham promotional materials in prominent places
- Provide nutritional information and/or recipes for qualifying menu options to the Needham Public Health Division
- Allow the Nourishing Needham initiative to use the name of my business in their promotion of the healthy eating week
- Notify the Needham Public Health Division if changes are made prior to the start of the healthy eating week to the Nourishing Needham menu items
- Work with the Nourishing Needham Restaurant staff members to identify additional menu items that may meet the "nutrition" criteria
- Complete an evaluation and provide any relevant data to the health department as available
- Make the patron survey available to customers and return completed surveys to the Nourishing Needham program

As a Nourishing Needham Restaurant, I understand that the **Needham Pubic Health Division will:**

- Provide in-store promotional items, including table tents, a certificate and menu inserts
- Provide nutrition analysis of menus submitted to be certified as Nourishing Needham
- List my establishment on the Nourishing Needham website, including a link to the restaurant website
- Provide patron surveys
- Share information collected through program evaluation
- Provide suggestions for making menu items meet the program criteria
- Highlight my establishment at community events

Thank you for your commitment to making Needham residents healthier.

_____ _____

Restaurant Representative Signature Date

_____ _____

Needham Health Division Signature Date

Nourishing Needham

Nourishing Needham Survey for Restaurants

Restaurant Name: _____

Person completing the survey: _____

Position: _____

Phone: _____ Email: _____

1. On a scale of 1 to 10, 1 being very easy to 10 being very difficult, how easy was the application to complete? Please circle one.

   1 2 3 4 5 6 7 8 9 10

2. How did you hear about the program?
   _____

3. How can the application process be made easier?
   _____

4. Has there been an increase in customers over the course of the Nourishing Needham week?
   _____

5. Has there been an increase in the number of people ordering your healthy options?
   _____

6. Have you added additional healthy menu items since participating in Nourishing Needham?
   _____

7. Would you consider adding more healthy options?
   _____

8. Did you advertise your Nourishing Needham status? If so, where?
   _____

9. Please share any other comments or suggestions about the week:
   _____
   _____
   _____
   _____
   _____
   _____
   _____
   _____

Nourishing Needham

Nourishing Needham Survey for Patrons

1. Why did you choose this restaurant today? Choose all that apply.

   ☐ Type of food
   ☐ Cleanliness
   ☐ Convenience
   ☐ Service
   ☐ Healthy options
   ☐ Other _____

2. How did you find out about this restaurant? Choose all that apply.

   ☐ Advertisement
   ☐ Website
   ☐ Other _____
   ☐ Word of mouth
   ☐ Nourishing Needham information/website

3. Does it matter that there are healthy choices available?

   ☐ Yes
   ☐ No

4. Would you a little more if you knew the food was certified healthy?

   ☐ Yes
   ☐ No

5. Will you visit this restaurant again?

   ☐ Yes
   ☐ No

6. Please share any other additional comments about the Nourishing Needham week:

   _____
   _____
   _____
   _____
   _____
   _____
   _____

Restaurant: _____

Location: _____

Tips for the Farmers Market

- Bring your own reusable bags.
- Dress for the weather. Don't forget your sunblock, hat, or umbrella.
- Come early to get the freshest produce and best selection
- Don't be afraid to ask questions. Most vendors are happy to tell you about what they're selling.
- Learn about growing seasons so you'll know in advance what should be available at the market.
- Don't be afraid to try new things!



Do you need a permit to sell at a Farmers Market?

You **do not need** a permit from the Needham Public Health Division if you are selling unprocessed foods, such as uncut fruits and vegetables.

You do **need** a food permit from the Public Health Division if you are selling processed, potentially hazardous foods, such as: meat products, dairy, seafood, cooked vegetables, canned foods (including jams and jellies), baked goods, nuts, or salsa.



Contact Information

For more information about food safety or farmers markets permitting, go to:
http://needhamma.gov/index.aspx?NID=377

Or contact:
Needham's Environmental Health Agent:
Diana Acosta
781-455-7940 ext. 220
dacosta@needhamma.gov

Needham Public Health
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Needham Farmers Market



Pocket Guide

Needham Public Health Division
Prevent. Promote. Protect.

Rosemary Recreation Complex
178 Rosemary Street
Needham, MA 02494

Tips for the Farmers Market

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Needham Farmers Market



Pocket Guide

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Rosemary Recreation Complex
178 Rosemary Street
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Food Safety

- Thoroughly wash all produce before eating.
- Check that meat and dairy products are kept cold in a cooler or refrigerator and are from an approved source before buying.
- Place meats and produce in separate bags so meat juices don't contaminate fruits and vegetables.
- Go directly home from the market or keep a cooler in your car.
- Don't leave perishable items sitting in the heat.



Always Wash Produce

- Wash your hands with warm water for at least 20 seconds before working with produce.
- Wash produce thoroughly before you use it, not when you bring it home. Washing produce before storage causes it to spoil faster.
- Rinse under clean, running water. Don't use soap or detergent.
- Rinse produce even if you plan to remove the peel. Any bacteria present on the outside of items can be transferred to the inside when you cut or peel them.
- Rub briskly – scrubbing with a clean brush or hands.
- Dry with a clean cloth or paper towel.



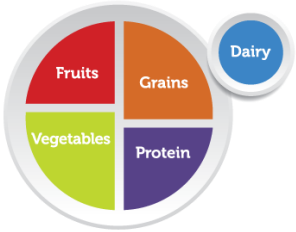
How to Store Produce

- Some produce – like apples and tomatoes – can be ripened on the counter.
- Most other produce is best kept in a refrigerator.
- Keep fruits and vegetables in separate crisper drawers.
- Fruits give off gases which shorten the life of vegetables, and some vegetables give off odors that are absorbed by fruits.
- Refrigerate produce in perforated plastic bags.
- Store meats below produce in your refrigerator to keep juices from dripping onto the produce.



Eating Healthy

Farmers Markets offer a colorful variety of locally grown fruits and vegetables to help you and your family eat right and stay healthy. Try them all!



- Make half your plate fruits and vegetables every day.
- Make at least half your grains whole.
- Choose low-fat dairy products.
- Vary your protein choice.

Food Safety

- Thoroughly wash all produce before eating.
- Check that meat and dairy products are kept cold in a cooler or refrigerator and are from an approved source before buying.
- Place meats and produce in separate bags so meat juices don't contaminate fruits and vegetables.
- Go directly home from the market or keep a cooler in your car.
- Don't leave perishable items sitting in the heat.



Always Wash Produce

- Wash your hands with warm water for at least 20 seconds before working with produce.
- Wash produce thoroughly before you use it, not when you bring it home. Washing produce before storage causes it to spoil faster.
- Rinse under clean, running water. Don't use soap or detergent.
- Rinse produce even if you plan to remove the peel. Any bacteria present on the outside of items can be transferred to the inside when you cut or peel them.
- Rub briskly – scrubbing with a clean brush or hands.
- Dry with a clean cloth or paper towel.



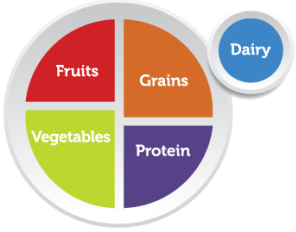
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Eating Healthy

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- Make half your plate fruits and vegetables every day.
- Make at least half your grains whole.
- Choose low-fat dairy products.
- Vary your protein choice.

Goal need a proposal to be submitted (as stated in recent email) — To extend order Bott to approve (show evidence that working to connec

Tara Gurge

From: Tara Gurge
Sent: Friday, May 17, 2019 11:07 AM
To: 'Tal Achituv'
Subject: RE: FW:URGENT- 57 walker lane HEARING WIL

Importance: High

Tal-

Thanks for the follow-up email. It is very helpful to know that these meetings and these sewer connection discussions are taking place. I was not made aware of that. When is your next meeting? The Health Division would like to attend. Let me know. I will also follow-up with the Town Engineer with this latest information that you provided.

Also – Just a reminder. Here are the email excerpts noted below that were discussed and agreed to when we allowed your pipe repair to be conducted, along with my follow-up email correspondence from my contact a MassDEP. This Enforceable Agreement Order was given by the Town of Needham Engineering AND Health Depts. back in November 2017, as you may recall. (See highlighted area.) See below:

On Thu, Nov 30, 2017 at 4:37 PM Tara Gurge <TGurge@needhamma.gov> wrote:

Tal -

Great – So I'm taking this as the most updated version. I just got off the phone with Tom Ryder from our Town Engineering Dept. **He is in agreement, that we can allow this pipe repair between the home and the septic tank, as long as you agree to sign an 'Enforceable Agreement' with the Health Department** which states that you will be connecting to the town municipal sewer system in the near future (next couple of years.)

Email from MassDEP – After we received your follow-up info. that you provided to me from your contacts at MassDEP, we again reached back out to our contact below and asked her if indeed **the septic system pipes, along with the septic system components, are all part of the complete septic system, and that if a pipe fails due to its age, then that is also considered part of the complete septic system,** thus a new compliant Title Five septic system needs to be installed and/or the property must be connected to the municipal sewer system? And here was her direct response. SEE BELOW:

Email excerpt from Claire Golden @ Mass DEP — (See attached - sent 3/13/19

There is an existing Enforceable Agreement for the upgrade which was consented to. The Enforceable Agreement is, to the best of my knowledge, in full force and effect.

The upgrade needs to happen either by enforcing the Agreement and/or pursuing other enforcement options. With orangeburg pipe you're likely looking at a 60 year old system that has outlasted standard systems and needs an upgrade.

I hope this helps.
Claire

MassDEP
Department of Environmental Protection

Claire A. Golden, EEIV
MassDEP Wastewater Management and Surface Water Permitting Programs
205B Lowell St
Wilmington, MA 01887
978-694-3244
978-694-3499 (fax)
claire.golden@mass.gov

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Visit our website at www.mass.gov/eea/agencies/massdep

PLEASE NOTE: If you cannot meet this Enforceable Agreement deadline, we must know this ASAP. We may be able to work with you on giving you a one-time extension, but you must submit a detailed sewer connection proposal to all Town Depts. involved in giving us all details on this project, which must also include strict timeframes for this sewer connection. This proposal will need to be submitted to the Board of Health for their final approval in a timely manner. (The BOH meets on a monthly basis.)

Please get back to me and let me know if you have any follow-up questions on that requirement. I will also need to hear back from you on when your next meeting is scheduled for, and where this meeting is taking place, etc.

Thanks for your continued cooperation in this urgent public health matter.

Thanks,

TARA E. GURGE, R.S., C.E.H.T., M.S.
ASSISTANT PUBLIC HEALTH DIRECTOR
Needham Public Health Division
Health and Human Services Department
178 Rosemary Street
Needham, MA 02494
Ph- (781) 455-7940; Ext. 211/Fax- (781) 455-7922
Mobile- (781) 883-0127
Email - tgurge@needhamma.gov
Web- www.needhamma.gov/health

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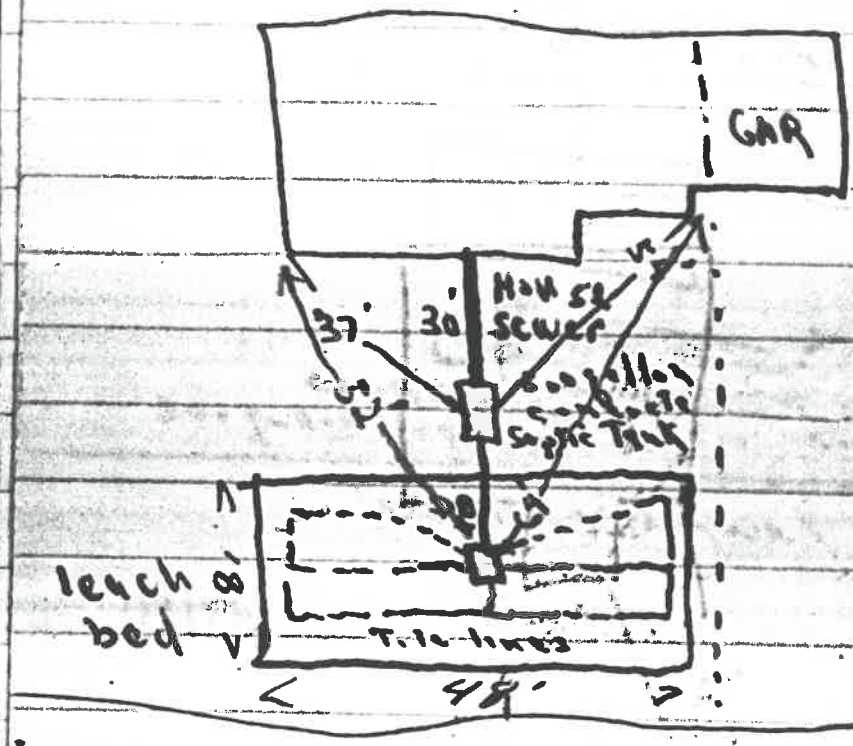
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42 ✓

B224 - 0

Jensen-Bielski - 57 WALKER LANE

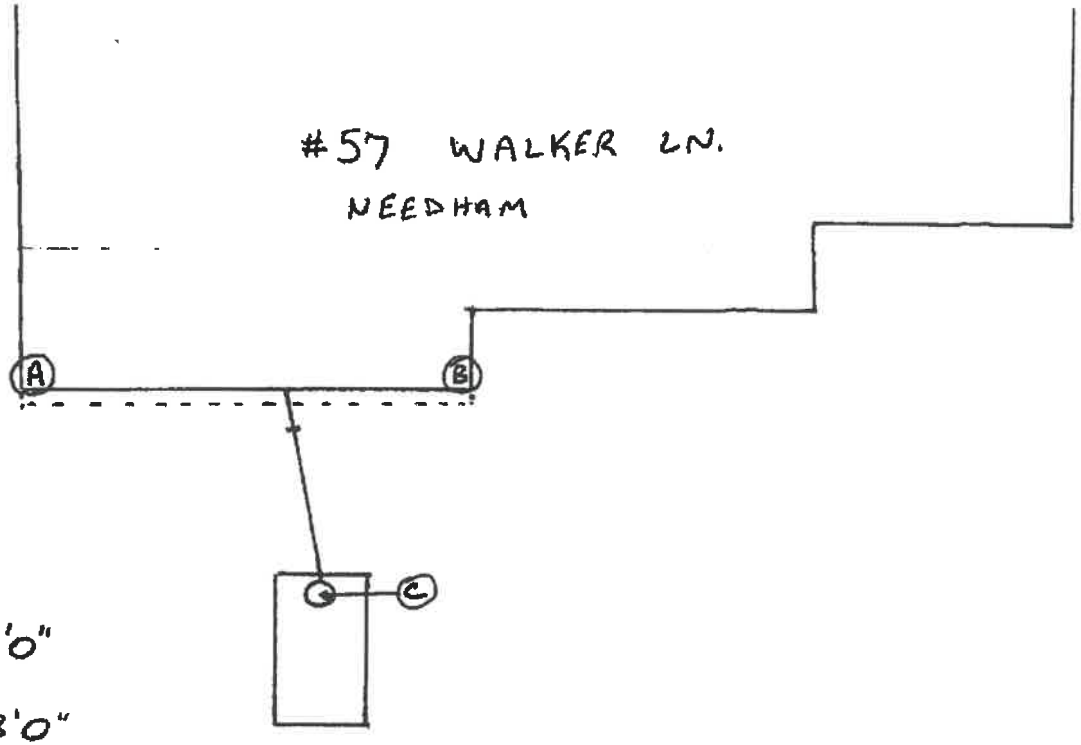


9/26/56 -

Leach system in properly but inlet line from Septic tank to Distrib. box seems lower than leach tile lines - nec. to raise.

10/15/56 - INLET LINE TO DISTRIBUTION BOX RAISED

FINAL APPR - 10/16/56



A TO C = 34'0"

B TO C = 28'0"

Pipe Replaced from Existing CAST IRON coming OUT OF HOUSE INTO Existing Septic tank. New inlet tee installed.

12/1/2017

KENNY JONES CORP.

P.O. Box 72

WALPOLE, MA 02081

508-850-5151

Tara Gurge

From: Tal Achituv <tal@achituv.com>
Sent: Thursday, November 30, 2017 5:07 PM
To: Tara Gurge
Cc: Rachel Achituv
Subject: Re: Repair to sewer main at 57 Walker Lane

Thanks Tara.

Kenny says he will be ready for inspection at 1.
On Thu, Nov 30, 2017 at 4:37 PM Tara Gurge <TGurge@needhamma.gov> wrote:

Tal -

Great – So I'm taking this as the most updated version. I just got off the phone with Tom Ryder from our Town Engineering Dept. He is in agreement, that we can allow this pipe repair between the home and the septic tank, as long as you agree to sign an 'Enforceable Agreement' with the Health Department which states that you will be connecting to the town municipal sewer system in the near future (next couple of years.)

We understand, due to your recent email, that you will not be finishing off your second floor addition space (as stated in the attached document that was in your septic file – done by previous owner), until you connect your property to the municipal sewer, once it gets brought down the street in front of your house.

The Enforceable agreement will be following in a separate email shortly. In the meantime, you may set up an appointment with Kenny Jones for the repair. I know you mentioned that you wanted to conduct this repair tomorrow, so right now we have some slots available at 9 AM, and also any time between 12-2 PM in the afternoon. We will have to meet with the septic installer on site to confirm that this pipe was replaced and that it's at the correct invert and that it's Schedule 40 PVC piping, etc.

Please let me know what time works best for the installer, so we can put that in our schedule.

Thanks,

Tara

From: Tal Achituv [mailto:tal@achituv.com]
Sent: Thursday, November 30, 2017 4:04 PM

To: Tara Gurge
Cc: Rachel Achituv
Subject: Repair to sewer main at 57 Walker Lane

Dear Tara,

To follow up on our conversation, I would like to summarize the conditions and plans regarding the sewage emergency at our house at 57 Walker Lane.

The situation is that there is a blockage in the pipe going from the house to the septic tank caused by deterioration of the orangeburg (cardboard+tar) pipe which connects the cast-iron main line to the septic tank.

This deterioration causes cracking/perforation, narrowing, and root-penetration into the pipe, which in turn also allows sewage to seep into the ground - since it is sitting in the blocked pipe which is no longer structurally sound, as well as backing up of sewage into the basement.

The house has an extension, built in 1996 by the previous owners, and we are aware that it cannot be turned into a bedroom without first making the necessary improvements to make such a remodel compliant with Title V (either through expanding/replacing the septic, or connecting to sewer).

Also, our intention is to connect to sewer, and we have been working as a group as part of an ongoing effort together with the town, primarily through Conservation (Matt Varrell), to understand the best way to deal with road reconstruction, utilities burial, gas service and sewer service. The main idea is to wait before taking any action until the residents and the town could design together a solution that incorporates all the environmental needs and requirements, and not only minimize cost and maximize effectiveness, but also minimize any risk to the environment by only opening up the road once and then replacing it with a proper modern road. The current state is that in this year's town meeting a budget has been approved to run a study to understand what is causing the deterioration of the pond. Pending the study's finding, our hope is that together with the town we can deal with floodwater infiltration, roof runoff, and replacement of septic systems to help address the level of nutrients flowing into the pond causing it to become unusable to the public.

Given that these bureaucratic processes take years, it is hard to predict by when we would be able to finalize all of these plans. I am encouraged that the study that we worked hard to get is due in the next few weeks, and that the new director of conservation seems to be as eager as Matt Varrell to work with the neighborhood towards finding a solution for the pond. This has been 2+ years of meetings, and I hope that we could arrive at a solution for walker lane in as little time as possible. It greatly depends on the rate in which the town will be moving forward with planning and recommendations for remediation of the nutrient overflow into the pond.

Had it been easier (or even feasible) to connect to sewer we would have chosen to do that over fixing the orangeburg pipe. But since the sewer main is two houses away, and more than 10 feet deep (well below the water table) it is a complicated and expensive process that cannot be feasibly done before the ground freezes anyway. I have been assured of this by several contractors. The ones that have the necessary equipment to pump out the water while they work are either overbooked, not licensed in the town, or unreachable at this time.

I had hoped to avoid having to deal with replacement of the orangeburg pipe through alternative means of opening up the clogged pipe but since Chris Seariac, the superintendent of water/sewer strongly advised against it, I am left with no other option but replacing the portion of the pipe that is deteriorated, for which we require a permit from the board of health.

Given this situation, the background, and the future plans, I hope that you can approve the permit for this work.

Best regards,

Tal Achituv.

Needham Public Health Department

1471 Highland Avenue, Needham, MA 02492 781-455-7500 ext. 511
www.needhamma.gov/health 781-455-0892 (fax)

Needham Public Health
Prevent. Promote. Protect.

December 1, 2017

Mr. Tal Achituv
57 Walker Lane
Needham, MA 02492

Re: Septic System Enforceable Agreement for #57 Walker Lane in Needham

Dear Mr. Achituv;

As you recall, we recently issued a Septic Construction permit to allow you to replace the Orangeburg pipe leading from your home to your septic tank, at the property address noted above, which according to our records is only an 800 gallon septic tank, which does not meet today's Title Five Septic System standards. The Town Engineering and Water and Sewer Departments, along with the Public Health Division, allowed this repair under the agreed to condition that an ***Enforceable Agreement*** would be signed and dated by you, which states that you will be connecting to the municipal sewer system in the next couple of years. (NOTE: We allowed you to conduct this repair in lieu of submitting a failed Title Five Septic System report, where if your system was found to be in failure, due to this compromised pipe (which you reported that raw sewage was actively backing up into your home), PER MASS DEPARTMENT OF ENVIRONMENTAL PROTECTION (MA DEP) REQUIREMENTS, YOU MUST CONNECT THIS SEPTIC SYSTEM WITHIN TWO YEARS FROM THE DATE OF THE FAILED TITLE FIVE INSPECTION REPORT, which obligates you to connect on or before the date that your emergency repair was made, which was on **December 1, 2017**.

Since at this time, it is not possible to connect to the municipal system (which is located two houses down), we are requiring that this ***Enforceable Agreement*** be set up and adhered to in order to meet our septic system abandonment/connecting to sewer requirements. This is an agreement between the Public Health Division and the property owner.

See Enforceable Agreement noted below:

I, Tal Achituv, who owns the property located at **#57 Walker Lane in Needham, MA**, agrees that the property will be fully connected to the municipal sewer line on the street on or before December 1, 2019. I agree that once the property is connected to the municipal sewer system, that a Septic Abandonment Form (see attached) is filled out and signed/dated, and submitted back to the Public Health Department for review/approval. (**NOTE**: I agree that this property is currently being evaluated and a decision will be made on the timing of this connection in the near future. I will continue to keep the Public Health Dept. in the loop on that.)

Property owner – Print: Tal Achituv / Sign: _____

Date: 12/15/17

Please call me if you have any questions at (781) 455-7500; Ext. 262.

Sincerely,

Tara E. Gurge, R.S., C.E.H.T., M.S.
Assistant Public Health Director

WalkerLane-#57EnforceableAgreementConntoSewer-17

Tara Gurge

From: Golden, Claire (DEP) <claire.golden@state.ma.us>
Sent: Wednesday, March 13, 2019 11:35 AM
To: Tara Gurge
Cc: Brander, Kevin (DEP)
Subject: RE: Enforceable Agreement question

Tara,

There is an existing Enforceable Agreement for the upgrade which was consented to. The Enforceable Agreement is, to the best of my knowledge, in full force and effect.

The upgrade needs to happen either by enforcing the Agreement and/or pursuing other enforcement options. With orangeburg pipe you're likely looking at a 60 year old system that has outlasted standard systems and needs an upgrade.

I hope this helps.
Claire

MassDEP
Department of Environmental Protection

Claire A. Golden, EEIV
MassDEP Wastewater Management and Surface Water Permitting Programs
205B Lowell St
Wilmington, MA 01887
978-694-3244
978-694-3499 (fax)
claire.golden@mass.gov

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Visit our website at www.mass.gov/eea/agencies/massdep

From: Tara Gurge [mailto:TGurge@needhamma.gov]
Sent: Tuesday, March 12, 2019 9:23 AM
To: Brander, Kevin (DEP)
Subject: Enforceable Agreement question
Importance: High

Kevin –

Hello – Hope you are doing well. I have a question - Is it true that the septic system pipes, along with the septic system components, are all part of the complete septic system, and that if a pipe fails due to its age, then that is also considered part of the complete septic system, thus a new compliant Title Five septic system needs to be installed and/or the property must be connected to the municipal sewer system?

We had a septic system fail in town near a pond that had 'Orangeburg' piping that had collapsed that needed immediate Emergency replacement, and we allowed the emergency repair ONLY under the condition that the system would be

properly decommissioned and then tied into the municipal sewer system within a 2-year time frame. So we issued an Enforceable Agreement as a result. (We are approaching the 2-year deadline, and we are now getting push-back from the owner that is now stating that this was a simple 'plumbing issue' and not a septic issue, and the Enforceable Agreement does not apply in his case??? Is that accurate?

Please let me know.

Thanks,

TARA E. GURGE, R.S., C.E.H.T., M.S.
ASSISTANT PUBLIC HEALTH DIRECTOR
Needham Public Health Division
Health and Human Services Department
178 Rosemary Street
Needham, MA 02494
Ph- (781) 455-7940; Ext. 211/Fax- (781) 455-7922
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Web- www.needhamma.gov/health

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July 12, 2019

Tara E. Gurge
Assistant Public Health Director
Needham Public Health Dept.
1471 Highland Ave.
Needham, MA 02492

Dear Ms. Gurge,

At your request I am writing to describe the efforts that I have made since the signing of the "Enforceable Agreement" on December 1, 2017, approximately 18 months ago. At that time I had contacted the Town because I believed my septic system may have failed. As we now know, the septic system did not fail, but the "Orangeburg pipe" which connected my septic system to the house did fail. In the process of my investigations, I learned that this kind of pipe which is much like cardboard, was used during the war and post war era instead of cast iron. The septic related problem I experienced has now been resolved by replacing that piping with regulation PVC piping suitable for a 21st century system.

I understand that the Agreement requires that "per Mass Dept. of Environmental Protection (MA DEP) requirements, I must connect this septic system within two years from the date of the failed title five inspection report". I will provide below details on the efforts I've made to comply with this agreement. There are two additional conditions that relate to this compliance.

1. My septic system has been tested and confirmed that it is indeed in good working condition, and in fact did not fail.
2. My conversations subsequent to my original contact with the Town have reinforced an understanding that I would be required to take "reasonable means" to comply with the agreement and connect to Town sewer.

While I considered asking you to waive this Agreement now that we know the septic system has not failed, I do want to make clear that I am still very committed to connecting to the Town sewer system. However, as you will see in the information below, the steps required to connect by December 1 do not, in my belief, meet the standards of "reasonable means".

When this first happened and I began the process to cost out and undertake a remedy to the situation, I was given an estimate by the both town engineering staff, as well as contractors, that I should expect to pay between $20K-$30K to connect my home to the Town sewer. I assume that $40K would be the upper range of what the Town would expect to be a "reasonable" cost to comply with the Agreement. Had the estimates I received come anywhere close to this estimate, I would have proceeded. But the estimates I received (and I'm summarizing here, more details are below) led to a likely price of closer to $95K-$120K range and possibly higher when the terrain of the land and proximity to the pond is considered. More important, a decision to act unilaterally to solve my own problem would involve interfering with or even blocking the longer range plans of my Walker Pond neighbors.

Initially, since the agreement was signed just as the ground was starting to freeze, we had to wait till spring before any contractor would seriously engage. Early in the spring of 2018 I started reaching out to contractors, and once some started coming on-site it became clear that this kind of job cannot be done by most contractors due to the complex conditions including length, depth, proximity to wetlands, need to work under the water table, etc. It has been extremely difficult to get contractors due to these reasons.

Of the ~50 contractors I contacted, the vast majority was incapable of doing this. The contractors who can, of which there are only a few in this area, are very busy. Additionally, the complexity-to-size ratio makes this job of no interest to some (such as Lynch Development). Bigger contractors who aren't scared away by the complexity-size ratio are booking into 2021 (such as Fed Corp). The initial efforts through the spring and summer of '18 have come up with two willing and able contractors (Malone & Murphy), only one of which would acutally communicate and come for a site visit (Murphy).

Cost estimates from Bob Murphy were in the 80-100k range, exclusive of engineering/permits/fees. The town engineer pushed back on these costs, but the town engineer's estimates were not taking into account some of the complexities that are apparent in the field and were plans that did not take into account the need to not block the neighbors from being able to connect as well, like the need for the sewer to stay deep enough, and the need for a manhole, etc.

After several iterations between Bob and Tony, either way you look at it the project comes out at 90-130k with the engineering costs of $10K-$30K excluded. The high engineering costs make even looking into getting a more serious quote from Bob than the one you'll find attached infeasible. Moreover, the engineering process is only likely to cause further increases in the costs rather than savings due to extra findings that may come up.

In our meeting with the town, which you attended back in May, Tony the town engineer had mentioned the option for the town engineering department to develop such a plan for the neighborhood, if we exhaust all options for finding a feasible solution for connecting my house to the town sewer. He had pointed out that he knows at least one more contractor who is currently doing similar work, and which was not on my lists of contractors -- Jones Contracting.

After finally getting Jones Contracting on site, you'll find the estimate attached below, which is in-line with Bob Murphy's estimates, if not a little 'worse' (more expensive). Jones also pointed out that in the work done elsewhere in Needham, at similar depth and also near water, additional costs of tens of thousands of dollars kept being added due to findings on the ground (unsuitable material, digging depth required wider trenches and more road reconstruction, etc.) and suggests that this would likely cost more.

I have also been in touch with MA DEP, in efforts to understand the requirements and limitations that may be in effect, as well as the rest of the neighbors in order to attempt to bring (average) cost and complexity down, and I am glad to report that the neighbors on the road who are on septic systems are generally looking forward to being able to connect to sewer, if costs are reasonable.

At the DEP I reached out to Marybeth Chubb, and Claire Golden; The advice I received from both the Boston office as well as the North East Regional Office supports my assesment that while it is important that we seriously look into connecting to sewer, that the failure of the pipe leading from my house to the septic system is not a cause for failing of the septic system itself. They also mentioned that the two year requirement is not a MA DEP requirement, but rather that timing on these cases are entirely within the control of the LAA (in our case, the Needham BoH).

We are also very optimistic, through the neighborhood efforts, that through an integral approach to the all the issues at the town involving the road, walker lane, and walker pond, we will be able to come to the best outcome - of everyone connecting to sewer.

While most of my efforts have been invested towards finding a way to connect to sewer, I have also looked into replacing the septic system, and you'll find a quote for a system that is suitable both for my house, and to the proximity to the pond (a presby EnviroSeptic) which comes in at $30K.

I hope that we can all agree that it is worth putting time and effort on all sides to figure out how we might be able to connect to sewer, rather than end up installing a septic system. I think that this process has taught both you and me a lot about the situation that we did not realize at the beginning, and I hope that you would agree that the complexity uncovered merits reconsideration.

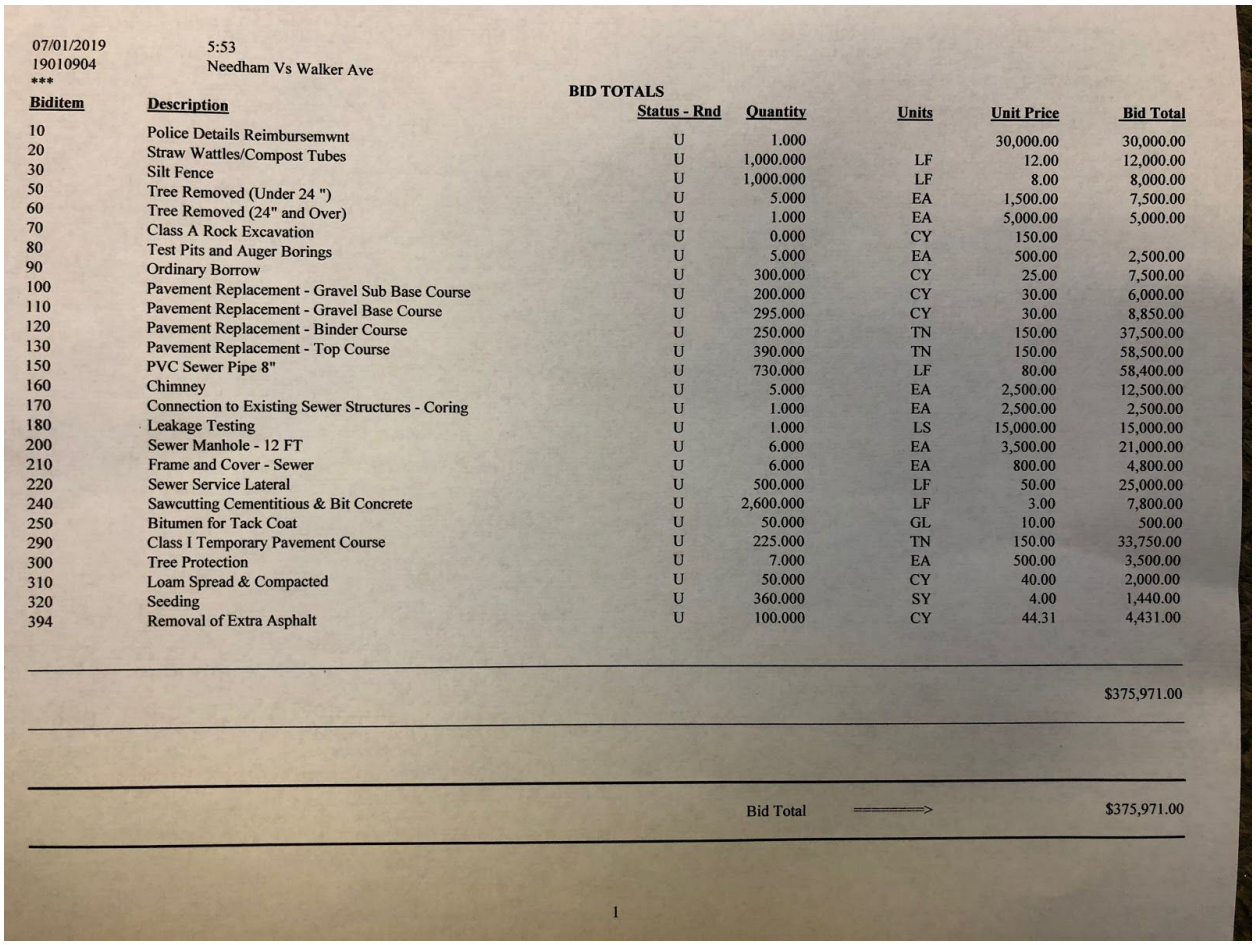
In summary, I signed the agreement with the understanding that this was, at most, a $30K-$40K problem, that it was required by MA DEP and that our septic system has failed. I submit below evidence of my good faith efforts to comply with the Agreement. Because none of these understandings are correct I respectfully request that the Agreement be set aside or voided. I further suggest that because the Town and the Walker Pond neighborhood have a long range interest in permanently resolving the potential of septic failures, and have a long range interest in preserving and protecting Walker Pond that the Dept of Public Health replace that Agreement with an Agreement to engage with the Walker Pond neighbors to explore the problems and potential solutions, involving a range of public and private experts, to develop a consensus plan of action.

Please find attached below:

- Timeline of my efforts to comply with the agreement
- Partial list(s) of contractors I have contacted
- Sewer Cost estimates from Bob Murphy
- Sewer Cost estimates from Jones Contracting
- Report from Kenny Jones after inspecting the septic system recently
- Septic (EnviroSeptic) estimate from Kenny Jones
- Map showing the other locations of sewer in the vicinity, showing that there are not better options for sewer than the one explored (initially we were hoping that the sewer on Central Ave is closer)

Sewer Estimates

From Russell Jones - Jones Contracting



07/01/2019 5:53
19010904 Needham Vs Walker Ave
***

BID TOTALS

Biditem	Description	Status - Rnd	Quantity	Units	Unit Price	Bid Total
10	Police Details Reimbursemwnt	U	1.000		30,000.00	30,000.00
20	Straw Wattles/Compost Tubes	U	1,000.000	LF	12.00	12,000.00
30	Silt Fence	U	1,000.000	LF	8.00	8,000.00
50	Tree Removed (Under 24 ")	U	5.000	EA	1,500.00	7,500.00
60	Tree Removed (24" and Over)	U	1.000	EA	5,000.00	5,000.00
70	Class A Rock Excavation	U	0.000	CY	150.00	
80	Test Pits and Auger Borings	U	5.000	EA	500.00	2,500.00
90	Ordinary Borrow	U	300.000	CY	25.00	7,500.00
100	Pavement Replacement - Gravel Sub Base Course	U	200.000	CY	30.00	6,000.00
110	Pavement Replacement - Gravel Base Course	U	295.000	CY	30.00	8,850.00
120	Pavement Replacement - Binder Course	U	250.000	TN	150.00	37,500.00
130	Pavement Replacement - Top Course	U	390.000	TN	150.00	58,500.00
150	PVC Sewer Pipe 8"	U	730.000	LF	80.00	58,400.00
160	Chimney	U	5.000	EA	2,500.00	12,500.00
170	Connection to Existing Sewer Structures - Coring	U	1.000	EA	2,500.00	2,500.00
180	Leakage Testing	U	1.000	LS	15,000.00	15,000.00
200	Sewer Manhole - 12 FT	U	6.000	EA	3,500.00	21,000.00
210	Frame and Cover - Sewer	U	6.000	EA	800.00	4,800.00
220	Sewer Service Lateral	U	500.000	LF	50.00	25,000.00
240	Sawcutting Cementitious & Bit Concrete	U	2,600.000	LF	3.00	7,800.00
250	Bitumen for Tack Coat	U	50.000	GL	10.00	500.00
290	Class I Temporary Pavement Course	U	225.000	TN	150.00	33,750.00
300	Tree Protection	U	7.000	EA	500.00	3,500.00
310	Loam Spread & Compacted	U	50.000	CY	40.00	2,000.00
320	Seeding	U	360.000	SY	4.00	1,440.00
394	Removal of Extra Asphalt	U	100.000	CY	44.31	4,431.00

$375,971.00

Bid Total ==========> $375,971.00

1

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Septic Evaluation

Kenny Jones
CORPORATION
Excavating Contractors
(508) 850-5151

2092 Main St.
Walpole, MA 02081
Office: (508)-850-5151
Cell: (774)-259-4062
www.kennyjonescorp.com
kenny@kennyjonescorp.com

Septic System Examination:

RE: 57 Walker Ln. Needham, MA

On Friday 6/28/19 I examined the existing septic system at 57 Walker Ln. Needham, MA. I opened the septic tank covers and found that the inlet and outlet tees were in place and that the level in the tank was good.

I located the distribution box and found that the level was at the bottom of the outlet lines and that all outlet lines were taking effluent when water was added to the box with a garden hose.

Kenneth A. Jones, Jr. – President Kenny Jones Corp.

Septic Estimate

Kenny Jones Corporation
P.O. BOX 72
Walpole, MA 02081
Phone 508 850-5151
kenny@kennyjonescorp.com
www.kennyjonescorp.com

ADDRESS
Tal Achituv
57 Walker Ln.
Needham, MA 02492

PROPOSAL 1781

DATE 06/30/2019

ACTIVITY	QTY	RATE	AMOUNT
Engineering Proposal submitted for work at 404 N. Main St. Sharon, MA. Price includes the following: SEPTIC SYSTEM DESIGN WORK: $4,775 - Provide backhoe services to dig for perk test = $400 - Provide permit fees to Town of Needham = $1,375 - Provide services of Glossa Engineering, Inc. to provide the following: = $3,000 - Perform soil analysis and perk test - Create septic system design plan - Once system is installed create "as-built" plan Note: Additional costs may be incurred if Notice of intent / Order of conditions are required by Needham Conservation Commission	1	4,775.00	4,775.00
Septic System Conceptual Esstimate submitted for work at 57 Walker Ln. Needham, MA. Based on site visit on 6/28/19 and other worked performed in the area. A firm proposal will be created once design plans have been completed and approved. Price includes the following: - Furnish & install 125' of filter mitt erosion control barrier - Pump, crush, and remove existing septic tank and leaching area as necessary to get new system in - Furnish & install new, 1,500 gallon, H-10 loading, 2-compartment septic tank with risers & covers - Furnish & install new H-10 distribution box with riser & cover as necessary - Furnish & install septic sand / ASTM C-33 concrete sand as necessary (approx. 200 yards) - Furnish & install 240' of Presby Enviro-septic leaching pipes - Furnish & install observation ports in leaching area - Furnish & install vent pipe including granite post style vent concealer - Furnish & install magnetic locator tape over system components - Backfill and grade site per plan, blend in yard to try to smooth out remove excess fill (approx. 100 yards) - Loam & hydro-seed areas disturbed by system installation	1	26,000.00	26,000.00

Payment to be made as follows: 1/2 payment at start of job, and balance upon completion. Any deviations or alterations from above specifications, involving extra costs will be executed only upon written order, and will become an extra charge over an above original proposal. *Ledge is an extra charge.
Requests for additional Hydro seeding after initial application (if included in proposal) is an additional charge.

Contractor assumes no responsibility for any damage to underground sprinkler systems or driveways.
All agreements are contingent upon strikes, accidents or delays beyond our control. Acceptance of the Proposal constitutes a contract.
Proposal will be honored for thirty (30) days from date of issue.

TOTAL **$30,775.00**

Accepted By

Accepted Date

Return to Home Page

Partial list of contractors contacted

Updated 3/14/2019

CONTRACTOR LICENSE LIST

PAID FEE

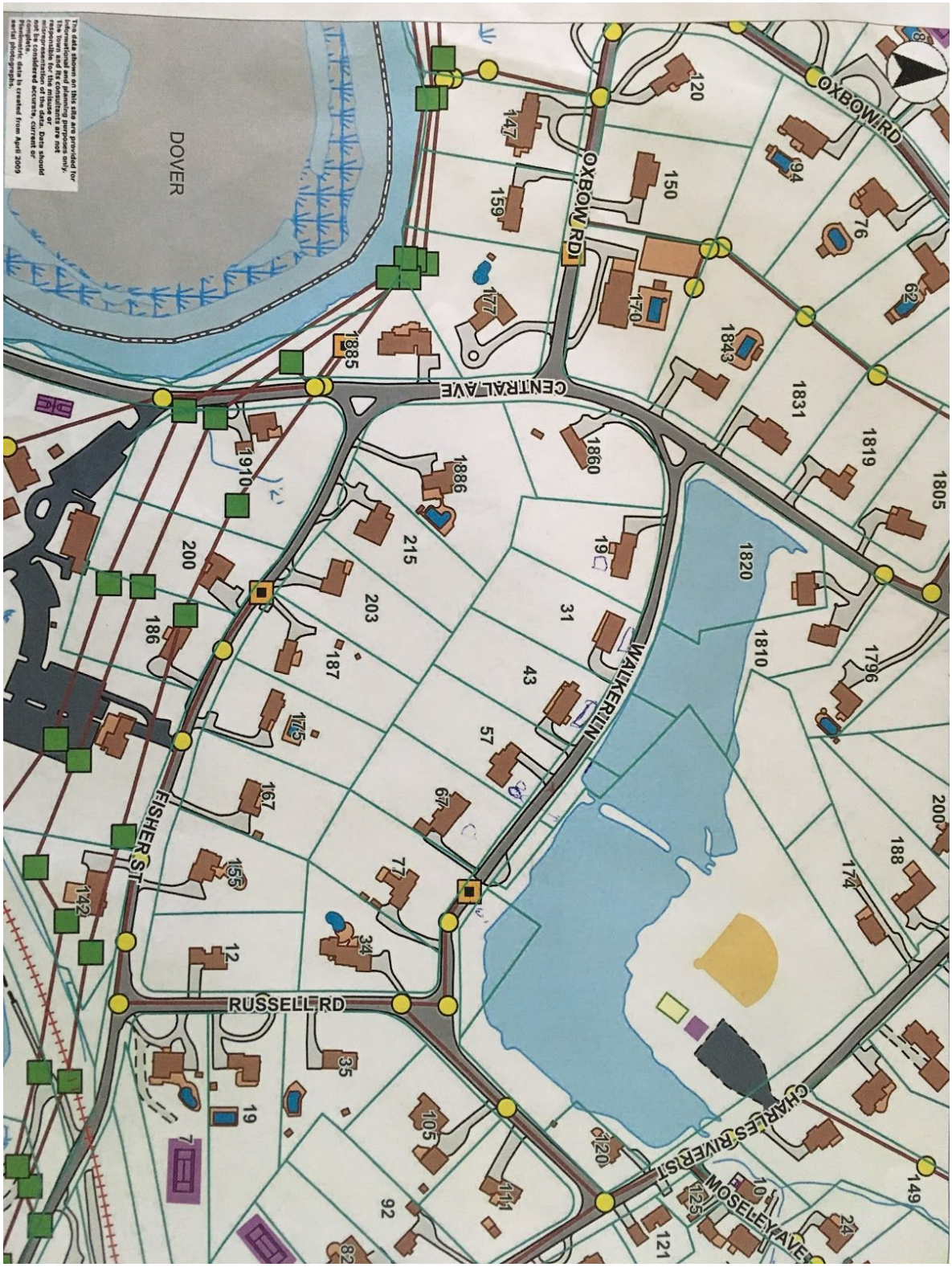
Contractor	Expiration Date	Phone Number	Address
Alden Building Company	12/1/21	978.750.9660	212 Centre St, Danvers, MA 01923
Arello, R.B. Company	12/1/21	508.633.0793	157 Southbridge Rd, N. Oxford, MA 01537
B.P. & Sons Inc	12/1/21	508.376.5720	840 Main St, Millis, MA 02054
Early Contractors Inc	12/1/21	978.374.8033	66 Emerson St, Haverhill, MA 01830
Ernest Gugil & Sons	12/2/21	781.999.0194	10 Tech Cir, Natick, MA 01760
Fed Corp.	12/1/21	781.329.1044	1039 East St, Dedham, MA 02026
Frotton, S & T Inc.	12/1/21	978.265.7231	70 Donohoe Rd, Dracut, MA 01826
Gunite, Andrews Co., Inc.	12/1/21	978.663.0724	6 Republic Rd, N. Billerica, MA 01862
Larter, H.C. Company	12/1/21	508.434.4328	2 Mechanic St, Woodville, MA 01784
Lussier Corp.	12/1/21	508.651.2333	193 Oak St, Natick, MA 01760
Lynch Development Corp	12/1/21	617.839.6024	97 Chapel St, Needham, MA 02492 not interested
Malone, Jack Company	12/1/21	781.444.7860	20 Chestnut St, Needham, MA 02492
McCarthy, G.D.	12/1/21	781.589.3650	721 Central Ave, Needham, MA 02494
Middlesex, the Corp	12/1/21	978.875.0990	1 Spectacle Pond Rd, Littleton, MA 01460
Modern habitat LLC	12/1/21	617.803.8629	Box 582, Lincoln, MA 01773
Mofford, Vinny Excavation	12/1/21	508.654.7917	5 Bryant Circle, Middleboro, MA 02346
Negoshian, John M. Co	12/1/21	617.775.8180	1101 South St, Needham, MA 02492
New England Boring Contractors	12/1/21	603.437.1610	Box 165, Derry, NH 03053
Oakcrest Builders	12/1/21	508.958.6070	4 Hopedale St, Mendon, MA 01756
O'Donoghue Construction	12/1/21	781.724.9423	644 West St, Braintree, MA 02184
Parkside Utility Construction LLC	12/1/21	617.952.7395	37 Ayer Rd, Littleton, MA 01460
PBZ Construction Inc	12/1/21	781.828.6471	28 Tosca Dr, Stoughton, MA 02072
Perdoni Construction	12/1/21	781.492.0330	10 Shattuck St, Natick, MA 01760
Shea, Michael Company	12/1/21	617.719.1794	Box 858, Walpole, MA 02081
Slicklen Builders	12/1/21	781.444.8956	21 Upland Rd, Needham, MA 02492
V & A Construction Corp.	12/1/21	781.329.2353	84 Gaffney Rd, Dedham, MA 02026
Western Professional Builders	12/1/21	781.762.4606	136 Highview St, Westwood, MA 02090

T:public works/copy of License List

Page 1

Updated 3/14/2019

Sewer location in the area



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Timeline

Date	Event
November 1, 2017	Sewage in basement - Talk to Water/Sewer (Chris) - showing video - recommended against pipe-in-pipe,
November 29, 2017	Spoke to Kenny Jones
November 29, 2017	Sent plans to Karen Fruci
November 30, 2017	Acknowledged plans - said Kerry Malone will be in touch
November 30, 2017	Showed plans to Tom @ DPW/Engineering
December 1st 2018	Got permit + Work done -- E-mail understands connecting to sewer once it is in front of my house
December 15, 2017	Signed Enforceable Agreement given to Tara
March - April	Called contractors (see list attached)
May 4, 2018	Touch base w/Tara
May 8, 2018	Tara response
May 18, 2018	Tara check-in
June 27, 2018	Neighborhood meeting
July 16, 2018	Emailing with CRWA and MA River Alliance
July 23, 2018	Call with MA River Alliance
August 14, 2018	Neighborhood meeting - Pond + Road + CRWA + MARA + Garlick [Tal, Dan, Peter and Mark]
September 6, 2018	Sent plans to Bob Murphy [Asked that he try to come by before the 16th]
September 11, 2018	Town meeting about stormwater by-laws
September 25, 2018	Bob Murphy too busy
September 26, 2018	Spoke to Malone on the phone, emailed plans AGAIN
September 28, 2018	Bob Murphy follow up
October 4, 2018	Meeting on-site with MA Rep. Garlick re: pond, sewer

October 10, 2018	Reach out to MA Rep. Garlick in effort to help understand State requirements
November 2, 2018	Tara Check-in, Kerry Malone claims to not have documents (sent months ago, and then again)
November 2, 2018	Response to Tara - Malone not reponding
November 5, 2018	Tara check-in
November 5, 2018	response to tara
November 5, 2018	Tal <> Tara
December 19, 2018	Tara check-in
Feb-Mar 2019	Back and forth with Bob Murphy, looking for NEW engineering plan
March 7, 2019	DEP - Sanh.Tran [310 CMR 15.305 - LAA can set own deadline for completion of upgrade]
March 12, 2019	Bob Murphy + Buckley Engineer @ Bay Colony Group
March 20, 2019	Tara check in- follow up on engineering, Tony suggest a <60k solution (which won't work)
March 25, 2019	Quote from Bill Buckley at Bay Colony Group - $12k + 3 months turnaround
March 27, 2019	Neighborhood meeting - Quotes on road, further discussion on septics and sewer
March 29, 2019	DEP - Phone Marybeth Chubb / Claire Golden / Kevin Brander
April 1st 2019	DEP - Olusegun Onatunde -Forwarding to NERO
April 15, 2019	(date approx) Phone conversation with Claire Golden
April 24, 2019	Neighborhood meeting - Road re-pave delayed while we wait for sewer answers; Agreed to patch soon as we wait
April 26, 2019	Tara Checks in
May 14, 2019	Tara Check-in
May 16, 2019	General overview update to Tara
May 30, 2019	Tara checking in with town Chris/Tony 'have not heard from me in a while'
May 31, 2019	Meeting @ DPW with Tara, Tony+Tom(Engineering), Sean (Water/Sewer), and Deb (Conservation)
June 2019	Contacting Jones contracting working on Winding River Rd
	Quote from Jones Contracting comes in at > $100k per house, even after aggregation
June 27, 2019	Discussion with Conservation Commission
June 30, 2019	Kenny inspects Septic, find it to be functioning properly, provides quote for EnviroSeptic

Verizon-Related Section of Select Board Packet from Meeting on 06.25.19

SELECT BOARD
June 25, 2019
Needham Town Hall
Agenda

Note: Agenda subject to revision, start times are approximate and agenda items may be discussed at earlier or later times.

	6:45	Informal Meeting with Citizens *One or more members of the Select Board will be available between 6:45 and 7:00 p.m. for informal discussion with citizens. While not required, citizens are encouraged to call the Select Board's Office at (781) 455-7500 extension 204 in advance to arrange for an appointment. This enables the Board to better assure opportunities for participation and respond to citizen concerns.*
1.	**7:00**	Pride Month Proclamation
2.	**7:00**	Change of Beneficial Interest- Needham Cabot Concessions LLC. • Andrew Upton, Attorney
3.	**7:00**	Public Hearing- New Alcoholic License Latin- A Group, LLC d/b/a Latina Kitchen and Bar (30 Dedham Avenue) • Antonio DeTrizio, Proposed Manager
4.	**7:00**	Public HearingVerizon Small Cell Wireless Antenna Grant of Location- 228 Brookline Street • Victor Manougian, McLane Middleton
5.	**7:20**	Director of DPW • Sign Notice of Traffic Regulation- Gibson Street • Sign Notice of Traffic Regulation- First Avenue
6.	**7:25**	Set Water & Sewer Rates • Kate Fitzpatrick, Town Manager • David Davison, Assistant Town Manager/Finance
7.	**7:30**	Set Transfer Station Rates • Kate Fitzpatrick, Town Manager • David Davison, Assistant Town Manager/Finance
8.	**7:35**	Approval of the Sale of Notes • David Davison, Assistant Town Manager/Finance • Evelyn Poness, Town Treasurer/Collector
9.	**7:40**	Town Manager • Board Support for Open Meeting Bill • Town Manager Report
10.	**7:45**	Board Discussion • Town Manager Performance Evaluation Policy • Committee Reports

APPOINTMENTS

	See Attached.	

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Select Board
TOWN OF NEEDHAM
AGENDA FACT SHEET

MEETING DATE: 06/25/2019

Agenda Item	Public Hearing - Verizon Wireless
Presenter(s)	Victor Manougian, McLane Middleton

1. BRIEF DESCRIPTION OF TOPIC TO BE DISCUSSED

Cellco Partnership d/b/a Verizon Wireless requests permission to install install one (1) small cell wireless antenna, and all necessary sustaining and protecting fixtures, on an existing utility pole, located on a public way on Verizon Site Name Needham SC02, Utility Pole Number 16/16 at 228 Brookline Street in Needham, MA.

The Department of Public Works has approved this petition, based on Verizon's commitment to adhere to the conditions in the Order for this petition.

2. VOTE REQUIRED BY SELECT BOARD

Suggested Motion:
Move that the Select Board approve and sign a petition from Cellco Partnership d/b/a Verizon Wireless to install a wireless small cell antenna and supporting equipment on Verizon Site Name Needham SC02, Utility Pole Number 16/16 at 228 Brookline Street, Needham.

3. BACK UP INFORMATION ATTACHED

a. Grant of Location Petition Review Sheet from DPW
b. Petition Letter of Application
c. Order
d. Petition Plan
e. Notice Sent to Abutters
f. List of Abutters

Supporting documentation (Affidavit of RF Engineer, report of Donald Haes, Jr., Radiation Specialist, FCC Authorization, Map of Needham Antenna Sites) on file in Office of Town Manager.

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TOWN OF NEEDHAM
PUBLIC WORKS DEPARTMENT

P.O. Box 920364 NEEDHAM, Ma. 02492 Telephone: (781) 455-7550
www.needhamma.gov/dpw

RECEIVED
TOWN OF NEEDHAM
SELECT BOARD
2019 JUN 12 P 1:16

TO: Nikki Witham, Selectmen Office
FROM: Judy Laffey, DPW Office
DATE: 6/12/19
RE: 228 Brookline St.

For Selectmen Meeting of June 25, 2019

Abutters list & labels at Assessors Office.

Please email confirmation date & time of hearing

GRANT OF LOCATION PETITION REVIEW

DATE OF FIELD REVIEW: 5-31-19 REVIEWER: RWW.

SITE LOCATION: #228 BROOKLINE ST. UTILITY REQUESTING: VERIZON

Conduit Work Area Description

A Sidewalk/Grass Strip Crossing Only Peer Review _____

B Work Within Paved Road Perpendicular Crossing Peer Review _____

C Work Within a Plaza Area/Landscaped Island/Parallel Along Roadway
Peer Review _____ Div. Head Review _____

(D) Other CELL TRANSMITTER ON POLE Peer Review TM Div. Head Review TM for MLD 6/12/19

- ☐ Petition Plan Consistent with Field Review
- ☐ Diameter of Conduit N/A
- ☐ Depth of Conduit N/A
- ☐ Utility Conflicts
- ☐ Crossing Perpendicular to Road N/A
- ☑ Public Road
- ☐ Double Pole ND
- ☐ Old Pole Removed N/A
- ☐ Cables Transferred to New Pole
- ☐ New Riser on Pole N/A
- ☐ Visible Trench Patch across Road/Sidewalk N/A
- ☐ Abutters List Complete
- ☐ Photos Included

Department Head R.P. Merrin ok

COMMENTS:

INSTALLATION OF CELL TRANSMITTER ON POLE #16/16
IN FRONT OF #228 BROOKLINE ST

Click to Home Page

MCLANE MIDDLETON

RECEIVED
TOWN OF NEEDHAM
SELECT BOARD
2019 MAY 24 A 11:00

VICTOR V. MANOUGIAN
Direct Dial: 603-628-1310
Email: victor.manougian@mclane.com
Admitted in NH, MA and ME
900 Elm Street, P.O. Box 326
Manchester, NH 03105-0326
T 603.625.6464
F 603.625.5650

May 23, 2019

Town of Needham
Board of Selectmen
1471 Highland Avenue, First Floor
Needham, MA 02492

Re: **Grant of Location to Install a Wireless Antenna and Related Equipment on an Existing Utility Pole in the Public Right of Way**

Applicant: **Cellco Partnership d/b/a Verizon Wireless ("Verizon Wireless")**

Location: **Utility Pole 16/16, 228 Brookline Street**

Dear Chair Bulian and Select Board Members:

The purpose of this letter is to submit a Grant of Location Petition to install wireless communications equipment on utility pole number 16/16 in Needham's public right of way in accordance with Chapter 166, Section 22 of the Massachusetts General Laws.

I. APPLICATION MATERIALS

Enclosed please find a check in the amount of fifty dollars ($50.00) made payable to the Town of Needham along with the following:

1. One (1) Petition;
2. One (1) Order;
3. One (1) Radio Frequency Report;
4. One (1) RF Emissions Report;
5. One (1) Federal Communications Commission ("FCC") License;
6. One (1) Verizon and Eversource Pole Attachment License;
7. One (1) 11" x 17" plan-set dated February 8, 2019 and
8. Excerpts from the FCC Order 18-133.

26' to house
2' to driveway

II. PROJECT NARRATIVE & SMALL CELL TECHNOLOGY

Verizon Wireless has identified significant coverage and capacity gaps in its wireless network in the Town of Needham. To address these gaps, Verizon Wireless seeks to install "Small Cell" wireless antennas as part of a Cloud Radio Access Network ("CRAN") it plans to deploy to provide the required capacity relief and improve network service in Needham. Installation of the CRAN will immediately improve Verizon Wireless's wireless service in Needham and pave the way for future 5G technology.

Over the last three years, Verizon Wireless has rapidly introduced CRAN technology across the Commonwealth, including in Needham (through grant of location petitions approved by the Board of Selectmen). This technology's stealth antenna equipment provides a pinpointed approach to the continued deployment of Verizon Wireless's LTE, AWS, and burgeoning 5G network in Massachusetts. In essence, CRAN systems mount small wireless antennas disguised as electric transformers to existing utility poles. This allows Verizon to increase network capacity by accessing fiberoptic infrastructure connected to offsite and centrally located processing stations. Here, the CRAN technology's combination of targeted, camouflaged antennas and centralized processing would benefit Needham, where network capacity is weighed against municipal aesthetics.

The Small Cell installation proposed in this Grant of Location Petition will primarily consist of a 38.7" tall by 12" wide canister antenna that will be mounted on the side of the existing utility pole at an antenna centerline height of 19'7"± above ground level. As noted above, the antenna itself is enclosed in a cylindrical gray fiberglass container designed to specifically resemble electric transformers used on utility poles throughout the United States. All equipment proposed herein 1) complies with applicable FCC radio frequency emissions regulations, 2) requires minimal maintenance, and 3) does not impact utility, school, traffic or other municipal resources.

Additionally, this proposal is part of Verizon Wireless's regional initiative to improve voice and data coverage in Massachusetts while developing 5G technology throughout greater New England. To this end, Verizon secured master licensing agreements with National Grid and Eversource expediting licensing and attachment of CRAN antennas to utility poles in Massachusetts, including in Needham.

III. MUNICIPAL REVIEW OF CRAN AND SMALL CELL TECHNOLOGY

Under Massachusetts law, the grant of location process enables municipalities to oversee infrastructure development in the Commonwealth's public ways. M.G.L. c. 166, § 22. This process balances the goal of maintaining useable and navigable public ways with the Commonwealth's continued need for infrastructure development, and directly intersects with

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federal telecommunications laws. M.G.L. c. 166, § 21; 47 U.S.C. § 332(c)(7). Generally, federal telecommunications law seeks to expedite wireless infrastructure development by imposing certain limitations on local regulation of wireless facilities. 47 U.S.C. § 332(c)(7). As such, when considering Grant of Location Petitions for wireless telecommunications facilities, Select Boards must consider that Massachusetts and the federal government specifically seek to encourage expedited development of wireless communications infrastructure, and that the TCA prohibits municipalities from taking action that prohibits or delays such development.

More recently, the FCC issued an interpretation of the effective prohibition standard contained in the Telecommunications act of 1996 and issued an order that became effective in January of this year. The Town of Needham conditions regarding grant of location for installation of antennas and related equipment were adopted before this FCC Order. We have attached a copy of the first page and the section referenced below of the FCC for review by the Town and its legal counsel. (The entire Order contains 116 pages and is too large to submit with this grant of location petition).

Conditions 9 and 10, regarding the 50' and 20' set back requirements (from homes and driveways, respectively) run afoul of the recent FCC Order. The small cell separation requirement, which attempts to prohibit in installations within 50 feet of a home and 20 feet from a driveway appear intended to address RF emissions. Where small cells meet the FCC's emission standards, however, Section 332 of the Act proscribes local regulation of the facilities on the basis of the effects of RF emissions. See 47 U.S.C. § 332(c)(7)(B)(iv). To the extent the concern here relates to aesthetic impact, the provision is unreasonable and discriminatory. Small cells are intended to add capacity to those areas most frequently traversed by wireless users, which are often near the very buildings listed in the conditions. The FCC made clear in the Order that anything that materially inhibits a provider's ability to improve its existing network (which includes densification) or add new technology will constitute an "effective prohibition" under Section 332. See Order at ¶67." As a result, we have eliminated those two requirements from our proposed grant of location order.

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IV. CONCLUSION

For the aforementioned reasons, Verizon respectfully requests that the Board of Selectmen execute the Grant of Location Order submitted herein. Please contact me with questions at 603-628-1310 or victor.manougian@mclane.com.

Sincerely,

Victor V. Manougian

VVM/jle
Enclosures
ec: R. Colorusso, Nexius

PETITION FOR POLE AND WIRE LOCATIONS
UNDER MGL c. 166, §§ 22 and 25A

May 23, 2019

Board of Selectmen
Town of Needham, Massachusetts
1471 Highland Avenue
Needham, Massachusetts 02492

Cellco Partnership, d/b/a Verizon Wireless ("Verizon"), hereby requests permission to locate small cell wireless antennas, and all necessary sustaining and protecting fixtures, on an existing utility pole, located on a public way on **228 Brookline Street in Needham, Massachusetts**, and as more particularly shown on plans titled **Needham SC02 MA**, dated **February 9, 2019**, and attached hereto as Exhibit A.

Verizon requests after requisite notice and hearing, that it be granted location and permission to erect and maintain equipment on said utility pole, including, but not limited to:

- Antennas;
- Radio Units;
- Meters;
- Mounting brackets;
- Groundbars;
- Conduits;
- Cables;
- Disconnects; and
- All other necessary sustaining and protecting fixtures.

CELLCO PARTNERSHIP, D/B/A VERIZON WIRELESS

Victor V. Manougian, Esq.
Attorney for Cellco Partnership d/b/a Verizon Wireless

106589\14587346

n to Home Page

SITE NAME:

NEEDHAM_SC02_MA

LOCATION CODE:

390168

SITE ADDRESS:

UTILITY POLE NO.: 16/16
228 BROOKLINE STREET
NEEDHAM, MA 02492

LEASE EXHIBIT



APPROX. NORTH

1 KEY PLAN
SCALE: 1" = 50'

50 0 50 100 200
GRAPHIC SCALE: 1:50 (IN FEET)

POLE COORDINATES	LATITUDE (NAD83)	LONGITUDE (NAD83)
	42° 17' 15.34" N	71° 13' 26.59" W
GROUND ELEVATION	220' A.M.S.L. (NAVD88)	

PREPARED BY:

NEXIUS
TRANSFORM YOUR BUSINESS...THROUGH WIRELESS

A&E OFFICE:
300 APOLLO DRIVE, SUITE 7
CHELMSFORD, MA 01824
1 (972) 755-1882

PROFESSIONAL STAMP:

COMMONWEALTH OF MASSACHUSETTS
JIMMY CHENDANA
STRUCTURAL
No. 53634
REGISTERED PROFESSIONAL ENGINEER

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DRAWING SCALES ARE INTENDED FOR 11"x17" SIZE PRINTED MEDIA ONLY. ALL OTHER PRINTED SIZES ARE DEEMED "NOT TO SCALE".

SUBMITTALS

REV	DATE	DESCRIPTION	BY
0	01/24/19	FOR CONSTRUCTION	AA
1	03/28/19	REVISED PER COMMENTS	NT
2	05/30/19	REVISED PER COMMENTS	NT
3	08/08/19	FINAL LE	AA

SITE INFO:

SITE NAME:
NEEDHAM_SC02_MA

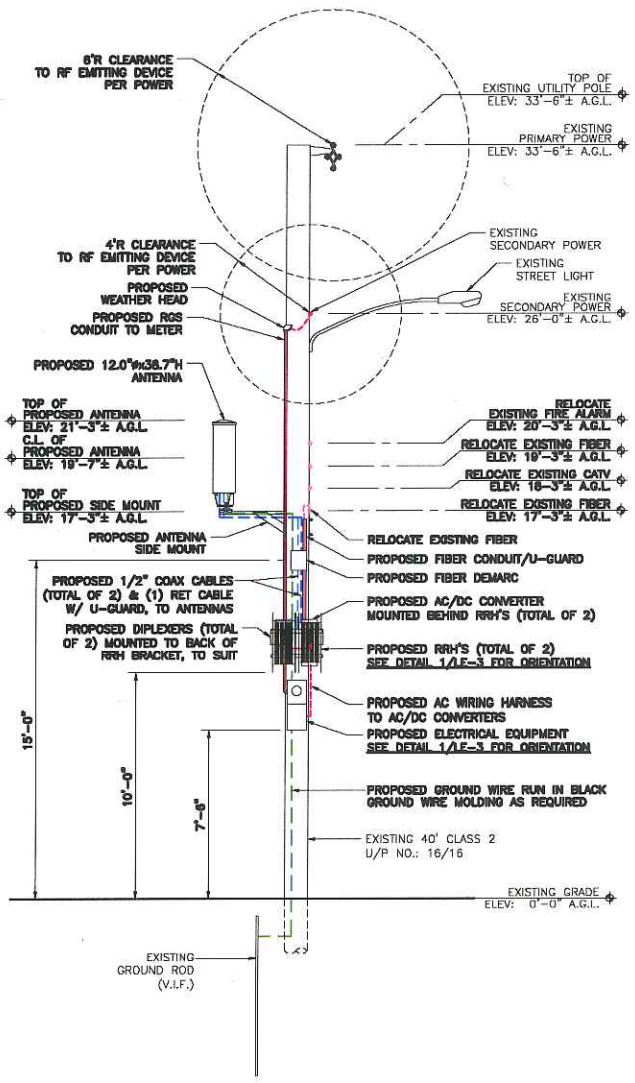
SITE ADDRESS:
U/P NO.: 16/16
228 BROOKLINE STREET
NEEDHAM, MA 02492

CHECKED BY:	DATE:
KB	02/08/19

PROJECT NUMBER:

SHEET NUMBER:

LE-1



1 ELEVATION
3/16" = 1'-0"

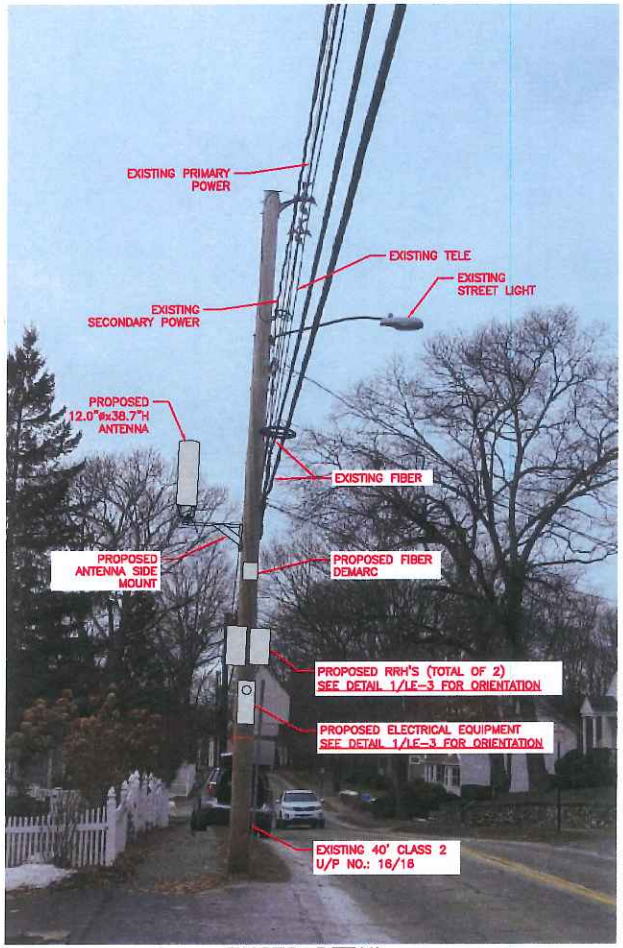
0 4 8 16
GRAPHIC SCALE: 1/8"=1'-0"

NOTES:

1. LESSEE SHALL MAKE ARRANGEMENTS WITH THE LOCAL ELECTRICAL UTILITY, TO LOWER THE POSITION OF THE EXISTING OVERHEAD PRIMARY POWER LINES AT SUBJECT UTILITY POLE TO PROVIDE THE REQUIRED CLEARANCE FOR THE INSTALLATION OF THE PROPOSED LESSEE ANTENNA. THE PROPOSED INSTALLATION OF THE ANTENNA AND ALL APPURTENANCES SHALL MEET THE REQUIREMENTS OF NATIONAL GRID AND THE 2012 NATIONAL ELECTRICAL SAFETY CODE.

LEASE EXHIBIT

THIS LEASE PLAN IS DIAGRAMMATIC IN NATURE AND IS INTENDED TO PROVIDE GENERAL INFORMATION REGARDING THE LOCATION AND SIZE OF THE PROPOSED WIRELESS COMMUNICATION FACILITY. THE SITE LAYOUT WILL BE FINALIZED UPON COMPLETION OF SITE SURVEY AND FACILITY DESIGN



2 PHOTO DETAIL
N.T.S.

LEASE EXHIBIT

PREPARED BY:

NEXIUS
TRANSFORM YOUR BUSINESS...THROUGH WIRELESS
A&E OFFICE:
300 APOLLO DRIVE, SUITE 7
CHELMSFORD, MA 01824
1 (972) 755-1882

PROFESSIONAL STAMP:

COMMONWEALTH OF MASSACHUSETTS
JIMMY CHENDANA
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REGISTERED PROFESSIONAL ENGINEER

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SUBMITTALS

REV	DATE	DESCRIPTION	BY
0	01/24/19	FOR CONSTRUCTION	AA
1	02/28/19	REVISED PER COMMENTS	KT
2	03/20/19	REVISED PER COMMENTS	KT
3	06/06/19	FINAL LE	AA

SITE INFO:

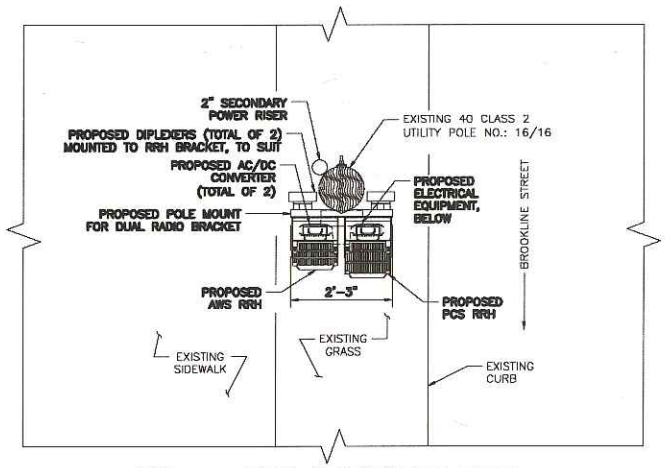
SITE NAME:
NEEDHAM_SC02_MA

SITE ADDRESS:
U/P NO.: 16/16
228 BROOKLINE STREET
NEEDHAM, MA 02492

CHECKED BY:	DATE:
KB	02/06/19

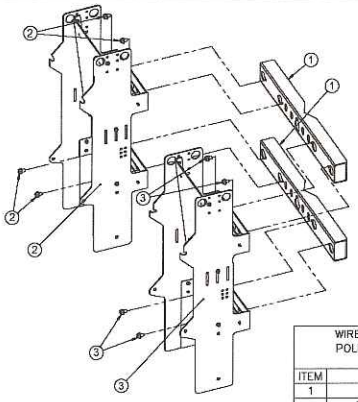
PROJECT NUMBER:

SHEET NUMBER:
LE-2



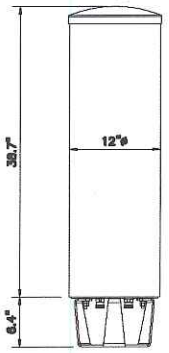
APPROX. NORTH

1 RRH ORIENTATION PLAN
N.T.S.



WIRELESS CONSTRUCTION, INC. POLE/WALL MOUNT FOR DUAL RADIO BRACKET		
ITEM	DESCRIPTION	QTY.
1	DOUBLE MOUNT	2
2	700MHZ RRH RACK W/ SUPPLIED HARDWARE	1
3	AWS RRH RACK W/ SUPPLIED HARDWARE	1

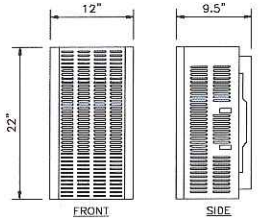
2 RRH MOUNTING BRACKET SPEC.
N.T.S.



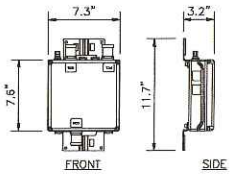
ANTENNA SPECIFICATIONS	
COMMSCOPE – NH360QM-DG-2XR	
DIMENSIONS	12"ø x 38.7"
WEIGHT	33.7 LBS

3 ANTENNA SPEC.
N.T.S.

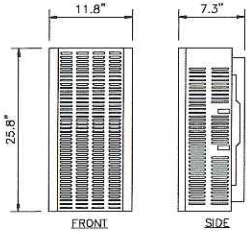
LEASE EXHIBIT



PCS RRH
WEIGHT: 55.0 LBS.



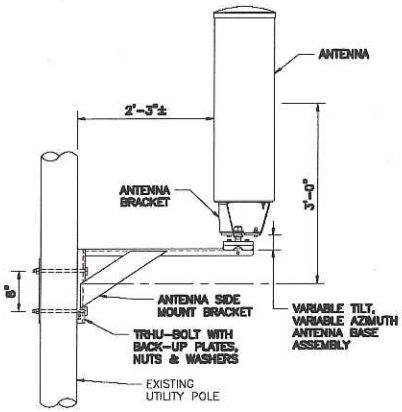
WEIGHT: 6.6 LBS.



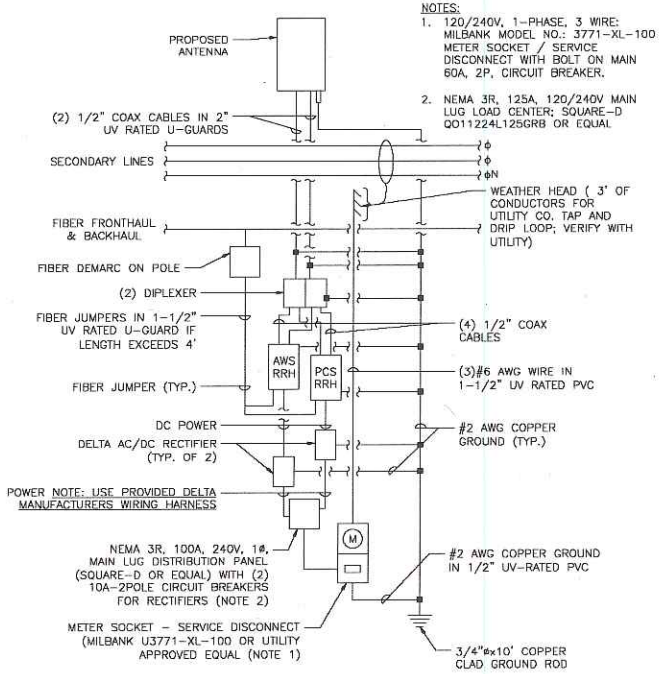
AWS RRH
WEIGHT: 56.8 LBS.

4 DIPLEXER SPEC.
N.T.S.

5 RRH SPEC.
N.T.S.



6 ANTENNA MOUNTING DETAIL
N.T.S.



NOTES:
1. 120/240V, 1-PHASE, 3 WIRE: MILBANK MODEL NO.: 3771-XL-100 METER SOCKET / SERVICE DISCONNECT WITH BOLT ON MAIN 60A, 2P, CIRCUIT BREAKER.
2. NEMA 3R, 125A, 120/240V MAIN LUG LOAD CENTER; SQUARE-D QO11224L125GRB OR EQUAL

7 GENERAL WIRING DIAGRAM
N.T.S.

PREPARED BY:

NEXIUS
TRANSFORM YOUR BUSINESS...THROUGH WIRELESS

A&E OFFICE:
300 APOLLO DRIVE, SUITE 7
CHELMSFORD, MA 01824
1 (972) 755-1882

PROFESSIONAL STAMP:

COMMONWEALTH OF MASSACHUSETTS
JIMMY CHENDANA
STRUCTURAL
No. 53634
REGISTERED PROFESSIONAL ENGINEER

Jimmy Chendana

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DRAWING SCALES ARE INTENDED FOR 11"x17" SIZE PRINTED MEDIA ONLY. ALL OTHER PRINTED SIZES ARE DEEMED "NOT TO SCALE".

SUBMITTALS

REV	DATE	DESCRIPTION	BY
0	01/24/19	FOR CONSTRUCTION	AA
1	02/28/19	REVISED PER COMMENTS	KT
2	03/20/19	REVISED PER COMMENTS	KT
3	03/08/19	FINAL LE	AA

SITE INFO:

SITE NAME:
NEEDHAM_SC02_MA

SITE ADDRESS:
U/P NO.: 16/16
228 BROOKLINE STREET
NEEDHAM, MA 02492

CHECKED BY:	DATE:
KB	02/08/19

PROJECT NUMBER:

SHEET NUMBER:
LE-3

TOWN OF NEEDHAM
BOARD OF SELECTMEN

ORDER FOR POLE AND WIRE LOCATIONS
UNDER MGL c. 166, §§ 22 AND 25 A

In the Town of Needham, Massachusetts,
Notice supplied and public hearing held, as provided by law,

IT IS HEREBY ORDERED:

That Cellco Partnership d/b/a Verizon Wireless ("Verizon") is granted location and permission to install and maintain wireless equipment and all sustaining and protecting fixtures on an existing utility pole located on a public way on **228 Brookline Street in Needham, Massachusetts**, as requested by Verizon's Petition for Pole and Wire Locations Under MGL c. 166 §§ 22 and 25A, dated **May 23, 2019**.

All construction under this order shall be in accordance plans titled **Needham SCO2 MA**, dated **February 8, 2019**.

All equipment shown on the aforementioned plans may be attached to said utility pole, including, but not limited to:

- Antennas
- Radio Units
- Meters
- Mounting Brackets
- Groundbars
- Conduits
- Cables
- Disconnects
- All other necessary sustaining and protecting fixtures.

Such plans, including all notes shown thereon, are hereby incorporated as part of this Order. This Grant of Location is made subject to the following conditions:

1. The Small Cell Attachment shall comply with the maximum permissible radio frequency ("RF") exposures adopted by the Federal Communications Commission, taking into consideration other RF sources at the site.

2. The Petitioner shall annually provide a certificate of RF compliance to the Office of the Town Manager, Needham Town Hall, Town of Needham, Massachusetts.

3. The Petitioner shall ensure that replacement poles (if necessary) are installed at the minimum height necessary to accommodate the small cell antenna equipment.

4. The Pole shall not be a "double pole" at the time of Small Cell Attachment installation. (A "double pole" occurs where a replacement utility pole is erected alongside the pole to be replaced for the purpose of transferring the electric, telephone, cable, and other wires from one pole to the other). In the event that, after installation of the Small Cell

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Attachment, the Pole must be replaced, the Petitioner shall work with the Pole owner(s) to mitigate and remove any "double pole" at the proposed location.

5. The approved small cell antenna and related equipment described in the plans identified in this Order (collectively, the "Small Cell Attachment") shall not include lights unless required under applicable federal or state law.

6. The Small Cell Attachment shall blend with the color of existing attachments on the designated utility pole (the "Pole") or with the color of the Pole itself.

7. The Small Cell Attachment shall not project over the public roadway or the sidewalk beyond the berm or curb, or otherwise interfere with the safety and convenience of ordinary travel over the public right of way or sidewalk.

8. The Petitioner shall seek to install side mount or top mount without extension equipment rather than top mount extension equipment.

9. The Petitioner shall seek to avoid locating Small Cell Antenna equipment that would negatively impact the health of public shade trees or that would require significant tree trimming as a result of the antenna location.

I hereby certify that this order was adopted at a meeting of the Board of Selectmen of the Town of Needham, Massachusetts, held on the _____ day of _____, 2019.

Town Clerk
Town of Needham, Massachusetts
1471 Highland Avenue
Needham, Massachusetts 02492

Received and entered in the records of location orders of the Town of Needham, at Book _____, Page _____.

Attest: _____
Town Clerk
Town of Needham, Massachusetts

_____

_____

_____

_____

_____

Board of Selectmen

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UPDATED: Please Note this notice has been updated with a new time and corrected house number. All other information remains the same.

NOTICE

To the Record

You are hereby notified that a public hearing will be held at the **Needham Town Hall, 1471 Highland Avenue, at 7:00 p.m. on June 25, 2019** upon petition of Cellco Partnership d/b/a Verizon Wireless dated **May 23, 2019** to install one (1) small cell wireless antenna, and all necessary sustaining and protecting fixtures, on an existing utility pole, located on a public way on Brookline Street in Needham, MA. The following is the public way or part of way along which the cell antenna above referred to may be installed: Verizon Site Name Needham SC02 MA, Utility Pole Number 16/16 at ~~288~~ **228** Brookline Street, Needham.

A public hearing is required, and abutters should be notified.

If you have any questions regarding this petition, please contact Victor Manougian of Mclane Middleton, at 603-628-1310.

John A. Bulian
Maurice P. Handel
Matthew D. Borrelli
Marianne B. Cooley
Daniel P. Matthews

SELECT BOARD

Dated: June 12, 2019

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Resident Submissions to Town Manager re: Verizon 5G Small Cell Sites

Marjanović AM, et al. *Biological Indicators in Response to Radiofrequency/microwave Exposure*. Arh Hig Rada Toksikol 2012;63:407-416

Russell, Cindy L. *5G wireless telecommunications expansion: Public health and environmental implications.* Environmental Research 165 (2018) 484-495

Dart, Paul et al. *Biological and Health Effects of Microwave Radio Frequency Transmissions.* A Report to the staff and directors of the Eugene Water and Electric Board. June 4, 2013

Williams, John Michael. *Biological Effects of Microwaves: Thermal and Nonthermal Mechanisms* – A Report by an Independent Investigator. September 29, 2016.

[European Commission] Scientific Committee on Toxicity, Ecotoxicity and the Environment. *Opinion on Possible effects of Electromagnetic Fields (EMF), Radio Frequency Fields (RF) and Microwave Radiation on human health.* October 30, 2001.

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Zothansiama, Mary et al. *Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicity of mobile phone base station.* Electromagnetic Biology and Medicine 36 (2017) 3.

Nielsen C, Hui R, Lui W-Y, Solov'yov IA (2019) *Towards predicting intracellular radiofrequency radiation effects*. PLoS ONE 14(3): e0213286

Chou, C.K. et al. *Long-Term, Low-Level Microwave Irradiation of Rats.* Bioelectromagnetics 13: 469-496 (1992).

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Belyaev, Igor. *Non-thermal Biological Effects of Microwaves.* Microwave Review November 2005: 13-29.

World Health Organization, International Programme on Chemical Safety. *Radiofrequency and Microwaves.* Environmental Health Criteria 16 (1981).

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DOI:10.2478/10004-1254-63-2012-2215

Review

BIOLOGICAL INDICATORS IN RESPONSE TO RADIOFREQUENCY/MICROWAVE EXPOSURE

Ana Marija MARJANOVIĆ, Ivan PAVIČIĆ, and Ivančica TROŠIĆ

Institute for Medical Research and Occupational Health, Zagreb, Croatia

Received in February 2012
CrossChecked in February 2012
Accepted in August 2012

Over the years, due to rapid technological progress, radiation from man-made sources exceeded that of natural origin. There is a general concern regarding a growing number of appliances that use radiofrequency/microwave (RF/MW) radiation with particular emphasis on mobile communication systems. Since non-thermal biological effects and mechanisms of RF/MW radiation are still uncertain, laboratory studies on animal models, tissues, cells, and cell free system are of extraordinary importance in bioelectromagnetic research. We believe that such investigations play a supporting role in public risk assessment. Cellular systems with the potential for a clear response to RF/MW exposures should be used in those studies. It is known that organism is a complex electrochemical system where processes of oxidation and reduction regularly occur. One of the plausible mechanisms is connected with generation of reactive oxygen species (ROS). Depending on concentration, ROS can have both beneficial and deleterious effects. Positive effects are connected with cell signalling, defence against infectious agents, and proliferative cell ability. On the other hand, excessive production, which overloads antioxidant defence mechanism, leads to cellular damage with serious potential for disease development. ROS concentration increase within the cell caused by RF/MW radiation seems to be a biologically relevant hypothesis to give clear insight into the RF/MW action at non-thermal level of radiation. In order to better understand the exact mechanism of action and its consequences, further research is needed in the field. We would like to present current knowledge on possible biological mechanisms of RF/MW actions.

KEY WORDS: *interactions, macromolecules, non-ionizing, non-thermal, radiation, reactive oxygen species*

For centuries human population has been exposed to natural electromagnetic sources such as radiation from sun, space, and earth. Today, besides this natural radiation and owing to rapid technological progress we are more than ever exposed to man-made electromagnetic radiation (EM). Various products and applications in our everyday life make use of some form of electromagnetic energy (1). Connection between technological development and increase in EM radiation doubtlessly exists. Levels of radiation have rapidly increased and man-made sources at specific frequencies now by far exceed those of natural origin. There is a particular concern regarding an increase in the number of appliances which use RF/MW radiation. Some of them have become an integral part of our lives like mobile phones, television, microwave ovens, medical devices, radars, and satellites (2). Besides the obvious benefits, there is also a widespread public concern about the potential health effects this technology can have on biological system and living beings. EM radiation can be described as the propagation of energy through space in the form of waves or particles (photons) and it is characterised by specific wavelength, frequency, and energy. Because of thermal agitation of charged particles generating

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electromagnetic field. Energy of the field is directly proportional to its frequency, with higher frequency meaning greater energy (3). Minimum energy capable of causing ionisation by breaking the intermolecular bonds and releasing electrons from an atom or molecule is considered to be 10 eV (1). Based on their ability to cause ionisation, we can distinguish two types of electromagnetic radiation; ionising and non-ionising radiation. Non-ionising radiation includes three frequency ranges; static (0 Hz) and extremely low frequency range (<300 Hz), intermediate frequency range (300 Hz-10 MHz), and radiofrequency range including RF and microwaves (10 MHz to 300 GHz) (2). Over the years, rapid increase in technology, especially telecommunication, has raised great concerns regarding possible adverse health effects of excessive RF/MW exposure. This is not surprising if we know that charged ions, molecules, and structures inside the body contribute to electromagnetic processes that are crucial for the normal functioning of every living organism. These processes are characterised by specific frequencies usually found in the microwave region of electromagnetic field (4).

Passing through a biological system, RF radiation can be reflected, transmitted, refracted or absorbed (1). Absorption of RF energy stirs up the motion of charged particles and rotation of molecules, primarily water, inevitably rising the temperature (5). Measure of absorbed energy within the organism is defined as the specific absorption rate (SAR) and is usually expressed in watts per kilogram (W kg^{-1}) (6). For general public, SAR limit for the whole body is 0.08 W kg^{-1} and for people occupationally exposed to RF energy limit is 0.4 W kg^{-1} (7). Based on the amount of absorbed energy within the biosystem, effects can be divided into thermal and non-thermal. Certainly the most acceptable mechanism of RF interaction is tissue heating. Thermal effects occur with the temperature increase exceeding 1 °C causing cellular and intracellular changes particularly at molecular level (1). The amount of heat depends on the radiation intensity, electrical properties of exposed tissue and body′s thermoregulatory mechanism (7). The World Health Organization stated that many biological effects of acute exposure to non-ionising radiation are consistent with responses to induced heating, resulting either in the rises in tissue or body temperature by about 1 °C or more, or in responses to minimising the total heat load. However, during low intensity radiation thermal homeostasis remains stable due to activated thermoregulation processes. The body temperature might rise by up to 1 °C without accumulation. Based on this statement basic exposure limits for occupational and general population have been established and are known as exposure standards (8). Consequently, the problem of a prolonged exposure to low intensity radiation and non-thermal biological effects derived from RF/MW sources remains open to science.

Biological mechanisms of RF/MW action

A number of published papers point at different modifications and biological effects caused by RF/MW radiation, while at the same time others lack significance. These contradictions are not surprising given the variety of factors influencing experimental procedure. Some of them include polarisation, duration of exposure, continuous or pulsed wave exposure, biological factors of exposed system and many others. All these factors have to be considered so that research results can be reproducible as it was proposed by Belyaev et al. (9) in 2000 and 2005 (10).

The exact mechanism of non-thermal electric and magnetic field interactions with biological structures is still unknown and many different theories suggest various explanations. Detectible changes can only be observed if the applied RF/MW radiation exceeds thermal noise caused by constant random movement of charges at temperatures above absolute zero. Minimum energy required for these processes should exceed 26 meV, the average energy of thermal noise measured at body temperature. Considering low energy level of RF/MW radiation, it is believed that changes could only be detected when biological system is resonantly sensitive to applied frequency (11).

Fröhlich was the first to propose a model based on vibration interactions between large molecules and components of biological systems. Trying to explain possible biological effects he suggested a particular coherent state of vibrations and the existence of specific frequencies within the RF/MW band of electromagnetic spectrum in which energy could be absorbed (12, 13). Under special conditions during vibration, electrically polar structures generate EM field. However significant effects can only be detected when these structures are in resonance with external electric field having the same frequency (11). Because of its ability to detect and amplify small signals against the background noise, organism could be easily compared with a radio receiver. Based on this mechani possibility

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of biological effects occurring at frequencies of mobile phones. These effects could only be observed if certain biological structures had the same vibration frequencies as the applied EM field (12, 14). Cell membranes were first considered a possible source of cellular vibrations until the discovery of cytoskeleton when much attention was given to microtubules. Microtubule reassembly was related with the peak of cellular EM field emission during replication suggesting the crucial role in their generation. Interestingly microtubules have the ability to vibrate in kHz to GHz frequency region (11).

Pokorný et al. (15, 16) proposed a model based on microtubule vibrations. However there were few remarks regarding potential vibration damping given the highly viscous medium surrounding them. Taking this into account, Adair (17) calculated and concluded that because of damping effect vibrations were too small to cause any biological effect. On the other hand, Pokorný (18) showed that damping effect on microtubules could be minimised due to a slip layer formed at the boundary of microtubules and cytosol. Changes in microtubule structure were also observed in several papers (19-22).

Bohr and Bohr (23, 24) suggested that some protein conformations had very similar energies and that transition between them corresponded to the frequencies of approximately few GHz. Based on the experimental results they concluded that MW radiation has the ability to change protein conformation by enhancing the kinetics of protein folding and denaturation, which could eventually lead to detrimental biological effects. De Pomerai et al. (25) also showed that aggregation of protein bovine serum albumin could be enhanced by microwave radiation. Other different approaches have been considered regarding the interactions between RF/MW radiation and biological systems. One of them is based on the interactions with small particles of ferromagnetic material magnetite. Magnetite is found not only in certain bacteria but also in human beings, especially in the brain. It strongly absorbs radiation at frequencies between 500 MHz and 10 GHz and converts the energy into acoustic vibrations dissipating it in cellular structures at microwave frequencies. These findings also led Kirschvink (26) to propose magnetite as a possible mechanism of interaction. Besides magnetic nanoparticles, there are other possible targets for magnetic field interactions like spinning magnetic moments in radical pairs or long-lived rotational states of some molecules (27, 28).

Radical pair mechanism is considered the most probable mechanism in explaining the interactions between cellular and static or extremely low EM field (ELF). At the same time researchers suggest that the proposed mechanism could also explain biological effects of radiofrequency radiation (1, 29). Radical pairs are formed during normal metabolic processes and although have very short lifetime they react with each other or other molecules and generate new radicals. They contain one or more unpaired electrons and their magnetic properties are related to electron spin. Electron spins of two radicals can be in either singlet or triplet state i.e. parallel or opposite from one another. Oscillations between two states depend on magnetic interactions of unpaired electrons with each other, nuclear spins, and external magnetic field (30). Stable molecules are formed only when two spins are opposite one from the other, while parallel spins first require a spin change. External magnetic field slows down the processes of spin change, causes radical pair separation and increases their lifetime and concentration. The process is even more expressed when radicals are attached to cellular structures such as cell membrane (31). A biophysical model for the effect of oscillating electric fields on cells has been given by Panagopoulos et al. in 2002. This model is based on forced-vibration of free ions on the surface of a plasma membrane caused by an external oscillating field. It was shown that coherent vibration of electric charge was able to affect electro sensitive channels on the membrane which could lead to the disruption of cell′s electrochemical balance and function. The proposed model theoretically proved that pulsed EM fields could be twice as effective biologically as the continuous ones (32). Furthermore there have been a number of papers connecting exposure of RF/MW radiation with excessive formation of free radicals (67-74). Action of free radicals is additionally enhanced in the presence of oxygen which further causes the formation of new radicals. These free radicals are also known as reactive oxygen species (33).

Reactive oxygen species

Under physiological conditions, ROS are generated everyday as a result of various metabolic processes. They are known to have both beneficial and deleterious effects. At low concentrations they are often involved in defence against infectious agents, cell signalling, and mitogenic response. On the other hand, overload of ROS [illegible] iency leads

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to cellular damage including membranes, lipids, proteins, and even DNA. Several diseases are associated with adverse effects caused by reactive oxygen species such as diabetes, atherosclerosis, chronic inflammation, malignant and neurodegenerative diseases, and many others (34, 35).

Balance between these effects is accomplished by redox regulation (34, 36). ROS include oxygen radicals like superoxide radical ($O_2^{\cdot-}$), hydroxyl ($HO^{\cdot}$), peroxyl ($RO_2^{\cdot}$), and alkoxyl ($RO^{\cdot}$) radicals as well as nonradical derivatives of oxygen like hydrogen peroxide (H_2O_2), hypochlorous acid (HClO), and ozone (O_3) (37).

Even oxygen molecule, having two unpaired electrons found in triplet state, qualifies as a free radical, or to be precise - biradical. However, because of parallel spins oxygen is able to accept only one electron at a time which consequently slows down its′ reactivity (Figure 1) (38).

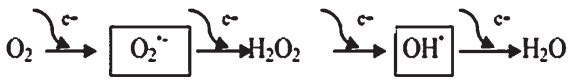


Figure 1 *One electron reduction of oxygen and formation of superoxide radical ($O_2^{\cdot-}$), hydrogen peroxide (H_2O_2) and hydroxyl radical ($OH^{\cdot}$) with water as a final electron acceptor.*

One of the major sources of ROS in the cell is mitochondrion (35). Out of total oxygen consumed, 1 % to 2 % is converted to oxygen free radicals, mostly at the level of complex I and complex III of respiratory chain (39, 40). Besides mitochondrion, there are several other sources of ROS in the cell. Some of them include peroxisomes, enzymes like xanthine oxidase, cytochrome P450, neutrophils, eosinophils, and macrophages (41, 42). Superoxide radicals are mostly generated in mitochondria as a result of electron leakage from electron transport chain and premature reduction of oxygen. They are known as the primary ROS able to generate "secondary" ROS by further reacting with other molecules. Superoxide radicals extract iron from iron-containing molecules and enable Fe^{2+} to participate in the Fenton reaction creating hydroxyl radical (Eq. 2). They also participate in the Haber-Weiss reaction (Eq. 3), which combines the reduction of iron and the Fenton reaction (Eq. 1 and 2) (43).

$$Fe^{+3} + O_2^{\cdot-} = O_2 + Fe^{+2} \quad (1)$$

$$Fe^{+2} + H_2O_2 = Fe^{+3} + HO^{\cdot} + OH^{-} \quad (2)$$

Equation 1, 2 - the Fenton reaction

$$O_2^{\cdot-} + H_2O_2 = O_2 + HO^{\cdot} + OH \quad (3)$$

Equation 3 – the Haber-Weiss reaction

Hydroxyl radicals can also be produced in reaction with other metals like copper, chromium or cobalt (44). However, reaction catalysed by iron is considered to be the major mechanism in the generation of highly reactive hydroxyl radicals (45). Because of a very short lifetime, these radicals are known to react in close proximity of the site of formation (43). Superoxide can also generate hydrogen peroxide in a reaction of dismutation. In biological systems, this reaction is additionally accelerated by superoxide dismutase (SOD) (46). Although not a radical, hydrogen peroxide is considered to be a reactive oxygen metabolite. It can easily pass the cell membrane and directly or indirectly cause damage to macromolecules even at a low concentration. Because of its lipid solubility H_2O_2 can also generate $HO^{\cdot}$ radical at localised sites containing iron or copper (47).

Excessive level of free radicals can cause severe damage to biological systems, which could eventually lead to disease development. Because of their high level of polyunsaturated fatty acids (PUFAs), cell membranes are particularly sensitive to oxidative damage. During the three-stage process of lipid peroxidation, aldehydes are formed as a final product (48). One of the most abundant products of lipid peroxidation is certainly malondialdehyde (MDA), which is also used as a biomarker of oxidative stress. MDA is a known mutagen and carcinogen. It reacts with DNA and forms adducts with deoxyguanosine, deoxyadenosine, and deoxycytidine (49, 50). Besides lipids, proteins are also highly sensitive to free radical exposure. They are involved in different biological functions and even the slightest change in protein structure or conformation could result with their loss of function. Modifications of amino acids, fragmentation of polypeptide chains or protein-protein cross-linkage are some of the changes that could be induced as a result of protein interactions with free radicals (51). Considering that different modifications are numerous, there are also various methods for detecting and quantifying them. Certainly the most measurable products of protein oxidation are protein carbonyls (52). They are characterised by carbonyl group generated at the protein side chains. Because of their stability, they can be easily detected (53). ROS can also react with nucleic acids, especially DNA, and cause different modifications, even single or double strand breaks. Guanine is most susceptible to oxidative damage and in reaction with ROS forms highly mutagenic and carcinogenic 8-oxoguanine (43). Because

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tochondria

and limited repair mechanism, mitochondrial DNA is particularly sensitive to free radicals (54).

Cell antioxidant defence system

Given the variety of possible damage that could be caused by free radicals, organisms have developed a whole spectrum of different defence mechanisms. They include preventive and repair mechanisms as well as physical and antioxidant defence. Antioxidant defence includes enzymes like SOD, glutathione peroxidase (GPx), and catalase (CAT), while non-enzymatic antioxidants include glutathione (GSH), vitamin E and C, carotenoids, flavonoids, and many others (34). Certainly one of the most significant compounds of antioxidant defence is glutathione. Glutathione is a low molecular weight antioxidant capable of preventing oxidative damage by reacting directly or indirectly with ROS (47). It is found in reduced (GSH) or oxidised (GSSG) form with their ratio often used as a measure of toxicity or antioxidant capacity (55). GSH can react directly with free radicals. This results in GSH becoming a radical itself that forms GSSG reacting with another GSH radical. Accumulation of GSSG causes disturbance of redox balance, which affects metabolic processes, homeostasis, and cellular integrity (56, 57). GSH is also known to act as a cofactor for several enzymes, participates in the transport of amino acids and helps the regeneration of vitamin E and ascorbic acid (47, 43).

As previously mentioned, SOD helps to remove superoxide radicals by producing hydrogen peroxide which is later removed by the activity of GPx and CAT. There are three SOD isoforms that exist in animal tissues; cytosolic CuZnSOD, MnSOD, and extracellular SOD (ECSOD), each dealing with decomposition of $O_2^{\cdot-}$ in different compartments (58).

DISCUSSION

It is known that altering magnetic field produces an electric field and vice versa, a varying electric field generates a magnetic field. Because of this interdependence, both fields jointly are considered a single entity - the electromagnetic field (59). Alternating electric fields have a wide range of effects on living systems. At extremely low frequencies, electric fields stimulate excitable tissues through membrane depolarisation, stimulate bone growth, and accelerate fracture healing (60-63). As the electric field frequency increases, the stimulatory effect disappears, ending in the so-called thermal effect, when tissue heating becomes a dominant event (64). In-between the desired stimulatory and undesired heating effects, there is this mostly unexplored biological potential of RF/MW radiation at a non-thermal level of exposure.

Since the expanded mobile phone use has caused a serious apprehension worldwide, along with the fact that relationship between low intensity RF/MW radiation and its undesirable bioeffects are very close, we attempted to recognise reasonable indicators which might give an insight into the mechanism of action. It seems that such approach has become more important than ever.

Considering the Fröhlich hypothesis, Pokorný at al. (65) investigated the non-thermal cellular effects of radiation in the microwave range. It was concluded that the observed intracellular changes are a consequence of macromolecular chain resonance caused by external radiation. In electrobiological entity such as a single cell, internal electromagnetic field created by own polar intracellular structures enters into a coherent state with external field, which means that oscillating electric field of low strength could cause significant non-thermal biological changes. As it was mentioned previously, it occurs when the wavelength of radiation is in the range of the properties of biological tissue. In the state of coherence, external field could cause attenuation or amplification of internal frequency field leading to disruption of homeostatic balance. Further, RF/MW radiation seems to induce electric oscillations that disturb cell membrane proteins, activating enzyme cascades that may transfer cell surface signals to the intracellular system (66).

Several investigations point at a possible connection between RF/MW exposure and ROS generation. Results of conducted researches are often contradictory and inconclusive because many factors have to be considered during the experiment. One of the reasonable pathways of RF/MW intracellular action is based on the generation of reactive oxygen species (ROS). Increased levels of ROS, antioxidants, and cellular damage were found in different types of investigations including cell cultures, laboratory animals, and even in the humans after RF/MW exposure (67-74). Xu et al. (75) exposed human lens epithelial cells to 1.8 GHz RF field at different SAR values. A[illegible]e, only the

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group exposed to smallest SAR value of 1 W kg^{-1} didn't cause increase in ROS concentration, while other groups of 2 W kg^{-1}, 3 W kg^{-1} and 4 W kg^{-1} did. In order to show the effects of cellular phone radiation on the brain and blood of guinea pigs, Meral et al. (76) exposed animals to 890 MHz to 915 MHz radiation for 12 h per day for 30 days. The brain concentration of MDA increased, while CAT and GSH decreased. On the other hand, the blood levels of MDA, CAT, vitamins A, D3, and E increased and GSH decreased. A study conducted by Moustafa et al. (49) examined the effect of acute exposure to 900 MHz radiofrequency field on 12 male volunteers. Results showed significant increase in plasma lipid peroxides and reduction in the SOD and GPx activity in erythrocytes supporting the interaction of radiofrequency fields with biological systems. However, numerous studies were unable to connect generation of ROS and oxidative damage with RF/MW exposure (77-80). In their study, Ferreira et al. (81) exposed rats to 834 MHz radiation to determine the effects on non-enzymatic antioxidant defence, as well as lipid and protein damage. After measuring the level of MDA and protein carbonyls in rat brain tissue, they concluded that there was no significant difference compared to the sham exposed group. Combining the effects of EM radiation and chemicals known to induce free radicals, researchers also tried to investigate the possibility that RF/MW radiation alters the effect of chemical agents. Zmyslený et al. (82) tested the effect of iron ions on rat lymphocytes exposed to continuous wave (CW) EM field. The authors compared two groups of lymphocytes, one treated with $FeCl_2$ and the other treated with $FeCl_2$ and exposed to 930 MHz. They noticed that after acute exposure for 5 min and 15 min ROS level was significantly higher in the exposed group. Similar experiments and results were published by Höytö (83) and Luukkonen et al. (84). It could be concluded that existence of non-thermal effects, including oxidative damage caused by RF/MW radiation, must not be denied. Thereafter, the International Agency for Research on Cancer (IARC) classified RF electromagnetic fields as possibly carcinogenic to human (85). Given the electromagnetic nature of living beings and a growing number of man-made sources of non-ionising radiation, there is also a constant need for better understanding the exact mechanism of interaction between radiation and cellular systems. What makes it particularly difficult is certainly the highly dynamic and complex organisation and function of every organism. A variety of factors contribute to research results, which is the reason why *in vitro* studies are frequently used in this kind of research. However, despite precisely defined and controlled studies, some results are still open to doubt. Future research should pay more attention to determining a possible connection between RF/MW radiation and generation of free radicals *in vitro*. Special consideration should be given not only to the concentration but also to the type of ROS, their origin and the changes in the antioxidant defence system, as well as to macromolecular changes.

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Sažetak

BIOLOŠKI POKAZATELJI KAO ODGOVOR NA IZLOŽENOST RADIOFREKVENCIJSKOMU/ MIKROVALNOM ZRAČENJU

Zbog ubrzanoga tehnološkog napretka tijekom godina zračenje iz umjetnih izvora mnogostruko je nadmašilo zračenje iz prirodnih izvora. Rastući broj uređaja koji rabe radiofrekvencijsko/mikrovalno (RF/MW) zračenje, osobito mobilni komunikacijski sustav, izaziva zabrinutost opće i znanstvene javnosti. S obzirom na to da su učinci i mehanizmi netermalnoga biološkog djelovanja RF/MW zračenja dvojbeni, laboratorijske studije u kojima se rabe životinjski modeli, tkiva, stanice i bestanični sustavi smatraju se izuzetno važnima u bioelektromagnetskim istraživanjima. Vjerujemo da takva istraživanja podupiru procjenu opasnosti od zračenja za živi organizam. Zbog mogućnosti jasnog odgovora stanice na RF/MW izloženost preporučuje se uporaba staničnog sustava. Zna se da je organizam složen elektrokemijski sustav, gdje se među mnogim drugima redovito događaju oksidacijsko-redukcijski procesi. Jedan od mogućih mehanizama djelovanja povezuje se sa stvaranjem reaktivnih kisikovih spojeva (ROS). Ovisno o koncentraciji ROS-ovi mogu štetiti, ali i djelovati korisno na biosustav. Povoljni učinci ROS-ova povezuju se s diobenom sposobnosti stanice, staničnim signalnim putovima i obranom protiv infektivnih čimbenika. Međutim prekomjerno stvaranje koje preopterećuje antioksidacijski obrambeni sustav dovodi do oštećenja stanica i mogućnosti razvoja bolesti. Čini se da je hipoteza o povišenju koncentracije ROS-ova u stanici zbog zračenja biološki valjana, jer može pojasniti mehanizam netermalnih učinaka RF/MW zračenja. S ciljem boljeg razumijevanja točnog mehanizma, kao i njegovih posljedica potrebna su dodatna istraživanja. Ukratko su prikazane postojeće spoznaje o mogućim biološkim mehanizmima djelovanja RF/MW zračenja.

KLJUČNE RIJEČI: *makromolekule, neionizirajuće zračenje, netermalno zračenje, reaktivni kisikovi spojevi*

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5 G wireless telecommunications expansion: Public health and environmental implications☆

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ABSTRACT

The popularity, widespread use and increasing dependency on wireless technologies has spawned a telecommunications industrial revolution with increasing public exposure to broader and higher frequencies of the electromagnetic spectrum to transmit data through a variety of devices and infrastructure. On the horizon, a new generation of even shorter high frequency 5G wavelengths is being proposed to power the Internet of Things (IoT). The IoT promises us convenient and easy lifestyles with a massive 5G interconnected telecommunications network, however, the expansion of broadband with shorter wavelength radiofrequency radiation highlights the concern that health and safety issues remain unknown. Controversy continues with regards to harm from current 2G, 3G and 4G wireless technologies. 5G technologies are far less studied for human or environmental effects.

It is argued that the addition of this added high frequency 5G radiation to an already complex mix of lower frequencies, will contribute to a negative public health outcome both from both physical and mental health perspectives.

Radiofrequency radiation (RF) is increasingly being recognized as a new form of environmental pollution. Like other common toxic exposures, the effects of radiofrequency electromagnetic radiation (RF EMR) will be problematic if not impossible to sort out epidemiologically as there no longer remains an unexposed control group. This is especially important considering these effects are likely magnified by synergistic toxic exposures and other common health risk behaviors. Effects can also be non-linear. Because this is the first generation to have cradle-to-grave lifespan exposure to this level of man-made microwave (RF EMR) radiofrequencies, it will be years or decades before the true health consequences are known. Precaution in the roll out of this new technology is strongly indicated.

This article will review relevant electromagnetic frequencies, exposure standards and current scientific literature on the health implications of 2G, 3G, 4G exposure, including some of the available literature on 5G frequencies. The question of what constitutes a public health issue will be raised, as well as the need for a precautionary approach in advancing new wireless technologies.

1. Introduction

The adoption of new 5G technology promises to give the public a transformative communication network with an explosion of speed, volume of data and number of devices with unlimited computing instantly to anyone in the world. High tech companies are already marketing the Internet of Things to businesses, healthcare systems, schools and the public. The promise to connect our phones and appliances, will virtually eliminate many day-to-day household and business functions including driving. This will, according to industry, create a superior, connected society and unprecedented economic growth. What is missing in this discussion is the maturing literature on adverse biological, physiological, and psychological health effects of the 2G, 3G, and 4G radiofrequencies we are already exposed to, in addition to indications from the scientific literature that 5G frequencies could also be hazardous.

Many important but unanswered questions merit serious consideration. Is the widespread deployment of this pervasive higher frequency small cell distributed antennae system in our cities and on our homes safe for humans and the environment? Will it add to the burden of chronic disease that costs our nation, according to the CDC, an estimated 2.3 trillion dollars annually (CDC, 2017)? Are we already digitally over connected, shrinking our gray matter and becoming a dysfunctional addicted nation because of it (Weng et al., 2012)? How

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will this affect our privacy, cyber security and the security of our medical records? Will physicians be able to recognize the emerging adverse health effects of new millimeter technology let alone that of current wireless devices? These important questions have not been addressed, yet industry and government policy have already moved forward with advertising, manufacturing and legislating the adoption of these new technologies.

2. Methods

A review of the literature was performed which included health effects of wireless technologies, controversies related to radiofrequency health effects, telecommunications 5G innovations and specifications for wireless technology as well as related policies affecting public health.

3. Results

3.1. Controversy persists as evidence of harm increases

The controversy over health effects of radiofrequency electromagnetic radiation (RF EMR) from commonly used wireless devices such as cell phones, cordless phones, WiFi routers and cell tower infrastructure remains problematic. RF research in the U.S. is poorly funded and even when a study is robust it never seems to answer the question of long term safety or provide appropriate precautionary limits. (Wyde, 2016). In 2011 the International Agency on Research on Cancer (IARC) listed non-ionizing radiofrequency radiation from cell phones and other wireless devices in Group 2B: Possibly carcinogenic to humans, based on a thorough analysis of current scientific evidence (IARC, 2011; IARC, 2017). Some researchers feel this listing should be changed to a Group 2A: Probably carcinogenic to humans or to Group 1: Carcinogenic to humans classification (Morgan et al., 2015; Sage and Carpenter, 2012). This is based on the recent National Toxicology Program Carcinogenicity Studies of Cell Phone Radiofrequency Radiation that report a significant increase in heart and brain tumors with RF-EMR exposure (Wyde, 2016). This is in addition to the abundance of basic scientific studies that show a clear health risk associated with exposure to radiofrequencies, especially with long term exposure (Hardell et al., 2013a, 2013b; Adams et al.al., 2014; Bortkiewicz et al., 2017; Carlberg and Hardell, 2017; Hassanshahi et al., 2017; Liu et al., 2014; Levitt and Lai, 2010). Many of these studies demonstrate effects well below the heat threshold of current safety standards (Wyde, 2016; IARC, 2011; Sage and Carpenter, 2012; EPA, 1992; Esmekaya et al., 2011; Grigoriev et al., 2010; Belyaev, 2005; Yu and Yao, 2010). Radiofrequencies are absorbed by and pass through living systems that contain water. Pregnant women and children are more vulnerable to developmental harm from microwave radiation due to immature organ systems (Birks et al., 2017; Othman et al., 2017a, 2017b). Research also shows children absorb more microwave radiation per body weight than an adult, however, standards were developed for adult bodies (Morgan et al., 2014).

3.1.1. Industry bias and scientific results

Industry continues to state that the weight of evidence regarding harm from RF-EMR is inconclusive. Studies that review the sources of funding and scientific bias regarding cell phones and brain cancer indicate otherwise. Huss et al. (2007) performed a systematic review regarding the association of cell phone use and brain tumors in relation to funding. He found that industry studies showed a positive association 33% of the time, whereas non-industry studies showed an 82% association. In addition, they discovered that none of the 31 peer reviewed journals listed conflicts of interest for the authors.

Myung et al. (2009) performed a meta-analysis and found that there was a small but significant elevation in brain tumors with long term cell phone use when high quality studies were examined. He noted Hardell's research to be more robust, as “all of the studies by Hardell et al. used blinding to the status of patient cases or controls at the interview and were categorized as having a high methodologic quality when assessed based on the NOS, whereas most of the INTERPHONE-related studies and studies by other groups did not use blinding and were thus categorized as having low methodologic quality”. Prasad et al. (2017) investigated the results of 22 case-controlled studies which showed an increased risk of brain tumor with long-term exposure to mobile phone radiation while industry-funded research tended to underestimate the risk.

An analysis of the Interphone study by Morgan (2009) noted eleven design flaws, including1) selection bias, 2) insufficient latency time, 3) definition of 'regular' cellphone user, 4) exclusion of young adults and children, 5) no cosideration for cell phone exposure in rural areas where they would be radiating at higher power levels, 6) exposure to other transmitting sources are excluded, 7) exclusion of brain tumor types, 8) recall accuracy of cellphone use, and 9) funding bias.

In the first court case to award damages to a plaintiff for a brain tumor caused by cell phones, an Italian court excluded cancer-based studies related to cellphones that had been financed by telecommunications companies., according to a news articles (Williams, 2017).

3.2. Current Federal Communications Commission (FCC) radiofrequency guidelines

Physicists and engineers point out that non-ionizing radiofrequency radiation, which we use in modern telecommunications today, has too low an energy unit per photon to move electrons in an atom, causing ionization, as seen with radiation from X-rays and radioactive materials (WHO, 1981). They argue that heat is the only measure of harm which is meaningful with regards to health and safety of RF EMR. Scientists, however, have elucidated other mechanisms whereby cellular functioning can be disrupted by non-thermal exposures to radiofrequency radiation.

Current FCC Guidelines for non-ionizing radiation exposure were developed over two decades ago and are based on heating of tissues over short exposure periods (6 min for occupational/controlled and 30 min for public/uncontrolled exposure) (FCC, 1997, 2015; FCC, 2013). There are no long term exposure guidelines, nor are there guidelines for low level, non-thermal or biological effects considered in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) standards which are the basis for standards used worldwide (ICNIRP, 2009; Hardell, 2017).

With the passage of the federal Telecommunication Act of 1996 responsibility for safety of non-ionizing radiation was passed from the EPA to the FCC (1996). At the time, the EPA was preparing recommendations for long term exposure which were not included in the FCC guidelines (EPA, 1981; EPA, 1992). In a 1993 scientific conference sponsored by the US EPA Office of Air and Radiation and the Office of Research and Development, the EPA discussed its concerns about public RF exposure and the need for additional research. The report noted health issues that remained unsolved including “potential effects of long term, low level exposure; and biophysical mechanisms.” (EPA, 1993).

A World Health Organization summary of Environmental Health Criteria from a Warsaw conference in 1973 stated “More data on the relationship between biological and health effects and the frequency and mode of generation of the radiation, particularly in complex modulations, are needed.” They further state, “Prevention of potential hazards is a more efficient and economical way of achieving control than belated efforts to reduce existing levels.” (WHO, 1981).

Sage and Carpenter, among others, note that for adequate public health protection a biological safety standard is needed that considers current research indicating cellular harm, long term effects of constant exposure and effects on vulnerable populations (Sage and Carpenter,

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2012; Blank et al., 2015). FCC recommendations have not been updated to include current literature on cellular affects at levels below FCC guidelines or effects of long term exposure (EPA Letter, 2002). It is notable that Section 704 of the 1996 Telecommunications Act specifies the following: "Section 704(a) of the 1996 Act expressly preempts state and local government regulation of the placement, construction, and modification of personal wireless service facilities on the basis of the environmental effects of radio frequency emissions to the extent that such facilities comply with the FCC's regulations concerning such emissions (FCC, 1996). This policy directly contradicts current evidence of harm.

3.2.1. FCC guidelines and specific absorption rate

In 1985, the FCC adopted thermal guidelines to be used for evaluating human exposure to radiofrequency (RF) emissions, incorporating electric and magnetic field strength and power density limits for Maximum Permissible Exposure (MPE) for transmitters operating at frequencies between 300 kHz and 100 GHz. These were updated in 1996. Limits are defined by either Specific Absorption Rate (SAR) or power density (PD). SAR is a measure of heat absorption in the body expressed in watts per kilogram and is typically used for near field exposure to cell phones and wireless devices. For the general population the SAR limit in the U.S. is 0.08 W/kg as averaged over the whole-body and for localized heating (typically for cell phones) the SAR limit should not exceed 1.6 W/kg as averaged over any 1 g of tissue. These SAR standards apply at operating frequencies between 100 kHz and 6 GHz (ICNIRP, 2009). This guideline gives a heating safety factor of 50 (ICNIRP, 2009; Hardell, 2017).

The closer the device is to the body, the higher the absorption of radiation and heat generated, thus in manufacturers device information inserts, the SAR is usually listed with safety recommendations for limiting close proximity to the body. The recommendation for devices such as tablets and portable laptop computers in FCC documents Page 5 states "For purposes of RF exposure evaluation, a mobile device is defined as a transmitting device designed to be used in other than fixed locations and to be generally used in such a way that a separation distance of at least 20 cm is normally maintained between the transmitter's radiating structures and the body of the user or nearby persons." (FCC, 1997).

For cell phones, the distance from the head to comply with SAR standards varies between different phones and manufacturers. Usually a minimum separation of millimeters from the head is noted in the manufactures literature. For example, the Samsung model SM-G920A insert states "Body-worn SAR testing has been carried out at a separation distance of 1.5 cm. To meet RF exposure guidelines during body-worn operation, the device should be positioned at least this distance away from the body." (Samsung SAR) Although implantable medical devices are now shielded from external RF EMR to prevent interference, manufactures may still include safety information. Samsung notes, "A minimum separation of six (6) inches should be maintained between a handheld wireless mobile device and an implantable medical device, such as a pacemaker or implantable cardioverter defibrillator, to avoid potential interference with the device." (Samsung Guide).

3.2.2. Higher frequency radiation FCC measurement standards: 6–100 Ghz

For higher frequencies energy is measured as power per unit area or power density (PD). Power density is typically expressed in terms of watts per square meter (W/m^2) or milliwatts per square centimeter meter (mW/cm^2). The conversion is 10 W/m = 1 mW/cm^2. It is also expressed as microwatts per square centimeter ($\mu W/cm^2$) for lower power measurements (1 mW/cm^2 = 1000 $\mu W/m^2$) (SLAC, 2015). Power density limits vary with frequency but at cell phone frequencies of 1500 MHz the FCC limit is 1 mW/cm^2 (or 1000 $\mu W/m^2$) in the U.S. (Madjar, 2016). The FCC notes in the OET Bulletin 65, that "devices that operate above 6 GHz (*e.g.,* millimeter-wave devices) localized SAR is not an appropriate means for evaluating exposure. At these higher frequencies, exposure from portable devices should be evaluated in terms of power density MPE limits instead of SAR." (FCC, 1997).

3.2.3. EMR frequencies

Wireless communication uses electromagnetic frequencies to carry data through the air. Typically, this includes both a carrier wave and an operating wave. Frequency is measured in cycles per second. 1 Hz (Hz) is one cycle per second. A Kilohertz (KHz) is 1000 cycles per second, a Megahertz (MHz) is a million cycles per second and a Gigahertz (GHz) pulses at a billion cycles per second. The typical 2.4 GHz Wi-Fi pulses at 2.4 billion cycles per second. Broadband was introduced in the 2000's as a high capacity transmission technology that allows a wide band of radio frequencies to operate simultaneously. This multiple frequency technology can be delivered with copper wires, fiberoptic, cables or through wireless transmission (Chiou, 2005; Goleniewski, 2001). In order to carry data at faster speeds, each new generation of telecommunications uses higher frequency radio waves. The higher frequencies used for new technology are added to the existing frequencies of older technology (Chávez-Santiago et al., 2015; 5G Vision EU). This creates an increasing mix of electromagnetic frequency exposures.

3.2.4. The electromagnetic spectrum and wireless devices

Radio frequency (RF) comprises a continuum of the electromagnetic spectrum wavelengths below visible and infrared light from about 3 kHz to 300 GHz. The wavelengths in the radio frequency range in size from hundreds of meters to fractions of a a centimeter.

Radio communications operate with long waves that are a meter to many kilometers wide. These are in the 3 Hz to 300 MHz band. AM Radio operates from 540 to 1600 kHz. FM Radio operates from 76 to 108 MHz. Long radio communication wavelengths are also known as groundwaves and can follow the earths contours beyond the horizon an thus transmit far distances.

Microwave radio frequencies are 300 MHz to 300 GHz. Higher frequency and shorter wavelength radio frequencies (microwaves) are now widely used in modern digital communications. First generation (1G) to Fourth generation (4G) radio frequency wavelengths are centimeters to a meter in width and were first used in military communications decades ago. These shorter wavelengths transmit information in a straight line of sight path but for shorter distances. Cell towers thus can transmit dozens of miles away versus typical radio communication towers that can transmit for 100's of miles, depending on the power output, height of the tower, weather and topography. New proposed 5G small cells, with millimeter waves, will transmit only 300 m.

As telecommunication has advanced, the frequencies used have shorter wavelengths and faster data transfer. More data channels can be compressed into the shorter frequency bands enabling more data to be transferred simultaneously. This means more data at faster speeds. Older cell phones and cordless DECT phones use 900 and 1800 MHz wavelengths. Today almost all newer wireless devices use a small range of frequencies clustered near 2.4 GHz, *i.e.* Cell phones, cordless phones, Wi-Fi routers, and Bluetooth. This is the same frequency as microwave ovens but with much less power. To eliminate interference from multiple devices, 5.0 GHz frequencies have been introduced into newer wireless devices. Smart meters operate with both a 900 and 2.4 GHz signals.

Proposed fifth generation (5G) technologies will use frequencies between 30 and 100 GHz which are shorter millimeter wavelengths (1–10 mm) (Nordrum, 2017). This technology is said to carry wireless data 10 times faster than 4G with 1000 times the data.

3.2.5. Generational cell phone frequencies

1G - Analog- Advanced Mobile Phone Service (AMPS) was commercially introduced in the 1980's and operated with voice only at 800 MHz with a continuous wave signal.

2G - Global System for Mobile Communications (GSM) and Code Division Multiple Access (CDMA), are variants of 2G systems,

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introduced in 1990's providing text messaging, multimedia messaging and internet access. These were used in the first digital cell phones. Frequencies are a combination of 850 and 1900 or 900 and 1800 MHz.

3G - Universal Mobile Telecommunications Service (UMTS)- Introduced in 1998 with broadband features providing data transfer, mobile internet and video calling. There are dozens of frequency bands available in the 800–900 MHz range and the 1700–2100 MHz range depending on the carrier.

4G - Long Term Evolution (LTE) –Was released in 2008 with higher frequency broadband supporting faster web access, gaming, video conferencing, and HD Mobile TV. These frequencies are in the 700 MHz, 1700/2100 MHz and the 2500–2690 MHz range.

5G- Device-to-Device Communication, Proposed for expansion of the Internet of Things (IoT). Uses wavelengths from 30 to 100 GHz and possibly up to 300 GHz.

3.3. The science of biological harm from non-ionizing radiation

A growing body of scientific literature documents evidence of non-thermal cellular damage from non-ionizing wireless radiation used in telecommunications. This RF EMR has been shown to cause an array of adverse effects on DNA integrity, cellular membranes, gene expression, protein synthesis, neuronal function, the blood brain barrier, melatonin production, sperm damage and immune dysfunction (Dasdag et al., 2015a; Dasdag et al., 2015a, 2015b; La Vignera et al.al., 2012; Levine et al.al., 2017). Human health effects associated with wireless radiation include infertility, neurodegenerative changes and brain cancer (Wyde, 2016; IARC, 2011) (; Sage and Carpenter, 2012; Kim et al., 2017; Kesari et al., 2011; Kesari et al., 2012a, 2012b; Zhang et al., 2016; Agarwal et al., 2011, 2008; Al-Quzwini et al., 2016; Banik, 2003; Consales, 2012; D'Andrea and Chalfin, 2000; Desai et al., 2009: Prasad et al., 2017). In addition, electrosensitivity to wireless and electrical devices is being increasingly recognized by scientists and physicians (Hojo et al., 2016; Singh and Kapoor, 2014; Belpomme et al., 2015). A biologically based standard has been recommended with a scientific benchmark to a "lowest observable effect level" for RF EMR at 0.003 uW/cm^2 (Sage and Carpenter, 2012). There is also growing evidence of harm to trees, wildlife and other biosystems (Sivani and Sudarsanam, 2013).

3.3.1. Oxidation mechanism of cellular harm

A well-studied potential mechanism of harm from radiofrequency radiation is one of cellular oxidation. Healthy biological systems require a balance of oxidation and antioxidation to fight infection and prevent disease (44, 45, 46). A review of the literature by Yakymenko et al. (2016) confirmed that in 93 of 100 studies, non-ionizing radiofrequency radiation caused a cellular stress response with excessive reactive oxygen species. He concluded, "oxidative stress induced by RFR exposure should be recognized as one of the primary mechanisms of the biological activity of this kind of radiation."

Reactive oxygen species (ROS) are a normal part of cellular processes and cell signaling. Overproduction of ROS that is not balanced with either endogenous antioxidants (superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), glutathione (GSH), melatonin), or exogenous antioxidants (Vitamin C, Vitamin E, carotenoids, polyphenols) allows the formation of free radicals that oxidize and damage DNA, proteins, membrane lipids and mitochondria. Mitochondrial DNA is more susceptible to DNA damage than nuclear DNA as it lacks histones, has a reduced ability to repair DNA, and is not protected from mitochondrial reactive oxygen species (Görlach et al., 2015). Excess ROS have been associated with exposure to toxic chemicals, pesticides and metals (Abdollahi et al., 2004; Sharma et al., 2014: Drechsel and Patel, 2008). Oxidative damage from ROS has been increasing linked to the development and/or exacerbation of a number of chronic diseases and cancer (Thannickal and Fanburg, 2000; Valko et al., 2006; Bouayed and BohnBohn, 2010; Görlach et al., 2015; Alfadda and Sallam, 2012).

3.3.2. Electrosensitivity

An increasing number of people are reporting a variety of symptoms with exposure to wireless devices and infrastructure, including headaches, insomnia, dizziness, nausea, lack of concentration, heart palpitations and depression. These are now recognized as signs of electrosensitivity or electromagnetic hypersensitivity. A personal communication and case history was recently described by Dr. Scott Eberle, a hospice physician who, after an inciting event, became electrosensitive, and discovered his continuing physical symptoms were due to wireless radiation from his computer and cell phone. (Eberle, 2014; Eberle, 2014, 2017). Reports of electrosensitivity with these non-specific but sometimes debilitating symptoms have incidences from 1.5% of the population in Sweden to 13.3% of the population in Taiwan (Hedendahl et al., 2015).

The United States Access Board recognizes "that multiple chemical sensitivities and electromagnetic sensitivities may be considered disabilities under the ADA if they so severely impair the neurological, respiratory or other functions of an individual that it substantially limits one or more of the individual's major life activities." (ADA, 2014).

It is notable that these same symptoms were described in military personnel working near radar communications systems. A 1981 NASA report, "Electromagnetic Field Interactions: Observed Effects and Theories", described microwave sickness with a host of symptoms recorded, including headaches, eyestrain, fatigue, dizziness, disturbed sleep at night, sleepiness in daytime, moodiness, irritability, unsociability, hypochondriac reactions, feelings of fear, nervous tension, mental depression, memory impairment, pulling sensation in the scalp and brow, loss of hair, pain in muscles and heart region, breathing difficulties, and increased perspiration of extremities (NASA, 1981).

3.4. 5G technology would be a mix of microwave frequencies

The vision of the next generation of communications technology, 5G, is to have instantaneous delivery of large volumes of multimedia content over a seamless wireless connection anywhere at any time (Chávez-Santiago et al., 2015; Greenemeier, 2015). To do this, new high frequency, faster delivery bands and a wider spectral bandwidth would need to be allocated in the 6–100 GHz range. Because the shorter frequencies transmit across short distances (hundreds of meters), a dense network of cellular antennas would need to be deployed throughout cities and neighborhoods, including extensive battery backup systems.

This system proposes to be additive with a blended architecture. Plans are in the works to adopt underused licensed frequencies throughout the spectrum. It will be a network of networks, with multiple layers of frequencies, multiple devices, and multiple user interactions (Jacobfeuerborn, 2015). Small cell deployments can be used as high capacity Wi-Fi hotspots forming an outdoor mesh network with an intergenerational mix of communications networks with 5G added later. It is not a completely new technology which will be deployed, according to Chavez-Santiago et al. (2015), but a spectrum-usage combination. "5G

3.4.1. 5G deployment by 2020

The start of commercial deployment of 5G systems is expected in 2020 with rapid expansion thereafter" to support more than one thousand times today's mobile traffic volume" (Chávez-Santiago et al., 2015).

The development of this technology has been underway for several years with research and development funding from many sources. Public, private and academic partnerships have been developed to advance this initiative. There is a race for R&D with significant resources invested with expected much higher return on investment. In 2012, the University of Surrey in the United Kingdom secured £35 million in funding for the 5G Innovation Centre, 5GIC, which offers testing facilities to mobile operators developing spectrum technologies. This year

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they announced their first 5G digital gaming initiative (University of Surrey, 2017). 5G Americas are planning to boost development of broadband technologies in Latin America as well (FCC Letter, 2016; 5G Americas, 2017).

3.4.2. Are there downsides to 5G telecommunications technology?

Industry papers discussing 5G, talk about markets, business models, and start-ups. New white papers have focused on needs for public safety, emergency response and earthquake preparedness. How much benefit will there really be for adding all this hyper-connecting technology compared to public health and environmental consequences? A more thorough investigation is needed with all the downsides included in the analysis, including E-Waste, global climate change, toxics emissions, occupational safety, privacy, security, public safety from widespread battery backup systems, and most critically, direct human health and environmental risks. We already have 911 and satellite communications for emergencies. If this technology is adopted we will lose our critical copper landline wires that are safer, more secure, and require no battery backups. Regulations regarding cost, access and usage of this widespread internet system have yet to be determined. Health and psychosocial effects are largely absent from business discussions.

3.4.3. More antennas and more frequencies are needed for a seamless connection

5G millimeter waves (MMW) are extremely high-frequency (30–300 GHz) electromagnetic radiation. In general, the longer the wavelength the longer it travels and the farther apart broadcast stations are placed.The 5G short higher frequency millimeter wavelengths travel shorter distances (a few hundred meters) thus to achieve a seamless integrated wireless system the “small cell” antenna are proposed to be placed about every 250 m. The exact frequencies of MMW desired for the next-generation of high-speed wireless technologies are not yet configured but industry letters to the FCC seek to open all the frequencies up to 100 GHz, with some suggesting even higher frequencies (FCC Letter 5G Americas). These MMW frequencies will be mixed with current longer microwave frequencies to achieve integration of systems. At higher power densities, cell tower studies show that symptoms of electrosensitivity occur within about 300 m of a cell tower (Santini et al., 2002; Zothansiama et al., 2017). The added frequencies and close proximity of small cell antenna in this dense network are a valid concern for residents. MMW are absorbed by anything with water such as foliage thus causing attenuation of the signals and making connections with the system line of sight only (Rappaport and Deng, 2015). Millimeter waves also do not penetrate walls. This has been a problem for designers, who are still trying to figure out a solution.

3.4.4. FCC exposure limits for 5G millimeter waves

SAR levels are used for cell phones, tablets and other handheld wireless devices to determine regulatory compliance. For millimeter wavelength devices and infrastructure power density above 6 GHz (FCC) and above 10 GHz (ICNIRP) needs to be measured with power density (FCC, 1997; Wu et al., 2015a) This is due to the higher energy absorption in a shallow area that causes heating more rapidly resulting in much higher SAR levels. The FCC maximum permissible exposure (MPE) in terms of power density for frequencies between 1.5 and 100 GHz is 10 mW/cm^2 over a 30 min period (FCC, 1997; Romanenko et al., 2014). Heat generated is a concern in handheld devices for 5G but is still considered the only valid measure of harm, no biological cellular alterations are considered (Wu et al., 2015a).

3.4.5. Studies on millimeter wavelenghts

Millimeter waves (MMW) are absorbed by water in living plants, bacteria, insects and human skin with variable effects. Because of shallow penetration of MMW, the eyes and skin are of primary concern. Bacterial effects have also been examined with evidence of antibiotic resistance caused by MMW. In humans, the penetration depth of more than 90% of the transmitted power is absorbed in the epidermal and dermal layers (Wu et al., 2015a). Because the depth is so superficial, higher heating occurs more quickly with less dissipation. Many biological responses to MMW irradiation can be initiated within the skin (Isaac et al., 2012; Ziskin, 2013; Gandhi and Riazi, 1986). Systemic signaling in the skin can result in physiological effects on the nervous system, heart, and immune system mediated through neuroendocrine mechanisms (Pakhomov et al., 1998). Currently MMW is used for some high speed wireless networks (Sundeep et al., 2012) and radar sensors for car navigation (Menzel, and Moebius, 2012). Considering planned ubiquitous and continuous MMW exposure there is a need to understand any potentially negative health effects of these frequencies (National Research Council US, 1983; Liu et al., 2014; Drean et al., 2013; Mahamoud et al., 2016; Nelson et al., 2000).

3.4.5.1. Skin effects. Numerous experimental studies have shown that surface effects of low intensity MMW can be quite substantial, inducing a number of biological changes, even at non thermal levels, including cell membrane effects (Feldman et al., 2009; Ramundo-Orlando et al., 2009; Feldman et al., 2008; Millenbaugh et al., 2006; Enin et al., 1992; Ramundo-Orlando, 2012; Ziskin, 2013; Hayut et al., 2014; Ney and Abdulhalim, 2011; Chernyakov et al., 1989). There are MMW studies showing both beneficial and adverse effects, depending on frequency, modulation, power density, polarization, and exposure time (Belyaev et al., 2000). MMW has been used for many years as a non-invasive therapeutic modality in complementary medicine in many Eastern European countries for pain therapy (Taras et al., 2006) with some evidence that short term application of certain frequencies stimulate release of endogenous opioids in the skin (Ziskin, 2013). For a contrary purpose, the military are using 95 GHz MMW for non-lethal active denial systems (Gross, 2010). It appears that the 95 GHz MMW range affects the cutaneous nociceptors and act as a threatening stimulus without heating or thermal damage (LeVine, 2009). The mechanism has not been fully elucidated but researchers have proposed the sweat glands as a target. Feldman et al. (2008; 2009) demonstrated that the sweat ducts in human skin are helically shaped tubes, filled with a conductive aqueous solution. Their research indicates that sweat ducts in the skin could behave as antennas and thus respond to millimeter waves.

3.4.5.2. Ocular effects. There is particular concern for 5G applications as the eyes would also receive significant radiation especially for near field exposures. Cataracts remain the leading cause of blindness in the world, and are a societal burden due to the high incidence, cost and consequences to quality of life (CDC, 2015). NIH statistics from 2010 show there is a 17.11% overall prevalence of cataracts over age 40 (NIH NEH, 2010) and a steady rise in cataract surgeries (Gollogly et al., 2013). An eight-year study showed the total Medicare costs for cataract surgery alone was approximately 3.6 billion, which is 60% of all eye care costs (Ellwein and Urato, 2002). Well established risk factors in the development of cataracts are age, smoking, diabetes, and UVB exposure. Research is pointing towards oxidative damage as a general mechanism for age related cataracts (Spector, 1995; Ye et al., 2001; Abraham et al., 2006). Microwave radiation is also a known cause of cataracts with heat being an undisputed mechanism. The eyes lack sufficient blood flow to dissipate heat effectively. There is some evidence that repeated low level exposures to microwave radiation could cause cataracts but researchers agree that more studies are needed (Vignal et al., 2009; Carpenter and Van Ummeren, 1968; Moss et al., 1977; Foster et al., 1986; Van Umersen and Cogan, 1976; Riva et al., 2005; Ryzhov et al., 1991; Drean et al., 2013; Morgan et al., 2015).

Frey (1985) elucidates the reasons why the earlier Appleton and McCrossan study found no cataractogenesis from microwave exposure after reviewing their data. He found 3 major flaws in the study design and interpretation. These were 1) the exposed group likely included

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people with little or no exposure 2) control group consisted of people working with equipment known to cause eye damage 3) they never performed a statistical analysis on their data. Nevertheless, their study was held up as proof there were no harmful effects from radiofrequency radiation. Frey notes the need to critically review negative studies as this contributes to the distortion and distrust of science.

Lipman et al. (1988) noted that microwaves most commonly cause anterior and/or posterior subcapsular lenticular opacities both in experimental animals, epidemiologic studies and case reports. They indicate that cataract formation is related to the power of the microwave radiation and duration of exposure. Lipman concludes that until further definitive research is conducted on the mechanisms of injury and protective measures identified, mechanical shielding is recommended to minimize the possibility of development of radiation-induced cataracts.

Cutz (1989) in his publication "Effects of microwave radiation on the eye: The occupational health perspective", looked at occupational exposure to RF EMR noting that eye effects from microwave radiation can be thermal or non-thermal and that lens opacities can be generated experimentally in animals with relatively high intensity RF EMR (power density above 100 mW/cm^2). He states that for lower intensities cumulative exposures may cause damage. He also reported that microwaves caused degeneration of retinal nerve endings. Long term effects were not determined, pointing to the need for additional research.

Kues and Monhan (1992) at John Hopkins University, researched the effects of low-level microwave radiation on the primate eye using 1.25 and 2.45 GHz wavelengths for 4 h daily for 3 consecutive days. They identified damaging ocular effects including corneal lesions, increased vascular permeability and degeneration of photoreceptors in the retina. They found that pulsed microwave exposure produced abnormalities at lower power densities than continuous wave exposure. These were relatively short exposure periods.

Prost et al. (1994) was one of the first to study the effects of millimeter microwave radiation on the eye. He noted that microwaves of different wavelengths have been implicated in the development of cataracts. His research found that low power millimeter waves produced lens opacity in rats over a 58-day period (10 mW/cm2), indicating MMW is a predisposing factor for cataracts.

Bormusov et al. (2008) examined the non-thermal effects of high frequency radiation from cell phones and other wireless devices on lens epithelium. They found both reversible and irreversible ocular changes and notes that the effects they saw with short term exposure at low levels could translate to similar effects with cataracts over a 10–20 year period of cumulative exposure. They state "It is recommended to use cell phones from a distance to minimize exposure, thus reducing any potential harmful effects of cell phone use on the lens."

Yu and Yao (2010) reviewed literature on microwave radiation and induction of cataracts. Reports of non-thermal biologic effects of microwave radiation include alteration of cell proliferation and apoptosis, inhibition of gap junctional intercellular communication, stress response and genetic instability. They concluded that further *in vivo* studies are needed.

Shawaf (2015) reported on an acute bilateral cataract development in a healthy young radar worker due to accidental high power microwave exposure. He notes "there are also non-thermal effects of microwave energy on the eye including pressure waves and physical stretching, deformation, and tearing of the membranes of the lens cells."

In a 2014 publication in the Institute of Electrical and Electronics Engineers journal, IEEE Transactions on Microwave Theory and Techniques, Sasaki et al. (2014) reported their *in vivo* rabbit experiments for operating frequencies ranging from 24.5 to 95 GHz, measuring temperature elevation. Their studies suggest that corneal damage occurred at an incident power density of 300 mW/cm^2. They conclude that ocular heating should be the basis for safety guidelines for near field exposure. It is mentioned however that only a few experimental studies in the miilimeter wavelengths were used to determine the current exposure guideline limits.

In another IEEE publication looking at MMW health effects, Wu et al. (2015b) support current standards of safety based on heat but point out that the MMW research on biological effects is sparse relative to that of longer microwave frequencies. They advise that additional studies may be needed to examine the potential biological effects of MMW radiation in order to develop appropriate consumer guidelines, especially where antennas are located close to the body.

From the available literature it appears that microwave frequencies including MMW proposed for 5G can have non-thermal biological effects on the lens of the eye. 5G deployment will add shorter wavelengths to longer wavelengths which have not been adequately tested for long term exposure. With the expected rise of wearable ocular digital technology devices such as virtual reality for gaming, entertainment, the social sciences and healthcare, there will be significantly more exposure to microwave radiation very close to the orbit. Current safety guidelines are based on heat measurements. The paucity of current literature on ocular effects of millimeter wavelengths highlights the need for much more independent research and precaution moving forward to prevent an epidemic of ocular pathology.

3.4.5.3. Review of effects. In a very thorough review article, Pakhomov et al. (1998) looked at the biological effects of MMW. He examined dozens of studies and cites research demonstrating profound effects of MMW on all biological systems including cells, bacteria, yeast, animals and humans. Some effects were clearly thermal, however, many of the studies showed non-thermal biological effects at low intensities. Both negative and positive responses were seen depending on frequency, power, resonance and exposure time. Researchers found at times even small difference in frequencies could have very different biological effects.

Pakhomov summarized the studies and included effects on heart rate variability, teratogenicity, and bacterial growth alterations with antibiotic resistance. Chernyakov et al. (1989) induced heart rate changes in anesthetized frogs by microwave irradiation of remote skin areas. Complete denervation of the heart did not prevent the reaction. This suggested a reflex mechanism of the MMW action involving certain peripheral receptors. Potekhina et al. (1992) found certain frequencies from 53 to 78 GHz band continuous wave changed the natural heart rate variability in anesthetized rats. He showed that some frequencies had no effect (61 or 75 GH) while other frequencies (55 and 73 GHz) caused pronounced arrhythmia. There was no change in skin or whole body temperature.

One study of MMW teratogenic effects was performed in Drosophila flies by Belyaev et al. (1990). Embryos were exposed to 3 different GHz frequencies for 4–4.5 h at 0.1 mW/cm^2. He found that irradiation at 46.35 GHz, but not at 46.42 or 46.50 GHz, caused marked effects including an increase in morphological abnormalities and decreased survival. It was felt the MMW disturbed DNA-protein interactions at that particular frequency. Bulgakova et al. (1996) in studies with 14 different antibiotics showed how MMW exposure of the bacterium *S. aureus* affects its sensitivity to antibiotics with different mechanisms of action. The MMW increased or decreased antibiotic sensitivity depending on the antibiotic concentration.

Pakhomov warned that there was a possibility of significant bioeffects of millimeter wave technology at current safety standards and more study was needed. He called for replication of studies especially long term effects of MMW.

Pakhomov concluded that the effects were not necessarily linear as different individuals may react differently, there were unknown and uncontrolled factors affecting sensitivities, and electrosensitivity to millimeters may be real with 30 to 80% of test subjects able to feel low intensity millimeter wave radiation.

3.4.5.4. Immune system. Kolomytseva et al. (2002), looked at the function of peripheral blood neutrophils under whole-body exposure

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of healthy mice to low-intensity extremely high-frequency electromagnetic radiation (EHF EMR, 42.0 GHz, 0.15 mW/cm^2, 20 min daily). The study showed 50% suppression of phagocytic activity of neutrophils after a single exposure to MMW radiation with the authors noting a profound effect on nonspecific immunity.

Lushnikov et al. (2003) investigated cell-mediated immunity and nonspecific inflammatory response in mice exposed to low-intensity extremely high-frequency electromagnetic radiation (EHF EMR, 42.0 GHz, 0.1 mW/cm2, 20 min daily). They found that MMW radiation reduced both immune and nonspecific inflammatory responses (130). Other research by the same group corroborated an anti-inflammatory effect of MMW that appeared mediated by the immune neuro-endocrine system. This could explain some of the reported beneficial effects. Long term exposure was not mentioned.

Gapeev et al. (2003) showed for the first time that low-intensity extremely high- frequency MMH electromagnetic radiation *in vivo* causes effects on spatial organization of chromatin in cells of lymphoid organs. Chromatin is a complex of DNA and proteins that forms chromosomes within the nucleus of eukaryotic cells. He exposed mice to a single whole-body exposure for 20 min at 42.0 GHz and 0.15 mW/cm^2. He suggests that the effects were due to involvement of the neuroendocrine and central nervous systems.

3.4.5.5. Tumor suppression. Makar et al. (2005) showed that MMW irradiation at 42.2 GHz can up-regulate natural killer (NK) cell functions with short exposures. An increase in TNF-alpha was also identified. Logani et al. (2006) investigated inhibition of tumor growth transplants with short 30 min pretreatment with MMW. They found a reduction in tumor metastasis by MMWs mediated through activation of NK cells. Long term exposure was not investigated.

3.4.5.6. Gene expression. Chen et al. (2008) found upregulation of some genes in human keratinocytes with MMW exposure at low power density (1.0 mW/cm^2 millimeter).

Habauzit et al. (2014) looked at gene expression in keratinocytes with 60 GHz exposure at the upper limit of current guidelines and concluded, “In our experimental design, the high number of modified genes (665) shows that the ICNIRP current limit is probably too permissive to prevent biological response.”

3.4.5.7. Bacterial antibiotic resistance. Bulgakova et al. (1996) irradiated staphylococcus cultures with different frequencies of MMW with non-thermal intensities with short exposure periods (minutes). He found changes in bacterial sensitivities developed in 5 of 14 antibiotics used in sublethal concentrations with both suppression and stimulation of growth.

Shcheglov et al. (2002) examined MMW on *E. coli* cells at various cell densities and frequencies. His work suggests that cell-to-cell communication may be involved in bacterial responses to weak EMF.

Isakhanian and Trchunian (2005) irradiated water and buffer solution with low intensity MMW and found that the irradiated water had a bactericidal effect that disappeared after repeated exposure and the buffer solution increased growth of bacteria. They concluded this was due to membranotrophic effects. Repeated irradiation reversed the bactericidal effects indicating that a compensatory mechanism was involved.

Torgomyan and Trchounian (2013) reviewed research on the mechanisms of bactericidal and antibiotic resistance after exposure to low intensity MMW. They suggest that alterations in water structure, cell membrane or the genome leading to changes in metabolic pathways could account for these effects. The importance of this research is emphasized in light of ongoing concerns about bacterial resistance to antibiotics.

Soghomonyan et al. (2016) found that MMW affected growth and antibiotic sensitivity of *E. coli* and many other bacteria via non-thermal mechanisms. This may lead to antibiotic resistance.

3.5. Data gaps need to be closed before launching 5G millimeter devices

5G technology with its diverse blend of frequencies and densely packed cell antenna network will substantially increase exposure to electromagnetic radiation. Significant data gaps exist for research into both MMW and mixed frequencies for biological effects, long term exposure and vulnerable populations (children, pregnant women, chronically ill). Considering current peer reviewed science, predictable harm to life forms within the mixed frequency mesh networks with negative consequences appears likely over time. For electrosensitive individuals, it will add to their physical symptoms and isolation, with significant reduction in non-exposed safe havens. There is an urgent need for independent studies to guide development of effective public health standards and policies.

3.6. Technology addiction: overuse and over-connection

Overuse of technology and mental health is another related but no less important issue. Physicians, social scientists and educators are concerned with the over-connection to technology, especially in children and adolescents. Psychiatrists have reported an increase in technology addiction, cyberbullying, depression, insomnia, loss of empathy and impaired social-emotional learning in their young patients. Internet game disorder has been found to have psychological and neural effects similar to other types of impulse control disorders and addictions which are both substance and non-substance-related (Chi et al., 2016; Király et al., 2017; Meng et al., 2015; Sanchez-Carbonell et al., 2008; Tamura,Tamura et al., 2017; Feng et al., 2017) Lack of outdoor play and psychological well-being for young children is also of growing concern (Xu et al., 2016). We should begin to question the supposed benefits versus the true risks of a hyper-connected society.

3.7. What is public health?

There are many definitions of public health but one succinct definition is, “Public health is what we, as a society, do collectively to assure the conditions for people to be healthy.” (Upshur, 2015). Public health involves the science and art of preventing and controlling disease, promoting health, monitoring populations for health assessments, identifying causes, identifying effective interventions and assuring equity in populations and communities (APHA, 2017; CDCCDC, 2017).

Public health involves an ever widening range of topics. John R. Goldsmith, MD, MPH, a pioneer in public health, wrote a seminal article in 1997 called “From Sanitation to Cellphones: Participants and Principles Involved in Environmental Health Protection” (Goldsmith, 1997a, 1997b). This work details the history of public health over his decades working in this field. He describes four phases of public health issues: sanitation (prior to 1914), industrialization (1915–1950), emissions constraints (1951–1995) and then globalization (1996 on). He notes three common principles of public health which apply through all those phases, 1) The need for regulation by government 2) Need for a market by which protection of environmental health is economically attractive compared to alternatives and 3) Social acceptability, with cultural norms endorsing protective versus risk generating behavior.

3.7.1. Wireless technologies: a question of public health

A growing number of scientists have articulated the need to recognize that the increase in wireless technologies is a serious emerging and neglected public health threat. (Blank et al., 2015; Goldsmith, 1997a, 1997b; Sage and Carpenter, 2012). In a recent poll, public health scientists were asked what they consider to be emerging public health issues (Bernier, 2017). Responses included issues such as racism, bullying, gun violence, gang violence, adult obesity and climate change. They were also asked what defines a public health issue. The open forum identified the following criteria.

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1. The health impacts are preventable and modifiable.
2. There is a high prevalence of a risk factor.
3. There is an increase in incidence and prevalence.
4. There is an economic impact.
5. There is disability, morbidity and mortality.
6. It can affect a large population.
7. A collaborative effort is needed to solve it.
8. The problem can be recognized unencumbered by lack of funding, cultural norms, or politics.

For wireless technology to be considered a public health issue in this regard there would need to be broad recognition and consensus that wireless technology could cause or contribute to diseases such as brain cancer, neurodegeneration, developmental defects, infertility, electrosensitivity and addiction. The cost and burden could then be calculated. Wireless technology could fulfill the other criteria in that there is an unprecedented high prevalence in the use of wireless devices, it can affect the population as a whole, and will require collaborative action to solve. The biggest obstacles appear to be of a cultural, economic and political nature along with a noted lack of funding in the U.S. for independent scientific research on health effects of RF EMR that is free of industry influence or bias. As with tobacco, the science was denied and doubt created until overwhelming research and evidence of harm decades later shifted the debate and protective regulations followed. Chemical companies followed tobacco with similar methods to dismiss and manipulate science that was not in their favor (Michaels, 2008).

4. Conclusion

Although 5G technology may have many unimagined uses and benefits, it is also increasingly clear that significant negative consequences to human health and ecosystems could occur if it is widely adopted. Current radiofrequncy radiation wavelengths we are exposed to appear to act as a toxin to biological systems. A moratorium on the deployment of 5G is warranted, along with development of independent health and environmental advisory boards that include independent scientists who research biological effects and exposure levels of radiofrequency radiation. Sound regulatory policy regarding current and future telecommunications initiative will require more careful assessment of risks to human health, environmental health, public safety, privacy, security and social consequences. Public health regulations need to be updated to match appropriate independent science with the adoption of biologically based exposure standards prior to further deployment of 4G or 5G technology.

Considering the current science, lack of relevant exposure standards based on known biological effects and data gaps in research, we need to reduce our exposure to RF EMR where ever technically feasible. Laws or policies which restrict the full integrity of science and the scientific community with regards to health and environmental effects of wireless technologies or other toxic exposures should be changed to enable unbiased, objective and precautionary science to drive necessary public policies and regulation. Climate change, fracking, toxic emissions and microwave radiation from wireless devices all have something in common with smoking. There is much denial and confusion about health and environmental risks, along with industry insistence for absolute proof before regulatory action occurs (Frentzel-Beyme, 1994; MichaelsMichaels, 2008). There are many lessons we have not learned with the introduction of novel substances, which later became precarious environmental pollutants by not heeding warning signs from scientists (Gee, 2009). The threats of these common pollutants continue to weigh heavily on the health and wellbeing of our nation. We now accept them as the price of progress. If we do not take precautions but wait for unquestioned proof of harm will it be too late at that point for some or all of us?

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BIOLOGICAL AND HEALTH EFFECTS OF MICROWAVE RADIO FREQUENCY TRANSMISSIONS

A REVIEW OF THE RESEARCH LITERATURE

A REPORT TO THE STAFF AND DIRECTORS OF THE EUGENE WATER AND ELECTRIC BOARD

June 4, 2013

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EXECUTIVE SUMMARY

The FCC regulations for permissable exposures to microwave radio frequency (RF) transmissions are only designed to protect against the thermal effects of high exposure levels. Representatives of the telecommunications industry usually assert that there is "no clear or conclusive" scientific evidence regarding the biological effects of low level or "nonthermal" RF exposures. But in actuality, a large body of scientific research documents that RF exposures at low levels can produce adverse biological or health effects.

The installation of RF-transmitting "smart meters" by our electric utility could significantly increase the level of RF exposure in Eugene's residential neighborhoods. Such an increase carries potential health risks. The nature of these risks needs to be carefully considered before making a decision to deploy this technology.

Any decision-making process that ignores this possibility of harm could cause significantly damage both to community health and to EWEB's goodwill in the community.

ELECTROHYPERSENSITIVITY (EHS)

Microwave RF exposures can produce acute symptoms in some individuals. These symptoms can include headache, sleep disturbance, difficulty in concentration, memory disturbance, fatigue, depression, irritability, dizziness, malaise, tinnitus, burning and flushed skin, digestive disturbance, tremor, and cardiac irregularities. This syndrome was described by Russian researchers in the 1950's, who called it "microwave sickness". Between 1953 and 1978 the Russian government purposefully targeted the U.S. embassy in Moscow with beams of microwave RF, producing symptoms of microwave sickness in many embassy employees.

In recent years, the buildout of the wireless telecommunications infrastructure has greatly increased the exposure of the general public to microwave RF, and this has led to an increased number of individuals experiencing symptoms that are now referred to as "Electrohypersensitivity Syndrome" (EHS). Multiple research studies have shown a correlation between these symptoms and residential exposure to radio, radar, and cell tower transmissions.

The prevalence of EHS appears to be increasing, as the exposure of the public to RF continues to expand. Based on recent epidemiologic research, it would be reasonable to assume RF exposures provoke some sort of symptoms in between 3 and 5% of the population of Eugene at the current time. Any significant increase in residential RF exposure is likely to make these individuals more symptomatic, and to produce some new cases of EHS by pushing some other individuals beyond their tolerance limit.

ALTERED PHYSIOLOGY

Laboratory research in animal and human subjects has shown that "nonthermal" levels of RF exposure can alter EEG, immune function, and hormone levels including adrenal and thyroid hormones, testosterone, prolactin, progesterone.

Research shows that low levels of microwave RF exposure can reduce melatonin levels in humans, and that some individuals are more sensitive than others to this effect. The adverse effects of nighttime RF exposure on melatonin secretion are particulary disturbing. The nocturnal rise in melatonin levels supports the natural function of sleep, and disrupting this cycle can produce insomnia. Melatonin is an extremely potent antioxidant, and helps to repair damaged DNA and heal the body from other

effects of oxidant stress.

Melatonin is also protective against the growth of cancer cells, and disruption of the circadian melatonin cycle has been shown to lead to increased tumor growth in a variety of cancer types. Women who have lower levels of nocturnal melatonin are at greater risk for developing breast cancer. Reduced melatonin levels may also increase the incidence of prostate cancer.

OXIDATIVE STRESS AND DAMAGED DNA

In contrast with Xrays and gamma rays, Microwave radiation does not have sufficient power to directly break covalent bonds in DNA molecules. But microwave RF can produce resonance interactions with ions and with charged macromolecules, and such interactions can significantly alter biochemical functions. A large body of research has shown that microwave RF causes an increased production of free radicals and reactive oxidant species in living tissues, and that this increased oxidant stress damages DNA. This damage can and does occur at power levels well below those levels that could produce damage by thermal mechanisms.

Any chronic exposure to conditions that damage DNA can lead to an increased risk of cancer. Evidence of increased risk of certain types of cancer has been demonstrated in groups with occupational exposure to microwave RF, including radio technicians in private industry, military personnel, commercial airline pilots, and ham radio operators. Elevated levels of cancer have been demonstrated in populations with increased residential exposure to radio transmission towers. And in the last ten years, studies fro Israel, Germany, Austria, and Brazil have documented significant increased in breast cancer and other cancers in individuals living less than 500 meters from cell phone towers, with measured exposure levels much lower than those permitted by current FCC guidelines.

Research has also shown that RF exposure levels well within current guidelines can cause DNA damage and reduced fertility in insects, birds, amphibians and mammals, and can lower sperm counts, sperm motility, and sperm motility in human beings.

RISKS OF CELL PHONE USE

Cell phone use expanded dramatically in Europe and the United States in the late 1990's. Early studies of the cancer risks of cell phone use were hampered by short latency periods of exposure. In general, studies funded by industry have reported lower levels of risk than independently funded studies. But in the last four years, all but the most poorly designed studies have shown an increased risk of brain tumors with more than ten years of use—a level of exposure which appears to double the risk of brain tumor on the side of the head where the cell phone is customarily held. This risk is higher in those who started using cell phones as children.

CONCLUSIONS

Existing scientific research offers strong evidence that the chronic exposure of the public to microwave RF transmissions produces serious acute and chronic health effects in a significant portion of the population. These findings can be summarized in the following precepts:

Basic Precepts for Residential Exposures to RF Transmissions:

- Excessive RF exposure can cause acute problems (headaches, insomnia, fatigue, vertigo, tinnitus, other symptoms of EHS).
- Excessive RF exposure can also cause chronic problems (oxidative stress, cancer, male infertility).
- Constant RF transmission is probably harmful, even at low levels, and should be avoided.
- Frequent and repetitive intermittent transmissions are also probably harmful, and should be avoided.
- Nocturnal exposures are more problematic than daytime exposures, because of RF's potential to suppress nocturnal melatonin secretion and disturb sleep, and because night is the time when we rest and heal from stresses (including oxidative stress).
- Occasional and infrequent daytime exposures are much less likely to cause an increase in chronic problems for the population at large.
- Occasional and infrequent daytime exposures are still likely to provoke acute symptoms in a small percentage of the population.

EWEB should adopt a policy of minimizing their RF footprint in the community.

A recognition of these precepts should lead EWEB to adopting a policy of minimizing their infrastructure's RF footprint in the community as much as possible during regular operations. This doesn't mean that staff would throw away their cell phones and communicate by semaphore. But it would mean that instead of combatting or ignoring the possibility that more RF in the community could cause harm, EWEB should acknowledge the potential risks of excessive residential exposure.

This would mean that such potential risks would be seriously considered in any discussion of the total risks and benefits involved (the "Total Bottom Line"), as EWEB decides *whether* to use RF technology for any given purpose. If, after such a discussion, a considered decision is made to use RF technology, then these same potential risks should be taken into serious consideration in determining *how* to use this technology in a manner that would minimize potential harm to the community.

In other words, don't use RF when you don't have to. Use hard-wired connections wherever it is feasible to do so. And if you do use RF, design the infrastructure in a way that uses as little of it as possible.

In the final section of this report, we discuss the perspectives that such a policy might bring to a consideration of the available AMI technologies.

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PREFACE

This paper represents the efforts of a group of physicians who have been in private practice in Eugene for decades. Our concerns are for the health of our patients as well as for our community as a whole.

When EWEB proposed installing a "mesh" smart meter network we became concerned. We know that there are people in this community who are highly sensitive to electromagnetic fields. The installation of the smart meter mesh would make Eugene a much more hostile environment for these individuals.

We also know that chronic exposures to microwave radio frequency (RF) transmissions can produce adverse long term physiological effects, even in individuals who do not consciously experience acute symptoms from exposure to such electromagnetic fields.

As we considered these issues, we were not sure if the policy makers at EWEB had sufficient current and applicable scientific information upon which to rely, as they evaluated the potential health effects of such an implementation. EWEB may have referred to FCC guidelines, without considering that the FCC regulations on radio frequency (RF) exposure are only designed to protect against the thermal effects of extremely high level RF exposures, and do not attempt to define a safe level of protection against other biological effects.

Because of these concerns, we have undertaken a sixteen month long investigation of the scientific literature, in order to present what we feel is a valid scientific basis for evaluating the potential health effects of a community-wide RF smart meter installation. This paper presents our findings to you.

We have organized this report into six sections:

1. An introduction into some of the issues involved in the "smart meter" Advanced Metering Infrastructure.
2. A review of the scientific research documenting the existence of acute reactions to "non-thermal" levels of RF exposure -- reactions which in their most severe form are called electrohypersensitivity syndrome (EHS).
3. A review of the function of melatonin, of evidence that RF exposure can suppress melatonin, and of the short and long term consequences of melatonin suppression.
4. A review of the long term effects of RF exposure, especially the production of oxidative stress that can lead to DNA damage and increased levels of cancer and infertility.
5. A review of current research regarding relationship of cellular and cordless telephone use to increased risk of brain tumors.
6. A discussion of our conclusions and recommendations to EWEB, based on this review of the scientific literature.

INTRODUCTION

AMI and the Smart Energy Grid

The Advanced Metering Infrastructure (AMI) technology is a key component of the smart energy grid that we heard discussed in very general terms in the 2008 presidential election. During the past two years, EWEB has been actively exploring the possibility of installing AMI in Eugene.

EWEB staff have described several purposes for going to an AMI "smart meter" infrastructure, including the following:

Reducing operating costs

Remote reading of meters would eliminate meter readers, allowing EWEB to save substantial costs in employee time and benefits, vehicle use, and gasoline costs. Smart meters can also be used to turn power on and off remotely, saving labor and travel costs when rentals become vacant or occupied.

Shifting time of use

Smart meters can measure and record total power usage for several intervals during the day. This will allow EWEB to bill customers more for electrical usage at peak use hours, typically the early morning (when people are getting up, taking showers, cooking breakfast) and late afternoon/early evening (when people return home from work, cook dinner, take showers, throw some clothes in the laundry, etc.). Time of use billing could create an incentive for customers to shift elective usage (laundry, recharging the electric car) away from peak usage hours.

Electrical utilities need enough generating capacity to meet peak demand. Reducing or restraining the growth of peak usage could reduce or slow the need to build more power generating capacity into the system.

Training customers to conserve electricity

Smart meter technology can allow home owners to monitor their usage in real time over a home network with the meter. EWEB hopes that this direct feedback will encourage people to reduce their energy consumption.

"Demand/Response" infrastructure

EWEB has invested a great deal in wind power. But the wind tends to blow hardest in the middle of the day and the middle of the night. At dawn and dusk (peak usage times for electrical consumers) the wind is more likely to calm down.

This creates a storage problem for the utility. When wind power production is high during the night, production can exceed demand, generating more electricity than can be used locally or sold interstate.

One way to distribute and store this energy is to put it in your water heater. Two way communication with your Smart Meter could allow the power company to turn your water heater on for 15 minutes in the middle of the night or the middle of the day, at a time when it would otherwise not be on [they can't turn it on for two hours, when it gets to the maximum heat setting the thermostat will turn it off]. EWEB would seek customers willing to volunteer to allow this arrangement.

With "demand/response" control, EWEB could store excess wind power as heat by turn on clusters of water heaters for 15 minutes, then turn them off and turn on other clusters of water heaters, and continue to rotate the usage around the community during the middle of the night.

Solar power generation creates another storage problem. Solar panel output can fluctuate rapidly during the day with changing cloud cover. Too sudden an increase in local production from multiple large panels could overload the grid. The AMI infrastructure would allow the utility to tell Smart Meters to turn off solar panel input into the electrical grid. Again, this requires rapid two-way communication between the utility and the Smart Meter, and between the Smart Meter and the solar panel in the house.

From an engineering point of view, the simplest and cheapest way to install this communications infrastructure is to have the meters communicate with the utility and with the "smart appliances" in the home using *wireless microwave radio technology*.

The use of this wireless technology for AMI communications has generated a good deal of political heat in the last two or three years. To understand where this heat has come from, it is instructive to review the history of the Pacific Gas and Electric Company's smart meter rollout in California.

PG&E in California, 2010 – 2011

In 2010 and 2011 PG&E rolled out an AMI infrastructure in multiple cities in California. The metering technology that they chose to install was the Silver Springs AMI "smart meter". These meters communicate with the utility by forming a "mesh" network in the neighborhood. The meters communicate with each other rather than with a central receiver, and pass data through this MESH network to the central collecting system of the electric utility.

The installation of such technology places a radio transmitter on every house in the community. Concerns about the potential health effects of this residential RF exposure led several members of the California Assembly to request that the California Council on Science and Technology (CCST) perform a study of whether current FCC standards for Smart Meters were sufficiently protective of the public health, and whether additional standards might be needed for such technology.

It should be noted that the regulatory standards established by the Federal Communications Commission are based on defining safe levels against the thermal effects of microwave radio frequency (RF) exposure (i.e. "Will it cook you?") For example, the FCC has established Limits for Maximum Permissible Exposure (MPE). (FCC, 1999, page 15). The FCC has explicitly stated that they do not make any regulations or assurances whatsoever regarding the "nonthermal" biological effects of microwave exposure (other physiologic effect besides heat damage). (Hankin, 2002)

The CCST released a report on "Health Impacts of Radio Frequency from Smart Meters" in January, 2011. (CCST, 2011) This report stated (on page 5) that Smart Metering technology met the FCC standards for "safety against *known thermally* induced health impacts". It also stated (on page 4) that *"To date, scientific studies have not identified or confirmed negative health effects from potential non-thermal impacts of RF emissions such as those produced by existing common household electronic devices and smart meters. Not enough is currently known about potential non-thermal impacts of radio frequency emissions to identify or recommend additional standards for such impacts."* The CCST report concluded that *"There is no evidence that additional standards are needed to protect the public from smart meters."* (page 26)

When the Draft Version of this CCST report was released, several experts in the field of research that studies the biological effects of RF communicated their disagree-

ment with the study's conclusions. It was pointed out that the content of the CCST document was in major part a repetition of a document produced by the industry-sponsored Electric Power Research Institute a few weeks before (Tell, 2010), and that the analysis of AMI smart meter exposure levels in the report was incorrect in its design. (Hirsch, 2011)

These experts offered evidence of multiple scientific studies documenting the nonthermal health impacts of RF. (Sage, 2011b) (Johansson, 2011) Independent research was presented to the CCST documenting that the Silver Springs meters produced levels of household exposures significantly higher than levels shown to have adverse health effects in current scientific research. (Sage, 2011a)

These objections from the scientific community did not alter the CCST's stance on smart meters, which continued to be installed in California.

What happened next in California

PG&E's approach to the AMI rollout didn't involve a lot of public education. They just switched out the meters. And some people found that they were having trouble sleeping, or experiencing headaches, ringing in the ears, vertigo, or other symptoms that hadn't been bothering them before. Soon the internet was awash in anecdotal reports and commentary about these adverse effects. (emfsafetynetwork.org, 2011)

PG&E's public posture was that the meters only transmitted for an average of 45 seconds per day. They asserted that the total power output over time was well below the FCC guidelines for thermal risk, and well below that of other RF exposures in the community. Videos began to crop up on You Tube showing that the picture wasn't that simple (for example, *http://www.youtube.com/user/thisirradiatedlife/featured*).

Finally PG&E was served with a court order to provide clear documentation of what the meters actually were doing. (Yip-Kikugawa, 2011) In the response to that court order, PG&E provided documentation from the manufacturer of the meters that the *average* meter in the mesh network transmitted data signals to the utility 6 times a day, network management signals 15 times a day, timing signals 360 times a day, and beacon signals to the mesh network 9,600 times a day. (Kim et al., 2011) This penciled out to an average of roughly 7 transmissions a minute, 24 hours a day, coming out of every meter in the community.

As reports of provoked symptoms increased, the situation became more and more politically heated. Santa Cruz County banned the installation of smart meters. PG&E continued to install them, and the Santa Cruz County Sheriff's office refused to enforce the ban. Individuals started purchasing refurbished analogue electric meters and swapping them out themselves, attempting to return the smart meters to the utility. PG&E publicly stated (a week or two before Christmas) that they would turn off the power of anyone who removed a smart meter from their service box—but backed down from that threat due to public backlash.

By the end of 2011, multiple cities in California had either banned smart meters or placed a moratorium on their continued installation, and a lawsuit has been filed against PG&E with the California Public Utilities Commission. (Wilner, 2011)

EWEB's Elster MESH AMI Trial

In 2010 EWEB set up a trial of AMI infrastructure, using the Elster REX2 Smart Meter. Like the Silver Springs meter used by PG&E in California, the REX2 operates on a mesh network. The meters upload usage data to a central collection meter 4 to 6 times

a day, but transmit short beacon signals to the network several times a minute.

EWEB stated on their website that these meters transmit "less than 10 seconds a day". But they were unable to state how frequently transmissions actually occurred. In our communications with their public relations staff, we were told that Elster was unwilling to release this information. Information on the power output of these meters is available on the ELSTER website. (TUV Rheinland, 2010) But Elster does not discuss the actual frequency of transmission of the meters.

In January 2012 we used a Gigahertz Solutions HF35C analyzer to evaluate the output of one of these Elster meters in a residential neighborhood in Eugene.

Background RF signals coming through the neighborhood were measured in a 360 degree circle around the monitoring position. The background RF averaged around 4 microwatts/square meter ($\mu W/m^2$), increasing to 8 or 10 $\mu W/m^2$ when we aimed our directional antenna at the radio towers on Blanton Heights or at a distant cell phone tower.

The Elster meter's transmission rate was variable. In our observations, they are definitely transmitting several times a minute, sometimes 4 or 5 times a minute, and occasionally in bursts of significantly higher frequency.

At 5 feet from the smart meter, the peak strength of the beacon signal coming off the meter measured from 3800 to 11,000 $\mu W/m^2$. At 20 feet from the meter, the power density of the signal ranged from 362 to 493 $\mu W/m^2$, with occasional bursts at higher power output.

This means that at a distance of 20 feet the power of the signal coming out of the Elster meter was *about 100 times* the power of the ambient background signal coming from any specific direction in the residential neighborhood.

This power density of 300+ to 400+ $\mu W/m^2$ was greater than the signal strength of the cell phone tower at 29th and Amazon, measured from about 200 meters away. So filling a neighborhood with a mesh network of the Elster smart meters would be similar to placing every house in that neighborhood closer than 200 meters from a cell phone tower, each house constantly being pinged by the chatter of multiple beacon signals from the mesh.

This was disconcerting, since recent research has shown that people living within 500 meters of a cell phone tower have increased incidence of headache, concentration difficulties, and sleep disorders, and also a significantly increased risk of some types of cancer. (Khurana et al., 2010) (Levitt and Lai, 2010) (Yakymenko et al., 2011) (Altpeter et al., 2006) (Abdel-Rassoul et al., 2007)

When you put these facts together, it is not so surprising that the installation of mesh smart meter networks in residential neighborhoods in California last year was followed by a surge of anecdotal evidence regarding headaches, insomnia and other health complaints. From a medical perspective, based on a familiarity with current research on the biological effects of RF, this was a predictable consequence of PG&E's smart meter MESH network rollout.

Formation of our Advisory Committee

By late 2011 EWEB staff were working towards setting a specific timeline for installing AMI in Eugene. From our perspective, the potential health risks of such a project did not appear to have received any realistic discussion. EWEB's web site implied that such risks were inconsequential. In January of 2012 EWEB's Public Rela-

tions staff started to test a public relations campaign promoting the AMI project. Their initial presentation minimized the possibility any health risks from this exposure.

Some physician members of our group became involved in discussions with EWEB staff. In these discussions, we tried to learn more about the technologies under consideration from EWEB engineers, and in turn we attempted to communicate our concerns about the potential health risks of this technology.

It became clear to us that EWEB staff did not have the time or the expertise to research this issue of health risks in any depth. Our sense of this was confirmed in April of 2012, when EWEB management presented the AMI Business Case to the EWEB Board. The discussion of "Potential Health Risks" in this document quoted government agency reports as if they were scientific studies, and stated that in an *"attempt to discover if there were any credible studies showing any health effect caused by long-term RF exposure in relatively high dosages (e.g. exposures much greater than an AMI meter) . . . no conclusive evidence was found that indicates that this higher magnitude RF exposure has created adverse health impacts."*

EWEB is a locally owned utility with a lot of goodwill in the community. We were concerned that if EWEB continued forward without taking a deeper look at this issue, decisions might be made that would have the potential to cause significant harm to the health of the community, or to create political strife that could significantly damage EWEB's local standing.

In an effort to help EWEB think this problem through in a more complete and considered fashion, we decided to form a group of physicians and other professionals with scientific and engineering expertise. Over the past 16 months, our group has studied the scientific literature on the biological effects of microwave RF. This report is the result of our efforts.

We hope that EWEB's staff and Board will examine this information carefully, and that it will help them to make prudent choices as they consider the various AMI technologies that are currently available to them.

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ELECTROHYPERSENSITIVITY

"MICROWAVE SICKNESS"

Acute symptoms provoked by microwave radiation were first described by Russian medical researchers in the 1950's. They described a constellation of symptoms including headache, ocular dysfunction, fatigue, dizziness, sleep disorders, dermatographism, cardiovascular abnormalities, depression, irritability, and memory impairment. (Liakouris, 1998)

In the years between 1953 and 1978 the Russian government harrassed the U.S. Embassy in Moscow by targeting it with radiation from a microwave transmitter. Concern about health effects led to a detailed study by A.M. Lilienfeld, an epidemiologist at Johns Hopkins University. (Lilienfeld AM, 1979)

The abnormalities found in this study were an embarrassment to the U.S. government, since the levels of exposure experienced by embassy staff were in the order of 2 to 28 microwatts/cm^2, a level dramatically below the described U.S. safety standards for microwave exposure. The conclusions of the study were altered to soft-pedal any abnormal findings. (Goldsmith, 1995b) (Cherry, 2000)

But outside epidemiologic analysis of the Lilienfeld report's published data showed that exposed embassy staff experienced a statistically significant excess of several problems, including depression, irritability, difficulty in concentrating, memory loss, ear problems, skin problems, vascular problems, and other health problems. Symptom incidence increased significantly with accrued years of exposure. (Goldsmith, 1995a) (Cherry, 2000)

THE EMERGENCE OF "ELECTROHYPERSENSITIVITY" AS A DIAGNOSIS

In recent years the buildout of cellular communication networks has created a markedly increased exposure of the public to RF transmissions. Each new generation of cell phone technology has occupied a higher frequency on the microwave scale, with potentially increasing impact on body physiology. (Cherry, 2002) As this has occurred, mounting evidence has pointed to the fact that a percentage of the population experiences adverse reactions associated with these exposures. The term "electrohypersensitivity" (EHS) has been used to describe a constellation of symptoms, including headache, sleep disturbance, difficulty in concentration, memory disturbance, fatigue, depression, irritability, dizziness, malaise, tinnitus, burning and flushed skin, digestive disturbance, tremor, and cardiac irregularities. Sleep disturbance, headache, nervous distress, fatigue, and concentration difficulties are the most commonly described symptoms. (Roosli et al., 2004)

These symptoms are identical to the symptoms of "microwave sickness" described by Russian physicians in the 1950's.

SYMPTOMS PROVOKED BY TRANSMISSION TOWERS

In 2002, Santini reported significant increases in such symptoms in individuals living closer than 300 meters to cell towers. (Santini et al., 2002) (Santini R, 2003)

In Poland, Bortkiewicz found similar increases in symptoms among residents near cell towers. Symptoms showed equal association to proximity of the tower, regardless of whether or not the subject suspected such a causal association. (Bortkiewicz et al., 2004) (Bortkiewicz et al., 2012)

In two studies, Abelin and Altpeter found evidence of disruption of sleep cycle

and melatonin physiology by RF transmission during the operation and subsequent shutdown of the short wave radio transmitter in Schwarzenburg, Switzerland. (Abelin et al., 2005) (Altpeter et al., 2006)

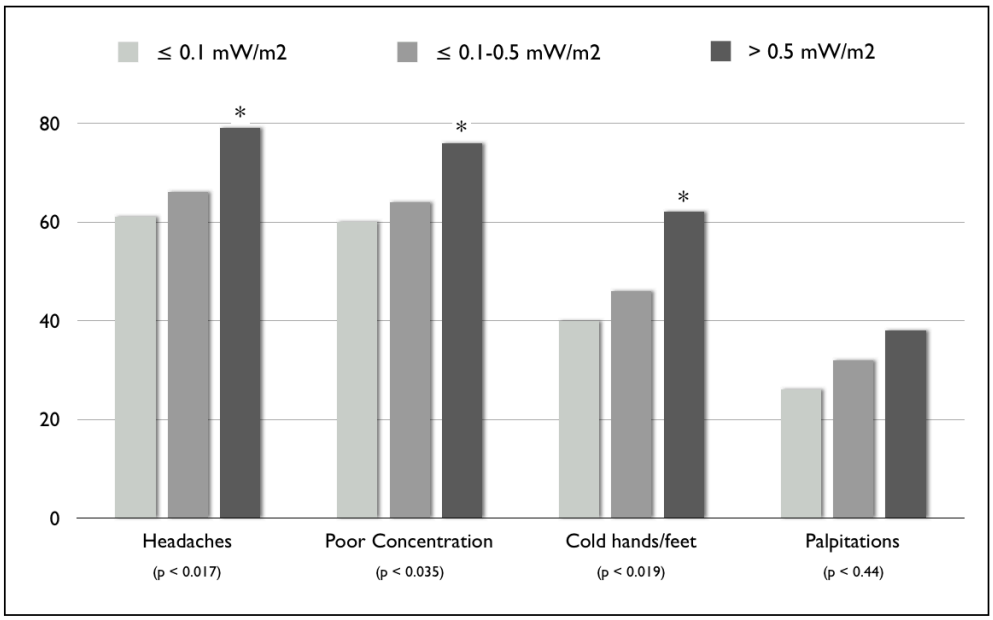


Figure 1: Percentage of subjects reporting symptoms, stratified by RF exposure levels as measured in subject's bedroom. (Hutter et al., 2006)

In a study done in urban and rural sites in Austria, Hutter found a clearly significant correlation between exposed signal power density and headaches and concentration difficulties—despite the fact that maximum measured power densities were only 4.1 mW/m^2 (= 0.41 $\mu W/cm^2$, well below established "safe" limits). (Hutter et al., 2006)

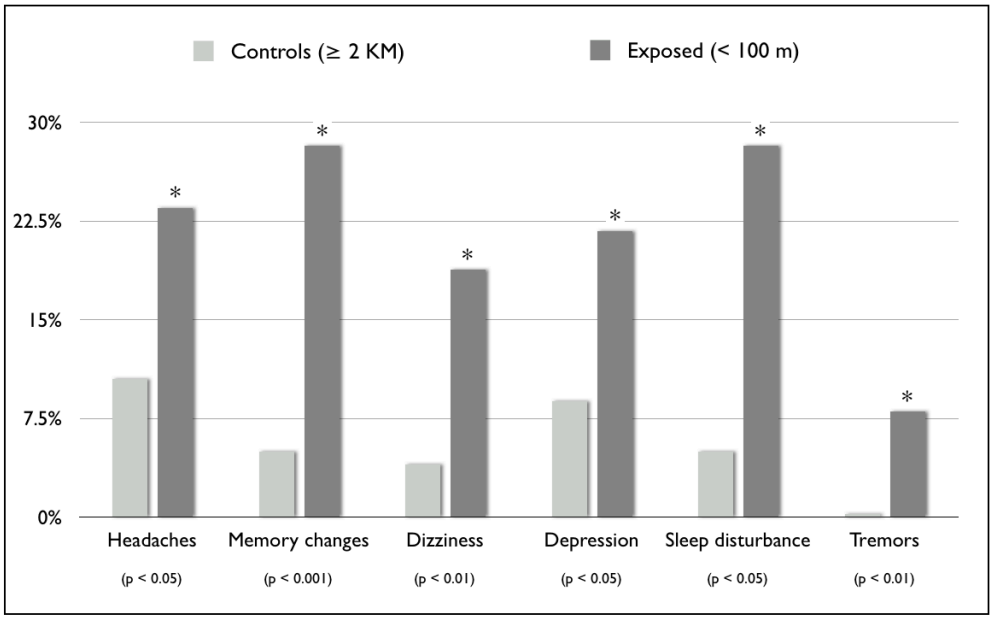


Figure 2: Percentage of subjects reporting symptoms, stratified by proximity to city's first cell phone tower. (Abdel-Rassoul et al., 2007)

In Egypt, a study of inhabitants living near the first cell phone tower in the city of Shebeen El-Kom found a significant increase in headaches, memory changes, dizziness, tremors, depressive symptoms, and sleep disturbance, with lower performance on tests of attention and short-term auditory memory. (Abdel-Rassoul et al., 2007)

Research at the military radar installation in Akrotiri, Cyprus, showed that residents of exposed villages had markedly increased incidence of migraine, headache, dizziness, and depression, and significant increases in asthma, heart problems, and other respiratory problems. (Preece et al., 2007)

Studies in Murcia, Spain yielded similar findings, and based on measured exposures the authors suggested that safe levels of indoor exposure should not exceed 1 $\mu W/m^2$ (0.0001 $\mu W/cm^2$) (Navarro et al., 2003) (Oberfeld et al., 2004)

In a study of residents of Selbitz, Bavaria, researchers found statistically significant increases in multiple health symptoms that demonstrated a dose-response relationship with cell phone tower transmissions. Individuals living within 400 meters of the cell phone tower had significantly more symptoms than those living > 400 meters from the tower. And individuals living within 200 meters of the tower had significantly higher symptoms than those living between 200 and 400 meters from the tower. (Eger and Jahn, 2010)

Two recent reviews provide a detailed overview of research in this area. (Khurana et al., 2010) (Levitt and Lai, 2010)

SYMPTOMS PROVOKED BY CELL PHONE USE

Multiple studies of cell phone users in the last decade found evidence of a similar pattern of symptoms to be provoked in some users. (Chia et al., 2000) (Oftedal et al., 2000) (Santini R, 2002) (Wilen et al., 2003) (Salama and Abou El Naga, 2004) (Al-Khlaiwi and Meo, 2004) (Balikci et al., 2005) (Balik et al., 2005) (Szyjkowska et al., 2005) (Meo and Al-Drees, 2005) (Soderqvist et al., 2008) (Landgrebe et al., 2009) (Hutter et al., 2010)

PHYSIOLOGY OF ELECTROHYPERSENSITIVITY

A variety of research models have demonstrated that RF exposure does not have a uniform effect on people. In many studies, a cohort of individuals has been identified that has a more sensitive response to RF in one way or another.

Reduced heart rate variability

In one study, patients with symptoms consistent with EHS were found to have dereased circadium changes in heart rate variability. (Lyskov et al., 2001) Similar changes in HRV were found in another study where subjects self-identified as having EHS symptoms from exposure to video display terminals, TV screens, fluorescent lights, or other electrical equipment. (Sandstrom et al., 2003) An occupational study of RF plastic sealer workers also found alterations in heart rate compared to normal controls.

Fatigue and reduced melatonin

In the more recent Schwarzenberg study, the effect of RF exposure on producing morning fatigue and reduced melatonin secretion was significantly greater in the subjects whose general quality of sleep was below the median. (Altpeter et al., 2006)

EEG changes

Alterations in EEG have been found in animals and in people with exposure to both magnetic fields and cell phone transmission frequencies. (Marino et al., 2003) (Marino et al., 2004)

Nanou et al found the EEG response to be gender dependent after exposure both to 900 MHz and 1800 MHz signals. (Nanou et al., 2005) (Nanou et al., 2009)

Bachman found EEG changes with 450 MHz microwave exposure in 25 to 30% of healthy volunteers (Bachmann et al., 2005) (Bachmann et al., 2006). In another study, EEG changes were 5 times as common in depressive subjects as in healthy controls. (Bachmann et al., 2007)

Landgrebe found decreased intracortical excitability in EEG after transcranial magnetic stimulation in self-identified EHS patients, as compared with normal controls. (Landgrebe et al., 2007)

Schmidt found alteration in sleep EEG after exposure to a 900 MHz RF signal modulated at two different frequencies, and noted a marked individual variation in sensitivity to this effect. (Schmid et al., 2011)

Loughran found alterations in non-REM EEG after cell phone RF exposure. These alterations were consistently stronger in one subset of his study group, over multiple tests. (Loughran et al., 2012)

Altered Immune Function

Exposure to both GSM and UMTS cellular transmissions at nonthermal exposure levels have been shown to alter DNA repair mechanisms in lymphocytes. (Markova et al., 2005) (Belyaev et al., 2009) Multiple additional studies have demonstrated non-thermal biological effects of RF radiation on immune cell function, as reviewed here. (Johansson, 2007) (Johansson, 2009b)

One of the most intriguing findings is Johannson's research showing that patients with electrosensitivity have higher levels of mast cells in their skin, and that these mast cells migrate closer to the skin surface. (Johansson, 2006) Mast cells are responsible for the itching, burning, and skin flushing that occurs after sunburn exposure. The presence of higher levels of mast cells in EHS patients provides an explanation for the symptoms of flushed, itching, and burning skin on the face and other areas that is described by these patients, who appear to be reacting to RF exposure like others might react to excessive sun exposure. Since mast cells are distributed throughout the body, the presence of mastocytosis in EHS patients may relate to some other symptoms as well.

Hormonal Changes

Chronic exposures to electromagnetic field effects have also been shown to cause alterations in secretion of multiple hormones. A study published in 2007 showed that physiotherapists working with various electromagnetic treatment modalities had significantly elevated secretion levels of the stress hormones cortisol, adrenaline, and noradrenaline. (Vangelova et al., 2007)

Another study measured urinary secretion of the stress hormones adrenaline and noradrenaline, along with levels of dopamine and phenylethylamine, prior to and over the 1 1/2 years following the installation of a GSM cell phone tower in Rimbach, Bavaria. Levels of adrenaline and noradrenaline showed a significant increase over the first six months after exposure, and never returned to baseline levels. Responses

showed a proportional relationship to residential exposure levels, and were clearly present at levels as low as 60 to 100 microwatts/m^2 (= 0.006 to 0.010 μW/cm^2). This suggested a chronic stress effect of the GSM microwave signal on the population. (Buchner K, 2011)

Chronic adrenal stress will in time lead to decompensation and symptoms of adrenal fatigue in a certain percentage of the population.

A recently published study evaluated human hormone profiles over six years of exposure to the microwave RF emissions of GSM cell phones or cell phone towers. Findings included highly significant decreases in ACTH, cortisol, both T4 and T3 thyroid hormones. In male subjects, serum testosterone levels gradually decreased with increased time of exposure. In females, alterations in serum prolactin and progesterone levels gradually increased over increased time of exposure. (Eskander et al., 2012)

Current Research

One of us had the opportunity this spring to visit the practice of Dr. Dominique Belpomme, Professor of Oncology at Paris Descartes University, who is conducting research on electrohypersensitivity with the Association for Research and Treatments Against Cancer (ARTAC) in Paris. The ARTAC group has been following several hundred patients with EHS over the last four years, and has documented that these patients have clear and consistent changes in oxidative metabolism, and also in blood flow to the limbic system (as measured by doppler studies). Dr. Belpomme considers these changes in the limbic system to directly correlate with many of the cognitive changes (memory problems, difficulty with concentration, etc.) that are experienced by these patients. The ARTAC group expects to publish a series of papers on their findings during the next year. (Dart, 2012)

PROVOCATION STUDIES

Over the last ten years, many attempts have been made to evaluate the nature of electrohypersensitivity through provocation studies. The limitations of these studies have been discussed in detail in some recent papers. (Loughran et al., 2012) (Regel and Achermann, 2011)

Problems of methodology that have compromised many provocation studies include:

- Many studies have been performed single-blind rather than double-blind.
- Many studies divide the study group and normal controls based on the individual's self-identification as having (or not having) electrohypersensitivity. Since it is certainly possible for people to have reactions to EMF without being aware of this connection, and since the entire population is exposed to EMF at this point in time, it is difficult to be sure that the "control" group is indeed composed of "non-reactors". This will tend to weaken the power of any study set up in this fashion.
- Many studies evaluate whether or not the subject can discern when the RF signal is present and when it is absent. Absence of the ability to make this judgement is taken as evidence that electrohypersensitivity does not exist. This is an extremely illogical assumption. A person can develop a headache during or after an RF exposure without knowing when the signal is "on" or "off", just as they can develop bacterial gastroenteritis without knowing what food was contaminated with the bacteria. Having symptoms from RF and being a reli-

able RF meter are not the same thing.

- Unspecified or inadequate control of background levels of RF/EMF is also a problem with some "negative" studies. For example, one recent study (Kim et al., 2008) was performed with background RF levels in the study area of of 0.5, 0.7, and 0.8 V/m from three different mobile phone service providers. This adds up to a reported 2.0 V/m of background RF, equivalent to several thousand microwatts/m^2, which is well above threshold levels reported to cause symptoms in many sensitive individuals.
- Many studies assume that all patients who complain of EHS will react to any constant RF signal, and that they will react to it every time. Yet some studies have demonstrated that patients vary in which frequencies they respond to, and that patients can react more strongly to the starting and stopping of a signal than they do to the presence of a steady signal.
- Furthermore, the assumption is often made that EHS symptoms will start when a signal is turned on, and stop when it turns off. These assumptions are problematic, since many patients with EHS report having symptoms that continue for a significant time (hours, in many cases) after a triggering exposure. Few studies discuss whether or not an adequate "washout time" was provided for before starting the study, or between provocational challenges. The absence of such washout times seriously weakens the power of these studies.

In order to do a reliable RF provocation study with EHS exposure, it is necessary to isolate the subjects from background RF levels, and to maintain them in this isolation for long enough that they stop reacting to any prior exposures which they have received, before attempting to provoke a new reaction.

Some studies that are designed to address all these methodologic issues have found clear evidence of electrosensitivity. For example, a study done in 1991 that was performed in an isolated EMF environment tested EHS patients with a variety of different frequencies of RF stimulus, to determine their individual reactivity spectrum. 100 patients who identified themselves as having electrohypersensitivity were tested single blind with a variety of RF frequencies. 25 of these 100 patients showed an increase in symptoms of 20% over baseline, with no more than one placebo response.

These 25 patients were retested in a double blind setting with 25 healthy controls. 16 of the 25 patients (64%) reacted to the positive challenges, which were performed at a variety of frequencies.

These 16 patients reacted to 53% of the 336 active challenges, and 7.5% of the 60 blanks. No patient reacted to all tested frequencies. The 25 healthy controls had no reactions to challenges or to blanks.

Finally, these 16 patients were again tested in a double blind setting, each patient challenged with the single frequency to which they were most sensitive. In this phase of the study, the patients reacted 100% of the time to the active transmissions (with both reported symptoms and autonomic changes on iriscorder) and did not report reactions to the sham transmissions. (Rea et al., 1991)

It must be reiterated that having an adverse reaction to a provoking RF signal and having the ability to determine when the signal is "on" and when it is "off" are two completely different things. A recent double blind study demonstrated that a patient can have consistent provocation of symptoms from a signal without having any clear awareness of when the signal is actually present. (McCarty et al., 2011)

These provocation studies involve short term exposures to the RF signal (typically an hour or less). Since a great deal of the physiology research shows a more powerful effect with chronic exposures, these short-term studies are probably not the most effective way to assess the clinical significance of reactions to RF.

PREVALENCE OF EHS

Research in Stockholm County, Sweden in 1997 found that 1.5% of the population reported being hypersensitive to electrical or magnetic fields. (Hillert et al., 2002)

In California in 1998, Levallois et al found that 3.2% of the adult population reported being sensitive to sources of EMF. (Levallois et al., 2002)

In Switzerland in 2004, researchers studying a representative sample of the Swiss population found that 5% of the population had symptoms attributable to EHS, with sleep disorders and headaches being the most common reported symptoms. (Schreier et al., 2006)

In Austria in 2004, 2% of the population was estimated to have electrohypersensitivity. In a survey performed in Austria in 2008, 29.3% of respondents reported having some sort of adverse response to electromagnetic pollution. Of this cohort, 2.1% reported intense disturbance, and 3.5% had experienced enough difficulty that they had consulted a physician about the problem. (Schrottner and Leitgeb, 2008)

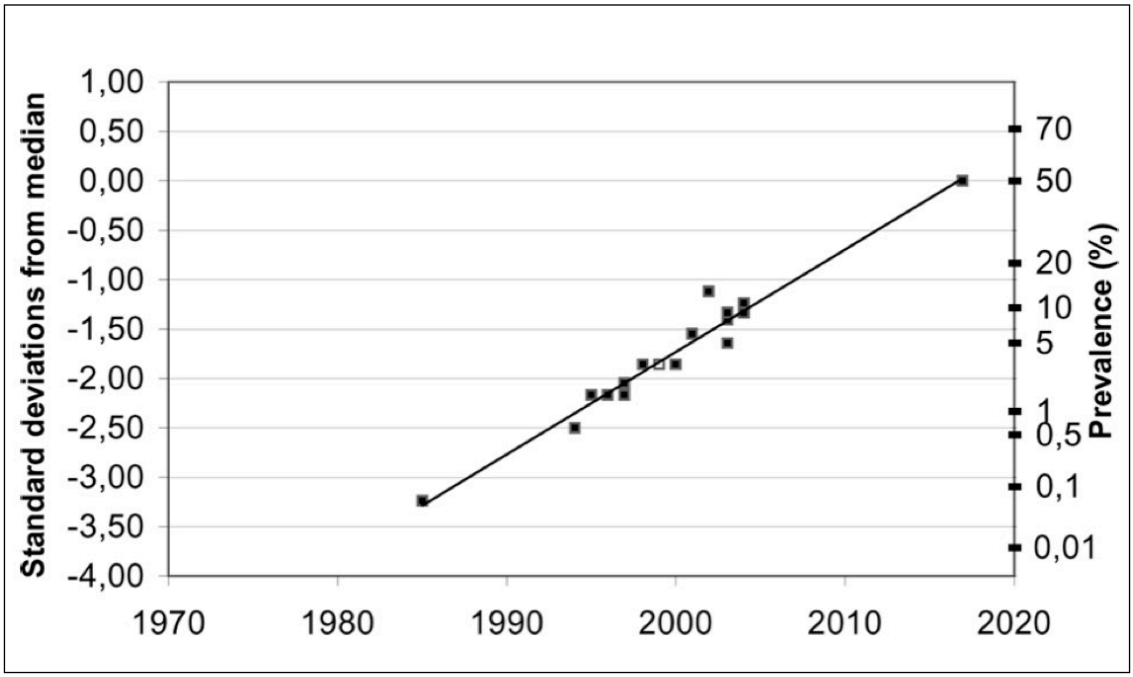


Figure 3: The prevalence of electrohypersensitivity syndrome is increasing. (Hallberg and Oberfeld, 2006

In much of the world, exposure to microwave radio signals has continued to significantly increase since the early 1990's. Reported electrosensitivity also appears to be increasing over time. In 2006, Halberg and Oberfeld reviewed research on this subject from 1985 forward, and estimated that if the trend in increased prevalence continues, fifty percent of the population could be reporting adverse effects from EMF by the year 2017 (Figure 1). (Hallberg and Oberfeld, 2006)

GOVERNMENTAL RESPONSE

The various forms of research described above have provided strong support for the fact that RF/EMF exposures can produce symptoms in human beings and that there is a percentage of the population that is more sensitive to this effect. Continued research is suggesting that this is not a static situation—that the prevalence of electro-hypersensitivity is a growing over time.

By the middle of the last decade, various government agencies were attempting to define the scope of the problem. (Irvine, 2005)

The rollout of mobile phone technology occurred earlier in scandinavia than in other places in the world, and governmental recognition of EHS as a health problem occurred earlier there than in other places. By the year 2000, EHS was recognized as a disability by the Swedish government. (Ministers, 2000)

In Stockholm, individuals with EHS can receive municipal support to reduce the presence of and penetration of EMF/RF into their homes. The construction of a village with houses specifically designed to mitigate this problem is being considered. Patients with EHS have the legal right to receive mitigations in their workplace, and some hospitals have build low EMF hospital rooms for use by such patients. (Johansson, 2006)

Various government reports or reviews on the question of electrohypersensitivity have been commissioned in the last few years. (Aringer et al., 1997) (Irvine, 2005) And legislation to address the problem has been proposed in some countries. (Snoy, 2011) (Parliamentary Assembly, 2011) Many libraries and schools in europe have banned WiFi due to concerns about health effects on employees and on the public.

REGULATORY RESPONSE

Regulations on exposure limits vary dramatically from country to country. In general, exposure limits have been mandated at a lower level in Russia and eastern Europe, where research on the health effects of RF exposure has been performed for a longer period of time. (Repacholi et al., 2012)

The regulatory standards established by the FCC and the World Health Organization are based on defining safe levels against the thermal effects of RF (i.e. damage from being cooked by high levels of microwave exposure). The FCC has not established exposure standards for potential nonthermal or biological effects of microwave exposure. (Hankin, 2002)

For example, the FCC has established Limits for Maximum Permissible Exposure (MPE). For the general population, the permissible level of exposure at 900 MHz is 600 $\mu W/cm^2$, and at 1800 MHz is 1000 $\mu W/cm^2$. (FCC, 1999) These exposure levels were last updated in 1996, and are considered to be protective against thermal effects of microwave radiation. However, current scientific research shows that these permissible levles of exposure are hundreds of times higher than the threshold levels for adverse "nonthermal" biological effects.

For the past ten years, the WHO has consistently equivocated on the issue of recognizing nonthermal biological effects from microwave RF exposure, despite the mounting research evidence of health problems and health risks produced by current levels of public exposure.

The following table shows exposure standards for various countries in 2001. (Firstenberg, 2001)

Country	($\mu W/cm^2$)
New South Wales, Australia	0.001
Salzburg, Austria (for pulsed transmissions)	0.1
Russia	2–10
Bulgaria	2–10
Hungary	2–10
Switzerland	2–10
China	7–10
Italy	10
Auckland, New Zealand	50
Australia	200
New Zealand	200–1000
Japan	200–1000
Germany	200–1000
United States	200–1000
Canada	200–1000
United Kingdom	1000–10,000

Figure 2: RF exposure limits (2001)

PHYSICIAN AND RESEARCHER RESPONSE

In response to this inaction on the part of government and international regulatory bodies over the past decade, a variety of groups of physicians and researchers in the field of RF/EMF health effects have called for regulatory action to address the documented biological consequences of the increasing exposure of the public to RF transmissions.

In 2000, the Salzburg Resolution suggested a total high frequency radiation limit of 100 mW/m^2 (10 $\mu W/cm^2$), and a total emission level of pulse modulated exposure (such as GSM) of 1 mW/m^2 (0.1 $\mu W/cm^2$). (Altpeter et al., 2000)

In 2002 a group of German physicians described a growing problem with adverse clinical effects from RF/EMF, and called for stricter safety limits on RF transmissions, restrictions on cell phone use by children and adolescents, and a ban on cellular and cordless phone use in preschools, schools, hospitals, nursing homes, event halls, public buildings, and vehicles. (2002)

Multiple similar appeals have been made by research groups and medical associations over the past ten years. (Association, 2004) (Leitgeb et al., 2005) (Association, 2012) (Dean A, 2012) (Johansson, 2011) (Johansson, 2009a) (Fragopoulou et al., 2010) (Israel et al., 2011)

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RADIOFREQUENCY EFFECTS ON MELATONIN

THE FUNCTION OF MELATONIN

Many physiologic functions in the human body are entrained in a circadium rhythm, fluctuating through the day/night cycle. The hormone melatonin, secreted by the pineal gland, is a key agent in coordinating these physiologic responses throughout the body. (Zawilska et al., 2009)

The entrainment of melatonin secretion with the day/night cycle is maintained by the suprachiasmatic nucleus in the hypothalamus, which receives input on the presence of light from the retina via the retinohypothalamic tract. In the presence of ambient light, melatonin secretion is suppressed. In the absence of ambient light, melatonin secretion increases. So melatonin secretion is high during the nighttime hours, peaking shortly after midnight. Higher melatonin levels are part of what makes us feel "sleepy" at night. Exposure to light during the nighttime hours will lead to a rapid suppression of melatonin secretion by the pineal gland, and this can cause disruption of sleep and derangement of the circadium rhythm.

Since the length of the day varies seasonally, melatonin also provides our physiology with information and influence produced by the different seasons of the year. This seasonal influence was obviously more profound prior to the widespread introduction of artificial electric lighting.

The circadian rhythm of high nocturnal melatonin levels supports the natural function of sleep, and disruption of this rhythm by bright light at night, night shift work, or travel to different time zones can produce sleep disturbances.

Melatonin is one of the most potent antioxidant molecules in the human body, and acts to reduce reactive oxidative processes in the body. Melatonin can quench the damaging free radical activity produced by inflammation. The presence of elevated melatonin at night is therefore a key factor in the healing and rejuvenating functions that we associate with "a good night's sleep".

Many body processes (serum cortisol levels, body temperature, patterns of digestive function, etc.) have a circadian rhythm that is coordinated by the timing signal of melatonin secretion. Melatonin has a protective effect on the health of the gastrointestinal tract. Melatonin is also protective against the growth of cancer cells, and disruption of the circadian melatonin cycle has been shown to lead to increased tumor growth in a variety of cancer types. (Reiter et al., 2011)

Research has clearly demonstrated that melatonin inhibits the proliferation, invasiveness, and metastasis of human breast cancer cells. Women who have lower levels of nocturnal melatonin are at greater risk for developing breast cancer. (Schernhammer et al., 2008) (Schernhammer and Hankinson, 2009) Breast cancer is more common in industrialized societies, and geographically the incidence of breast cancer is strongly associated with higher levels of "light-at-night". (Kloog et al., 2008) (Kloog et al., 2010)

Current research suggests that disruption of nocturnal melatonin signals by "light at night" can promote both the development and the growth of breast cancer. (Hill et al., 2011) (Stevens, 2009) In 2007 the International Agency for Research on Cancer declared night shift work to be a probable carcinogen. Subsequent epidemiologic research continues to support this finding. (Bonde et al., 2012)

Recent research has also suggested similar associations between "light at night" and the incidence of prostate cancer. (Kloog et al., 2009)

ELECTROMAGNETIC AND RADIOFREQUENCY EXPOSURES CAN REDUCE MELATONIN PRODUCTION IN THE PINEAL GLAND

In the 1990's, the Swiss government conducted a series of studies of sleep quality near the Swiss national short wave radio transmission tower in Schwarzenburg. These studies were initiated after the government received a petition stating that many residents living near the transmitter were experiencing problems including nervousness, headache, sleep disturbance, and fatigue.

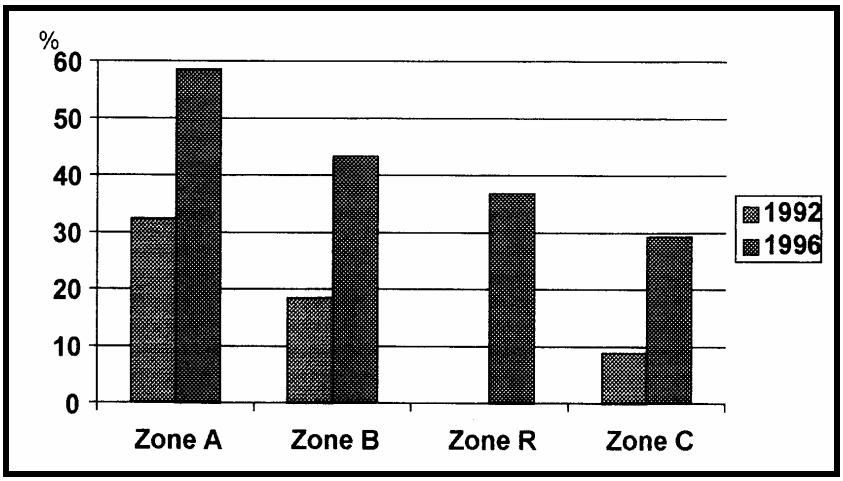


Figure 1: Sleep Disturbance by Proximity Zone in the Schwarzenburg Study. (Cherry, 2002)

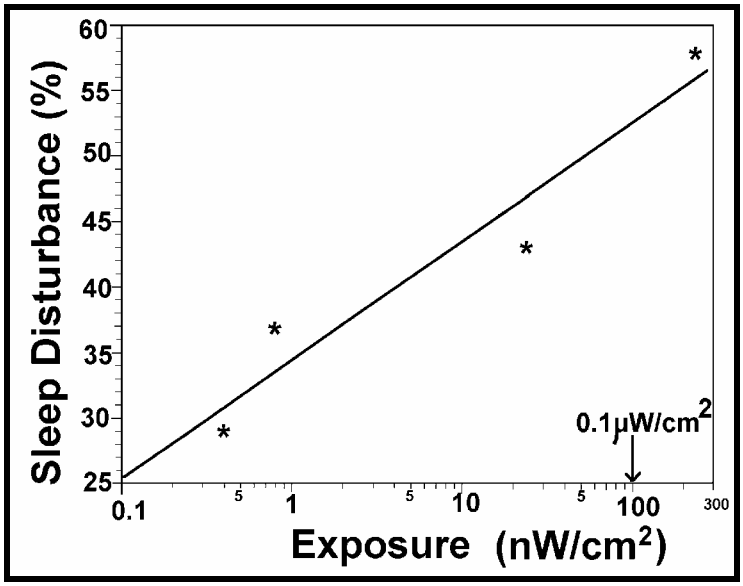


Figure 2: Sleep Disturbance by Exposure Levels in the Schwarzenburg Study. (Cherry, 2002)

In these studies, a statistically significant increase in sleep disturbance was found in residents living closer to the towers. Difficulty in maintaining sleep correlated with transmission field strength, at exposure levels as low as 0.1 nanowatts/cm^2. (Cherry, 2002) (Abelin et al., 2005)

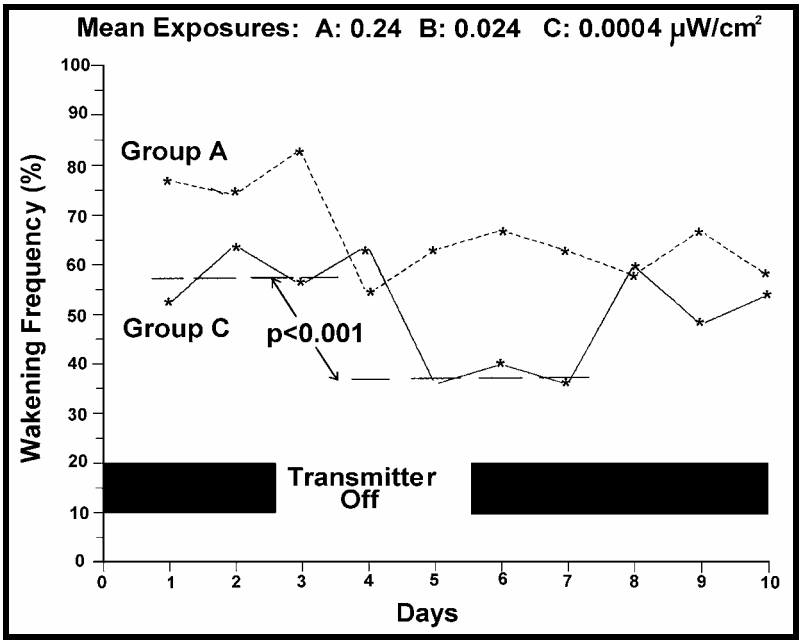


Figure 3: Reduction in Sleep Disturbance with Interruption of Tower Transmission in the Schwarzenburg Study. (Cherry, 2002)

During an interval when the transmitter was turned off for three days, statistically significant reductions in sleep disturbance were found in both the high and the low exposure groups (Figure 3). Note that Group C showed a reduction in sleep disturbance with absence of the signal, despite the fact that signal strength in Zone C averaged only 0.0004 μW/cm^2 (4 μW/m^2).

The Schwarzenburg transmission tower was shut down permanently in 1998. In a final research project, sleep quality and salivary melatonin levels were measured in a group of 54 community residents for an interval before and after the end of radio transmission.

Baseline sleep quality was assessed by analysis of sleep diary records, and subjects were stratified into two groups classified as either "poor" or "good" sleepers. Salivary melatonin samples were collected before breakfast, lunch, tea, dinner, and before bed. Subjects recorded morning tiredness and sleep quality, time of falling asleep, and duration of sleep. Exposure levels were calculated for each subjects home.

During the baseline exposure period, scores of morning tiredness directly correlated with increased levels of exposure, and melatonin excretion levels were reduced by a factor of 0.90 for each mA/m of increase magnetic field exposure level. Peak melatonin excretion times were delayed by 4.4 minutes for every 1 mA/m increase in exposure level.

After shutdown of the transmitter, subjects' morning fatigue scores improved by 1.74 units for each 1 mA/m of reduced exposure, and melatonin excretion levels increased by a factor of 1.15 per mA/m of reduced exposure. (Altpeter et al., 2006)

The Schwarzenburg shutdown study's findings were remarkable for two additional reasons. First, there were no other significant levels of short wave radio exposure in the community at the time of the study. So this study provides a true elimination and challenge test of RF exposure effects on a fairly large group of people in their normal environment. Such a study setting was difficult to arrange at that time, and

would be even more difficult to achieve today, as the number of sources of RF exposure in our communities have increased markedly with the rollout of the wireless telecommunications infrastructure.

Second, the stratification of the study group into "poor" and "good" sleepers allowed recognition of an important additional finding. Improvements in sleep quality and melatonin secretion levels after transmitter shutdown were significantly greater in "poor" sleepers than they were in "good" sleepers. This evidence supports the hypothesis that some individuals may be more sensitive to the effects of microwave exposure, a condition that has been called "electrohypersensitivity" or EHS.

Multiple additional studies in a variety of settings have demonstrated an effect of various forms of EMF/RF on melatonin physiology. Several comprehensive reviews of this research have been published in the last few years. (Cherry, 2002) (Davinipour and Sobel, 2007) (Davanipour and Sobel, 2009)

Performing large long-term studies of RF effects on humans in a sleep laboratory setting would be prohibitively difficult both logistically and financially. But several recent laboratory studies in animals have demonstrated suppression of melatonin by prolonged pulsed microwave RF exposures.

Kesari et al. exposed Wistar rats to 2.45 GHz mobile phone transmissions, 2 hours daily for 45 days, at a calculated SAR of 0.9 W/Kg. Pineal melatonin levels were significantly reduced in exposed animals. (Kesari et al., 2011)

Kumar et al. repeated this experiment with 2.5 GHz exposures of 2 hours per day for 60 days, at a much lower exposure level (power density of 0.21 mW/cm^2, calculated SAR of 0.014 W/kg). Even at this low level of exposure (= 210 mW/cm^2), serum melatonin levels were significantly reduced in exposed animals. (Kumar et al., 2011)

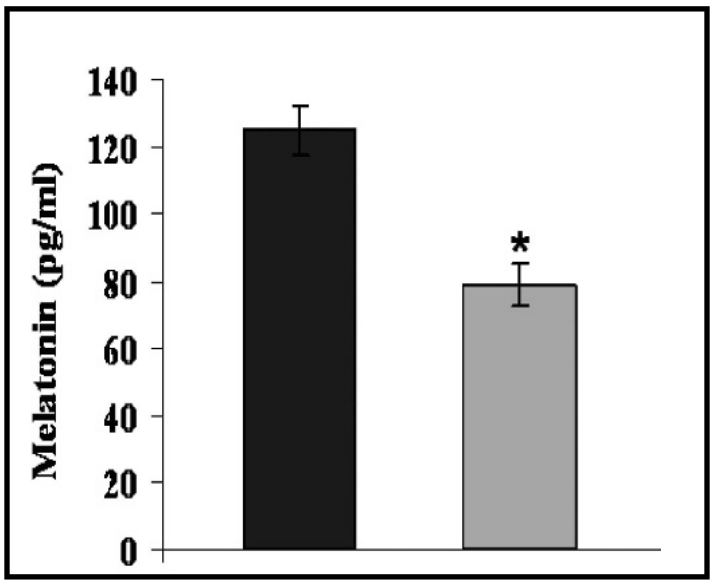


Figure 4: Serum melatonin levels in sham (black) and exposed (grey) Wistar rats after 2 hours daily exposure for 60 days to 2.45 GHz RF transmission at 0.21 milliwatts/cm^2. (from Kumar et al., 2011)

In another study, Kesari found significant reduction in pineal melatonin levels in rats exposed to 2.45 GHz mobile phone transmissions, 2 hours daily for 45 days, at a power density of 0.21 mW/cm^2 (calculated SAR of 0.014 W/kg). (Kesari et al., 2012)

CONSEQUENCES OF REDUCTION OF MELATONIN LEVELS BY MICROWAVE RF EXPOSURE

Reduction of melatonin levels by exposure to radio transmissions could be expected to cause sleep disturbance. Research findings like the Schwarzenburg studies strongly support this conclusion.

But melatonin has also been found to be protective against promotion of some types of cancer. If suppression of melatonin by "light at night" and night shift work can increase risk of breast cancer (as discussed above), then suppression of melatonin by radio transmissions could also be expected to increase cancer risk. Recently published research studies strongly support this conclusion.

A study in Israel found women living within 350 meters of a cell phone tower to have over 10 times greater risk of cancer than the community as a whole ($p < 0.0001$). (Wolf and Wolf, 2004)

A study of cancer patients in Germany found a 3.29 times greater risk of cancer ($p < 0.01$) in patients with residence closer than 400 meters to a cell pone tower. Risk of breast cancer was 3.4 times greater, and average age of diagnosis of breast cancer was 19 years earlier. (Eger et al., 2004)

In a case/control study of cancer patients residing near a cell phone transmission tower in Austria, those with external residential exposures of greater than 1000 $\mu W/m^2$ ($> 0.1\ \mu W/cm^2$) had a a breast cancer risk that was 23 times higher ($p = 0.0007$) and brain tumor risk was 121 times higher ($p = 0.001$) than controls. (Oberfeld, 2008)

A recent study from Brazil found a clearly elevated relative risk of cancer mortality at residential distances of 500 meters or less from cell phone transmission towers. (Dode et al., 2011)

Several recent published reviews discuss the multiple epidemiologic studies that have shown an association between residential RF exposure from microwave transmission towers and increased breast cancer risk. (Cherry, 2005) (Khurana et al., 2010) (Levitt and Lai, 2010) (Yakymenko et al., 2011) We will discuss this issue more thoroughly in Section 3.

RAISING THE LEVEL OF RADIOFREQUENCY TRANSMISSION IN RESIDENTIAL NEIGHBORHOODS CARRIES SIGNIFICANT RISKS

Unlike visible light, microwave radio transmissions penetrate walls and human bodies. They are not easily blocked out by window blinds or eye shades. If microwave radio waves can disrupt melatonin secretion in a portion of the population, then a significant increase in nocturnal RF transmission levels in a residential neighborhood would be expected to produce an increase in sleep problems, and over the long run, an increase in the incidence of breast and prostate cancer. The first evidence of such an effect would be a significant increase in complaints of sleep disruption. It might require several years of exposure for the increase in cancer incidence to reveal itself.

If we use complaints of sleep disruption as a marker for this effect, we can suspect that the recent installation of MESH-networking smart meters in California and in other municipalities around the world has pushed many residential areas across a threshold, producing chronodysruption in a significantly increased portion of the population. The early evidence for this is that these smart meter rollouts have been followed by a dramatic increase in complaints of sleep difficulties received by physicians, by public utility commissions, and in postings on the internet.

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RADIOFREQUENCY EXPOSURE INCREASES OXIDATIVE STRESS AND DAMAGES DNA

Over the past 20 years, a great deal of research evidence has accrued which demonstrates that EMF and RF can alter cellular physiology.

INDUCTION OF STRESS PROTEINS

When cells are stressed in a way that damages DNA in cells, an early response of the cellular physiology is to increase the production of proteins involved in the repair of these structures. These repair proteins are called stress proteins or "heat shock" proteins (since early research models used heat to stress the cells). Increased production of these proteins are direct evidence of physiologic stress and damage to cell DNA, as they represent the effort of the cell to protect against and repair that damage.

The physiologic stressors that trigger this response stimulate specific regions on the cell's chromosome. These regions initiate the transcription of the stress response genes that encode for these repair proteins.

In the late 1990's research demonstrated that EMF exposures can produce these stress proteins. (Lin et al., 1997) (DiCarlo et al., 1998)

Further research demonstrated that EMF/RF stimulation promotes gene transcription at different promotion sites than those triggered by heat stress (Lin et al., 1998) (Lin et al., 1999), and that this promotion by EMF/RF can occur at power levels that are not high enough to produce thermal changes in the cells. (DiCarlo et al., 1999) (Weisbrot et al., 2003) (Blank and Goodman, 2004) (Blank, 2007)

Subsequent research has shown that at DNA transcription sites activated by low level EMF and RF exposure, higher levels of exposure can lead to single or double strand breakage of the DNA chain. (Blank and Goodman, 2009)

Current research confirms production of the stress protein response by microwave signals in the 900 MHz and 1800 MHz bands. (Cao et al., 2011) (Jiang et al., 2012) (Calabro et al., 2012)

DNA DAMAGE

Many research studies performed in the last decade have demonstrated that radio frequency radiation at nonthermal levels can produce fragmentation of DNA.

In 2003, Ivancsits reported that intermittent low frequency EMF could cause single and double strand breaks in DNA at magnetic flux densities as low as 35 microtesla, well below levels producing thermal effects. Effects were time and dose dependent. (Ivancsits et al., 2003)

This work was confirmed in 2004 in a study showing that 24 to 48 hour exposures to a 0.01 mT 60 hz magnetic field could produce single and double strand DNA cleavage, apoptosis, and necrosis of brain cells in rats. These effects could be blocked with antoxidants, suggesting that free radicals played a role in the damage process. (Lai and Singh, 2004)

Subsequent research demonstrated that these effects also could be produced by nonthermal effects of radiofrequency microwave exposures—at power levels that were below the levels producing thermal effects—and that this nonthermal damage could be prevented by administration of antioxidant free radical scavengers. (Adlkofer, 2006)

The results of in vitro studies on DNA damage from EMF/RF are variable, since different cell types have different sensitivities to these effects. (Schwarz et al., 2008) Several detailed reviews of these studies have been published in the last five years. These reviews document multiple studies showing production of DNA damage at low power densities, with more prolonged exposure times producing more significant effects. (Lai, 2007) (Ruediger, 2009) (Phillips et al., 2009) (Levitt and Lai, 2010)

Current research continues to validate these findings. For example, Cam and Syhand found an increase in the production of single strand DNA breaks in hair root cells following 15 to 30 minutes of mobile phone use. (Cam and Seyhan, 2012)

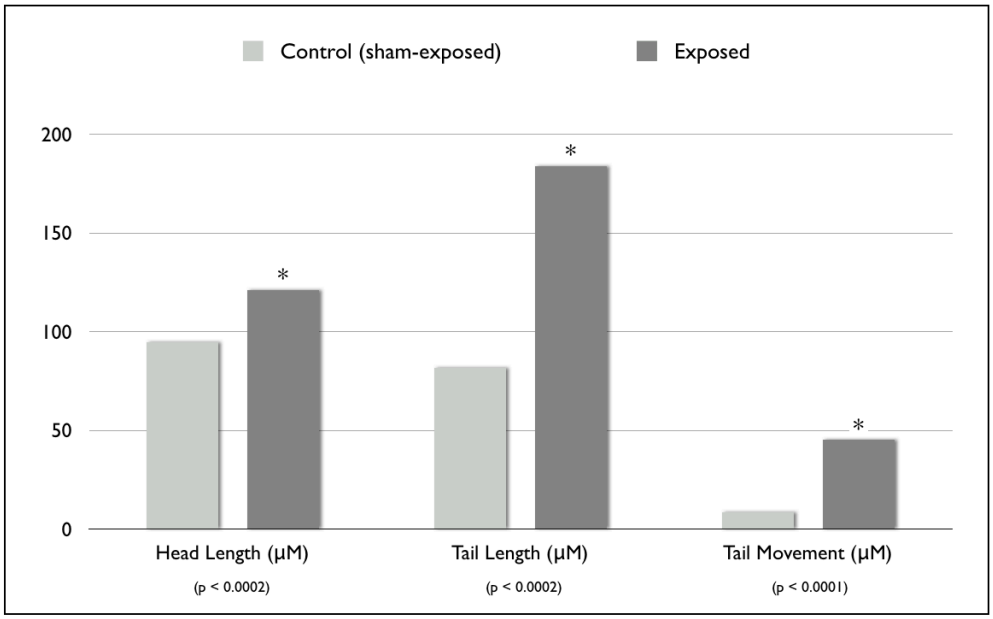


Figure 1: Comet Assay of DNA fragmentation in rat brains, produced by prolonged exposure to microwave RF. (Kesari et al., 2010a)

Kesari et. al. exposed Wistar rats to 2.45 GHz frequency at 0.34 mW/cm^2 power density (340 μW/cm^2, whole body SAR ~ 0.11 W/Kg), 2 hours a day for 35 days, and demonstrated increased double strand DNA breakage ($p \leq 0.0002$) in brain tissue. This was accompanied by decreased activity levels of glutathione peroxidase ($p < 0.005$) and superoxide dismutase ($p < 0.006$), and increased catalase activity ($p < 0.006$) suggesting that the microwave exposure produced severe oxidative stress. (Kesari et al., 2010a)

Kumar et. al. exposed Wistar rats to 50 GHz continuous source microwave transmission, 2 hours a day for 45 days, with a power density of 0.86 μW/cm^2 (calculated SAR 8.0 x 10^{-4} W/kg). Other rats were exposed to 10 GHz, 2 hours a day for 45 days, power density 0.214 mW/cm^2 (214 μW/cm^2, SAR 0.014 W/kg). Both forms of exposure produced significantly altered levels of reactive oxygen species, antioxidant enzyme activity, and blood cell micronuclei formation, demonstrating the production of oxidative stress with genotoxic effects. (Kumar et al., 2010)

RF EXPOSURE PRODUCES OXIDATIVE STRESS

It is a truism among apologists for the telecommunications industry that microwave radiofrequency transmissions cannot possibly cause cancer, because the energy of a photon of this wavelength is not powerful enough to directly break an ionic

bond the way an xray can, and therefor could not possibly cause mutations in DNA. Such an argument sounds like good physics, but it isn't good biology. Ionizing radiation is only one way to cause the mutations in DNA that can produce cancer.

Chronic inflammation can cause cancer. Cigarette smoke can cause cancer. Toxins and autoimmune disease can cause cancer. One common pathway shared by these causes is that they produce an inflammatory response in the body that increases the activity of free radicals (reactive oxygen species). These free radicals produce oxidative damage in the tissues.

This oxidative activity is the tool that our bodies use to destroy foreign bacteria, which can be completely broken up—DNA and all—and digested by our immune system. Free radicals are an important defensive weapon for our bodies, but an excess of oxidative activity can lead to damage of our own tissues. Such excesses have been associated with many chronic problems including autoimmune disease, heart disease, and some forms of cancer. Every week another article is published suggesting that taking antioxidants may be protective against some of these problems.

The mechanisms through which EMF/RF increase oxidative stress in living tissues have not been clearly elucidated, although some ideas have been proposed. (Liboff, 2010) (Georgiou, 2010)

But in the last decade, the scientific research clearly established that EMF and RF exposure cause an increase in reactive oxygen species in living tissues, leading to oxidant damage of DNA. (Shiroff, 2008)

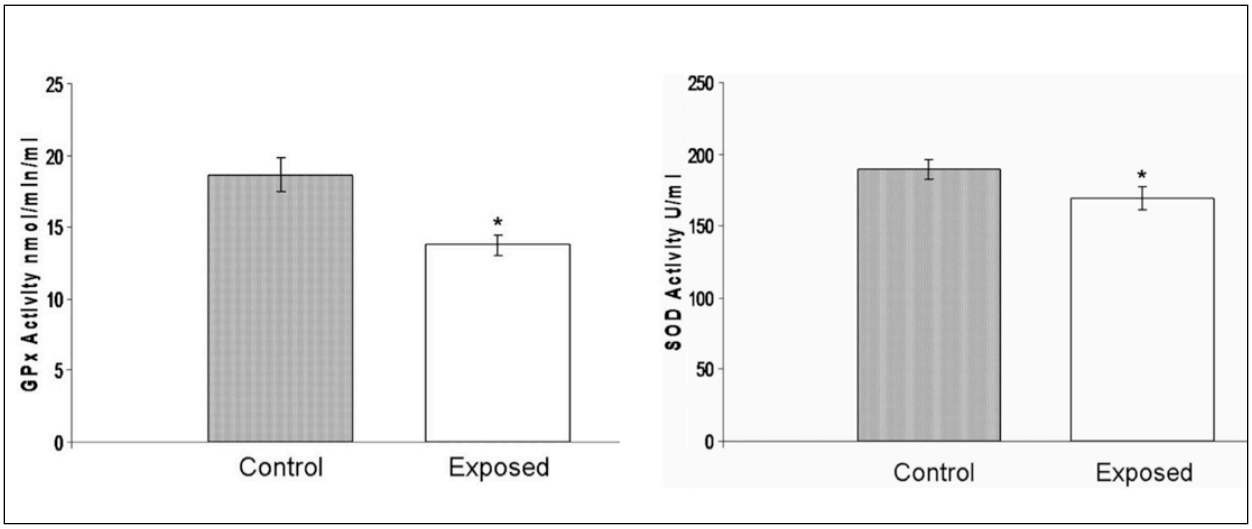


Figure 2: Depletion of antioxidants in RF-exposed rat brains, after exposure to 2.45 GHz, 2 h a day for 35 days at 0.34 mW/cm2 power density, 2.45 GHz frequency. (Kesari et al., 2010a)

Studies cited above document that microwave RF exposures at very low power densities produce oxidant stress accompanied by DNA damage. (Kesari et al., 2010a) (Kumar et al., 2010)

Other recently published studies also show that RF exposure can increase oxidant stress and tissue damage in brain tissue (Maaroufi et al., 2011) (Avci et al., 2012), liver tissue (Guler et al., 2012), white blood cells (Lu et al., 2012), and human salivary glands (Hamzany et al., 2012).

SUPPRESSION OF MELATONIN SECRETION COMPOUNDS THE PROBLEM.

The problems caused by increased oxidative stress from EMF/RF are compounded by the fact that EMF/RF can also suppress melatonin secretion by the pineal gland, since melatonin is one of the most potent antioxidant molecules produced in the body.

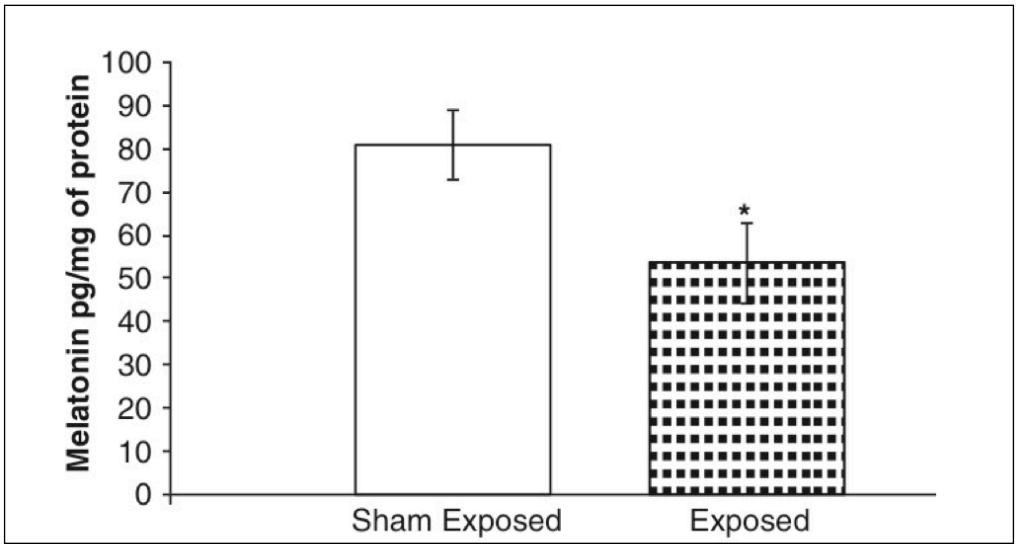


Figure 3: Suppression of melatonin secretion by 2.45 GHz RF, 2 hours a day for 45 days at 0.21 mW/cm2. (Kesari et al., 2012)

In recently published study, Kesari et. al. exposed Wistar rats to 2.45 GHz microwave radio transmission, 2 hours a day for 45 days, at a power density of 0.21 mW/cm^2 (210 $\mu W/cm^2$, whole body SAR ~ 0.14 W/kg). Pineal melatonin was significantly decreased in the exposed group. (Kesari et al., 2012)

Multiple studies have documented that exposure to microwave RF can reduce melatonin levels in animals and in people. (see Section 3).

CONSEQUENCES OF OXIDATIVE DAMAGE TO DNA

EVIDENCE FOR CANCER

When DNA is damaged, the body attempts to repair it. Errors in DNA coding sequence produced during the repair process can produce mutations. And it is hypothesized that such mutations in DNA are a major cause of cancer.

So if radio frequency (RF) and microwave (MF) exposure increase oxidative damage to DNA, we would expect to see evidence that chronic RF exposure increased the rate of some forms of cancer. A significant body of epidemiologic research in a variety of exposure settings suggests that this is indeed the case.

Electronics technicians

In the 1980's, Milham published evidence of increased leukemia in electrical workers (Milham, 1985b)

Another study of workers in the electronics industry found an increased risk of brain tumor associated with exposure to microwave radio transmission, with a highly significant increase in risk in those with more than 20 years of exposure. (Thomas et al., 1987)

A case/control study of brain cancer deaths in Maryland found a threefold greater brain cancer incidence in electrical or electronic engineers and technicians, compared to the reference population. (Lin et al., 1985)

A study of leukemia rates in different occupational groups in the U.S. Navy showed increased leukemia risk in electrician's mates. (Garland et al., 1990)

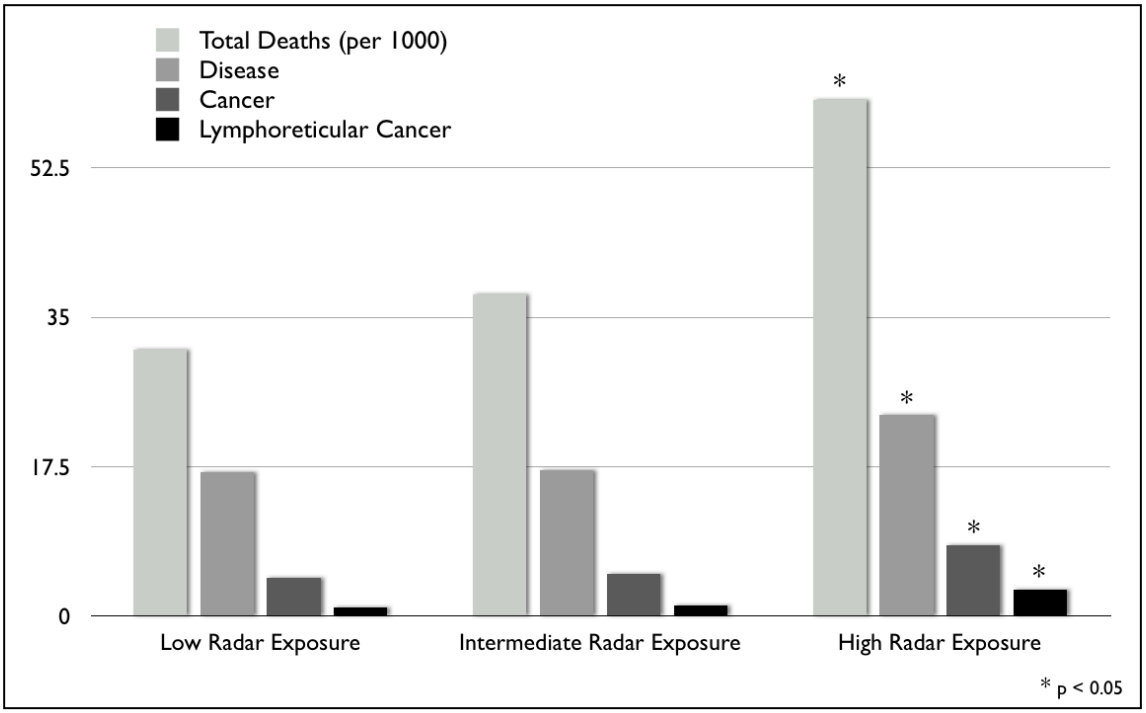


Figure 4: Mortality (1950–1974) in U.S. Navy Korean War Veterans, stratified by in-service levels of occupational radar exposure. (Cherry, 2002a, after Robinette, 1980)

A study performed for the U.S. military published data comparing a cohort of 20,000 Korean War veterans with higher occupational exposure levels to RF/MW exposure to 208,000 Korean war veterans with minimal occupational exposure during their service years. Mortality statistics were reviewed for the interval between 1950 and 1974. (Robinette et al., 1980) This data shows that the group with the highest rated occupational exposure level (aviation electronic technicians) had a significantly higher total death rate during the study period, and a higher death rate from disease, from malignancy, and from lymphatic and hematopoetic malignancies. (Goldsmith, 1997a)

A study of Polish career military personnel from 1971 – 1985 showed double the risk of cancer in personnel with occupational exposure to RF/MW transmission, as compared other personnel. The exposed cohort had higher morbidity rates for GI cancers (Observed versus Expected Ratio = 3.19 – 3.24), brain tumors (OER = 1.91), and hematopoetic malignancy (OER = 6.31), including chronic myelocytic leukemia (OER = 13.9), acute myeloblastic leukemia (OER = 8.62), and non-Hodgkin's lymphoma (OER = 5.82). (Szmigielski, 1996)

Radio Operators

Increased rates of acute myeloid leukemia and of other lymphatic malignancies have been found in large population based studies of amateur radio operators (Milham, 1985a) (Milham, 1988a) (Milham, 1988b).

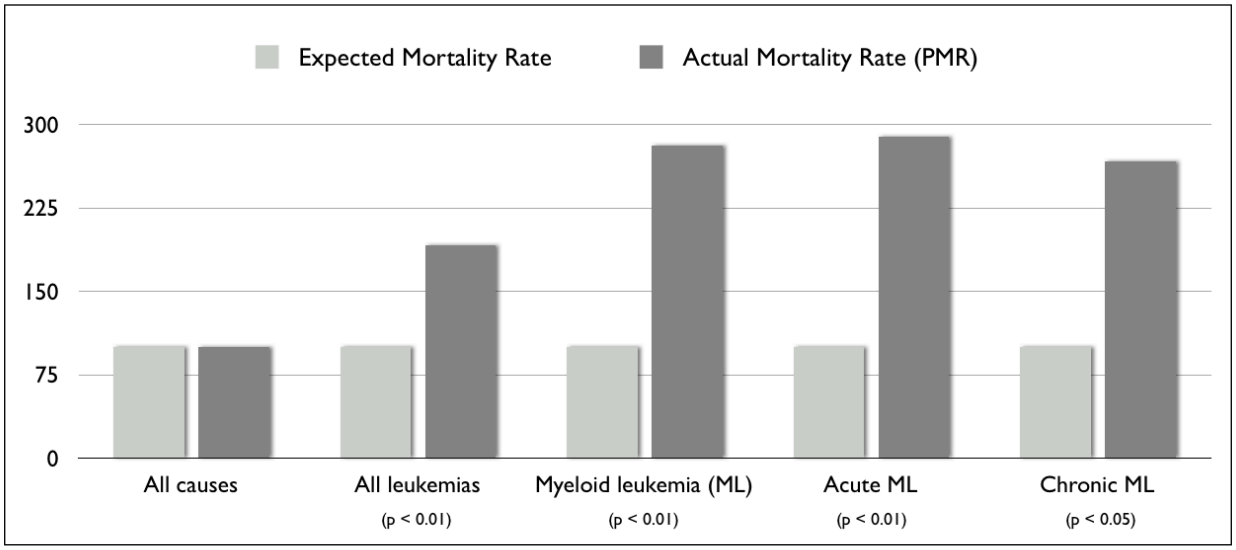


Figure 5: Analysis of leukemia deaths in male members of the American Radio Relay League resident in Washington and California, 1971 – 1983. (Milham, 1985a)

Another study of female radio and telegraph operators in Norway found an increased incidence of breast cancer in this group as compared to the standardized incidence rate in the female population of that country. (Tynes et al., 1996)

Police radar operators

Two studies have shown increased rates of testicular cancer (Davis and Mostofi, 1993), and of testicular cancer and melanoma (Finkelstein, 1998) in police officers with occupational exposure to handheld radar.

Airline pilots

Airline pilots have significant occupational exposure to RF/MF (radio frequency and microwave frequency) transmissions.

A study of U.S. Air Force personnel showed an increased risk of brain tumors associated with increasing rank, and associated with estimated exposures to both microwave radio and low frequency radio transmissions. No increased risk associated with exposure to ionizing radiation was found in this study population. (Grayson, 1996)

A study of commercial airline pilots in Iceland found an increased risk of malignant melanoma. (Rafnsson et al., 2000) Another study with Danish pilots showed increased risk of total cancer, melanoma, other skin cancers, and acute myeloid leukemia in commercial airline cockpit crews. (Gundestrup and Storm, 1999) Neither of these studies specifically controlled for RF/MF exposures as compared to other exposures (cosmic rays, tropical sun on the beach, etc.) incurred by flying personnel.

However, an extensive study of German commercial airlines crews (including 6,017 cockpit and 20,757 cabin crew members) showed an increased brain cancer risk for cockpit crew and an increased all cancer risk for cockpit crew with more than 30 years employment compared to those with under 10 years of employment. Notably, these increased risk were not found in cabin crew members, who share equal exposure to cosmic rays and tropical beaches, but are farther from the radios. (Zeeb et al., 2010)

U.S. Embassy Moscow 1953 – 1976

From the 1950's to the mid-1970's the U.S. Embassy in Moscow was exposed to a

constant low intensity radar signal, as a form of harassment by the Russian government. The exposure level on the outside of the west facade of the building was measured at 5 microwatts/cm^2, and was present for 9 hours a day. Since the wall and windows attenuated the signal, inside exposure levels were likely to be in the range of 0.02 to 0.1 $\mu W/cm^2$.

The State Department contracted an epidemiologic analysis potential health effects on exposed personnel and their dependents, which was performed by A.M. Lilienfeld M.D., and epidemiologist at John's Hopkins University. This report was published including all of the tabulated raw data. (Lilienfeld AM, 1979)

The report as finally released stated as a conclusion that personnel "suffered no ill effects" from the microwave exposure. However, the published conclusions differed from the original conclusions written by Dr. Lilienfeld, and evidence suggests that the final conclusions were "whitewashed". (Goldsmith, 1997b) One can presume that this might have been done to avoid embarrassment of the federal government, since any harm, if produced, would have been produced at levels of exposure orders of magnitude less than those exposure levels permitted by United States FCC guidelines.

A hematologic study performed on employees at the Moscow embassy was submitted to the U.S. government in October, 1976. This study showed significant abnormalities in hematologic parameters in this group, in comparison with studies of foreign service workers in the United States. (Goldsmith, 1997a)

The published data from the Lilienfield study of Moscow embassy workers and their dependents has subsequently been analyzed by other epidemiologists and found to show a statistically significant increase in total adult and childhood cancers, in breast cancer, and in childhood leukemia. (Goldsmith, 1995) (Cherry, 2002a)

Residential exposure to Radio/TV Transmission towers

By the late 1990's, a significant body of epidemiologic literature had accumulated that demonstrated an association between exposure to radar and RF radiation and the occurrence of certain types of cancer.

Evidence for association between radio transmission tower exposures and adult and/or childhood leukemia has been reported in studies from Hawaii (Maskarinec et al., 1994) and Australia (Hocking et al., 1996).

A study from England shows an increased risk of adult leukemia in those residing within two kilometers of the transmission tower, and decreased risk of leukemia, skin cancer, and bladder cancer with increased distance of residence from the tower. (Dolk et al., 1997b) A follow-up study involving multiple other sites in England also showed a statistically significant decline in risk of adult leukemia with increasing distance of residence from transmission sites. (Dolk et al., 1997a) (Hocking et al., 1998)

A study in Rome evaluated the incidence of adult and childhood leukemia as a function of residential proximity to the Vatican Radio transmission tower. Pediatric leukemia cases were more common than expected at less than 6 kilometers from the tower, and significantly elevated in adult men living within 2 km of the tower. Adult male leukemia mortality and childhood leukemia rates showed a significant decrease with increasing distance between tower and residence. (Michelozzi et al., 2002)

A study of cancer incidence in proximity to the Sutro radio/TV tower in San Francisco also showed a strong correlation of exposure and incidence of several types of childhood cancer. (Cherry, 2002b) This study was notable for its rigor in analyzing the actual exposure levels around the tower in relation to the data set. Power density/

exposure levels around UHF and VHF broadcasting antennae are not distributed in a simple and symmetrical regression ("with the square of the distance"). Transmission exposure levels form a series of peaks and valleys around these antennae, and the antennae can be arranged to focus more power in one direction than another, aiming a stronger signal at the target audience in a population center. Studies that fail to take this distribution into account and assume that exposure is in direct ratio to distance will mix higher and lower exposure groups together, diluting the power of the study and underestimating true risk in relation to exposure.

In another paper, Dr. Cherry analyzes this issue in detail, and uses his more rigorous approach to review and refine the analysis of data from many of the earlier studies on health effects of radio/TV broadcast towers. His analysis strengthens the evidence for increased cancer risk from these exposures. (Cherry, 2002a)

A large population case/control study in south Korea looked at 1928 leukemia patients and 956 brain cancer patients under 15 years of age who were diagnosed between 1993 and 1999 at 14 large hospitals in Korea. These cases were matched with 3082 age matched patients who received respiratory disease diagnoses (primarily asthma) at the same hospitals during the study period. Case and control exposure levels were calculated for 31 transmitters in South Korea that had a transmission power greater than 20 kW, using a mathematical model that was correlated with field testing. Children residing within 2 kilometers of a transmission tower had a significantly increased risk of leukemia as compared to children with residence greater than 20 km from the tower (OR 2.15, 95% CI = 1.00 to 4.67). (Ha et al., 2007)

Residential Exposure to Cell Phone Tower (Base Station) Transmissions

With the dramatic rollout of commercial cell phone service in the 1990's, large segments of the population became exposed to significantly higher levels of microwave RF exposure due to the installation of cell phone towers in urban areas. Several recent papers have reviewed the significant evidence for ill effects from these urban exposures. (Khurana et al., 2010) (Yakymenko et al., 2011) (Kumar, 2010)

Netanyu, Israel

Wolf and Wolf studied rates of cancer incidence during the second year of operation of a 1500 watt 850 MHz cell phone tower in Netanya, Israel. The study group was composed of 622 individuals who had lived in area A, within 350 meters of the tower, for the previous 3 to 7 years. A control group of 1,222 individuals living in an outlying area B was also studied.

During the study year, 8 cases of cancer occurred in the study group, and 2 cases occurred in the control group. The cancer rate for the entire town was 31 cases per 10,000. Relative cancer rates for females was 10.5 for the study group, 0.6 for the control group, and 1.0 for the town as a whole ($P < 0.0001$).

Signal power densities of the tower's transmissions in the homes of the cancer cases ranged from 0.3 – 0.5 $\mu W/cm^2$. [note that FCC limits are 600 – 1000 $\mu W/cm^2$.]

In the year following the close of the study, another 8 new cases of cancer occurred in area A, and another 2 cases occurred in area B. (Wolf and Wolf, 2004)

Naila, Germany

A cell phone transmission tower was placed in the town of Naila, Germany, in 1993. Eger, Hagen, et. al. reviewed the medical health records from 1994 to 2004 for around 1000 residents of the municipality (roughly 90% of the population). All

included patients had been living at the same address during the entire 10 years of observation.

Over the course of the entire study period, patients living in an inner area within 400 meter of the transmission tower had 2.27 times the relative risk of cancer incidence, compared to patients living more than 400 meters from the tower ($p < 0.05$). Cancer patients in the inner residential area also developed cancer an average of 8.5 years earlier in life than did cancer patients residing in the more distant area.

For the years 1999 to 2004 (after 5 years of tower operation) the relative risk of cancer incidence in residents less then 400 meters from the tower increased to 3.29 ($p < 0.01$). Relative risk of breast cancer was 3.4 in the inner area, where average age of diagnosis was 50.8 years, compared to 69.9 years in the outer area. (Eger et al., 2004)

Hausmannstätten and Vasoldsberg, Austria

Oberfeld performed a case/control study of cancer patients in the municipalities of Hausmannstätten and Vasoldsberg, Austria. All subjects had resided within 1,200 meters of an analogue cell phone tower that operated between 1984 and 1997 in the municipalities.

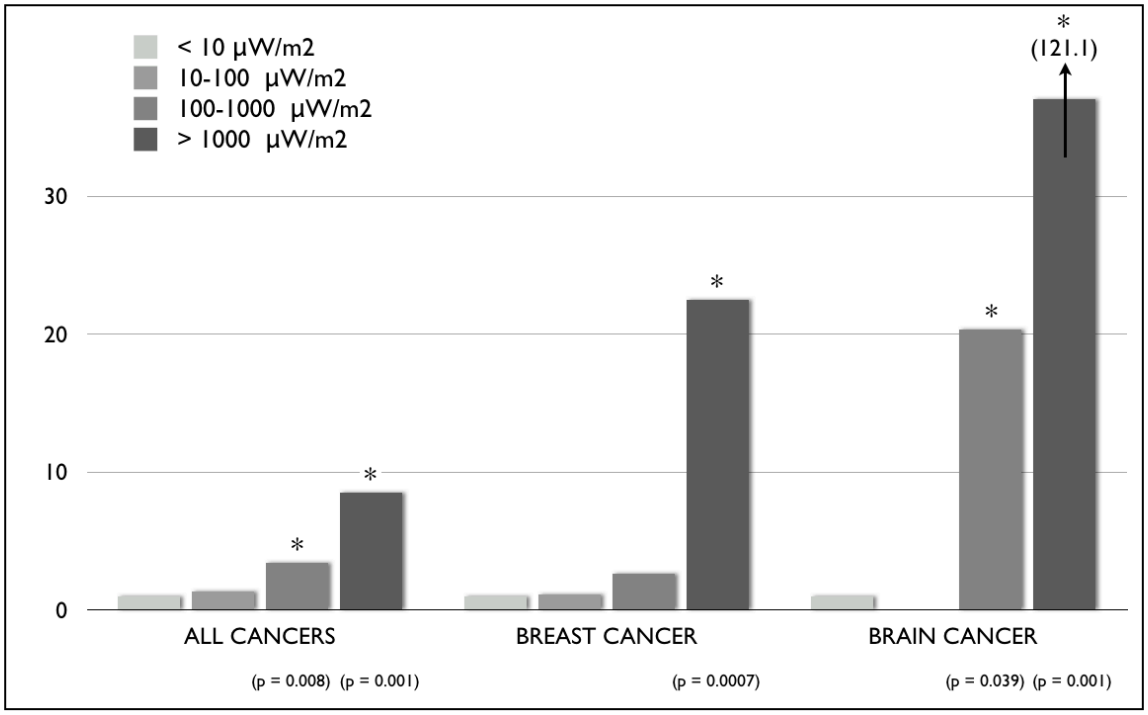


Figure 6: Odds ratio of cancer incidence, stratified by exposure levels (exterior to dwelling) in µW/m². (Oberfeld, 2008)

Residential outdoor exposure levels were measured, and three different case/control groups were assessed, for case exposure levels outside the residence of 10 – 100 $\mu W/m^2$ (= 0.001 – 0.01 $\mu W/cm^{2)}$), 100 – 1000 $\mu W/m^2$ (= 0.01 – 0.1 $\mu W/cm^2$), and greater than 1000 $\mu W/m^2$ (> 0.1 $\mu W/cm^2$). respectively. The reference exposure level for the control group was less than 10 $\mu w/m^2$ (= 0.001 $\mu W/cm^2$). [Note that FCC thermal safety limits are 6,000,000 to 10,000,000 $\mu W/m^2$.]

Cancer risk for all cancers was significantly elevated for all three elevated exposure categories, and was 5 to 8 times higher in the >1000 $\mu W/m^2$ (> 0.1 $\mu W/cm^2$) cate-

gory (p=0.001). In this highest risk group, breast cancer risk was 23 times higher (p = 0.0007) and brain tumor risk was 121 times higher (p = 0.001). (Oberfeld, 2008)

Belo Horizonte, Brazil

Dode et. al. studied deaths from cancer in the city of Belo Horizonte in southern Brazil from 1996 to 2006. This city of over 2 million inhabitants was rated by the United Nations in 2007 as having the best quality of life in Latin America. The researchers used the database of deaths by neoplasm of the City Health Department, the database of cell phone base station sites from the Brazilian Telecommunications Agency, and a database of the city census and demographics. Exposure duration was calculated from the date of installation of the first antenna to which the individual had been exposed, and residential distance from that exposure was calculated in 100 meter increments.

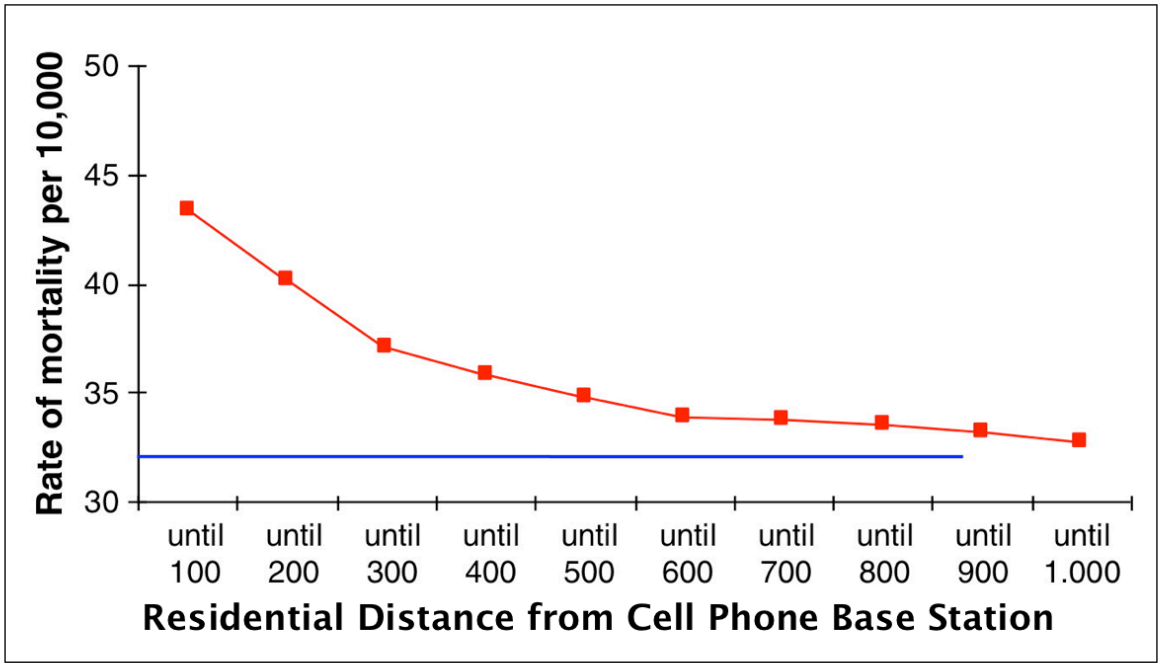


Figure 7: Cancer death rate as function of residential proximity to cell phone transmission towers in meters. Horizontal line = null hypothesis. (Dode et al., 2011)

The highest concentration of base stations was in the south central part of the city. In 2008, environmental monitoring of microwave radiation was performed at 400 sites, measuring frequency bands between 800 MHz and 1800 MHz. Signal intensity averaged 7.32 V/m (~ 14.2 μW/cm^2), with a range from 0.4 to 12.4 V/m (~ 0.04 to 40.7 μW/cm^2). These intensity levels are well below the ICNIRP guidelines for microwave radiation exposure, which are based on protection against thermal effects.

Analysis of the data showed that cancer mortality rates were higher near the cell phone transmission towers. Within the range of 100 meters of a tower, the mortality rate was 43.42 persons per 10,000 (compared to a rate of 32.12 per 10,000 for the city as a whole), with a relative risk of 1.35.

The mortality rate reduced in proportion to residential distance from cell phone tower. Relative risk of cancer mortality was clearly elevated at residential distances of 500 meters or less from a cell transmission tower (base station, or BS) as illustrated in Figure 7. (Dode et al., 2011)

Taiwan

Li et. al. performed a case/control study of 2606 children age 15 or less who were diagnosed with a neoplasm in Taiwan between 2003 and 2007. Each case was matched with 30 controls. Residential exposure of cases and controls was calculated based on the annual power density in watt-years per kilometer squared for each of the 367 townships in Taiwan, averaged out for the 5 year period prior to diagnosis in the township where the subject resided at time of diagnosis.

This study is notable for the large number of cases and controls, which should increase the power of the study. On the other hand, if elevated microwave exposure is associated with cancer risk, assuming that power density of cell phone tower transmissions is constant throughout each township would serve to minimize the effects of higher exposure levels closer to the towers, minimizing the distinction between higher and lower cohorts, and diluting the power of the study.

Case/control analyses were performed for "all cancer types", for leukemia, and for brain neoplasm. Odds ratio for cases of "all cancer types" with calculated exposure greater than median exposure value of controls were significantly elevated at 1.13 (95% CI = 1.01 to 1.28). Odds ratio for cases of leukemia with calculated exposure greater than median exposure value of controls were elevated at 1.23 (95% CI = 0.99 to 1.52). Odds ratio for cases of brain neoplasm with calculated exposure greater than median exposure value of controls were slightly elevated at 1.14 (95% CI = 0.83 to 1.55). (Li et al., 2012)

EVIDENCE FOR IMPAIRMENT OF FERTILITY

Toxic exposures that damage DNA can cause cancer. They can also cause damage to the production of healthy eggs and sperm, leading to infertility. If microwave RF exposure causes oxidative damage to DNA, this should lead to measurable alterations in function of reproductive function and fertility. Current research is beginning to prove the presence of this effect.

Laboratory studies in insects

In 2004, Panagopoulos et. al. demonstrated that exposure to a modulated GSM 900 MHz cell phone signal for 6 continuous minutes daily for two days decreased the fertility of both male and female fruit flies (Drosophila melanogaster). Exposure power density was ~ 0.436 milliwatts/cm^2 (= 436 μW/cm^2). (Panagopoulos et al., 2004)

In a later study, Panagopoulos et. al. exposed Drosophila fruit flies to a cell phone transmitting GSM 900 MHz at 0.40 mW/cm^2 (= 400 μW/cm^2—Group 1) or GSM 900 MHz at 0.29 mW/cm^2 (= 290 μW/cm^2—Group 2), or DCS 1800 MHz at 0.29 mW/cm^2 (= 290 μW/cm^2—Group 3). Transmission exposures were 6 consecutive minutes per day for six days. The exposure induced fragmented DNA during oogenesis. Cell death scores in the ovaries of female flies were 63% in Group 1, 45% in Group 2, and 39% in Group 3, as compared to 7.8% in the sham and control groups. (Panagopoulos et al., 2007)

Subsequent research exposed Drosophila fruit flies to GSM 900 MHz or DCS 1800 MHz signals for signal durations of 1 to 21 minutes a day for five consecutive days, at a power density of 10 μW/cm^2. Impairment of fertility increased linearly with duration of exposure (see figure 2). Even at 1 minute of exposure a day, fertility was significantly decreased in exposed versus sham exposure specimens ($p < 0.00001$). (Panagopoulos and Margaritis, 2010)

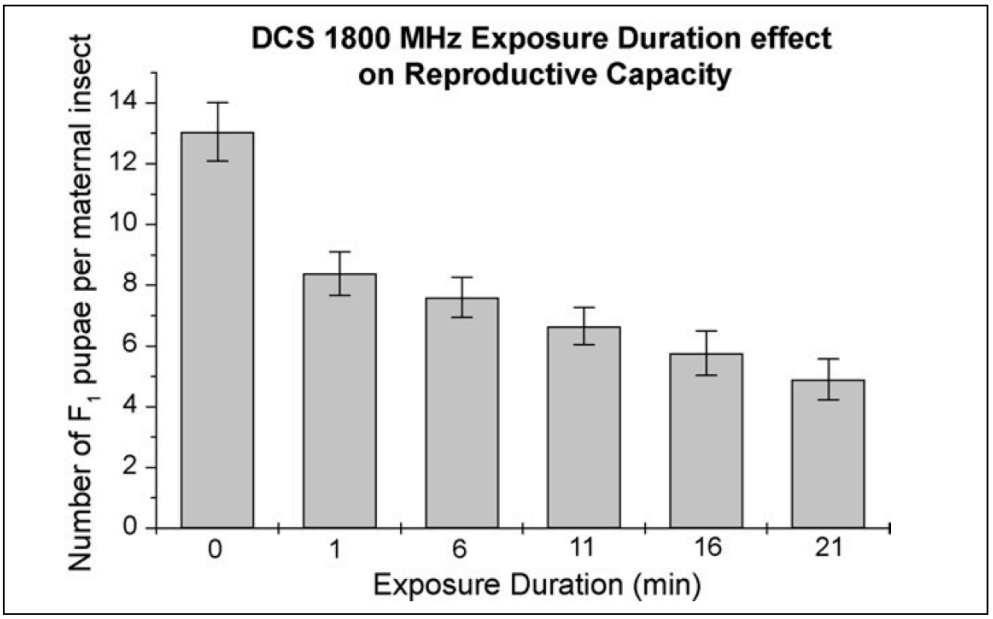


Figure 8: Decreased fertility of fruit flies at exposure level of 10 μW/cm^2. (Panagopoulos and Margaritis, 2010)

In another study using a GSM 900 MHz cell phone signal at 0.35 mW/cm^2 (= 350 μW/cm$^{2)}$, six minutes of daily exposure was divided into one, two, or three minute segments, spaced 10 minutes apart. This was compared with one 6 minute constant exposure and with two 3 minute exposures spaced 6 hours apart. DNA damage and cell death in the intermittent exposures sequenced 10 minutes apart was essentially the same as with the constant 6 minute exposure ($p > 0.92$), and markedly higher than in the sham group ($p < 10^{-8}$). The group with divided exposures 6 hours apart had less cell death than the more frequently exposed group, but still showed significantly higher infertility than the control group ($p < 0.002$). (Chavdoula et al., 2010)

In yet another study, the Panagopoulos group evaluated influence of GSM 900 MHz and 1800 MHz cell phone transmissions on Drosophila fertility using exposures of 6 minutes per day for 6 days, at exposure distances varying from 0 to 100 cm. They were able to demonstrate an adverse effect on fertility for all exposures at all power densities greater than or equal to 1 μW/cm^2. (Panagopoulos et al., 2010)

Recently Panagopoulos published another study demonstrating that exposure to a GSM 900 MHz modulated cell phone transmissions at ~0.35 mW/cm^2 (= 350 μW/cm^2) for 6 minutes during ovarian development can seriously retard ovarian maturation and reduce final size of ovaries in Drosophila fruit flies. (Panagopoulos, 2012)

Laboratory studies in animals

Magras and Xenos placed caged mice at various locations in an antenna park in Thessaloniki, Greece, at locations with RF power densities ranging from 168 nW/cm^2 (= 0.168 μW/cm^2) to 1053 nW/cm^2 (= 1.053 μW/cm^2). The mice lived in these locations for six months, during which time they were mated repeatedly. Numbers of newborns per litter decreased progressively, and ended with complete infertility by the fifth mating cycle. This infertility was not reversible with removal to an unexposed laboratory environment. (Magras and Xenos, 1997)

Meo et. al. exposed Wistar rats to cell phone transmissions for either 30 or 60

minutes a day for 3 months, and then measured serum testosterone levels. Testosterone levels decreased with increased duration of exposure, and the difference in testosterone level between subjects and controls was statistically significant in the 60 minutes per day group ($p < 0.02$) (Meo et al., 2010)

Otitoloju et. al. evaluated sperm head morphology in laboratory rats that were exposed to cell tower transmissions at two locations with mean RF exposure levels of 489 ± 43 mV/m (~ 0.6 μW/cm^2) and 625 ± 25 mV/m (~ 0.10 μW/cm^2). A control group was held in a laboratory with RF exposure levels of 59 ± 17 mV/m (~ 0.001 μW/cm^2). After six months of exposure, exposed rats showed mean sperm head abnormalities of 40% and 46%, versus 2% in control animals. (Otitoloju et al., 2010)

Kesari and Behari exposed male Wistar rats to 50 GHz continuous microwave radiation at a power density of 0.86 μW/cm^2 (calculated SAR 8×10^{-4} W/kg), 2 hours a day for 45 days. Sperm cells showed significant reductions of glutathione peroxidase and superoxide dismutase activity ($p \leq 0.05$) and increased catalase activity ($p < 0.02$), consistent with a significant increase in oxidative stress. Histone kinase activity was also increased ($p < 0.016$), and and significantly increased apoptosis (programmed cell death) and alteration in phases of sperm development were also present. (Kesari and Behari, 2010)

In a similar study, Kesari et. al. confirmed a significant increase in cell death through apoptosis, reduced sperm count, and reduced protein kinase C activity in male Wistar rats exposed to cell phone transmissions 2 hours daily for 35 days. Exposure power densities ranged from 0.1 – 2.0 mW/cm^2 (= 100 – 2000 μW/cm^2, calculated SAR 0.9 W/kg. (Kesari et al., 2010b)

In 2011 and 2012 Kumar and Kesari published four additional papers documenting the adverse effects of 10 GHz microwave exposure (2 hours daily for 45 days at power density of 0.21 mW/cm^2 (= 210 μW/cm^2, SAR 0.014 W/kg) on fertility in male Wistar rats. These studies document significant levels of pathological change including increases in reactive oxygen species, increased apoptosis (cell death) in sperm cells and altered sperm cell cycle (Kumar et al., 2011), increased free radical formation, decreased activity of glutathione peroxidase and superoxide dismutase, increased activity of catalase and malondialdehyde, decreased histone kinase (Kesari et al., 2011), reduced testosterone levels, shrinkage of seminiferous tubules and testicular size, distortion of sperm structure, decreased number and weight of progeny (Kesari and Behari, 2012), formation of micronuclei bodies in lymphocytes, DNA strand breakage, altered levels of histone kinase, altered percentage of spermatogenic phases, and (again) reduced testosterone levels and shrinkage of seminiferous tubules. (Kumar et al., 2012)

In 2012, Atasoy et. al. published a study of rats exposed to a WiFi router (802.11.g, 2.437 GHz) for 20 weeks, 24 hours a day. Histological and immunohistochemical examinations of the rats' testes showed evidence of DNA damage compared to controls ($p < 0.05$) and decreased activity levels of antioxidants (catalase and glutathione peroxidase, $p < 0.05$). (Atasoy et al., 2012)

Other animal studies

Experimental laboratory evidence clearly demonstrates that microwave RF radiation can adversely effect reproduction in insects and animals. Some evidence to support this is also available from studies of animals exposed to RF in their natural environment.

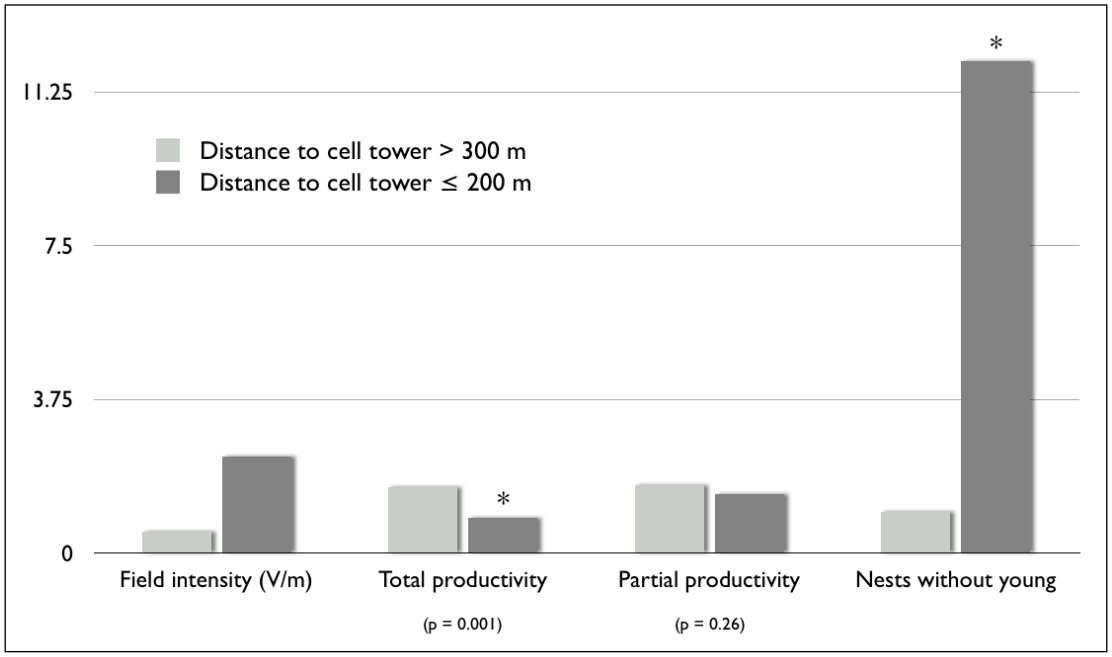


Figure 9: Impaired fertility in white storks nesting near cell phone towers. (Balmori, 2005)

Balmori studied a white stork population that was nesting near a cluster of cell phone towers in in Valladolid, Spain. Power densities at ground level ranged from 10 $\mu W/cm^2$ at 50 meters from the towers to 1 $\mu W/cm^2$ at 100 meters distance and a tenths of a $\mu W/cm^2$ at 150 to 200 meters distance. Total breeding productivity was significantly reduced at nests closer than 200 meters, compared to nests farther than 300 meters from the towers. (Balmori, 2005)

Balmori performed bird counts at 30 locations during 40 visits to Valladolid, Spain, over the interval between October 2002 and May 2006, and measured mean electric field strength at each counting site. Bird population density declined significantly over the observation period ($p = 0.0037$), and population density was significantly lower in areas with higher electric field strength ($p = 0.0001$). (Balmori and Hallberg, 2007)

Balmori also studied reproductive success of common frogs (Rana temporaria) at a breeding site 140 meters from a cluster of cell phone towers. Electric field intensities measured at 1.8 to 3.5 V/m (~0.9 to 3.2 $\mu W/cm^2$). Some eggs were in enclosures that were permeable to microwave radiation, and others were shielded in grounded Faraday cages. Exposed eggs showed asynchronous growth with varying tadpole size and a 90% mortality rate, while shielded eggs developed synchronously with a 4.2% mortality rate. (Balmori, 2010a)

Much more work needs to be done on in vivo studies of the effects of microwave cellular transmissions on animals and plants. Two reviews of the existing research have been published. (Balmori, 2009) (Balmori, 2010b)

Human studies

Human sperm counts have been declining for decades. In 1992 Carlsen et. al. published a meta-review of 61 studies published between 1938 and 1991, with 14,947 subjects. They found a decreased in mean sperm count from 113 million/ml to 66 million/ml ($p < 0.0001$) between 1940 and 1990, with a decrease in seminal volume from

3.40 ml to 2.75 ml ($p = 0.027$). Additionally, the percentage of men with sperm counts < 20 million/ml increased over this time period, while the percentage of men with sperm counts > 100 million/ml decreased. The incidence of testicular cancer increased between two and fourfold during this interval. (Carlsen et al., 1992)

Carlsen's analysis produced controversy initially. But subsequent analysis has shown that their results were essentially correct. Analytic approaches to their data set that refined the analysis to adjust for bias of various kinds have continued to support the validity of their conclusions. (Swan and Elkin, 1999)

In another meta-analysis, Swan et. al. looked at 54 of the most robust studies in the Carlsen data set, and at 47 additional studies, covering studies from 28 countries over a total time interval from 1934 to 1996. They found a rate of decrease in sperm counts of 0.80 million/ml per year in North America and 3.13 million/ml per year in Europe/Australia. (Swan et al., 2000)

And more recent studies have shown that this downward trend in sperm counts is continuing. Jorgensen et. al. found decreasing levels in sperm concentration, total sperm count, and percentage of morphologically normal sperm in Finnish men born in 1987 versus 1982 – 83 versus 1979 – 1981. (Jorgensen et al., 2011) Sperm counts in New Zealand sperm donors decreased 50% between 1987 and 2007, an average of 2.5% per year. (Shine et al., 2008)

In the early 1990's, it was hypothesized that this decrease in sperm counts and increase in testicular pathology might be due to exposure of male embryos to exogenous estrogens (DES, pesticide residues, plasticizers like Bisphenol A, etc.) early in development. (Sharpe and Skakkebaek, 1993) (Carlsen et al., 1995) (Irvine, 1997)

In 1994, Abell et. al. described higher sperm counts in members of a Danish organic farmer's association, as compared with Danish men who had occupational exposures to xenoestrogens. (Abell et al., 1994) Jensen et. al. found a 43.1% higher sperm concentration ($p = 0.033$) in 55 members of Danish organic foods associations who ate at least 25% organic foods, as compared with 141 normal controls. (Jensen et al., 1996)

Multiple studies in animal models have shown that in utero exposures to estrogenic chemicals can alter testicular health and function. Regional variations in sperm count and testicular cancer rates suggest the possibility of environmental influences. A recent paper by Nordkap et. al. reviews current perspectives on this subject. (Nordkap et al., 2012)

On the other hand, estrogenic xenobiotic chemicals have been present in the food chain since the 1950's. Adverse clinical effects of these exposures have been discussed since the early 1960's. (Randolph, 1962) Unless the human body burden of these chemicals has continued to significantly increase over the last 50 years, we would expect the influence of this effect on sperm counts to plateau.

But sperm counts have not plateaued. They have continue to decrease throughout the developed world. A recent study of 26,609 french partners of totally infertile women seeking in vitro fertilization found a 32.2% decrease in sperm concentration between 1989 and 2005, with projected sperm counts for a 35 year old man dropping from 73.6 million/ml to 49.9 million/ml. (Rolland et al., 2012)

This continued trend should be a cause for significant alarm. The World Health Organization defines sperm counts above 20 million/ml as normal. But studies have shown that couples take longer to get pregnant at sperm counts below 40 to 55 million/

ml. (Bonde et al., 1998) (Guzick et al., 2001) (Slama et al., 2002) In Israel, a recent study of sperm donors showed that over the last 10 to 15 years the average sperm count has dropped from 106 million/ml to 68 million/ml, an average decrease of 2.5 million/ml (0.8%) per year. 15 years ago, 66% of sperm donations were of acceptable quality; using the same criteria, at the current time only 18% of donations would be of acceptable quality. (Haimov-Kochman et al., 2012)

As discussed above, studies in insects and animals have demonstrated that microwave radio exposure at remarkably low power densities can have an adverse effect on male fertility. With the rollout of cellular and WiFi infrastructure, exposure to these radio frequencies has increased dramatically in the last 20 years. Would it be reasonable to ask if such exposures have played a role in the continued decrease in male fertility that has occurred during this time period? The result of several recent studies suggests that the answer to this question is "Yes".

Erogul et. al. split human sperm samples and exposed one part to signal from a 900 MHz cell phone. They found statistically significant decreases in motility of sperm in the exposed samples. (Erogul et al., 2006)

Fejes et. al. measured semen quality in a cohort of 371 subjects where confounding factors had been excluded, and found a significant decrease in sperm motility ($p < 0.01$) in individuals with talk time > 60 minutes/day versus talk time < 15 minutes/D. Decreased sperm motility also correlated with increased duration of cell phone ownership in months. (Fejes et al., 2005)

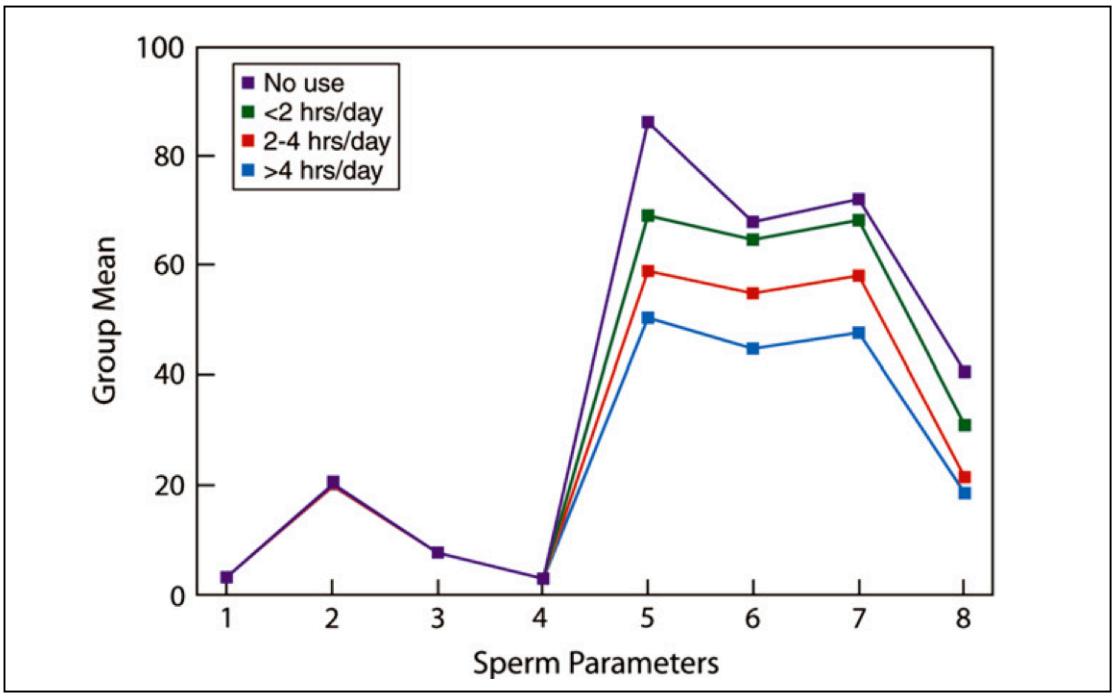


Figure 10: Decrease in sperm count (5), motility (6), viability (7) and normal morphology (8) with increased cell phone talk time. (Agarwal, 2008)

Agarwal et. al. studied semen quality in 361 subjects, divided into four groups based on daily cell phone usage (no use, < 2 hours/day, 2 to 4 h/D, > 4 h/D). They found that sperm count, motility, viability, and percent normal morphology all decreased with increased cell phone use. (Agarwal et al., 2008)

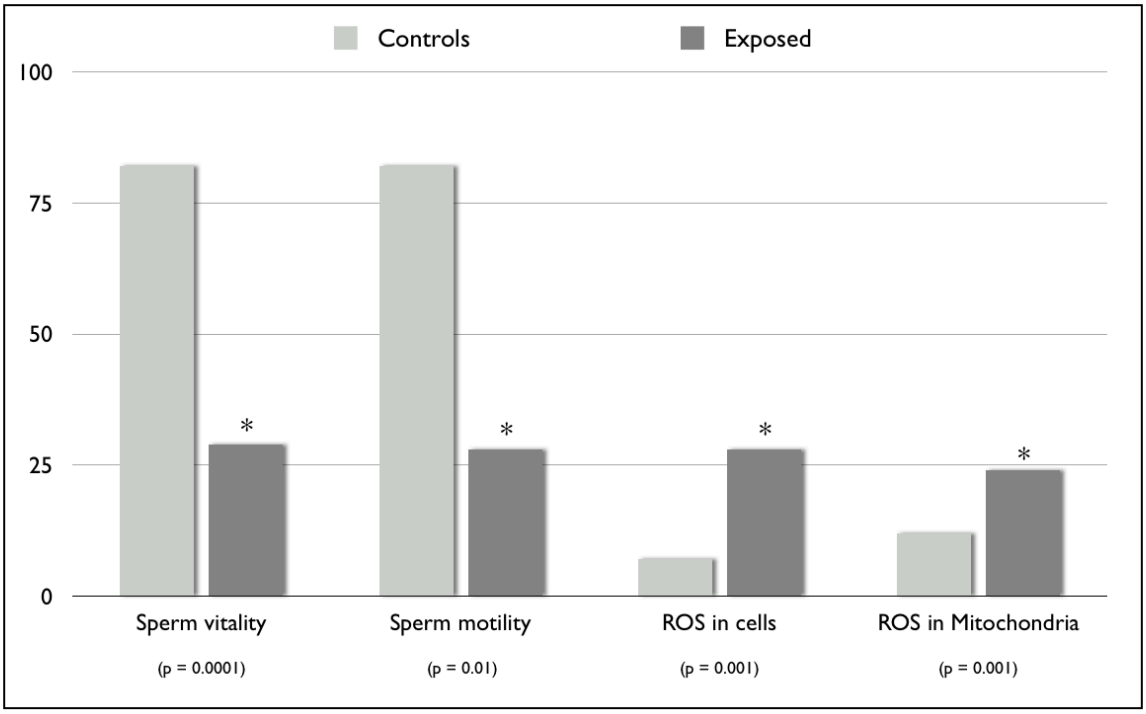


Figure 11: Sperm exposed in vitro to 1.8 GHz (SAR = 27.5 W/kg) for 16 hours @ 21°C (isothermal conditions). (De Iuliis et al., 2009)

De Iuliis et. al. exposed human sperm to 1.8 GHz microwave radio transmissions. Statistically significant decreases in sperm motility and vitality were demonstrate at exposure levels as low as 1.0 W/kg ($p < 0.01$). This study also found an increase in reactive oxygen species, oxidative damage to DNA, and DNA fragmentation, that was not dependent on thermal effects. (De Iuliis et al., 2009)

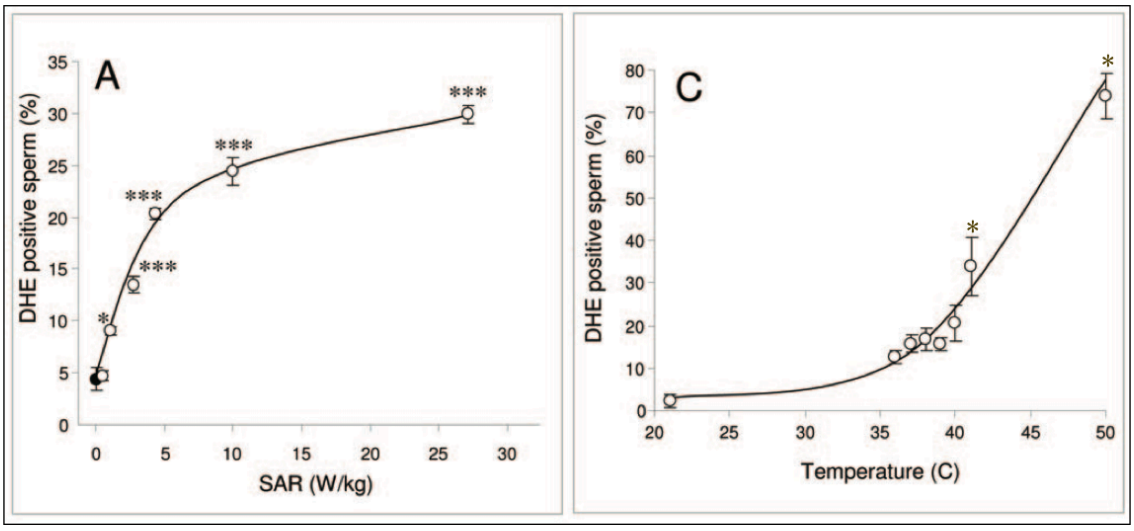


Figure 12: A) Production of ROS with increasing levels of microwave RF . B) Production of ROS with increasing levels of temperature. (De Iuliis et al., 2009)

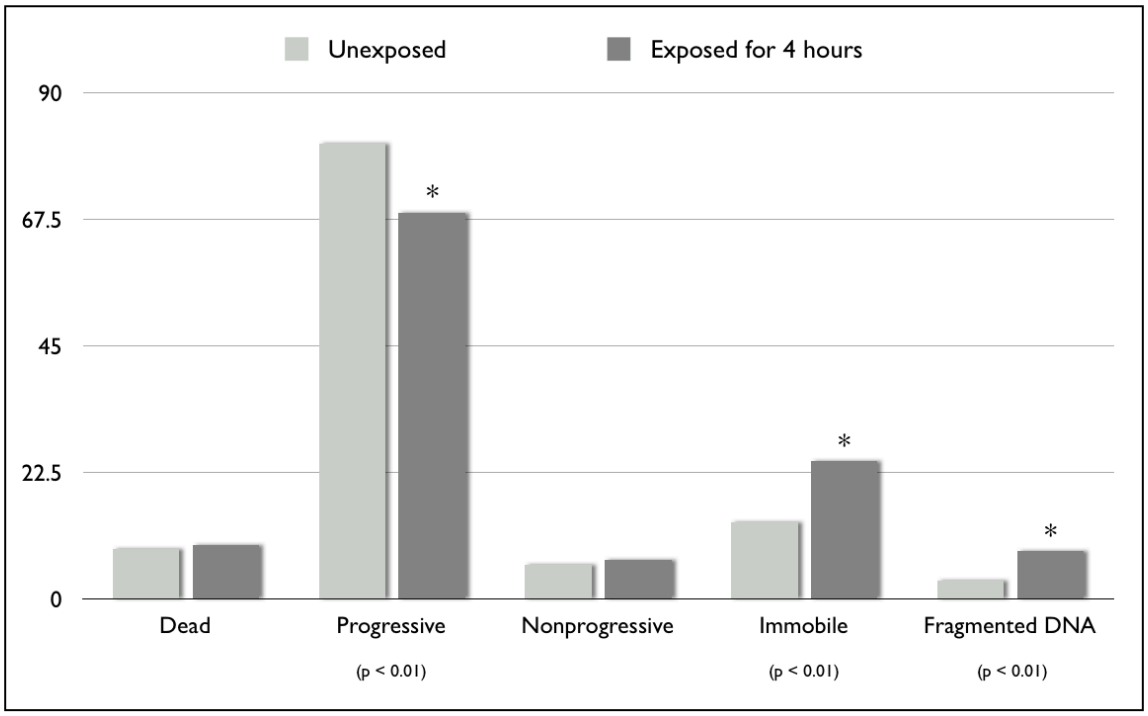


Figure 13: Sperm damage from exposure to laptop computer WiFi transmission. (Avendano et al., 2011).

Another recent study the effects of exposing motile sperm to 4 hours of WiFi transmission at a position 3 cm beneath a laptop computer, at power densities between 0.45 and 1.05 μW/cm^2. Temperature was maintained at a constant 25^{o}C. Exposed specimens showed a statistically significant decrease in sperm progressive motility, and a significant increase in non-motile sperm and in sperm DNA fragmentation. (Avendano et al., 2011)

The fact that multiple recent studies have demonstrated the ability of microwave RF exposure to cause nonthermal damage sperm function and sperm DNA with short exposure times and quite low exposure levels—the FCC exposure limit is 1000 μW/cm^2—should be a source of grave concern. The presence of constantly transmitting WiFi networks in homes and schools may be much less innocuous than is generally supposed.

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CURRENT RESEARCH ON CELL PHONE USE AND BRAIN TUMOR RISK

INTRODUCTION

To be complete, any review of the health hazards of microwave radio exposures must include a discussion of the research on possible associations between cell phone usage and brain tumors.

This research is a hot topic politically. Cell phone use has permeated our society, and no one wants to think that use of a cell phone is going to increase their personal risk (or their child's personal risk) of acquiring a terrifying disease.

The rollout of the cellular communications infrastructure has also created an extremely profitable industry. The telecommunications industry made $3.1 trillion in gross profits in 2010. (Plunkett Research, 2012) This industry has a powerful incentive to downplay the health effects of EMF, and has funded a good deal of research that serves to further that aim. Some studies regarding cell phones and brain tumors have been funded in large part by the telecommunications industry. These industry-designed studies have generally concluded that the use of cell phones does not create a health hazard. And these negative reports have received wide coverage in the news media. However, the study designs funded by industry are more likely to use unblinded protocols and to underestimate risk, as compared to studies funded by public bodies. (Levis et al., 2012)

When powerful financial interests are at play, industry funding of favorable research studies is often used to influence the political and scientific playing field. We've seen this play out in pharmaceutical research, where several recent scandals have highlighted the distorting effects of corporate financing on research outcomes. In the past few decades the production of research providing favorable (to corporate interests) results has become something of a science in itself, with corporations essentially gaming the academic system, funding studies designed to produce favorable outcomes for their products, and hiding studies that do not support their interests. The peer review process of the scientific journals has not proved to be an adequate defence against this problem. (Smith, 2005)

In the research on cell phones and brain tumors, the situation is further confounded by the fact that cell phone usage has only become wide spread in the last 15 years or so. The first digital cell phone infrastructure was pioneered in Scandinavia, and the first research that raised concerns about cell phone cancer risks was produced in Sweden in the late 1990's. But environmental influences that promote cancer generally take years to do so.

Take the question of the potential risk of cell phone use by teenagers. Does this cell phone use increase the risk of brain tumors later in life? The mass market for cell phone use by teenagers really started after 1995, and extended use of cell phones to surf the web ballooned after the introduction of the iPhone in 2007. Looking for brain cancer today in 30 year olds who started using a cell phone in 1997 would be similar to looking for lung cancer today in 30 year olds who started smoking in 1997 (and who would be most likely to develop lung cancer in their 50's or 60's).

This means we cannot find great reassurance in "negative" cell phone cancer risk studies performed 8 or 10 years ago. And similarly, any "positive" findings of cell phone cancer risk to date should produce real concern, since it is possible that they are identifying only the early cases of a larger problem.

Three major and ongoing research studies have been performed in the last 10 years. One is the INTERPHONE Study, which is funded in major part by the telecommunications industry. A second study which received much recent media attention is the "Danish Cohort" study. A third body of research has been produced by the Hardell group in Sweden, a research group with no financial support from the telecommunications industry.

THE INTERPHONE STUDY

The INTERPHONE Study is a large standard protocol study of brain and salivary gland tumor risk in relation to mobile telephone use, with branches of the study being performed in 13 countries, and combined together to increase the statistical power of the results. This study was funded in major part by the wireless communications industry.

The first major summary of this research was published in 2010. This "case-control" study looked at patients with brain tumors (2708 glioma cases, 2409 meningioma cases) and matched controls, and compared their estimated cell phone usage to determine if regular cell phone usage increased the odds of being a brain tumor patient. The authors concluded that "Overall, no increase in risk of either glioma or meningioma was observed in association with use of mobile phones." (Group, 2010)

This reported result was then widely quoted by the press and government agencies like the World Health Organization (IARC, 2010) as demonstrating the lack of risk of wireless technology.

However, this study defined a member of the risk group as any subject who *"had an average of at least one call per week for a period of 6 months"*. This definition of "regular cell phone use" diluted the risk pool out with lower risk individuals to the point that no difference between risk and control groups was visible in the study.

Interestingly, the study did report its statistics stratified by total time of reported use, and the top decile (greater than 1640 hours use over a ten year interval, averaging out as greater than 3 hours a week) had an increased risk of certain tumors. Individuals who accrued that greater than 1650 hours of use over a 1 to 4 year interval (ranging from 8 to over 30 hours a week) had a markedly higher odds ratio of meningioma (OR 4.80) or glioma (OR 3.27).

In the discussion of their data showing increased risk within the higher usage group, the authors failed to consider the possibility that this data showed a real risk. Instead, they discounted this trend of increased risk in the heavier users, stating that various "biases and errors limit the strength of the conclusions we can draw from these analyses and prevent a causal interpretation." And it is this "biases and error's" comment that has been quoted by industry apologists in subsequent publications, rather than the study's actual statistical findings of increased odds of brain tumor with cell phone talk time greater than 3 hours a week over a ten year period, or greater than 8 hours a week over a 1 to 4 year period.

The discrepancy between actual data and concluding discussion in this study was not highlighted by mass media coverage of this study. One must assume that reporters read the abstract rather than the complete article, and accepted the author's conclusions without question. Other researchers in the field were more critical in their assessments of the INTERPHONE project as compared to other published literature on the subject (Morgan, 2009), and pointed out that the INTERPHONE data really did

document an increased risk, consistent with studies published by researchers in the field that were more independent from industry funding sources. (Hardell et al., 2011a) (Levis et al., 2011)

A more recent study from the INTERPHONE group found an increased risk for acoustic neuroma in individuals with > 1640 hours of talk time over up to 5 years of exposure (OR = 2.79, 95% CI = 1.51 – 5.16). For those subjects who routinely used their cell phone on the same side of the head where they had the acoustic neuroma, the odds ratio was 3.74 (95% CI 1.58 – 8.83). (Cardis and Schüz, 2011)

The most recent study from the INTERPHONE group showed increased odds ratio of glioma and meningioma with greater than 10 years of mobile phone use. The author's conclusions acknowledged this finding, but stated that "the uncertainty of these results requires that they be replicated before a causal interpretation can be made". This is an interesting comment, considering that this study result itself was essentially a replication of the actual findings of the earlier INTERPHONE study. (Cardis et al., 2011)

THE DANISH STUDY

A study from Denmark on the risk of mobile phones and brain tumors was published in the British Medical Journal in 2011. The conclusions of this study were that "there were no increased risks of tumors of the central nervous system, providing little evidence for a causal association". (Frei et al., 2011)

This study was widely quoted in the media and by government organizations as refuting the link between cell phones and brain tumors, with headlines like BBC News: "Mobile phone brain cancer link rejected." (Triggle, 2011)

In this case-control study, the risk group was composed of native Danes who had acquired a cell phone contract prior to 1995. However, any prior to 1995 corporate users were excluded from the risk group (this was 32% of the original cohort). Also excluded were all prior to 1995 subscribers who were less than 18 years old at the time they obtained their first subscription. The study did not determine how often members of the risk group used their phones, or make any determination as to exposure to portable phones in the home for risk or control group members.

The control group was composed of all Danes aged 30 or older and born after 1925 in Denmark. This of course means that the control group included all the early corporate subscribers (whom we might call the "power users"), and also included the 85% of Danes who obtained a cell phone *after* 1995.

This contamination of the control group with large numbers of cell phone users made the conclusions of the study essentially meaningless. To the BMJ's credit, letters that pointed this out were printed in the same issue with the original article (but apparently not read by the members of the press). (Khurana, 2011) (Philips and Lamburn, 2011)

The net result of all this was that the public was falsely reassured by media reports of a peer reviewed article in a prestigious medical journal, when the negative conclusions of that article were essentially meaningless. (Soderqvist et al., 2012)

THE HARDELL GROUP STUDIES

The first digital cell phone network (2G) was launched in Finland in 1991, and the cell phone communication infrastructure expanded widely in Scandinavia during that decade. In the late 1990's case reports of brain tumors in cell phone users lead to

the first of multiple studies produced by the Hardell research group in Sweden. In this case control study of data collected between 1994 and 1996 from 233 living patients with biopsy-verified brain tumors, no clear distinction could be established between cell phone users and nonusers in the patient population, but a trend was observed of increased odds of tumor presence in the temporal or occipital lobe on the same side of the head habitually used to listen to the cell phone. (Hardell et al., 1999)

In 2002 Hardell et al. published another and larger case control study of 649 brain tumor cases diagnosed between January 1997 and June 2000. This study (and subsequent studies by the Hardell group) looked at exposure from both cellular phones and mobile (cordless) phones connected to land lines. Cumulative hours of cell phone use was calculated from questionnaires about phone usage habits. Increased risk of brain tumor was found for ipsilateral use (phone habitually on same side of head as brain tumor site) with both analogue and digital cellular phones and for cordless phones. Increased risk was also seen for increased duration of exposure. (Hardell et al., 2002)

Another expanded case control study with 1617 brain tumor patients diagnosed between 1997 and 2000 was published later that year showed similar findings, with the highest calculated risk being for ipsilateral acoustic neuroma in analog cellular phone users (the older technology). (Hardell et al., 2002)

Hardell et al. analyzed this same data set of 1617 patients for incidence of vestibular schwannoma (VS), and found an increased odds ratio for VS associated with the use of analogue cell phones. They found that the incidence of VS in Sweden had significantly increased during the time period from 1960 to 1998, with more of this increase occurring during from 1980 to 1998. All other brain tumors taken together had also showed a significant yearly increase between 1960 and 1998. (Hardell et al., 2003) (Hardell et al., 2003)

In 2006 and 2007, Hardell et al. published several more studies of brain tumor patients diagnosed between 1997 and 2003. Cell phones had been in wide use for a longer interval of time, and their data allowed evaluation of latency periods of > 10 years duration, and risk for subjects with first cell phone use at < 20 years of age. Cumulative lifetime use of > 2,000 hours showed elevated odds ratios for analog, digital, and cordless phones, and increased risk for malignant tumors with ipsilateral exposure. Risk of malignant tumors was more pronounced in individuals with first cell phone use at less than 20 years of age. (Hardell et al., 2006) (Hardell et al., 2006a) (Hardell et al., 2006b) (Mild et al., 2007)

Later in 2006, Hardell et al. published a pooled review of their data from all six of their previous case control studies. (Hardell et al., 2006) And they have subsequently published three more papers updating and consolidating their earlier findings. (Hardell and Carlberg, 2009) (Hardell et al., 2010) (Hardell et al., 2011b)

CRITIQUES AND REVIEWS

In 2004 Kundi et al. published a review of 9 existing epidemiologic studies on the relationship between cell phone use and brain tumor risk, and found that all studies approaching reasonable latencies of exposure time showed an increased relative risk (range 1.3 to 4.6) of brain tumor in cell phone users, with highest overall risk for acoustic neuroma (RR 3.5) and uveal melanoma (RR 4.2) (Kundi et al., 2004)

In 2007 Hardell et al. published a meta-analysis of two cohort studies and 15 case

control studies on the association between long-term use of cell phones and brain tumor. They found increased risk for acoustic neuroma and glioma with ≥ 10 years of exposure, with higher risk of tumor on the exposed side of the head. (Hardell et al., 2007a)

Hardell, Mild, and Kundi published exhaustive reviews of the existing literature on this subject in 2007 in the Bioinitiative Report. (Hardell et al., 2007b) (Kundi, 2007)

In 2008, Hardell et al. published two meta-analyses of the existing case control studies in the literature including ten studies on glioma and nine studies on acoustic neuroma. They found "a consistent pattern of association between mobile phone use and ipsilateral glioma and acoustic neuroma using ≥ 10 years latency period". (Hardell et al., 2008)

In another meta-analysis published in 2009, Hardell et al. again found "a consistent pattern of an increased risk for glioma and acoustic neuroma after > 10 year mobile phone use . . . with highest risk found in the age group < 20 years at time of first use of wireless phones." (Hardell et al., 2009)

In a 2009 review, Ahlbom et al. stated that existing studies "do not demonstrate an increased risk within approximately 10 years of use for any tumor of the brain". In a way, this statement is a somewhat backhanded acknowledgement of the fact that the published research to that date clearly does show increased risk with greater than 10 years of use. (Ahlbom et al., 2009)

In 2009 Khurana et al. published a metanalysis of the eleven existing long-term epidemiologic studies on cell phone use and brain tumor risk that met these criteria: Publication in a peer reviewed journal; inclusion of subjects with greater than 10 years of cell phone use; analyzing "laterality" of cell phone usage in relation to brain tumor incidence. Their conclusion was that "using a cell phone for ≥ 10 years approximately doubles the risk of being diagnosed with a brain tumor on the same ("ipsilateral") side of the head as that preferred for cell phone use". (Khurana et al., 2009)

In 2011 the WHO/International Agency for Research on Cancer (IARC) classified radiofrequency electromagnetic fields as "possibly carcinogenic to humans (Group 2B), based on an increased risk for glioma, a malignant type of brain cancer, associated with wireless phone use". (WHO, 2011) (Baan et al., 2011)

In 2012, Levis et al. published an analysis of published case control studies, pooled analyses, and meta-analyses on head tumor risk with mobile phone use. They found that "in studies funded by public bodies, blind protocols give positive results revealing cause-effect relationships between long-term latency or use of mobile phones (cellulars and cordless) and statistically significant increases of ipsilateral risk of brain gliomas and acoustic neuromas, with biological plausibility. In studies funded or co-funded by the cellphone companies non-blind protocols give overall negative results with systematic underestimation of risk; however, also in these studies a statistically significant increase in risk of ipsilateral brain gliomas, acoustic neuromas, and parotid gland tumours is quite common when only subjects with at least 10 years of latency or exposure to mobile phones (only cellulars) are considered." (Levis et al., 2012)

CONCLUSIONS

The current epidemiological research shows that greater than 10 years of cell phone use incurs a significantly increased risk of ipsilateral brain tumor (glioma or meningioma). This risk is greater in individuals that start using cell phones as children.

This means that the RF exposure guidelines for cell phone use cannot be considered to be adequately protecting the public.

In light of these findings, current public policy that essentially ignores biological or "nonthermal" levels of RF exposure need to be reconsidered and revised, in order to significantly reduce the risk to the public health that is produced by these technologies.

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CONCLUSIONS AND RECOMMENDATIONS

ADVERSE BIOLOGICAL EFFECTS—THE SCIENTIFIC EVIDENCE

In the previous sections we have reviewed the increasingly robust body of scientific evidence that excessive RF exposure can cause both acute and chronic adverse biological effects:

ACUTE EFFECTS

In susceptible individuals, excessive RF exposure can provoke acute symptoms. The most common symptoms are sleep disturbance, headache, irritability, fatigue, and concentration difficulties. Other symptoms may include depression, dizziness, tinnitus, burning and flushed skin, digestive disturbance, tremor, and cardiac irregularities.

As physicians, some of us have seen patients who are experiencing this problem, and are aware of the connection with RF exposure. Research suggests that 3 to 5% of the population fit into this category. If this is the case, there may be 4,700 people in Eugene who react to RF exposure in some way, and know it.

These symptoms are not uncommon in the population, of course. And in all probability there are many other people in Eugene who are having problems with insomnia or fatigue--problems provoked by EMF exposures--but are unaware of the connection between cause and effect.

Any significant increase in RF exposure in our residential areas will make these individuals more symptomatic. Such increases are likely to push additional individuals above their tolerance threshold, producing new cases of these problems. If increased RF levels from repeated daily transmissions between smart meters and their control towers pushed an additional 1% of the community into acute reactivity to RF exposures, this would mean an additional 1500 people in our city with insomnia, headaches, fatigue, ringing in the ears, or other debilitating symptoms.

CHRONIC EFFECTS

Chronic exposure to RF can also cause chronic physiologic changes, including altered endocrine function (both melatonin and other hormones), and increased oxidant stress that can lead to increased levels of cancer and male infertility. The public is already being subjected to increased levels of RF from wireless communications. Increasing the total load of transmission further will increase the occurrence of these adverse consequences.

PERSPECTIVE AS WE MOVE FORWARD

At the beginning of the last century, people began to use vehicles powered by internal combustion engines that burned gasoline. Gasoline power was cheap and convenient, and greatly increased the mobility of the population. And the companies that sold the gas and the cars made a lot of money.

This use of fossil fuels has had long term consequences--increased atmospheric CO2 which through the greenhouse effect would lead to global climate change. Initially, these consequences went unrecognized. Then the scientific community began to predict and measure them.

Public acknowledgement of these consequences has gone through several stages. First, the science was ignored. Then the science was attacked or denied by those whose economic interests were threatened by it. Public recognition of the problem is only arriving as the long term consequences of climate change are beginning to be felt.

The use of wireless communications technology is following a similar trajectory. Wireless communication is convenient, and increases our mobility. The installation of wireless networks is also significantly cheaper than installation of hard-wired networks. And the companies that provide these networks and the tools that we use to access them are making a great deal of money.

For decades, the biological consequences of this form of communication went unrecognized by both the public and the scientific community. As scientific evidence of biological and health effects began to emerge, this evidence was initially ignored by government regulating bodies, the media, and the public. As this evidence is getting harder to ignore, it is now being attacked or denied by the telecommunications industry. Wide public recognition of the problem and the science that describes it will arrive as the problem becomes more severe, and more people get sick.

The previous sections of this report describe the increasing body of science that clearly demonstrates the existence of adverse biological effects from chronic RF exposure. It is important for EWEB's Board and staff to recognize that this science is real, and that the science isn't going to go away. As the wireless communications infrastructure continues to grow, the magnitude and duration of public exposure are going to continue to increase, and the number of people with acute or chronic effects from this exposure will continue to grow. As recognition of the problem by the public increases, exposures and infrastructure that are currently unquestioned will become politically unacceptable.

EWEB has moved slowly in the process of investigating AMI technology. Recognition of the potential health effects of excessive RF exposure to the public should cause this appraisal to become even more deliberate and circumspect. EWEB needs to avoid investing millions of dollars on infrastructure that becomes part of the problem. Instead, EWEB needs to think about making engineering choices that recognize this problem, and seek to become a part of its solution.

RECOMMENDATIONS

BASIC PRECEPTS FOR RESIDENTIAL EXPOSURES TO RF TRANSMISSIONS

- Excessive RF exposure can cause acute problems (headaches, insomnia, fatigue, vertigo, tinnitus, other symptoms of EHS).
- Excessive RF exposure can also cause chronic problems (oxidative stress, cancer, male infertility).
- Constant RF transmission is probably harmful, even at low levels, and should be avoided.
- Frequent and repetitive intermittent transmissions are also probably harmful, and should be avoided.
- Nocturnal exposures are more problematic than daytime exposures, because of RF's potential to suppress nocturnal melatonin secretion and disturb sleep, and because night is the time when we rest and heal from stresses (including oxidative stress).
- Occasional and infrequent daytime exposures are much less likely to cause an increase in chronic problems for the population at large.
- Occasional and infrequent daytime exposures are still likely to provoke acute symptoms in a small percentage of the population.

Based on our review of the existing science, we suggest that the above basic precepts be considered when thinking about residential exposures to microwave RF transmissions. We consider this to be important for the population at large, and even more important for those in our community who suffer from symptoms of electrohypersensitivity. For all of us, our homes are the place where we rest and where we sleep, where we rejuvenate ourselves from the stresses of the wider world. It is important that our residential environments be a place where this can occur. Our homes need to be part of the solution, not part of the problem.

EWEB SHOULD ADOPT A POLICY OF MINIMIZING THEIR RF FOOTPRINT IN THE COMMUNITY

A recognition of these precepts should lead EWEB to adopting a policy of minimizing their infrastructure's RF footprint in the community as much as possible during regular operations. This doesn't mean that staff would throw away their cell phones and communicate by semaphore. But it would mean that instead of combatting or ignoring the possibility that more RF in the community could cause harm, EWEB should acknowledge the potential risks of excessive residential exposure.

This would mean that such potential risks would be seriously considered in any discussion of the total risks and benefits (the "Total Bottom Line") in deciding whether to use RF technology for any given purpose. If, after such a discussion, a considered decision is made to use RF technology, then these same potential risks should be taken into serious consideration in determining how to use this technology in a manner that would minimize potential harm to the community.

In other words, don't use RF when you don't have to. Go hard-wired wherever it is feasible to do so. And if you do use RF, design the technology to use as little of it as possible.

Current engineering choices in AMI technology have not been designed with these goals in mind, since the industry has not had an practical incentive to recognize the problem and to "work the problem". But EWEB as a purchaser of technology could choose to push vendors towards designing and providing hardware options that would address these goals. This would put EWEB in the position of being part of the solution rather than just another part of the problem.

FLAWS IN THE CONCEPT OF "OPTING OUT"

It has been suggested that people who have problems with EHS or concerns about health exposures to RF can be taken care of by creating an "opt out" program, allowing them to decline the installation of a smart meter on their home. This suggestion overlooks some obvious and important problems:

- You can't "opt out" of exposure to your neighbor's meter, that is ten feet away from your bedroom window.
- You can't "opt out" of all the meters on the wall of your rental apartment complex. Or the ones on the wall of the complex right across the alley from your apartment.
- You can't "opt out" of exposure to the meter on the other side of your bedroom wall if you are a baby in a crib.
- You can't "opt out" of exposure to transmissions from the radio tower 100 meters from your house.

The idea of an "opt out" program is an effort to address the concerns of people who are personally worried about RF exposures, either because they are aware of having acute reactions to these exposures, or because they have a general concern about the acute or chronic effects from such exposure.

But a voluntary "opt out" program does not protect the community at large from adverse effects that they are unaware of and unconcerned about. For example, the current research shows that cancer rates are higher in residences near cellular transmission towers. Most people don't know this. How does a voluntary "opt out" program help the person who develops breast cancer three years after installation of a transmission tower across the street from her house? She didn't know it was a problem . . .

DISCUSSION OF THE TECHNOLOGY OPTIONS

How would adopting these precepts and goals play out in practice? Several factors come into consideration:

- The scientific evidence on biological effects of RF, summarized in the basic precepts listed above.
- The various possible functional goals of the AMI program:
  - Reducing operating costs by reading and switching meters remotely.
  - Training customers to conserve electricity.
  - Shifting time of use by measuring and billing time of day usage.
  - Absorbing fluctuations in renewable energy supply by "demand/response" control of usage.
- The different AMI technologies that are available.

When our committee puts our best understanding of these three factors into consideration, and look at each choice in AMI technology through this combined frame of reference, the discussion runs something like this:

MESH Network

From a biological point of view, AMI meters that are transmitting several times a minute can be considered to be an essentially constant source of RF exposure. Where these networks have been established in the last two years, large increases in reported acute symptoms have occurred. We think it is medically probable that that this technology will be found to cause an increase in chronic health problems, including increased cancer, once sufficient time has passed for this to occur.

EWEB staff has already explored and tested a MESH option and chosen not to go forward on that path. We applaud EWEB's decision to steer away from this technology.

Powerline Communications (PLC)

From a public health point of view, PLC is less problematic than an RF AMI communication technology. And PLC could be used to reduce operating costs, train customers to conserve electricity using in-house monitors, and record and transmit time of day usage measurements to the utility.

EWEB has turned away from the choice of PLC for two main reasons. Firstly, because it won't allow measurement of water meter readings, limiting the reduction of operating costs from elimination of meter reading. Secondly, because PLC as currently designed does not have the bandwidth to sustain rapid "demand/response" control communications.

There are some other technical considerations that make PLC infrastructure more awkward to set up in an environment where some transmission wires are on poles and

others are underground.

If "demand/response" was not on the table, and if a Total Bottom Line analysis of the options included the potential health costs of using RF technology, the financial analysis of the PLC option might look different than it did in the AMI Business Case prepared by EWEB staff last April. A decision to read the water meters once every 3 months rather than monthly could also realize additional savings, if this option was under serious consideration.

Fiber Optic Communications

Fiber optic communication between the utility and the house meter is an ideal solution from a health/environmental point of view, providing ample bandwidth without RF transmission. However, this technology would be quite expensive to install, especially in the parts of Eugene where the power grid is underground. The cost might be prohibitive for EWEB at this point in time. Like PLC, fiber optics would not communicate with the water meters.

Tower Communications Network (SENSUS)

The engineering system that EWEB is currently considering is the SENSUS company's technology, where central towers communicate directly with the meters on the houses. SENSUS owns the sole rights to a certain transmission frequency on the communications bandwidth. This allows them to use more powerful radios on the smart meters, strong enough to communicate directly with a transmission tower without requiring that the message be passed from meter to meter across a MESH network. The community would be divided into about 13 zones, each of which would have a communication tower placed on an existing EWEB property within the zone, and these towers would communicate directly with the house electric meters and with radios on the house water meters.

With 88,000 electric meters and 52,000 water meters in the city, an average zone would have 6770 electric meters and 4000 water meters in the zone. How long a transmission interval would be required for a tower to collect the data from 10,770 meters? We don't know the answer to this question, and EWEB engineers may not know either, until they set up a trial system and test it out. But clearly, the RF footprint created by this sort of system could vary significantly, depending on how the system was used.

It is routine for utilities to collect data from these systems four times a day. But this routine was developed without consideration of the potential health risks of excessive RF transmission in the community. And usage data does not need to be collected this frequently to achieve the main goals of the AMI program. From a practical point of view, the utility will continue to bill once a month, and in theory could remotely collect that usage data once a month, minimizing the community's exposure to frequent and repetitive RF transmissions.

We think usage data should be collected from these meters at an interval of once every two to four weeks, with transmission occurring during the daytime hours. Transmission events at this level of infrequency would represent a minimal increase in the RF exposure to the community, and would be unlikely to significantly increase the risk of chronic health problems in the community.

Each data transmission event would still be likely to provoke acute symptoms in individuals with EHS who lived near these transmission towers. But if these events occurred at an interval of once every two weeks or longer, and at a predictable time of

day, this might be a manageable level of exposure for those individuals.

In our informal discussions with EWEB engineers, we have been told that they have looked into the issue of data collection frequency, and that the longest that they could go between data collection events with the SENSUS system would be about three and one half days.

This would appear to be a case where the technology has not been designed with an eye to minimizing RF transmission. Six daily time-of-use intervals times 30 days equals 180 intervals of usage data. We think that if an iPod can store 64 gigabytes of music, it ought to be possible to give a smart meter enough memory to store 180 readings before transmitting them to the utility. We would recommend that EWEB ask their potential vendors to provide a meter with enough memory to store two to four weeks of data, to enable the minimal RF footprint that we are recommending.

Tower communications and the water meters

Water usage is billed once a month, and a single monthly reading of the meters would collect this data with minimal RF exposure to the community. Again, this data collection should occur in the day time, not in the middle of the night.

Tower communications and "demand/response"

From a public health perspective, the use of the system for "demand/response" load control is more problematic. As we understand it, a lot of this transmission would occur at night, when wind power production is high and demand is low. Towers would be transmitting every 15 minutes, to turn one cohort of water heaters on and another cohort off. And the protocols required by the grid would require a two way communication with each meter in the cohort, acknowledging that house's participation in the cohort at that time.

This will involve a good deal of transmission in the system every 15 minutes, both from the towers potentially talking to hundreds of meters across the neighborhood, and from the 2 watt radios on each house in the cohort talking back to the tower.

Communication of this frequency from the towers would be a significant additional layer of frequent nocturnal RF signal exposure to the residences within a few hundred meters of the towers.

And enough cohorts of houses are involved, the transmissions from the meters on the houses could also increase the signal density in the residential areas enough to disrupt melatonin and sleep in a percentage of the population.

We think that this frequent level of activity in the demand/response system would be a significant additional RF burden on the community. It would make life in the residential area significantly more difficult for those individuals in the community that is currently already having acute problems. It would probably cause the onset of acute symptoms in a small percentage of the population who are not currently experiencing them. And it would be likely to further increase the incidence of chronic adverse RF effects in our community.

Demand/response and the in-home "Zigbee" network

Once the AMI smart meter on the house gets a demand/response signal from the control tower, it must tell the water heater in the house to turn on. Existing technology does this through wireless communication over a "Zigbee" WiFi network in the home. This network is maintained by constant transmissions of signals between the meter and the Zigbee appliances in the home network, 24 hours a day.

The research that we've reviewed above shows that biological effects can be produced by low power levels of RF exposure, and that prolonged, constant exposures can have effects even at extremely low exposure levels.

For demand/response to work in the community, at least 20% of the homes in the community will need to volunteer for the program, and have it set up in their houses. In undertaking to install demand/response infrastructure in its current form, EWEB would be making several presumptions:

- A presumption that the Zigbee system is low enough in power that it won't cause any harm.
- A presumption that public acceptance should be good, since the public at large isn't really concerned about the health effects of RF at this time.
- A presumption that since most people have WiFi now anyway, they aren't going to be concerned about the additional exposure.
- A presumption that because the system will be voluntary, so no one can or will complain about involuntary exposure.

While it may be true that the public isn't that worried at present, and that many people have WiFi in their homes and aren't worried about it at all, we do not think that EWEB can assume that this will continue to be the case throughout the investment lifetime of the installed demand/response infrastructure.

As we've discussed in the prior sections, signals of WiFi power are strong enough to cause severe symptoms in individuals with EHS. Several hours of WiFi exposure has been shown to cause damage to healthy sperm. The general public is unaware of these facts. But we think that this is less likely to be the case 8 or 10 years from now, much less 20 years from now. As increased exposure to wireless RF communications causes more health problems in the population, and the scientific evidence of this effect continues to become more robust, public attitudes about this exposure are going to change. Within 20 years, the public—especially parents with young children—will be much less open to having constant WiFi signal in their homes. If this assumption is correct, the purchase of many millions of dollars in demand/response infrastructure that is based on wireless in-home communications would appear to be an unwise investment.

The "demand/response" infrastructure is still immature

We think that the "demand/response? infrastructure is still immature. This technology may be mature from an engineering point of view, in that "it works". But from a public health perspective, it is completely immature. We state this because the technology has been designed around RF communications (because this infrastructure is quicker and cheaper to set up than a hard wired system) without any consideration of the health effects of exposure to excessive or prolonged RF transmissions, and without any considered effort to engineer the hardware or the software protocols in a way that would minimize such exposures.

The Zigbee network is a case in point. In modern construction, most electric meters are sitting on the outside of the circuit breaker box. Within that breaker box, there are dedicated circuits with hard-wired connections to the electric water heater, the electric stove, and the electric clothes drier.

Why not set up communications between these utilities with powerline communications protocols over these hard-wired connections? All it would take would be

some intelligent technology in the 220 circuit breakers for the appliances, and a smart switch at the other end of the circuit, and connections to the network controls in the smart meter that is plugged into the breaker box. All this could be done without putting any RF transmission into the house?

Why hasn't this been done yet? Because a wireless solution is easier to install? Because changing the hard wiring would require changing electrical codes? Because no one thinks it's necessary to get this clever, since no one is worried about RF exposures?

Solutions like this could be created, if industry and government had enough incentive to work the problem, rather than to deny the existence of the problem. Until such alternatives to constant in-home RF exposure are developed, we think that EWEB would be wise to avoid getting married to this technology. Developing demand/response using a constantly transmitting in-home RF network will mean investing a great deal of money in infrastructure that is likely to become extremely unpopular within the next 10 to 15 years. What we look at now as "quick and cheap" will come to be viewed as "quick and dirty".

Other communication options

We've been told that the powerline communication option is not a feasible solution for demand/response control, since it lacks the bandwidth necessary for rapid communications between server and meters.

We think that serious consideration should be given to the potential use of broadband internet connections for demand/response communications. We understand that EWEB does not have the financial power to build their own fiberoptic network at this time. But in 2010, 82% of the households in our part of the state had broadband internet connections, and this proportion continues to grow. Would it be technically possible to use these wired internet connections to communicate with the vast majority of the electric meters in our city, rather than building a new wireless infrastructure to do the job? Broadband internet communications would certainly have the bandwidth to do this, and a demand/response system is not expected to require the participation of every household in the community. If we acknowledge the health risks of RF communication (especially the robust night-time communication expected for demand/response control), then an internet-based demand/response control system should be given serious consideration.

IN CONCLUSION

We hope that our report and recommendations will be helpful to EWEB staff, the EWEB Board of Governors, and to members of our community. We think that review of this information should allow a more realistic appraisal of the health risks involved in establishing an AMI network that utilizes microwave RF communication. Such a measured and realistic appraisal is a necessary part of the Total Bottom Line Analysis that EWEB has promised to bring to any major initiative in our community.

This is a lengthy document, and discusses complex issues. We would welcome the opportunity to meet with EWEB staff and members of the Board, in order to give a more extensive audiovisual presentation and clarification of this material, and to answer any questions that you wish to ask us about this research.

We hope to be part of an ongoing dialogue about the potential health effects of RF technology, as EWEB continues to deliberate on the various choices that they face with the AMI program.

Biological Effects of Microwaves: Thermal and Nonthermal Mechanisms*

A Report by an Independent Investigator

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* Some of the present paper was submitted in 2001 to the U. S. Federal Communications Commission as a *Comment* on unlicensed operation of ultrawide-band devices: http://arXiv.org/pdf/physics/0102007. Also available for download at http://www.scribd.com/jmmwill/documents.

Abstract

For over sixty years, it has been reported that microwave electromagnetic radiation (EMR) had effects on humans which could not be explained by detectible heating of tissue. Auditory responses to radar, called *microwave hearing*, have been the best known of these phenomena. To account for microwave hearing, many studies in the literature have adopted a rate-of-heating hypothesis advanced by Foster and Finch in 1974. We show here that theoretical and experimental studies supporting this hypothesis are weaker than usually assumed.

We develop a simple framework of understanding of EMR that may be used to explain microwave hearing as a nonthermal, nonacoustic effect. We then extend this approach to other contexts, pointing out several fundamental misconceptions confounding the field.

EMR, especially wide-band EMR, primarily must have a nonthermal effect on living tissue before conversion to heat. Auditory and tactile sensations, central neurological disability, and blood pressure loss caused by EMR have been documented. Except microwave hearing, parameters of irradiation causing such effects have not been explored adequately and remain unknown. There appears not to be any forensic methodology to prove the cause of harm at nonthermal levels.

Key Words:

EHF Waves	Blood Pressure, Low
Electromagnetic Radiation	Headache, Vascular
Tinnitus	Medicine, Forensic
Microwave Hearing	Jurisprudence, Psychiatric

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Introduction

A good theory should be as simple as possible. But no more so.

-- Albert Einstein

Nontechnical Controversy

Claims that electromagnetic radiation (EMR) from radar or radio communication devices might have subtle biological effects have in the past opened the door to speculation and to ignorant as well as unwarranted accusations. The problem is that EMR is invisible and so can not be shown absent when a putative victim has experienced some personal harm -- for example because of crashing an auto or a plane, forgetting an appointment, or experiencing otherwise unexplained pain or disease.

Radar operators in the late 1940's sometimes remarked that they could hear things such as clicks or buzzes when standing in or near the beam of a transmitter (Chou *et al*, 1982). Because safe radio-frequency irradiation dosage levels were not well understood, experimentation was strongly discouraged. At that time, and perhaps even now, there was folklore that radar could have no effect but destructive heating, and that such sensations must therefore be an indication of mental incompetence.

Since the 1940's, there have been isolated and vague, often apparently paranoid, complaints of "mind control" or Nazi-like experiments using secret drugs or hidden electronic apparatus. U. S. Congressional inquiries (Ervin, 1974; Rockefeller, 1994) substantiated some of them and mandated new patient safeguards in medical research. Thus, the history suggests current or future similar claims about microwaves.

As documented in many peer-reviewed studies below, and experienced by the present author, microwaves can be heard. The apparent loudness can be almost deafening. Microwaves also can have distinct, often painful, tactile effects not resembling anything attributable to heat. Some of the author's own experience in measuring these effects has been posted online (Williams, 2013). A correspondent of the author claims he has observed handheld radar sets being used to flush deer from underbrush during hunting season. As will be shown, whereas such claims individually might be true or false, there is no more reason to doubt them *a priori* than to doubt the sanity of radar operators.

More recently, concerns have arisen about the safety of cell phones (Stewart, 2000 as updated by Swerdlow, 2003; Hyland, 2001; Adey, 2003; see also Barnett, 1994), and even of LORAN transmissions (Dawes, 2001). These concerns, actually often fears, are being stoked by rumors about covert use of portable radar by soldiers or police (Burton and Ohlke, 2000; Eisley, 2001; Jones, 2005), and by public but ambiguous announcements of military weaponry based on microwaves (Sirak, 2001), although such weaponry, even if effective, likely would be illegal in military engagement (Williams, 2001).

The underlying fear here revolves around the possibility of serious intentional injury or death delivered by microwave transmitting devices, with no forensic methodology to recognize the symptoms or identify the cause.

There does not seem to be any possible political resolution of these controversies, which are based often on empty suspicion about unobservable media; the only rational solution is greater understanding of the claims, based on a good understanding of the biological effects of EMR.

To lay groundwork for understanding, we focus on well-established nonthermal biological effects of microwaves, explaining how a thermal interaction might occur; then, we criticize the spread of heat (not light) which has replaced good physics in guiding research in this area. Throughout, we apply a rationale which should lead readers out of the morass of confusion into which many otherwise rational solutions have been collected.

Technical Controversy

Very little about the biological effects of EMR on living tissue appears in the literature until Frey (1961; 1962) announced that he had discovered some peculiar tactile and auditory effects while exposing humans to pulsed radar at average power far too low to heat tissue significantly. The auditory effects, including clicks, hisses, or buzzes, were easily demonstrated; they were dubbed *microwave hearing*.

Interest in the engineering and biomedical communities increased gradually, with numerous theoretical interpretations, and experiments on humans and animals, appearing through the late 1970's. A very thorough categorized list of the literature was published by Glaser (1972). We shall not review the literature here, but we refer the reader to the wide range of experiments published in a special supplement of *Radio Science* in 1977, and to reviews by Frey (1971), Adey (1981), Chou, *et al* (1982), Erwin (1988), Lai (1994) and Foster (2000). Related government studies have been published in Barnett (1994), U. S. Office of Technology Assessment (1989), Stewart (2000), Hyland (2001), Swerdlow (2003), and World Health Organization (2007). The problem also is of concern in Russia (Kositsky, *et al*, 2001).

Several hypotheses concerning microwave hearing were advanced to support one idea or another. Almost all the evidence indicated that bulk heating could not be responsible for the easily demonstrated tinnitus-like auditory effects of pulsed EMR. The issue apparently was resolved by Foster and Finch (1974), hereafter abbreviated FF74, who concluded that *rate of change of temperature* of tissue water could convert an EMR pulse to an acoustic one of very small amplitude, but large enough effectively to stimulate the cochlea. Thus, all biological effects of EMR either would be by temperature increase (at high average power levels) or by rate of temperature increase (at lower average levels). At high levels, the effects were predictable and harmful; at low levels, the effects were not predictably harmful.

Papers by Frey and others argued against the FF74 hypothesis. Thermal and other mechanisms were discussed by all concerned on several forums, notably as reported in Guy, *et al* (1975). The controversy reached its height in *Science* magazine (Frey and others, 1979); but, over time, the majority of researchers came to accept the FF74 hypothesis, although Foster himself maintained some reservation about its exclusiveness (Foster, 2000).

Some Biophysical Perspective

Explanatory note: The following biophysical approach is believed correct and complete insofar as it relates to the matters being discussed in this paper. An understanding of the biophysics deepens the understanding of the EMR mechanisms at work; however, this understanding is not itself necessary to comprehend the arguments below which criticize the elementary physical errors rampant in the EMR literature.

Readers uninterested in these details may skip to the "Problems With Thermal Causation" section below.

Membrane Functionality

The body cells, especially the individual nerves and sensory receptors, function as ordered systems of boundaries in fluid. The mechanism of action of nerves, muscles, and systems of them, has been described in terms of membrane polarization changes (Regan, 1971, ch. 1). These polarization changes occur because membranes not only are populated by structure-related dipoles as in the figures below, but also are more sparsely populated by specialized channels which can open or close to regulate an exchange of ions. These ions primarily are sodium (Na+) and potassium (K+), but also may include calcium or others.

Living cells internally generally are more negative than their local environment. They thus store some free energy in the electric potential across their bounding membranes. This potential difference is electrochemical and depends on continuous expenditure of energy to maintain higher intracellular K+ concentrations and lower intracellular Na+ concentrations than would be so during chemical (osmotic) equilibrium. The ion gradients are controlled by enzyme action which does its work using the adenosine triphosphate (ATP) energy store available to cells throughout the body. At rest, the membrane potential is maximal and therefore must maximally align dipoles in the membrane, so that the cumulative dipole moment orthogonal to the membrane surface also is maximal.

Specifically, resting neurons expend energy to operate a Na-K "pump" which keeps the potential inside the cell about 70 mV more negative than the outside (Regan, 1972, p. 7). An additional osmotic potential also exists. The membrane can liberate energy very locally by allowing some extracellular Na+ to flow in and some intracellular K+ to flow out. Dendritic depolarization (*e. g.*, "C" nerve fiber sensory response) may cause the –70 mV potential to drop close to 0 mV immediately adjacent to the depolarized areas of the cell membrane.

When the originally resting electric field across a nerve cell membrane develops a steep enough spatial gradient parallel to the membrane surface, some closed channels are opened, causing a spread of depolarization which may become an action potential under proper circumstances. The sudden depolarization during an axonal action potential may cause the resting potential of –70 mV to swing past 0 perhaps to +10 mV. Local

hyperpolarization may reduce, modulate, or prevent the generation of regular action potentials which maintain the state of the central nervous system. The equation of locally steep spatial gradients with locally sudden temporal ones is implied by diffusion and is essential in the Hodgkin-Huxley and similar approaches: For ion species *j* in concentration $u_j(x,t)$,

$$D\nabla^2 u(x,t) - \rho u(x,t) = \frac{\partial u(x,t)}{\partial t}\text{; so, over time, } \nabla^2 u - (\text{loss}) \propto \frac{\partial u}{\partial t} - (\text{system input}), \quad (1)$$

a linear description, but one adequate to show the principle. Eccles (1973) and references therein may be consulted for details on initiation and propagation of neural action potentials. We shall relate membrane spatial gradients to EMR action after describing the effects of EMR on membrane polarization and discussing their implications.

EMR and the Human Body

Unless otherwise noted, the EMR under discussion should be assumed to be in the microwave frequency range. Because coupling of magnetic fields to tissue is far weaker than that of electric (*E*) fields, we shall not discuss the magnetic fields which always accompany the *E* fields of EMR. Works such as those of Binhi and Chernavskii (2004) may be referenced on such topics. Here, we merely remark that a changing magnetic field can induce an *E* field which may cause thermal or nonthermal biological effects of interest to us.

EMR is attenuated exponentially with depth by any uniform body tissue. For example, a reasonably accurate equation relating the field intensity at depth *d* to the applied intensity in air, might take the form,

$$I_{\text{tissue}}(d,f) = I_{\text{air}} \cdot \exp(-k \cdot d \cdot f^{1/2}), \quad (2)$$

for *k* some tissue- and unit-dependent constant, and *f* the frequency. Penetration increases with decreasing frequency.

A zero frequency, direct-current (DC) voltage applied across the body will cause current to flow by ionic conduction in all conductive body fluids. When the DC coupling is through air -- for example by placing the body between two conductors at different voltages, but not touching -- the current flow quickly will stop because of the resistivity of air; but, displaced charges in the body, and in the coupling electrodes, will remain displaced to cancel the fields applied to those charges. The same occurs with the body replaced by a piece of conductive metal, such as aluminum.

When microwave EMR is applied to a piece of metal, most of it will be reflected; and, so, the penetration will be small. For such a medium, the internal field caused even by an applied DC potential will be close to zero. However, the reason the penetration in a metal is small is that the charge carriers in the metal, electrons, respond so actively that they cancel the field by their motion (in the case of EMR) or by their static relocation (in

the case of DC).

For the moderately conductive human body, a large fraction of which consists of conductive saline water, the penetration of EMR is limited by absorption as well as reflection. One expects from Eq. (2) that any biological effect, an oscillating flow of ions, will be large near the surface and will decline about exponentially with depth.

Regardless of penetration depth, we shall suggest in this work that whenever EMR is applied to well-ordered tissue or organ boundaries of the body, well-ordered interactions must be taking place before the end-result of heating takes place. The difficult question is how to apply the EMR so it is amplified by the living organism to a level unequivocally observable in a scientific experiment.

Dipole Rotation by EMR

A microwave EMR beam may be viewed as imposing time-varying forces on charged elements, monopoles, in tissue by virtue of its oscillating *E* field. Such charged elements may include atoms (ions), molecules, regions of bonding between molecules, or anything else with a localized excess of positive or negative charge. Such localized excesses of charge always are cancelled by oppositely charged elements not far away; tissue never has a significant, long-range net excess charge when compared with the total number of cancelled-out, neutralized, elements of which it is composed. On the scale of monopole spacing distances in tissue, a microwave beam presents a time-changing but spatially uniform *E* field to those elements; the vector potential also is effectively uniform on this scale, so tissue will have no direct magnetic interaction at all with the EMR (*e. g.*, Craig & Thirunamachandran, 1984, Sections 3.6 & 4.7).

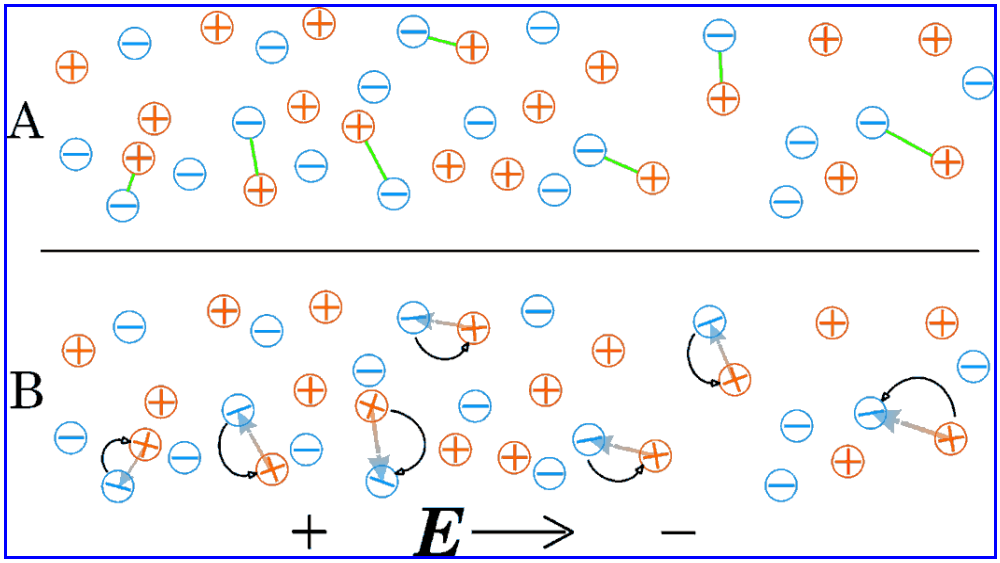


Figure 1. A: Charged elements in a matrix, some bound (straight lines) into dipoles. B: The effect of an E field in terms of rotating dipoles (straight arrows represent dipole moments; curved arrows represent rotation).

In whatever matrix in which they are found, fluid or not, monopoles of opposite charge may be connected more rigidly together as a *dipole* than to other nearby elements. Dipoles typically are distinct molecules, but not all molecules are dipoles.

If a uniform *E* field is applied parallel to the line between the poles in a dipole, it will cause attraction of one pole and exactly equal repulsion of the other, causing some insignificant bond length change coupled with a zero net displacement of the dipole in the matrix. If the field is applied in a direction perpendicular to the line between the two poles, the poles will be displaced in opposite directions and the dipole then will be rotated. In this case, the distance between the poles will not have to change, so no work will have to be done by the EMR field in the relatively strong potential binding the poles. Furthermore, the dipole itself, being neutral, will not be displaced in the matrix, requiring no work done there, either. This is the concept of dipole rotation by EMR illustrated in Fig. 1 above.

In empirical fact as well as theory, weak EMR of relatively long wavelength locally affects nonmetallic objects just as described: It rotates dipoles if they have time to respond to the field oscillations, but it stretches bonds between monopoles insignificantly. If the oscillation frequency is adequately low, the net effect continually is to change alignment of the dipoles against the field so that the EMR field locally always is kept minimized in the tissue, given that the EMR force is cancelled. See the section below on "Time Domain Patterns" for a quantification of this approach in terms of stimulation of human neural response.

Conversion of EMR to Heat

Consider a tissue boundary such as the mucous membrane of the stomach wall or the endothelium of a large blood vessel. Such a boundary will be enclosed in electrically polarized cell membranes with a regular coulomb structure, the orientation of the membrane dipoles being completely organ dependent in the absence of EMR. How could EMR raise the temperature of such a structure?

Suppose we had a coherent microwave beam producing a standing *E*-field wave, as in a microwave oven: How would we understand the effect of the EMR? We shall disregard here the phase-mixing technology in a real microwave oven as infinitely slow when compared with its 2.4 GHz cycle rate. We know that an EMR standing wave pattern can diffract moving, charged particles into highly organized patterns (Nairz *et al*, 2001), so why should a standing pattern cause random motion -- heat -- in anything?

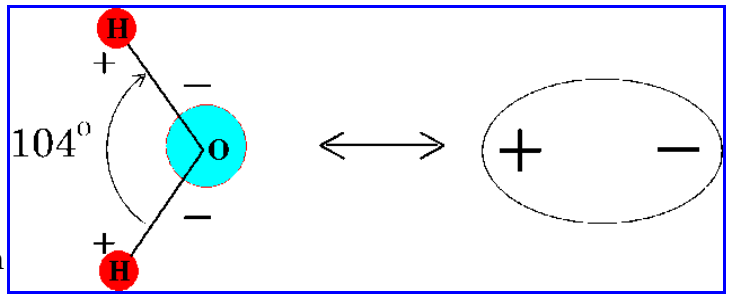


Figure 2. Simple, idealized water molecule. Left: The planar arrangement of atoms in a water molecule. Right: The equivalent electric dipole element.

First, let us examine the action on the fluid enclosed by some such tissue boundary. How would microwave EMR raise the temperature of the fluid?

As shown in Fig. 2, a simplified explanation invokes the structure of the water molecule, which consists of an oxygen atom covalently bonded to two hydrogen atoms. The hydrogens interact and are drawn together somewhat, so that they are almost at right angles. The hydrogens are positively charged, and the oxygen negatively, so a triangular, planar arrangement equivalent to a dipole results.

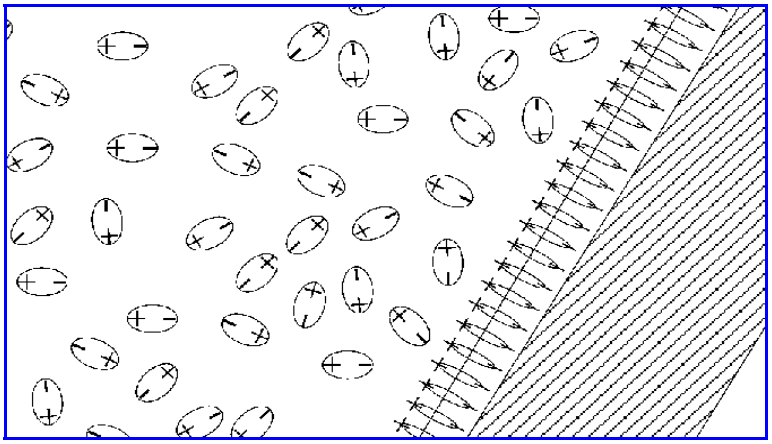


Figure 3. Unaligned electric dipoles in a fluid (left) bounded by solid tissue with a membrane layer of aligned dipoles. No scale implied.

Some discussion of the structure of an isolated water molecule may be found in Tsiper (2004). An aqueous fluid then may be viewed as a collection of electric dipoles. For example, without much loss of generality, let us take a structure bounded by a solid tissue with its electric dipoles aligned with positive poles locally pointing into the fluid. This is shown in Fig. 3: Let each fluid dipole in Fig. 3 represent a water molecule, as modelled simply above. The dipoles initially may be assumed arranged more or less at random with respect to one another, and in random thermal relative motion. When they are rotated (torqued) together, all magnitudes in phase with the EMR, the dipoles interact, as expected, at random distances and phases with respect to one another.

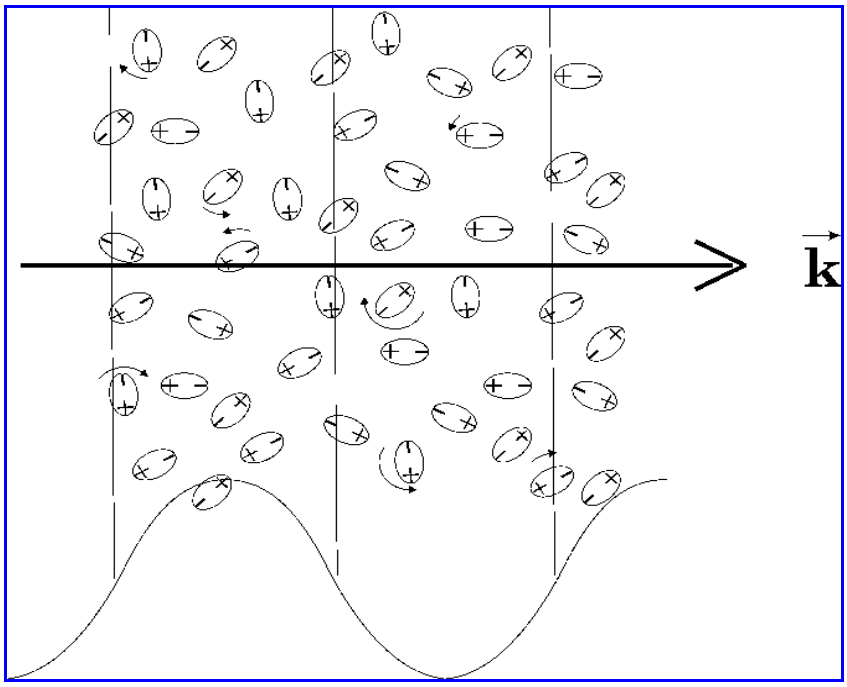


Figure 4. Sketch of the effect of a plane EMR wave propagating in a bulk fluid of polar elements, with a net result of increasing the temperature. The *E*-vector magnitude and polarity (+ up) is shown on an arbitrary vertical scale drawn through nodes of the wave; the horizontal scale is for illustration only. The EMR torque on a few of the polar elements is shown as a vector in the $\pm\vec{\mathbf{H}}$ direction.

For this reason, then, even coherent EMR-induced motions must contribute random momentum and therefore random energy. This is shown in Fig. 4, where the wave vector $\vec{\mathbf{k}}$ is drawn for EMR propagating as a plane wave from left to right, with a few illustrative EMR torque angles shown for individual dipoles. The wave vector is given only to define the direction of the incident EMR as that of $\vec{\mathbf{E}} \times \vec{\mathbf{H}}$ in our simplified representation.

The EMR energy converted by a polar fluid, then, is completely disordered on the scale of anything macroscopic which we might insert into the fluid; therefore, the EMR energy is heat energy.

Conversion of EMR by the Body

The human body does not consist of a bag of fluid but rather of a system of organs, each with its own, well-defined boundary from the others. The different tissues in different organs each have their own dielectric properties, as described in Durney, *et al* (1999). The accurate representation of human response to microwave radiation is exceedingly complex, as discussed and approximated in Cundin and Roach (2010). In any case, organ boundaries may function as diffractive, refractive, and reflective interfaces for microwave EMR of wavelength comparable to the boundary extent.

On a finer but still macroscopic scale, let us next consider EMR near the fluid boundary on the right of Fig. 3 above. The boundary is more ordered than the bulk of the fluid. The effect of EMR is sketched in Fig. 5 below, where a vertically limiting beam envelope is assumed. The amplitude of the beam in that figure is maximum near the horizontal line near the middle of the figure on the left; this amplitude dies off away from the middle, upward and downward, perhaps as a Gaussian function.

Near the fluid boundary in Fig. 5, some EMR energy will be delivered to the membrane as mechanical energy, doing work on the membrane associated with the linear and angular momentum of the EMR, which therefore would not be work associated with heat dissipation.

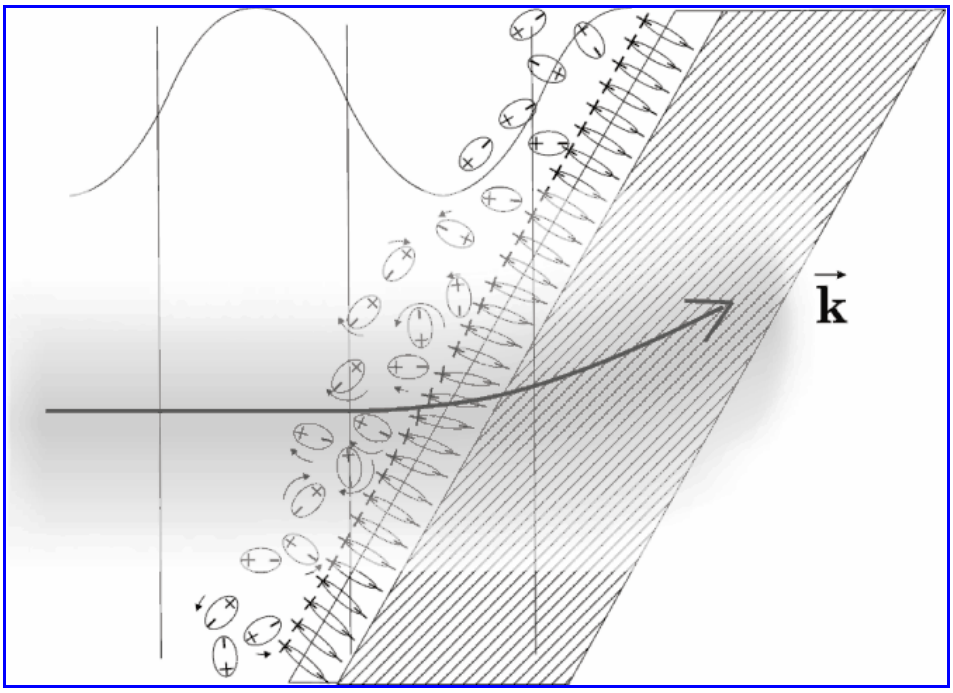


Figure 5. Sketch of the effect of an EMR beam propagating from a polar fluid into tissue bounded by a polarized membrane. Nothing to scale. The refraction proves that some work will be done on the boundary, so that some nonthermal energy will be transferred.

Otherwise stated, this mechanical work would be equivalent to free energy delivered by a heat engine, not to heat merely transferred by a temperature difference according to the laws of thermodynamics. It is not physically possible that no free energy would be delivered, because delivery of pure thermal energy would require complete disorder in the spacing and orientation of the bounding polar elements.

So, at least some energy transferred to the body by EMR will be not be thermal, because of body structure. The EMR will impose a pattern with spatial periodicity approximately equal to half of the projected wavelength (in the surrounding medium) on all boundaries. Polarized molecules in the bounding membrane but away from the EMR nodes will be rotated on temporal average away from their rest positions. Because of reduced cancellation of the ionic potential, the time-averaged membrane polarization on the boundary thus will be increased except at nodes of the EMR. For nerve cells or some muscle cells, the membrane will develop a changing spatial hyperpolarization pattern possibly interfering with the normal changes responsible for its normal functionality. We shall discuss this last in more detail later. Ingalls (1967), for example, adds in a final note that the same pulsed radar which humans could hear also reduced the measured nerve impulse threshold in the dissected sciatic nerve of a frog.

If we assume in general that the wave vector $\vec{\mathbf{k}}$ will not be perfectly perpendicular to the boundary, then the interaction in Fig. 5 (above) will deliver some linear momentum transverse to $\vec{\mathbf{k}}$; the EMR beam will be refracted. The angle of refraction will be related to the amount of free energy delivered to the boundary dipoles. The right side of the figure shows this refraction as a bending upward of the wave vector.

The momentum transferred by the reaction force of the refracted beam will be delivered to the membrane and will correspond entirely to free energy, doing work by energy associated with linear and angular momentum from the microwave photons; no heat will be involved. Other energy may be transferred by the EMR, depending on the nature of the medium at and beyond the boundary. Absorbed energy need not be thermal; in terms of broad categories, it might be mechanical, optical, chemical, biological, *etc*. We ignore here the dielectric and other properties quantifying the direction and amount of refraction. We also merely mention diffraction and reflection(s), which might set up standing wave modulations in the incident beam.

From all this discussion, it seems clear that the burden of proof should be on any claim that microwaves act like microwave ovens and do nothing but cause heat to be transferred to living tissue. Because human tissue is formed into organs with distinct boundaries, based on the *prima facie* argument of this section, EMR should be assumed to have nonthermal effects on living tissue unless explicitly provable otherwise.

Complexity of Water and Cellular Contents

In this section, we lean heavily on Chaplin (2002) for a better understanding of water. Individual water molecules maintain their identity at ordinary temperatures for perhaps a millisecond (Chaplin, 2002), but pairs of them are intrinsically unstable. There is no way two planar water-molecule dipoles could line up in the three dimensional bulk of a fluid so as to have the negative (oxygen) pole of one stably associated with the positive (dual hydrogen) pole of another; therefore, larger groups of water molecules have to be formed. In actuality, the hydrogen atoms in each molecule form hydrogen bonds which chain these groups of molecules together in all directions. Because water is liquid at biological temperatures, groups of molecules are formed only transitorily; but, as discussed in detail by Chaplin, large assemblages can persist on the average for relatively long times.

The theory of water by no means is settled, but Chaplin presents a convincing and widely accepted way of explaining many of the puzzles of water: The explanation postulates that the dominant structure in liquid water is a spherically symmetrical one, an icosahedron of twenty 14-molecule tetrahedra, with volume containing a total of 280 water molecules. The tetrahedra are described in Krisch, *et al* (2002); dodecahedra apparently are resolved by Miyazaki, *et al* (2004) and Shin, *et al* (2004). In water, regardless of the precise structure, the time for a hydrogen bond to be created is about 10^{-4} ns (Asbury, *et al*, 2003). Individual hydrogen bonds persist without breaking apart for perhaps 10^{-2} ns and usually re-form in the same relation in which they were formed before breaking.

The icosahedra are a huge 3 nm in diameter, about 1/3 the thickness of a typical cell membrane. Very approximately, a compressional sound vibration at 1500 ms^{-1} in water would propagate across the diameter of such an icosahedron in about $2 \cdot 10^{-3}$ ns, far shorter a time than the lifetime of one of the hydrogen bonds keeping the icosahedron intact. Other vibratory modes of sound would propagate more slowly than the compressional mode, but it seems clear that such icosahedra could sustain internal vibrations which greatly would reduce the heat energy made available immediately from an absorbed microwave photon.

Larger structures of 13 icosahedra are believed to form. Smaller, transient linear chains form, and so do fragments of these latter; but, the icosahedra tend to persist longest because they are the minimal structures with complete stability conferred by their symmetry. A simulation study of a dipole model of liquid water by Higo, *et al* (2001) confirms that water should contain stable structures approximately corresponding in size to the postulated icosahedra. The Higo, *et al* simulation was run only for 1/3 ns, but the result suggests that these structures should be expected to persist for some indefinite time greater than 1 ns. Other simulations not producing such long persistences have been performed but typically are based on assumptions of spherical symmetry *a priori* expected to negate the correlations being sought (*e. g.*, Kumar, *et al*, 2005). Theoretical flaws implied by spherical symmetry are discussed in a different context below.

Returning to the Chaplin model, each icosahedron has two main conformations, an expanded state (ES) and a collapsed state (CS). The ES is a true icosahedron, everywhere convex, but the CS has one or more vertices buckled inward, creating small local concavities. Chaplin presents figures clearly showing this difference. The equilibrium between ES and CS depends on temperature. At lower temperatures, ES dominates; at higher temperatures, CS dominates. The volume occupied by 280 water molecules is less in the CS state than in the ES, so the effective density of CS is greater than that of ES. To explain the empirical 4 C density maximum of water, one merely assumes that density increases between 0 C to 4 C because some ES moves over to CS. Above 4 C, yet more CS occurs, but fragmentation increases also; every stable structure possesses independent thermodynamic degrees of freedom. Because of fragmentation, the density therefore decreases above 4 C.

Because most of the content of a body cell is H_2O, the cellular contents must be assumed built upon a structured water substrate, in addition to being highly structured themselves.

EMR Effect on Water

Application of EMR would be expected to affect molecular dipoles in liquid water much the way it affects dipoles on a tissue boundary: If below some limiting power level, and in a low enough frequency range, EMR should rotate dipoles in the icosahedra or other longer-range structural units, bending hydrogen bonds and deforming them, but should not destroy those units. A cyclic but constrained rotation of dipoles should cause elastic deformation waves within any large-scale water structure.

Under such conditions, then, EMR only should be converted to heat at the random boundaries among the water structural units, and this should occur only in a relatively small fraction of the volume of any given quantity of water. The main fraction of the EMR energy input would persist in bond deformations or internal vibrations. It should be easy to see that in the limit of a completely structured object, such as a single, solid piezoelectric crystal, a nondestructive pulse of EMR merely would deform the lattice elastically, causing no immediate temperature rise at all.

Thus, conversion of EMR to heat in water under conditions of limited power would be expected to develop relatively slowly, as the rotated structural dipoles propagated mechanical changes from the water structures to their structurally random boundaries, and as the limited lifetimes of the water structures caused them to break up. Consideration of the structure of water will be applied in the discussion of the FF74 experiment below.

Interaction with Macroscopic Body Geometry

EMR interacts not only on tissue boundaries but also by antenna-like interaction with the gross dimensions of the human organs. The "resonance region" (Foster, 2000) for the human body varies with the organ or body part involved. In this region, between

frequencies of about 30 MHz and 500 GHz, wave lengths and body part lengths may cause complicated near-field interactions difficult or impossible to calculate. We shall refer to this as the *diffractive* region of the spectrum, keeping in mind that, in it, the local geometry of body structures can concentrate or attenuate fields -- perhaps by as much as a factor of ten. We shall not distinguish interference from diffraction in this usage.

An antenna-like amplification of EMR by the human body can be demonstrated easily with a simple monopole antenna and an instrument such as an oscilloscope: Attach the antenna and observe the normal, ubiquitous background RF noise as displayed by the instrument. Then, grasp the antenna with the hand: The amplitudes will increase by a factor of two to ten, depending on conditions. The three-dimensional human body is far better a generic antenna than any one-dimensional monopole of comparable length.

In the human body, there will be acoustic resonances, too. Given a sound speed of under 600 m/s in the normal human head (Bekesy, 1948), a 5 kHz sound wave, well within the normal human auditory range for sensation of a hiss or crackle, would have a wavelength of about 12 cm. This would be in the *acoustic* diffractive range for a region about the size of the human head.

So, at frequencies around 1 GHz, there would be both an electromagnetic and a possibly fed-back acoustic contribution to EMR diffractive influence in the human head. This coincidence would not hold the same way for animals with substantially smaller heads, such as the majority of dogs, or for rhesus monkeys, cats, rats, or mice. Sound waves in the audible range produced in the human head by any mechanism would find the geometry conducive to diffractive effects such as coherent superposition.

It is unknown whether auditory response to microwaves actually would be increased by the combined effect of the EMR and acoustic diffractive effects; to the present author's knowledge, no experiment or simulation has addressed the question. However, the use of microwave-produced acoustic resonances to be recorded by external diagnostic instrumentation is described in Wang *et al* (1999) and Xu *et al* (2001), the former reporting that the microwave-induced acoustic pressure was proportional to the microwave intensity.

It should be mentioned here that some initial applications of microwaves in mineral analysis and mining are described in (Monti, *et al*, 2015), although human responses were not measured.

Problems With Thermal Causation

We first discuss the FF74 study, an approach which has provided the best and most elegant result in support of a thermal basis for biological response to microwaves. We suggest that the argument for an exclusively thermal cause of auditory stimulation is weaker than previously has been recognized. We then point out problems with supporting arguments often advanced to confirm the Foster and Finch hypothesis, but which are not central to it.

Microwave Hearing: The Foster and Finch Hypothesis

To produce microwave hearing according to Foster's (2000) description, pulses optimally would be about 5 μs wide, in the frequency range 1 to 10 GHz, and should deliver perhaps ~10^4 W/m^2 ; this is the power during the pulse.

Note that 10^4 W/m^2 is the same as 1W/cm^2. Each 5 μs , 1W/cm^2 pulse produces the sensation of a distinct "click" or "pop" when directed at the head of a human with normal hearing for high frequencies. The loudness, according to Frey (1962) and others, may vary from barely perceptible to 60 dB or more. At 5 pulses per second, the duty cycle would be only $25 \cdot 10^{-6}$, making the time-averaged power just 25 μW/cm^2 .

At 1 GHz, the EMR wavelength would be about 30 cm in air; at 10 GHz, 3 cm -- all in the diffractive range for the human head. Under the FF74 hypothesis, in response to an EMR pulse, the head would vibrate as a whole, and the microwave hearing would be an acoustic response mediated by bone conduction to the cochlea. As an aside, we add here that there also might be acoustic diffractive contributions, as suggested above, unique to a human-sized head.

According to FF74, the thermoacoustic effect is supposed to be mediated by the power transferred as a minute temperature rise during each pulse. A 5 μs pulse would contain some 5,000 to 50,000 cycles of the carrier at 1 to 10 GHz, respectively. Because, then, according to this theory, almost none of the heard microwave energy could be delivered by the pulse edge transients, the thermoacoustic effect should be described as entirely a pulse envelope (low-pass) phenomenon. This alone would imply a different mechanism from that of Frey (1962), who reported that the sensations he was studying seemed to be associated with noise riding (high-passed) on each of his radar pulses.

To verify their idea quantitatively, FF74 used a hydrophone to measure an acoustic response to 27 μs pulses of 2.4 GHz EMR in a somewhat larger than head-sized container of pure water above, at, and below the 4 C temperature at which liquid water reaches its maximum density. They found that the acoustic wave amplitude declined to zero as the temperature was lowered to 4 C, and a nonzero amplitude returned with phase reversed as the temperature was lowered below 4 C.

The null result at 4 C can not be explained any obvious way except by a superposition

of two scalar acoustic waves of equal amplitude but opposite phase. The null point for their sound wave being at the same 4 C as the turning point of water density, FF74 concluded that their radar pulses were delivering temperature pulses to the water. The reversal in phase strongly supported this conclusion.

To argue further in favor of the concept of specifically thermoacoustic such waves, FF74 cited calculations and data by Gournay (1966) which indicated that a high-power optical pulse could cause acoustic waves in water by thermal means.

FF74 postulated a temperature increase per pulse of at most 10^{-5} K. This estimate is consistent with acoustic calculations and results by Bacon, *et al* (1999). Let us assume a human head 20 cm in longest dimension, and an auditory system sensitive to linear displacements of some 10^{-11} m amplitude (Bekesy, 1948; Bekesy and Rosenblith, 1951). Then, for a fundamental-mode, lossless vibration at absolute threshold, this amount of temperature increase would imply a linear coefficient of thermal expansion, X, given by, $10^{-11} < (20/100)\cdot 10^{-5} X$. Higher-order (odd) modes would cause far smaller acoustic contributions, no more than a dB or so, and will be ignored. So, approximately, a threshold sensation would require $X > 5\cdot 10^{-6}$ / K. The linear expansion coefficient X_{H_2O} for water is about $3.7\cdot 10^{-4}$ / K at body temperature (Chaplin, 2002), and common materials differ in linear coefficient on the order of 10^{-5} / K, so the idea definitely seems consistent quantitatively with known properties of the human auditory system. The sequence of events is sketched (not to scale) in Fig. 6.

Accepting Foster and Finch's estimated maximum temperature increase per pulse, the thermoacoustic effect from each temporally distinguishable pulse should contribute a click no more than about $(X_{H_2O} / X)^2 \cong (10^{-4} / 10^{-6})^2 \cong 40$ dB above auditory absolute detection threshold; this is about the level of the softest whispered speech. EMR or acoustic wave diffraction, if present, could alter this estimate by perhaps an order of magnitude.

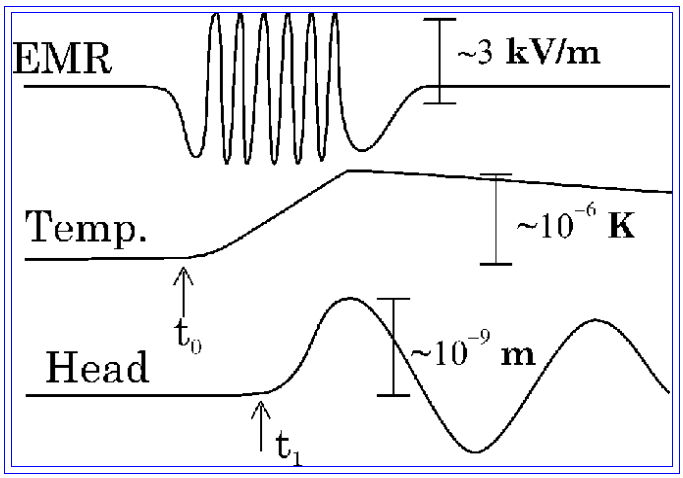


Figure 6. Sketch of events in the Foster and Finch (FF74) hypothesis. No scale. The EMR pulse arrives at the head at time t_0; the head begins to oscillate at time t_1.

Support for a cochlear source of auditory response both to EMR and to ordinary sound stimulation was reported by Lebovitz and Seaman (1977), who recorded single-cell responses in the cat auditory nerve. They concluded at the time that the FF74 hypothesis was consistent with their results. For cells responding comparably to EMR and sound stimuli, many of the Lebovitz and Seaman EMR pulses were calculated to be equivalent to a sound click 60 to 70 dB above (human) absolute threshold.

The problem here is that 60 to 70 dB seems orders of magnitude too high for the thermoacoustic hypothesis above, given the small size of the cat skull. The 60 dB figure would require a cat skull bigger than an elephant's. Furthermore, the problematic Lebovitz and Seaman data don't seem explainable in terms of special properties of the cat auditory system, because data by Cain and Rissmann (1978) indicate that cochlear sensitivity to sound or EMR is not much different for cats than for humans. Seaman and Lebovitz (1987) subsequently decided that the FF74 thermoacoustic hypothesis was not tenable for cats, but their changed conclusion essentially was ignored by thermoacoustic proponents.

There are other ways in which the thermoacoustic idea does not seem to be a complete explanation of microwave hearing. First, purely theoretically, Gournay (1966) assumed that the thermal contribution would be the only one in his experiment, and he calculated optical-acoustic wave efficiency from that. There is no easy way to test such an assumption from his study or his calculations. FF74 seem merely to have repeated back Gournay's assumption to support their own conclusion.

Also, even if the Gournay assumption was entirely correct, the FF74 extrapolation from Gournay's visible light to frequencies more than 10^5 lower should be substantiated more directly by data in the microwave range. The Gournay experiment was performed at frequencies far above the empirical first resonance point of water, which is about 30 GHz -- so far above, that hydrogen bonds in water could not possibly be stretching or bending in synchrony with the EMR. The FF74 experiment was performed at frequencies so far below this point that the main electromagnetic response of the water would be in dipole-mediated, bending changes in hydrogen bonding (Chaplin, 2002). Thus, the mechanism of response of water to Gournay's *versus* Foster and Finch's EMR had to be quite different, whether "thermal" or not. The same argument would apply to subsequent findings by Olsen and Lin (1983), who demonstrated the presence of acoustic waves caused by radar pulses applied to animal tissue.

A Structural Acoustic Alternative to Foster and Finch

The FF74 demonstration can be explained by a nonthermal acoustic mechanism. Recalling the water structure discussion above, suppose each EMR pulse in the FF74 frequency and power range randomly merely caused some small fraction of all dipoles on the boundaries of the ES icosahedra to rotate their hydrogen bonds enough to buckle inward, which is the equivalent of shifting some ES to CS. Little or no additional random motion would be involved (although the new CS icosahedra would store some new energy), so there would not be any significant temperature pulse. Buckled molecules on the surfaces of the icosahedra would disconnect their hydrogen bonds from other, bounding structures; these other structures would be to some extent fragments, which we know increase in number with temperature.

There would be three different, temperature-parameterized cases:

- Below 4 C, an EMR pulse would be converted to a ES → CS density-increase pulse unrelated to any immediate change in the heat content of the water.
- At 4 C, the ES → CS density increase would be cancelled by the density decrease caused by newly freed fragments.
- Above 4 C, CS+fragments would dominate over ES, so a pulse would deliver a density-decrease pulse unrelated to any immediate change in heat.

The point here is just that the peculiar density maximum of liquid water at 4 C results from its special intermolecular structure, not from temperature. Of course, whatever the mechanism, eventually most of the EMR energy delivered to the water and not converted to an acoustic wave will remain in the water as heat, raising slightly the water temperature.

We prefer to reinterpret the FF74 observations using the icosahedral ES – CS equilibrium espoused by Chaplin (2002); however, any theory accounting for the 4 C density maximum of water would seem indifferently to support either a temperature pulse or a structural pulse as the cause of the acoustic wave demonstrated by FF74.

Thus, the dodecahedral (over 0.5 nm diameter) or smaller water structures measured by Miyazaki, *et al* (2004) or Shin, *et al* (2004) can not strengthen the FF74 hypothesis, whereas the many FF74 inconsistencies with the observed data, expanded upon below, tend to refute it except possibly at very low, "nonthermal" levels.

Structural Acoustic Hypothesis Tests

The preceding structural explanation of an EMR-created acoustical wave is meant to show that the FF74 pure-water conclusion is not necessarily correct, and that another explanation is tenable. However, the explanation also implies testable hypotheses about microwaves and water:

One test would be to examine GHz-range EMR pulses on a fine time scale.

According to FF74, the water is delivered thermal energy, some of which may be carried off by an acoustic wave. The temperature rise during a pulse is simultaneous with the density change launching the acoustic wave.

Under a structural hypothesis, as the EMR pulse continues, structural change accumulates, increasing (or decreasing) water density and thus launching the acoustic wave.

Looking at finely resolved temporal details, and assuming a water temperature away from 4 C, a structural explanation should be favored by (*a*) a density change in the water preceding the first temperature increase; or, (*b*) a dip in water temperature during the EMR pulse.

Another test would be to measure the total heat delivered to the water at 4 C and at nearby temperatures.

The FF74 hypothesis assumes that the water should show the same pulsed temperature increase at 4 C as at nearby temperatures. At temperatures other than 4 C, the acoustic wave must carry away some energy. So, the total heat delivered by the pulse should be equal or less at 4 C than at nearby temperatures, because the given temperature pulse should be attainable at 4 C with a minimum of heat input.

In a structural hypothesis, the density change follows structural energy absorption; almost all EMR energy which will be absorbed is absorbed into structural change before it becomes a density change. Thus, at 4 C, the energy which otherwise would go into the acoustic wave remains in the water: An EMR pulse should deliver more total heat to the water at 4 C than at slightly different temperatures.

A Nonacoustic, Nonthermal Direct Hearing Hypothesis

The present author's preferred explanation of microwave hearing is that the EMR causing microwave hearing interacts directly with the cochlea, for example electrically or mechanically. In doing so, this EMR directly would affect sensory elements of the cochlea, possibly the individual hairs of the hair cells. In turn, these cells, or local regions nearby, would propagate the effect through the rest of the auditory system, ultimately causing auditory nerve impulses, as would have an acoustic stimulus.

However, EMR has no anatomical basis for coherently or sequentially moving larger structures of the cochlea, such as the basilar or tectorial membrane, in the way an acoustic stimulus would. There would be no travelling wave or place specificity as would occur for a real sound; so, EMR could not produce a cochlear response equivalent to that caused by an acoustic stimulus either by bone conduction or by air conduction. Therefore, direct cochlear stimulation by EMR could not correspond to a physically possible acoustic stimulus. The EMR in effect would be uncorrelated -- randomized -- with respect to any physically possible overall cochlear response to a sound originating in the real world.

This would be why, in microwave hearing, the listener can not perceive the loudness or pitch of the "sound" very well. Also, localization of the source of the apparent sound would be poor, as is reported for microwave hearing, because the stimuli in the two cochleae, processed by the auditory system as though acoustic, in general would be random and incoherent with respect to any possible acoustic stimulus. This last might be tested by irradiating the two temporal regions of the head with EMR pulses differing by a time delay equivalent to a localization delay known effective for normal human audition.

Microwaves as Auditory Stimuli

Obviously, in microwave hearing as in normal hearing, morse code or other click-encodings are possible; and, chirpy tones have been reported (Guy, *et al*, 1975); but, transmission of speech or music has been found difficult (Guy, e*t al*, 1975, *Discussion*). Early reports of intelligible speech by microwave (see Justesen, 1974) have not been

confirmed and probably were mistaken.

Under an acoustic hypothesis, microwave hearing should permit speech or music transmission by microwave, simply by modulating pulse amplitudes (envelopes) and timing so as to synthesize appropriate bone-conducted acoustic patterns in the human head. A clever EMR transmitter system under computer control should be able to synthesize sound waves in the head from acoustic pulses, because the human head is on the large side of the acoustic diffractive range, as mentioned above.

Under a direct EMR hypothesis, microwave hearing would not be expected to permit modulation to speech or music, because temporally modulated random (direct EMR) responses would not be expected to be anything but further randomized in space and time in the cochlea. One might hope that a complicated spatial, diffraction-pattern, modulation of microwave pulses might be generated, perhaps under computer control, so as to interfere in the cochlea to synthesize time-changing patterns the same as acoustic travelling waves corresponding to speech or music patterns. The difficulty here is that the cochlea is only a few mm in size, and microwave hearing in humans has not been reported for EMR frequency content above about 10 GHz (Foster, 2000), implying a wavelength of several cm. The cochlea is on the small side of the diffractive range for microwaves even at 10 GHz. So, sound-synthesizing spatial patterns could not be resolved using EMR at wavelengths known capable of producing microwave hearing sensations.

A possibility under a direct EMR hypothesis would be to create auditory effects depending on widely spaced clicks, beyond the cochlear summation interval for EMR. For acoustic stimuli, this interval is around 200 μs (Bekesy and Rosenblith, 1951). This would suggest the possibility of transmitting very low-pitched speech or music, by modulating EMR pulses delivered at, say, one or two kHz. The voice quality would be very low, like speaking through a kazoo.

Finally, if an acoustic effect indeed were present in microwave hearing, in addition to a direct EMR effect, possibly some way of producing the acoustic effect in the absence of any direct EMR effect might make microwave transmission of speech or music feasible in very quiet surroundings.

The Underlying Thermal Problem

There would seem to be a need for improved understanding of the acoustic effects on cold water of pulsed EMR in the GHz microwave range. Whatever these effects might be, though, a temperature-induced acoustic wave only 40 dB above absolute threshold would not seem loud enough to explain microwave hearing.

Moreover, Sommer and von Gierke (1964) were able to produce microwave hearing sensations with audio-modulated electric fields, thus ruling out any possible thermal input. None of the spatial characteristics of diffractive-range EMR were present, as also pointed out by Guy, *et al* (1975), which perhaps might account for the much higher hearing threshold than was obtained by Frey (1962), who used radar pulses.

Any acoustic hypothesis depends on bone-conducted vibrations of the head and would

predict considerably higher thresholds in small-headed animals than in humans. On the other hand, a direct-action hypothesis would predict no difference, because the action would be on some commonality of the cochlear sensorium, which is about the same for all mammals. Small-animal microwave hearing thresholds have been measured equal to human thresholds within about a factor of two (Cain & Rissmann, 1978; see also Seaman & Lebovitz, 1987), so the evidence seems to favor a direct EMR action.

There must be a mechanism for microwave hearing not related to the thermoacoustic one described in FF74. The thermoacoustic explanation predominates in the review by Chou, *et al* (1982), in Erwin (1988), and in other similar papers. Swerdlow (2003) explicitly adopts a "thermal" view of microwave hearing. Many authors, even through the years following 2010, seem to have picked up the idea of a thermal mechanism from FF74, to have fixated upon this one explanation, and to have ignored other, possibly more consistent, explanations. Even worse, the thermal approach to microwave hearing has been applied indiscriminately to discredit the existence of any microwave biological effect not caused by conversion of EMR to heat. Conceptual difficulties thus have impeded progress in this field and often have led to contradictory and irreproducible findings.

We now pass from microwave hearing proper, to unrelated concepts often invoked pro or con the FF74 hypothesis.

Spherical Assumptions

In describing the microscopic level of response of living organisms to EMR, a "cell" of two or more concentric spheres, a convenience in solving the the Laplace equation, often has been assumed. This is quite unrealistic but would be justified because of the limited computational resources which were available in past years.

Assuming a sphere for a cell is an oversimplification reminiscent of the one that microwaves induce only heat, because heat can be calculated and measured easily.

The spherical cell approach was used by Drago, *et al* (1984): They simulated a multiple-shell spherical model and ostensibly found a sensitivity of such constructs to 100 Hz EMR. Foster (2000) discusses the spherical model at length, raising some partially correct questions about the Drago, *et al* conclusion. To avoid confusion of the reader, we should emphasize that the Drago, *et al* study is being cited here because of the cellular model, not because of evidence of a 100 Hz biological interaction.

Foster (2000) concluded from a spherical-cell model that the response to microwaves would be negligible. However, this conclusion seems incorrect for humans, if not for the Drago, *et al* simulation model. The underlying problem is that spherical symmetry introduces field cancellations generally inapplicable to living, multicellular organisms. The sphere cancels mathematical complexities of the problem, but it cancels biological effects, too. The only spherical cells in the human body are fat cells or perhaps some kinds of blood cell; modelled as ellipsoids, sensory or motor nerve cells would have eccentricities on the order of 10^4 or more. We introduce a new approach below, showing

how hyperpolarization even of a sphere could occur; but, for now, we address the spherical symmetry as a hindrance to be overcome.

Because of the unrealistic symmetry, we are led to assume here that, in general, spherical models must be irrelevant to the question of nonthermal interaction with human cells. However, perhaps a spherical model might be adapted to the shapes of actual living cells:

Consider a fairly straight cell process with diameter of 10^{-5} m and length of 10^{-1} m; many human nerve cells would fit this. Given the eccentricity of 10^4, one might approximate such a process by a chain of 10^4 of the objectionable spheres, each of twice the cell radius to ameliorate surface vector cancellation because of symmetry. Using Eq. (12) of Foster (2000), the capacitivity to conductivity ratio would increase lengthwise by a factor of about 10^4; radially, it would decrease by $2/2^2 \cong 1/2$. The result would be a time-constant of maybe 0.1 μs perpendicular to the long direction, but one of about 1 ms in a lengthwise direction. The membrane potentials in Fig. 6 of Foster (2000), then, would vary by some factor between 1 and 10^4, depending on direction of the EMR. So, one would expect a membrane potential between 10^{-6} and 10^{-2} V for a 1 V/m incident E field. Pulsed ultrawide band (UWB) fields may be expected to reach several V/m, so EMR-induced membrane potentials several times the normal neuronal resting levels of -70 mV should be possible. This conclusion, using the same basic model as does Foster (2000), but without the symmetry, is opposite to the one reached by Foster.

A more recent simulation of a small number of spherical cells in close proximity of one another (Sebastian, *et al*, 2001) tends to confirm these rough calculations for chained spherical elements.

Time-Domain Patterns

As mentioned above, reflections of incident EMR wave components will be found in the diffractive region everywhere near organ boundaries, especially where muscle and either bone or skin are close. For GHz-range microwaves, the medium always being absorptive, the reflected wave amplitude will be smaller than the incident, creating an oscillating, standing field with a net flow of energy into the tissue component, the polarity depending on local phases (Durney, *et al*, 1999, 3.2.12). The geometry of the resultant field essentially will be unrelated to incident frequency, except for being multiple half-wavelengths in size, but it will be fairly closely related to the geometry and tissue properties of the organism. If the incident field is moving in phase, or if the organism is moving in space, the standing patterns may be transitory, persisting perhaps for milliseconds or seconds. Under proper conditions, the time-change of the field amplitudes should be able to impose centimeter-scale, changing, diffractive spatial patterns on nerve cell receptive processes, which should cause sensory responses.

It is not our purpose to present a fully developed theory here; we wish only to lay conceptual groundwork for correct understanding. Still, let us examine the effect of these patterns in some detail, showing just how they would represent changing patterns

of membrane polarization:

Consider any membrane fragment large enough in area to contain several of the dipoles represented in the previous figures. As shown in Fig. 7 below, the membrane polarization may be represented as an electric potential difference, V, and viewed as a dipole. This dipole creates an E field perpendicular to the membrane surfaces which tends to cancel the field created by the ionic concentration differences on opposite sides of the membrane. Although other dipoles will be present in the polar fractions of membrane molecules, this dipole is the one in the membrane bulk or pores which cancels the applied voltage; it is what causes the membrane permittivity to exceed greatly the vacuum permittivity. The same permittivity increase is responsible for the increase in capacitance of an air-gap capacitor, when an insulating sheet is positioned between the plates.

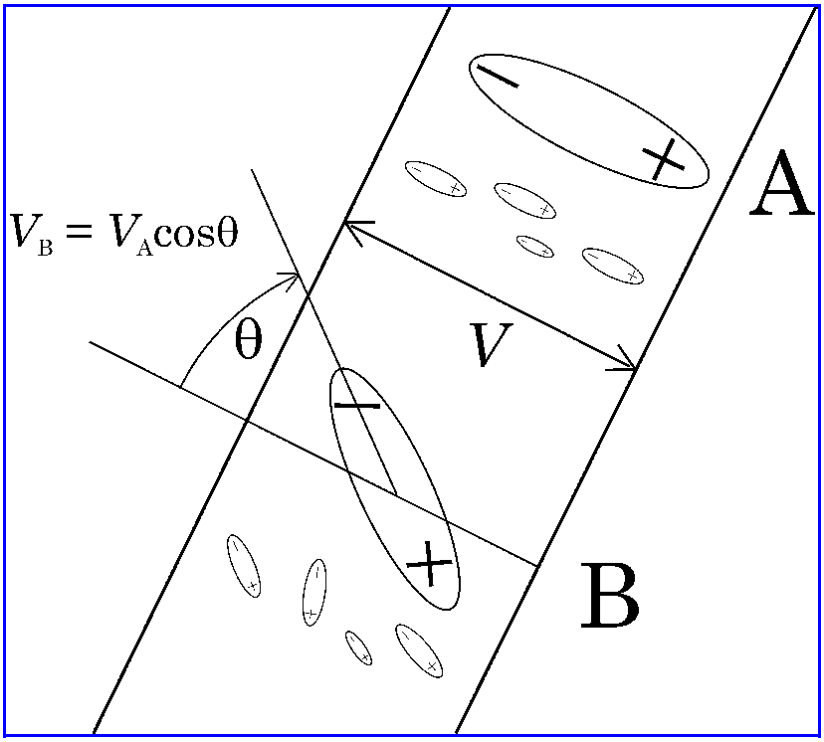


Figure 7. Hyperpolarization of a membrane by EMR. The large dipole represents a sum of smaller ones in the membrane which tend to cancel the membrane ionic potential. The dipole potential V across the membrane in A is less in B after rotation of the membrane dipoles over some angle, θ, causing a net increase in total membrane potential.

In the upper part of Fig. 7, labelled "A", the polarization in the absence of EMR is represented as because of a single dipole. The actual structure of the membrane would suggest that this dipole should be the resultant of the sum of divers smaller ones also shown schematically in the figure. Thus, the measured voltage V_T across the membrane may be represented as a sum of the ionic potential V_I and an opposing polar potential, V; therefore, $V_T = V_I - V$. If V is decreased, the membrane potential V_T will increase, so the membrane will hyperpolarize.

If we assume that the EMR frequency is reasonably low enough, some or all of the dipole(s) in the membrane will rotate almost in phase with the EMR, because a reasonably low frequency will allow the dipoles enough time to relax in the opposing forces of (*a*) the incident EMR and (*b*) the structural, or perhaps functionally active, bonds internal to the membrane. Such a rotation angle is shown in part "B" of Fig. 7.

If we also assume that biological events on the scale of such a membrane fragment

occur slowly when compared with the EMR frequency, the biology will see not the instantaneous dipole fields, but rather their time average.

Both of these assumptions will be fulfilled for EMR in the GHz range below about 10 GHz.

The rest is trivial: We represent the time averaging of the dipole potential by the absolute value of the time-average angle, which we call $|\theta|$; the value of $|\theta|$ necessarily must exceed 0, if any rotation occurs at all. The cosine of an angle always is less than 1, unless that angle is 0. Of course, rotation in either direction, clockwise as shown in Fig. 7, or counterclockwise, has the same effect of decreasing V, thus increasing the total potential across the membrane; this is the reason for the absolute value. Therefore, if incident EMR causes rotation of membrane dipoles by $|\theta| > 0$, it must hyperpolarize the membrane. This rotation eventually may generate heat in the membrane or surrounding tissue or fluid; however, such heat clearly will be incidental and will not be related directly to the hyperpolarization.

Note also that even for a membrane surrounding a spherical or (more realistic) circular-cylindrical inner space, the symmetry will not cancel this hyperpolarizing effect; rather the hyperpolarization will sum over the entire area of the membrane, provided only that the wavelength of the incident EMR considerably exceed the diameter of the inner space.

Finally, note that there will be inertial forces, and mechanical (elastic) restoring forces, not only electrical ones, that determine the extent of the dipole rotation in an incident EMR beam. The numbers can be deceptive: True, the transmembrane E field because of a resting potential of 100 mV across a membrane 10 nm wide would be about 10^7 V/m; this might suggest substantial, essentially immovable, rigidity of the dipoles. However, as pointed out in the discussion above ("EMR and the Human Body"), charges in body fluids during irradiation by EMR will be rotated as dipoles, or displaced, to cancel the forces exerted by EMR-induced potentials. So, almost any EMR E field superposing a potential in the millivolt range would be expected to be capable of strengthening an otherwise resting membrane field: The impedance of charge movement would be across the same membrane, of the same width, as was sustaining the comparable resting potential. The enormous, microscopic E field is only apparent and easily is modified by comparably microscopic events.

It should be kept in mind that hydrophobic dipoles exist in the bulk of the membrane, while membrane hydrophilic dipoles exist only at the membrane surface(s) and in the channels which control membrane functionality. So long as the average dipole moment differs in the membrane (or channel) from the fluid media surrounding it, microwaves will cause a voltage difference across the membrane, although the actual difference may vary from that to be estimated below.

Now, arriving at an opportunity for quantification, first let us look into the question of the amplitude of dipole rotation in terms of mechanical characteristics of the dipole. We want, above all, to be sure that some rotation can occur at a reasonably low EMR power density. Even a few percent change in membrane potential probably would be enough of

a hyperpolarization in a sensory nerve dendrite or end-organ to initiate a response of some kind -- a response well correlated with the presence of the EMR. It isn't hard to show this, at least within an order of magnitude:

Assume a membrane width d and a dipole molecule with charge separation $2a$ and thus with electric dipole moment $2qa$ (q = 1 unit of electric charge). Let the dipole molecule mass be m. Also assume a dipole molecule moment of inertia of $I = m(2a)^2/\kappa$, with $2.5 \le \kappa \le 12$ a shape parameter varying from spherical up to that of a thin rod. We shall at first ignore the applied EMR field strength and assume that the angular frequency ω of dipole rotation will be equal to that of the external EMR. This is meant to allow some estimate of the dipole rotational amplitude solely in terms of its mechanical characteristics.

From the above, then, the energy state of such a dipole in the membrane field E_m may be written as

$$\frac{1}{2} I\omega^2 = 2qaE_m(1-\cos\theta). \tag{3}$$

So, to estimate the average dipole displacement angle θ, we may use the formula,

$$\cos\theta = 1 - \frac{ma\omega^2}{\kappa q E_m}, \tag{4}$$

Let's assume that the dipole shape is somewhat ellipsoidal, say $\kappa = 4$, and thus approximate the volume of the dipole molecule by $V = \pi a^3$. We know that the density of water is 1 $\mathrm{g/cm^3}$, which is the same as 10^3 $\mathrm{kg/m^3}$. Assuming the effective density of a typical membrane dipole molecule to be $3/4$ that of water, we shall use 750 $\mathrm{kg/m^3}$ as the density of such a dipole. Eq. (4) then becomes,

$$\cos\theta = 1 - \frac{(750\cdot\pi a^3)a\omega^2}{4(1.6\cdot10^{-19})E_m} \cong 1 - \frac{3.7\cdot10^{21}\cdot a^4\omega^2}{E_m}, \tag{5}$$

For membrane width d = 10 nm and membrane potential of 70 mV, we have the field $E_m = 7\cdot10^6$ V/m. With EMR of 1 GHz, a reasonable range of values for the relation of the angle θ to the half-length of the dipole given by Eq. (5) is plotted in Fig. 8 below.

Looking at Fig. 8 below, there is a significant amplitude of rotation for a dipole of half-length anywhere over about 1 nm, so the idea at least of some minimal membrane hyperpolarization by dipole rotation is supported on this account.

Naturally, rotation over large angles, say $|\theta| > \pi/4$ would imply either broken bonds, and thus a damaged membrane, or rotation in a fluid; so, we shall proceed further on the assumption of a rather small angle θ.

The preceding calculation obviously leaves much to be desired: Clearly, for the cosine to be defined by Eq. (4), we must have values $0 \le ma\omega^2 \le 2 \cdot \kappa q E_m$, so there is missing at least a proper description of the effect of changing the frequency.

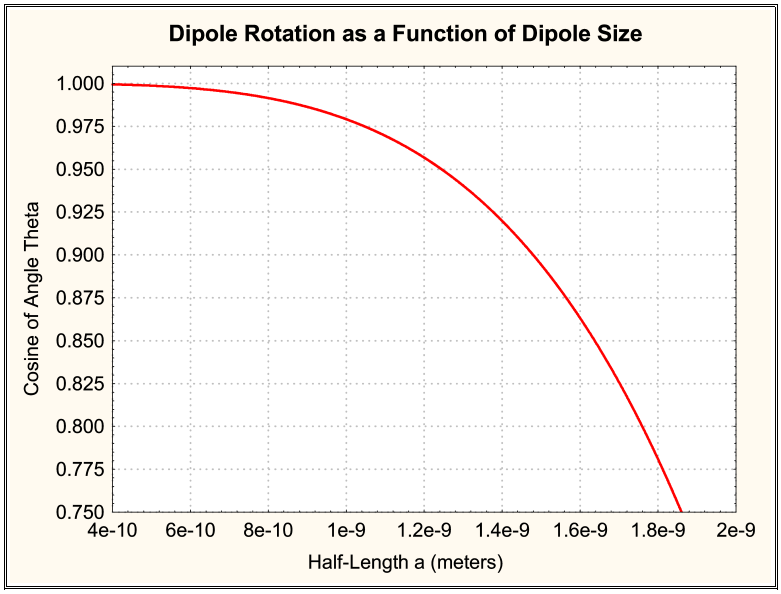


Figure 8. Mechanical response to 1 GHz EMR of a somewhat ellipsoidal dipole, according to text Eq. (5). The resting membrane electric field is assumed to be 7×10^6 V/m.

For example, to criticize the preceding calculations, an increased frequency perhaps should force segmented rotation, reducing the length and mass of the average dipole able to follow the phase of the applied EMR. Not unrelated to this shortcoming, the elastic, Hooke-like restoring forces of the dipole-matrix bonds are ignored in Eq. (5); for a given amplitude of EMR, these would reduce the average angle θ. Such restoring forces by definition are assumed small compared with those keeping the dipole together. A related difficulty in further quantification is in the local change of E_m to displacement changes in the membrane charges caused by coherent rotation of numerous dipoles. The value of E_m in Eq. (3) would be increased in a region of membrane populated by numerous dipoles, all rotated to some phase angle greater than 0, thus decreasing the rotation angle below that expected from Eq. (5) or from the equations below.

With all this in mind, let us look at the problem in terms of the EMR field strength. In the previous calculation, we took for granted that the EMR could rotate the dipole *because of* its mass, or, more precisely, because of its rotational kinetic energy. However, $F = ma$ implies $a = F/m$; and, clearly, from the left side of Eq. (3), the driving EMR must accelerate the dipole constantly. A very massive dipole hardly would rotate at all in the EMR field, meaning that $|\theta| \sim |\phi|/m$ will go to zero as dipole mass $m \to \infty$.

So, ignoring nonlinearities and other complications, let us examine this problem more closely by assuming some minimal dipole rotational amplitude and rewriting Eq. (3), replacing the mechanical energy with an expresssion for the required driving EMR energy, U_{EMR}, in number of photons:

$$U_{EMR} \equiv n\hbar\omega = 2 \cdot qaE_m(1-\cos\theta) \;\Rightarrow\; n = \frac{2}{\hbar\omega} \cdot qaE_m(1-\cos\theta)\,. \tag{6}$$

Then, again for the same ω and E_m as above, the required number of microwave photons n is given by,

$$n \;= 3.4 \cdot 10^{12} a(1-\cos\theta)\,. \tag{7}$$

This result is plotted as a set of contours in Fig. 9.

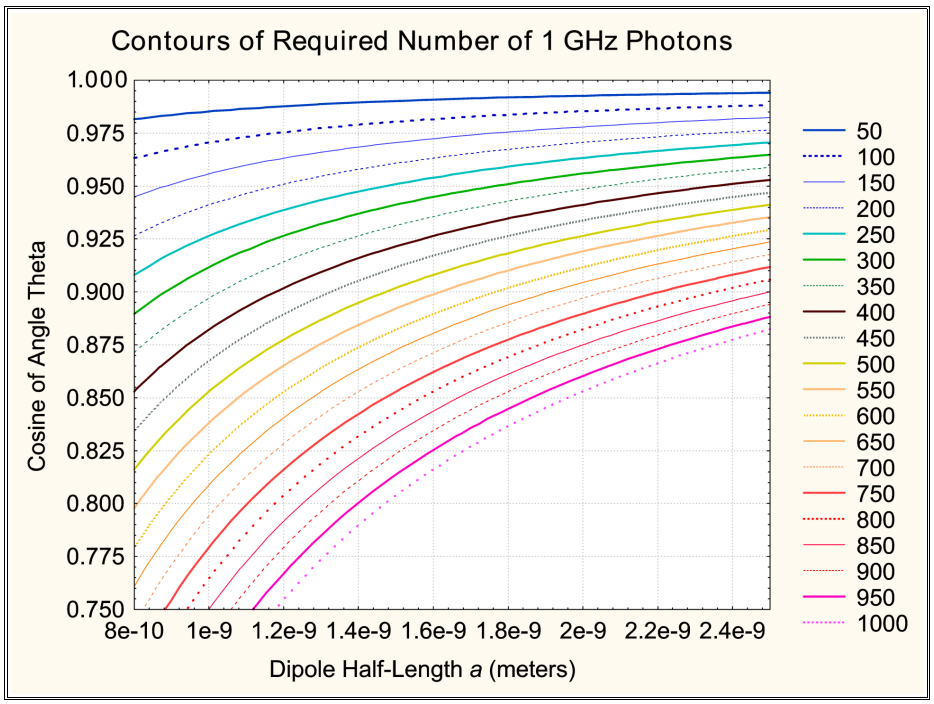


Figure 9. Number of 1 GHz photons required to rotate a dipole of half-length *a* to an angle of cosine θ in the assumed membrane electric field, as given by text Eq. (7).

Looking at the vertical axis of Fig. 9, anywhere there are contours would give a rotation angle probably capable of causing a neural or muscular hyperpolarization causing some sort of noticeable effect. However, we prefer small angles with cosine no less than, say, 0.9; so, we are restricted to about the upper third of the figure.

Looking at the horizontal axis and comparing Fig. (8), any dipole length at all in Fig. (9) probably would be consistent with our assumptions. So, something around 100 photons per dipole would be required for a 2% (1.2 degree) rotation.

We are interested in the energy delivered by the EMR per unit area, so we should restate Eq. (6) or Eq. (7) in terms of membrane area. Taking into account some ellipticity in the dipole shape, the result is,

$$U_{EMR} = \frac{3.4 \cdot 10^{12}\,\hbar\omega \cdot a(1-\cos\theta)}{(3/4)\pi a^2} \equiv \frac{2 \cdot qaE_m(1-\cos\theta)}{(3/4)\pi a^2} \cong 9.5 \cdot 10^{-13}\,(1-\cos\theta)/a\,; \qquad (8)$$

and, this is plotted in Fig. 10.

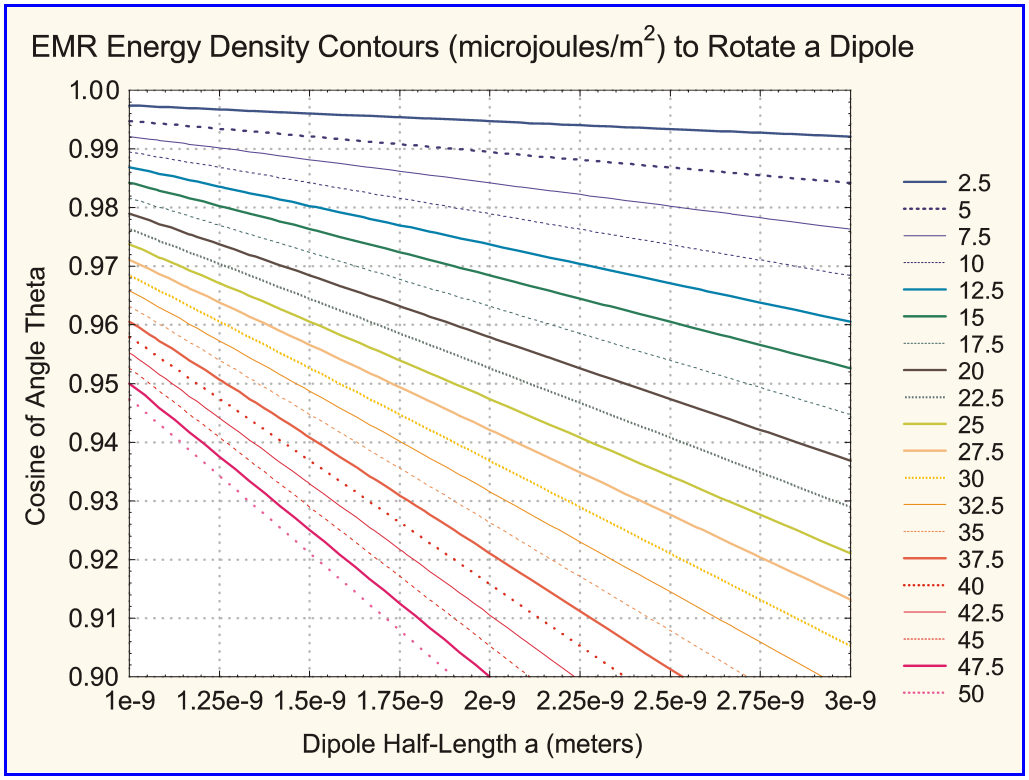


Figure 10. Energy per unit area required to rotate an ellipsoidal dipole in a membrane field of 7x10⁶ V/m by 1 GHz EMR, according to text Eq. (8).

To examine this result more closely, let's pick a dipole 4 nm long (2 nm half-length) in Fig. (10) above. The energy density required, from the figure, would be under 15 $\mu\mathrm{J}/\mathrm{m}^2$.

During successive EMR cycles, a large fraction of the energy required for rotation would be returned to the system by elastic response of the bonds holding the dipole in its membrane matrix, but even requiring that the EMR supply as much as 15 $\mu\mathrm{J}/\mathrm{m}^2$ per cycle, at 1 GHz the irradiant power would be about 15,000 W/m^2 or 1.5 W/cm^2. This could be within safe thermal exposure limits, by current national or international rules.

One final thing: Our calculations here are based on a resting membrane potential and its accompanying very high local field of some $7 \cdot 10^6$ V/m. However, during normal function, during ordinary slow depolarization or passage of an action potential, a nerve or muscle membrane may develop a much lower field, even one close to zero V/m. In these occasional conditions, incident EMR would be expected to rotate membrane dipoles over far greater angles than those calculated above. Thus, active muscle or nerve cells would

be expected to be affected more by EMR than those in a resting state. So, our calculations above are for a very worst-case membrane state -- very conservative in terms of demonstrating the plausibility of membrane polarization as an effect of EMR.

Although this entire formulation leaves plenty of room for refinement, we conclude that the results are in the range of the possible; and, the idea of polarization change by EMR dipole rotation seems tenable quantitatively, the main uncertainty depending on computational assumptions mentioned above.

This polarization change implies something very interesting in terms of the time-domain patterns of irradiation: The human skin is innervated with "C" sensory nerve fibers which mediate various tactile sensations, notably pain. These sensory processes are unmyelinated, very small in diameter, and very close to the surface of the skin. The small diameter and superficial location implies that they would require a relatively low power input to drive their membrane potentials to follow the location on the skin of moving EMR amplitude nodes or antinodes. One would expect this driving to establish spatial patterns of hyperpolarization on these sensory fibers.

It seems reasonable that dynamically changing spatial patterns of centimeter-scale standing microwave components on these "C" fibers would provide a theoretical basis for use of UWB or other pulsed radar transmitters to harass living humans and animals. However, sensations possibly caused by "C" fiber irradiation have not been studied systematically, to the present author's knowledge.

Thermal Noise and EMR

A common argument is that the random velocity of ions in solution would be some orders of magnitude greater than the velocity added to one of them even by a field of, say, 1 kV/m; therefore, all EMR effect on charge carriers in a cell or cell membrane would be drowned out in thermal noise.

Boltzmann's formula may be used to relate heat energy to the kinetic energy of molecules of mass m, by setting $kT \propto mv^2$. The energy of a microwave photon at 1 GHz is just $E = \hbar\omega \cong 4\ \mu\text{eV}$; from $\frac{3}{2}kT$, the energy of an elementary, ideal gas, particle at 300 K is about 40 meV; so, apparently, such a photon could contribute no more than about $1/10{,}000$ the energy of the (somehow conceived as ambient) temperature. This energy actually is an expectancy, and the contribution of temperature to velocity in any specific direction will be just $\frac{1}{2}kT$. Any way, the velocity added to an absorbing element by such a photon would be expected to be something around $1/100$ that of any one random, thermal collision. Thermal noise also is invoked by Foster (2000). However, there are serious pitfalls to avoid:

First, the extracellular fluids are not just filled with small ions, but also with macromolecular assemblages (Regan, 1972, p. 1) with much greater organization than the "ideal gas" on which Boltzmann's formula is based. In addition, water itself is far from a

liquid of independently moving water molecules, as has been explained above. At a given temperature, then, the thermal velocities of biologically important assemblages will be far less than the ones presented, for example, in Foster (2000). Much of the fluid thermal energy will be internal to the assemblages and will not be available to add noise to EMR-membrane interactions. Schulten (2000, p. 61), for example, remarks that "[proteins and RNA] work at physiological temperatures and thus experience thermal motion, yet their function, which requires correct alignment of parts and steering of reactions, is executed with precision."

Second, the quantification based on Boltzmann's ideal gas becomes even more inaccurate near a boundary surface or membrane, away from the central bulk of a fluid. Near any boundary in a living cell, there will be a partially screening region of high molecular correlation which separates the membrane proteins from the somewhat more gas-like bulk fluid. Drago, *et al* (1984) represented this screening by the "bound water" layer in their spherical model; it is a general property even of pure liquid water and is discussed also in Chaplin (2002). Molecular size and screening correlation both reduce the velocity of random thermal motion.

The effect of a photon on a large, relatively slowly moving structure does not fit the simple Boltzmann analysis above. For a 25 kiloDalton membrane segment or large protein molecule, the thermal speed would be just $1/\sqrt{25{,}000} \cong 1/150$ that of a hydrogen atom at the same temperature, making the expected velocity added to a constituent hydrogen atom by an absorbed 1 GHz microwave photon greater than that added by the average thermal collision.

Finally, the effect of an *E* field on a fluid is to cause a drift in the mean position of the charge in the bulk by rotating polar elements or, at low frequencies, by displacement of the mean charge. The field does not somehow have to segregate and accelerate a subpopulation of the charge carriers against a thermally randomizing background. This last highlights an underlying conceptual problem with the thermal argument: Live membranes, as discussed above, have no need for the functionality of the P-N junction of a diode to convert incident EMR into work. Such membranes operate by polarization, not by rectification. The model of a radio receiver in a living organism, making it work by detecting signals against a background of membrane noise, is completely wrong.

A reader disagreeing with the *E*-field drift statement above might try a simple experiment: Take a 9 V transistor-radio battery (approximately 10 V/cm spacing of the terminals; or, 1 kV/m) and touch both terminals briefly to the tongue; see whether random molecular motion from body heat can drown out the current flow! Of course, such a battery can supply chemically-powered current to fulfill Ohm's law of the tongue; an *E*-field in space would be loaded down substantially -- an issue completely overlooked by the random-noise argument. Nevertheless, a transmitter producing a continuous microwave output with amplitude 1 kV/m might be unhealthy for anyone nearby; if it could deliver the power, for example in the reactive near field, to maintain 1 kV/m in the bulk of a nearby human body, it might well be deadly. A cell phone held to the ear puts the head in the reactive near field of the phone's antenna; however, the field would not be anywhere near 10 V/cm (1 kV/m).

Random thermal motion simply is not relevant to microwave *E* field effects on ions in solution, unless the discussion has been limited to one concerning microwave ovens. There are at least two good reasons that a UWB microwave transmitter does not produce painful electrolysis in everyone nearby, and they have nothing to do with thermal randomization: (*a*) Duty cycle: Typical duty cycle for a pulsed UWB transmitter with peak field of 10 V/cm would be, say, 0.001. So, the (rectified) average electrolyzing potential would be about equivalent to that of a few mV/cm continuous field, producing little or no noticeable thermal or electrolytic effect. (*b*) Distance: Intensity typically falls off as the inverse square of distance. A small antenna transmitting an average of 1 W typically will be nondirectional. Even in a device held against the head, no more than about 40% of the power radiated (0.4 W) will be intercepted by the user's head (Li, *et al*, 2000). In an open area, a bystander 1 m away will intercept no more than an average of about 0.05 W from such a transmission.

However, the entire point of the present work is not that some thermal or electrolytic effects are small, but rather that the nonthermal effects of some EMR transmissions require much more investigation.

Dipole Moment Arguments

Foster (2000) defines *E*-field torque by $|torque| = E\mu\cos\theta$, with μ a dipole moment and θ the angle between the field and the dipole. Then, his Eq. (20) represents the response time constant τ for dipole alignment as, $\tau = 4\pi\eta a^3/(kT)$, in which a is the dipole element radius (membrane half-width) and η is a Stokes-law viscosity presumed to cause the interaction to be inelastic by thermal energy loss. Foster's Table II applies this formula to various biological bipolar structures, with the result that very large field strengths seem to be required for significant energy transfer to the structure. Foster reasons that only heat will be generated by such rotation because his model contains only a viscosity (dissipative) parameter.

Entirely ignoring the discussion above concerning time-domain polarization change, there are several other specific difficulties with this argument. The reasoning seems to be that if the time-constant τ above is too low, then the dipole moment must be small, so very little torque can be applied, and the mechanical interaction of the field with the membrane will be small. If the time-constant is too high, the dipole can not reorient and perhaps just scatters the EMR or is transparent to it.

EMR causes dipoles to rotate; the energy associated with the angular momentum transfer is converted from the energy of the incident photons. Dimensional analysis of the equation for τ above shows that the numerator may be seen as the product of a momentum and a distance -- which is to say, it represents a factor of an angular momentum. The distance in the numerator might be seen as a lever arm, and the momentum as that transferred at the point of application of a force. The energy associated with this momentum transfer is converted from the energy of the incident photons. For coherent EMR applied to a tissue boundary as in Fig. 5 above, there is no

reason why the resulting mechanical wave in a population of such dipoles could not exert a pressure exceeding the radiation pressure (linear momentum) transferred directly to the dipole population by the incident microwave photons.

One difficulty in the dipole-moment approach of the Foster review is that it depends on individual dipoles in what is effectively a free, gaseous state. It can not be applied accurately even to liquid pure water at room temperature, because of the inherent long-range structure of water. The free parameter η can be estimated *effectively* for water at an absorptive resonance point, but it can not be interpreted microscopically to represent the "viscosity" associated with a water molecule dipole in such a context. Thus, it can not be cited reliably in attributing either thermal or nonthermal interaction to the dipole.

Also, Stoke's law strictly applies only to constant velocities, not to perpetually accelerated, reversing oscillations; so, it should not be assumed microscopically accurate in a single-molecule context.

Another difficulty is that when Foster's adaptation of this approach is applied to large, elongated elements such as DNA molecules, they are treated as though they were rigid bodies.

In the present author's opinion, the small value of τ as interpreted by Foster probably should be read as implying only that nonthermal energy was being ignored. A better interpretation would seem to be that, with a small value of τ, the membrane dipole can rotate freely and that therefore the membrane will have plenty of time to relax while receiving mechanical free energy. This was pointed out in the section above on time-domain problems.

The argument from the time constant then depends on an EMR frequency far above that of a membrane resonance. For example, Foster (2000, Table II) gives 20 GHz as the frequency corresponding to relaxation time τ of liquid water. Therefore, EMR at, say, 5 GHz should have no difficulty rotating a water-sized dipole in a membrane by some considerable amount determined not by a constant viscosity, but by nonconstant elastic restoring forces applied to the dipole by nearby bonds in the membrane. See Fig. (5) and Fig. (7) above.

Nonthermal Causation

At this point, we turn to some evidence of specifically nonthermal biological interactions. The studies described below are selected for relevance to the theme of the present work. Because the present theme solely is a proper understanding of the fundamental physical interaction between microwaves and elements of tissue, many entirely valid biochemical and microbiological studies have been omitted; such may be found in the references of works cited, or in the reviews listed at the beginning of the present work.

To understand the variety of ways experiments are reported, it is useful to recall that for plane-wave EMR, power $P = E^2/Z$, in which E is electric field strength and Z is impedance. In SI units, P is in watts/m^2, E is in volts/m, and the plane-wave impedance of vacuum or air is $Z = 120\pi = 377$ ohms. Thus, a plane-wave EMR field of 100 V/m delivers $P = 26.5$ W/m^2 or 2.65 mW/cm^2. To determine absorbed energy, the SAR (Specific Absorption Rate) of the tissue involved must be known in the appropriate frequency range; the result usually will be a spatiotemporal average power expressed in mW/kg of tissue.

Some Evidence

Frey (1962) describes various auditory and tactile sensations including a feeling of "buffeting" of the head, and "pins and needles", when stimulating humans with audio-range pulse modulated RF between 0.4 and 3 GHz at average power density under 1 mW/cm^2. He also reports headaches from microwave exposure (Frey, 1998). For microwave hearing, as confirmed in Frey and Messenger (1973), the pulse peak power, not average power, determined the detection threshold. The Frey and Messenger auditory response apparently depended upon electronic noise or high-order oscillator harmonics riding on the pulses.

Frey (1962) estimates that in an audio noise-free environment, a human could detect this kind of transmission at power levels of 3 $\mu\text{W}/\text{cm}^2$. Frey notes that, assuming that the auditory system responds to EMR reduced already by a factor of ten by absorbance of the surrounding tissue, the auditory receiving-site input would be equivalent to about 300 nW/cm^2, a sensitivity within one order of magnitude of that of a 1960's vintage broadcast radio receiver. This of course includes any possible macroscopic antenna-like functionality of the body parts as described above. Ingalls (1967) writes that he was able to confirm Frey's thresholds approximately.

Directly demonstrating a nonthermal, not even biological, effect of EMR is the report by Sharp, *et al* (1974), who used GHz-range, pulsed radar to show that certain ordinary materials, such as crumpled aluminum foil or microwave-absorbing foam rubber, could emit sounds audible to nearby human observers. The Sharp, *et al* pulses were around 10

μs wide, and their power at audible threshold was around 50 mW/cm^2 per pulse. These values are below those of Frey and Messenger's (1973) or FF74's typical microwave hearing parameters, even though the Sharp, *et al* sounds were being heard through the air some distance from the listener's head. Because aluminum metal reflects or scatters almost all the power of an incident pulse, it can not easily be argued that expansion because of absorbed heat accounted for the sounds under this condition in their study. Various sizes of object were tried, down to a few mm on a side (see also Justesen, 1974); Sharp, *et al* therefore would seem to have eliminated acoustic geometrical resonance (*cf.* of the head) as responsible for the sounds. These authors calculate that radiation pressure (linear momentum of the microwave photons) could explain their results.

Guy, *et al* (1975) reported having confirmed the Sharp, *et al* observations approximately; they studied the effect closely with microwave-absorbing coatings on plastic discs. They concluded that acoustic waves in the discs showed higher pressures than those calculated from the momentum of the microwave photons applied. This is hardly surprising, because photons, being massless, necessarily deliver the minimum possible momentum per unit energy. So, any form of energy, thermal or not, converted by the discs from EMR, would permit of the possibility of pressures higher than the radiation pressure. What is important is that only random momentum can accompany random energy (heat); so, all truly thermoacoustic materials must provide structure which randomizes the momentum delivered, whether linear, or angular, or both.

The *E*-field experiments such as those of Westerhoff, *et al* (1986) and Sommer and von Gierke (1964) provide important data at the low-frequency extreme of the EMR spectrum. Slowly varying *E* fields are similar in effect to low-frequency EMR irradiation. The *E* field provides a potential in which tissue will have time to remain relaxed in its lowest energy state, and in which current (charge carriers) will be flowing with differentially slow rate of change over almost all the time of a laboratory measurement. EMR of very long wavelength has a similar action; but, as frequency approaches the microwave region, the wave nature of the EMR photons begins to dominate the effect. As the gigahertz range is approached, we enter the diffractive region for humans. Sommer and von Gierke found *E*-field hearing thresholds far above those of Frey (1962); however, they did not use EMR stimulation, so the spatial interactions with tissue would be expected to be less than in the Frey studies. One should note that Ingalls (1967) writes that he could not produce auditory sensations with electrostatic fields alone.

Sanders and Joines (1984) used heat-stressed rats with and without application of continuous (unpulsed) 591 MHz EMR at less than 15 mW/cm^2 to the animals' heads. Unpulsed presentation eliminated any possible thermal rate contribution. They found that the EMR had no measurable effect on body temperature, but that it caused dramatic depletion of brain ATP and related neural energy stores, beyond that normally caused by increased metabolism during hyperthermia. They concluded that microwaves can reduce brain metabolic rate. Presumably this would imply impaired brain function, although rat behavior was not measured.

Microwaves have been found to cause cellular heat-stress responses far more easily than other kinds of stress -- including stress caused by heat (M. Blank, in Sage &

Carpenter, 2012, Section 7).

Generalizing on the cellular commonality shared among insects and humans, Panagopoulos and Margaritis (2002) exposed fruit flies to GSM (~900 MHz) cell phone radiation at very low levels for just six minutes per day during the several days it takes such flies to hatch from newly-fertilized eggs. The levels averaged between about $7\,\mu\mathrm{W/cm^2}$ and under $3\ \mathrm{mW/cm^2}$. The exposed groups in their adult life showed a loss in reproductive activity varying between 15% and 60%, depending on estimated irradiance. The authors conclude that GSM radiation may be capable of serious biological damage to human cells. While the theory proposed by these authors is not compatible with that proposed in the present work, their data may be taken to validate an interaction consistent with a nonthermal theory.

Lu, *et al* (1999) applied spark-gap generated UWB microwave pulses to rats at too low an average level to cause thermal effects and found that the blood pressure dropped reliably; heart rate was not affected. The peak fields were close to 100 kV/m; but, with 1 ns pulse width and only 500 to 1,000 pulses per second, the duty cycle was just 0.5 to 1.0 $\times 10^{-6}$. So, the average exposure was less than 0.3 mW/cm^2, delivering only an estimated 100 mW/kg rat body mass, well below recommended safety limits based on thermal effects only. The exposure was for one six-minute period; the pulse shape given in the paper shows frequency components above 5 GHz, corresponding to wavelengths of a few cm in air, easily in the diffractive range for a rat's body. Lu, *et al* calculated that their microwave pulses were below microwave hearing threshold for the rat, based on the threshold power summation law ("Bunsen-Roscoe law") common to all sensory organs; the summation had been observed for microwave hearing by Frey and Messenger (1973), Guy, *et al* (1975), and others.

The Lu, *et al* drop in blood pressure persisted at least for several weeks, indicating a long-enduring or perhaps permanent effect. The blood pressure effect, as well as Frey's (1962) report of "pins-and-needles", is entirely consistent with loss of smooth muscle or nerve function caused by standing patterns of microwaves. Because migraine headache may be caused by dilation (reduced depolarization of muscle cells and thus loss of smooth-muscle tonus) of arteries in the scalp (Berkow, 1987, p. 1355), Frey's (1998) headaches and Lu, *et al*'s blood pressure drops may very well share a common cause.

Hocking and Westerman (2001) reported an incident in which the head and upper body of a worker inadvertently were exposed to ~850 MHz digital (pulsed) communication tower microwaves at average levels well below thermally-based safety limits. The exposure lasted a couple of hours; it caused general malaise and measurable dysfunction of the central nervous system, as well as neurologically confirmed, long-lasting loss of tactile sensitivity of the facial skin, the loss being most marked for sensation mediated by "C" fibers. The worker recovered gradually over a period of months.

More recently, Salford, *et al* (2003; see also Adey, 2003) have reported anatomical changes in rat brain caused by two-hour exposures to continuous 915 MHz microwave irradiation. Apparent neuronal degeneration in localized brain regions was

demonstrated at irradiances of around 1–10 $\mathrm{mW/cm^2}$, far below any threshold of harm based on a thermal argument. Salford, *et al* observed an apparent breach of the rat blood-brain barrier and suggest that the neuronal damage may have resulted from it. These results have not yet been replicated under circumstances studying EMR diffraction by the rat's anatomy and the confining cage.

In a double-blind analysis of variance experiment, Zwamborn, *et al* (2003) found that 2.1 GHz EMR, simulating digital base-station transmissions (UMTS/3G protocol) at a maximum field strength of 1 V/m, significantly bothered certain persons either representing themselves as "electrosensitive" or not, but that other protocols (GSM at 900 or 1800 MHz) had no discernible effect. Several reaction-time tasks apparently were facilitated by RF irradiation. It seems reasonable to assume that facilitation of simple tasks would have been because of selective neural hyperpolarization of inhibitory processes, most of the brain having an inhibitive function. Zwamborn, *et al* conclude that their effects were nonthermal.

Some Implications

By Fourier transform theory, temporally narrow pulses imply wide frequency bands; and, wide frequency bands require high-frequency components with sharply defined spatiotemporal features. So, for standing patterns, wide-band microwaves would be associated with relatively sharp spatial patterns on organ boundaries. Briefly sustained sharp spatial patterns would affect nerve and muscle in a way equivalent to sudden temporal changes such as action potentials, as pointed out in the discussion of Eq. (1) above.

If we assume that nonthermal interactions only cause changes in membrane polarization at cell boundaries, then we can explain *microwave hearing* as perhaps a combination of thermal (FF74) and nonthermal effects ultimately causing a response in the cochlea. We also can explain Frey's (1962) anecdotal report of tactile sensations, some reports of radar harassment, and even reports of therapeutic sexual stimulation (*e. g.*, Gorpinchenko, *et al*, 1995). We easily can explain the findings by Lu, *et al* (1999) and Hocking and Westerman (2001).

In a phenomenological review, Hyland (2000) has speculated that nonthermal interactions might depend strongly on individual differences, this being a reason that clear effects have not yet been reproducible or recognized more widely. This does not apply to *microwave hearing*, which has been universally and easily reproducible; no one in the modern peer-reviewed literature has denied that it could be caused reliably by pulsed microwave EMR.

Hyland's suggestion is supported by the present approach: Simple individual differences such as size of head, length of limb, or volume of stomach or lungs would be dominant under the assumption that spatial interactions with organ boundaries determined the nonthermal effects. In addition, reproducibility in past studies may have been inhibited by misunderstanding of the basic physics of the interaction of microwaves with tissue, a problem hopefully solved in the present work.

Cancer

On a macroscopic scale, it is not obvious how microwaves could damage the self-repairing genetic material of body cells more severely than the nongenetic material, if their effect solely was because of diffraction at tissue boundaries.

Ionizing radiation, such as ultraviolet light or gamma radiation, has wavelengths below one micrometer, well below the microwave domain. Each ionizing photon or charged particle damages anything with which it interacts. This damage to cell material occurs at random and may be permanent, occasionally selectively damaging genetic material in a way putting the cell irreversibly into a cancerous state.

Microwaves span thousands of cells with a single wavelength, the *E* fields rotating dipoles and setting up alternating electrical currents. Presumably, a dipole rotation which broke, rather than merely stretched, the bonds holding the dipole would damage the protein or other molecule involved, as well as the membrane holding it.

As already mentioned, EMR parameters distinguishing mere hyperpolarization from damage have not been studied well, mainly because of thermal confusion; and, thus, they can not be described here. The same or higher EMR irradiance damaging membranes presumably would cause destructive heating or local electrolysis. In terms of tissue or organ boundaries, or diffraction, then, it would seem that a microwave current which damaged the genetic material also would damage everything around it, too, leaving little for the damaged genetic material to use for cancerous proliferation.

But, there are different inferences which are possible: On a microscopic scale, EMR might cause cells to become cancerous by direct action on dipole elements in protein molecules. A protein may shift between metabolically active and inactive states merely by a small refolding. The dipoles in any molecule as complex as a protein will be irregularly distributed. So, inserting energy irregularly throughout such a protein might cause it to change its folding state -- its conformational state -- as has been shown at very low frequencies by Westerhoff, *et al* (1986). The conformation depends heavily on hydrogen bonding, just as does the structure of water. The barrier to a protein conformational change would be the stretch of a bond by a few bond-lengths (Bruscolini & Pelizzola, 2002). Su and Heroux (2012) studied 60 Hz fields within cell-culture equipment and warned of this kind of interaction, citing several studies showing modification of cell development caused by such fields. Because of the possibility of field-induced conformational changes, according to a British *Telegraph* newspaper report, an Italian court has ruled that prolonger daily use of a cell phone was the cause of a brain tumor in one individual (Alleyne, 2012). The same report also mentions that the World Health Organization (WHO) has classified mobile telephones as Class B carcinogens. Some fairly firm evidence that prolonged cell-phone use can increase the probability of leukemia in children is presented in various reports editted by Sage and Carpenter (2012) -- notably in their entire section 12.

However, why should not such subcellular changes also just as likely reduce the cancer

rate (relative to diseases of other kinds)? Yes, microwave EMR *might* activate certain enzymic changes possibly increasing the cancer rate; however, more specific hypotheses about oncogenesis should be formulated before such changes were to be linked meaningfully to EMR exposure.

Vehicle Safety and Cell Phones

Rothman (2000) suggests that cell phones should be elevating the death rate from auto accidents far more than the rate from cancer. In view of the effect of some pulsed microwaves on blood pressure (Lu, *et al*, 1999), one should hope for caution in introducing wideband cellphones into automobiles: They might trigger fainting or some other brief, unnoticed loss of consciousness at the wheel. Many more recent reports of increased auto accident rate because of cell phone use simply depend upon distraction; however, one factor in this distraction would be, of course, effectiveness of the brain function while driving. Also, even a brief reduction in blood pressure to the brain may cause mild stroke (transient ischemic attack) in a vulnerable individual (Berkow, 1987, p. 1382). Accidents from the EMR of wideband cell phones, so far as known to the author, can not currently be distinguished from accidents of inattention or sudden, presumably EMR-unrelated, illness.

The exact mechanism of the blood pressure and headache effects described above requires elucidation: A handheld device emitting narrow pulses at 10 kV/m near the antenna tip might deliver a localized field intensity equal to those of Lu, *et al*'s experiment, if held against a (diffractive) human head.

Tinnitus

Microwave hearing resembles tinnitus, a symptom of cochlear damage. Tinnitus is a sensation of a hissing, buzzing, or sizzling sound in the head (Meikle, *et al*, 2000); it may be intermittent and triggered by a loud noise. Inner-ear electrical abnormalities may accompany tinnitus (Mayo Clinic, 2001). The sometimes-identifiable pathology has been reviewed by Lockwood, et al (2002).

It seems certain that some cases of tinnitus, especially if intermittent, actually must be reports of microwave hearing. The present author is not aware of any documented, diagnosed case of tinnitus later found to be microwave hearing. However, a systematic field investigation at several locations in Germany, including some blinded trials, has reported that a variety of tinnitus-like symptoms were mitigated by shielding the head with aluminum foil but not with paper (Mosgoeller and Kundi, 2000).

Keeping in mind the possibly harmful side-effects, perhaps a study of microwave hearing in tinnitus patients would reveal special vulnerabilities in such persons. Such a study might lead to insight permitting amelioration of the tinnitus, or possibly to new diagnostic techniques.

Summary

We have indicated the importance of being able to investigate meaningfully, and thus resolve, claims of misuse of EMR in ways harmful to humans. We enumerated several of the current political problems hinging on the success of such investigations.

We then stepped back and examined the basics of EMR biological interaction, reviewing how EMR can cause temperature to rise in tissue. We pointed out that there must be nonthermal interactions at a cellular level at all tissue or organ boundaries. We also pointed out a second, diffractive, antenna-like interaction on the scale of the gross human anatomy. To lay groundwork for subsequent criticism, we explained some peculiarities of the structure of liquid water.

We presented the FF74 hypothesis, which describes microwave hearing purely as a thermoacoustic effect. We showed that, based on vibrations of the human head, this hypothesis could account for microwave hearing only slightly above absolute detection threshold. We showed that a study by Gournay, cited by FF74, did not independently support the hypothesis.

We pointed out that the crucial phase reversal at 4 C in the FF74 experiment did not necessarily demonstrate that a temperature pulse was occurring. We showed that a structural explanation of the phase reversal was possible and could be tested empirically. We then presented a complementary nonacoustic hypothesis of microwave hearing which assumed direct EMR interaction with the cochlea and which better fit the data than did the FF74 hypothesis.

Generalizing our criticism, we then addressed several basic misconceptions in the literature of bioeffects of microwaves. These included the use of a spherical model of a living cell, ignorance of time-domain patterns on tissue boundaries, invalid invocation of thermal noise arguments, and incomplete understanding of the meaning of an electric dipole on a boundary as opposed to one in the bulk of a fluid cavity.

Having come to the end of the criticism, we next listed several reliable experimental results demonstrating clear biological effects not explainable in terms of a thermal or thermal rate mechanism.

Finally, we elaborated a few implications of the nonthermal mechanisms presented, including possible effects related to cancer, to vehicle safety, and to the microwave-hearing-like auditory symptom, tinnitus.

Conclusion

Bothersome or unhealthful effects of EMR within thermal safety limits have been demonstrated empirically and are supported theoretically. The microwave spectrum in certain bands, or under certain conditions, probably should be treated more like a pharmacist's shelf than the temperature knob on an oven. Decisions as to safety should be steered by persons more knowledgeable in medicine than has been the case in the past.

A particular worry, in light of the political controversy at the start of the present work, is that the widespread miscomprehension of biological effects of EMR implies that misuse of microwave devices can not be identified reliably by examination of a purported victim. Means do not exist, based on forensic evidence, for prosecuting malicious misuse causing distress, pain, injury, or death.

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EUROPEAN COMMISSION
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SCIENTIFIC COMMITTEE ON TOXICITY, ECOTOXICITY AND THE ENVIRONMENT (CSTEE)

Opinion on

Possible effects of Electromagnetic Fields (EMF), Radio Frequency Fields (RF) and Microwave Radiation on human health

Expressed at the 27th CSTEE plenary meeting

Brussels, 30 October 2001

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Background

The Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) was requested to prepare an update of the opinion (1) of the Scientific Steering Committee (SSC) on health effects of electromagnetic fields (EMF) dated 25-26 June 1998, which endorsed the guidelines published by the ICNIRP (International Commission on Non Ionising Radiation Protection) and served as a basis for the Council Recommendation of July 5, 1999, which limited the exposure of the general public to EMF.

The request derived from the increasing exposure to EMF consequent to the further growth in the use of electricity from the continuous development of the telecommunications industry and to a rapid increase in the installation of transmitter masts used as radiotelephone base stations. These transmitters are frequently sited close to houses, business premises and schools, and therefore an increasing proportion of the public is chronically exposed to ELF fields and RF. Moreover, the visibility of such masts has heightened the public concern about the risks from electromagnetic radiation. This is a complex field from a research viewpoint.

EMF cover a wide range of frequencies (0 Hz – 300 GHz) (Annex 1). In a discussion of their sources of exposure, and of their potential harmful effects, it is customary to distinguish between extremely low frequency electromagnetic fields (ELF) and radiofrequencies and microwaves. The present report deals with ELF (1 Hz – 1 kHz), RF (1 MHz – 1 GHz) and microwaves (1 GHz – 300 GHz). In addition to domestic, industrial and medical electrical appliances and devices, the high-voltage overhead transmission lines (and to a lesser extent underground cables) are a major source of exposure to ELF in the environment. The ELF frequency band is limited to 50 Hz in Europe and to 60 Hz in North America. The RF and lower microwave frequencies are of particular interest for broadcasting, mobile telephony. The 2.45 GHz frequency is mainly used in domestic and industrial microwave ovens.

The CSTEE was asked

> *"… to provide, in the light of new knowledge and developments in technology and applications of sources and practices giving the exposure to electromagnetic fields, an update of the opinion delivered in June 1998 on:*
>
> *A. Non thermal, long term health effects of exposure to EMFs in particular addressing epidemiological evidence and also biophysical and biological evidence on genetic and carcinogenic effects, effects on the immune and circulatory system and effects on the nervous system affecting or local part of the body or general behaviour of people exposed. The opinion should indicate whether any new recommendations for exposure limits can be made.*
>
> *B. Whether for thermal and non thermal effects, the technical annex for the Council Recommendation[1] setting up basic restrictions and reference levels limiting the exposure to non-ionising radiation and based on the guidelines published by the International Commission on Non-Ionising Radiation Protection is still the appropriate scientific basis for a system of health protection against risks from non-ionising radiation".*

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[1] OJ N° L 199/59 dated 30.07.1999

In order to reply to these questions, the CSTEE appointed a Working Group that included members of the CSTEE[2] as well as external experts[3] and Members of other scientific committees of the Commission[4]. The Working Group met on June 13, September 10 and October 18, 2001. It was decided to first address question A, *i.e.* to evaluate whether scientific findings, resulting from new investigations on non thermal effects of electromagnetic fields should lead to changes of the scientific evaluation underlying the June 1998 SSC opinion. Given the availability of a number of excellent scientific reviews of previous studies, the WG used these as a principal literature source upon which to elaborate its own conclusions.

Since the present report aims at giving a basis for an update of the 1998 Opinion of the Scientific Steering Committee, emphasis is given to issues for which there is new information. Thus, acute thermal health effects – which have been well established for the high frequency class of EMF – are not dealt with in the present report.

Expert Reviews (3-9), were utilised along with the scientific literature on specific subjects (*e.g.* neurobehavioral changes). Given the questions that have been posed to the CSTEE, the focus was on any finding with the potential to induce a reconsideration of the exposure limits recommended in 1999. Epidemiological studies aimed at identifying associations with cancer risks were discussed in depth. In interpreting epidemiological findings, reference was made to the classical criteria suggested almost 40 years ago by Austin Bradford Hill (see below).

Given the possibility of different mechanisms of action, separate consideration was given to two circumstances, *i.e.*:

- exposure to extremely low frequency electromagnetic fields – ELF, *i.e.* up to 50-60 Hz, emitted by overhead and underground power lines and cables and certain electrical domestic and industrial appliances, and

- exposure to intermediate, radiofrequency and microwave frequencies from 1 kHz up to 300 GHz, emitted by sources such as visual display units, television sets and induction heaters, RF heaters, mobile phones, radio and TV broadcast, microwave communication and domestic and industrial microwave ovens.

The ICNIRP guideline for 50/60 Hz electric and magnetic fields is based on a maximum current density in the body of 10 mA/m². This results in the ICNIRP reference levels for the general public of 5 kV/m and 100 µT for the electric and magnetic field respectively.

[2] Prof/Dr. B. Terracini (WG chairman), J. Vos and C. Lambré
[3] A. Ahlbom (Karolinska Institut.Se), G. Decat (VITO.Be), J. Joussot-Dubien (Laboratoire PICOM.Fr) and C. Roy (WHO.CH)
[4] M. Maroni (SCP), W. Klein and V. Silano (SSC)

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The following table roughly summarises the underlying effects of static, ELF, RF and microwaves which possibly could induce a biological change.

Frequency	**Mechanism**	**Unit of deposition**
Static magnetic field 0 Hz	Magnetic induction and magnetomechanical interactions	
ELF 30 Hz – 300 Hz ELF	Current induction in body	$A/m^2 = H_{A/m} \times f \times$ Body length
RF & microwaves 0,1 MHz – 10 GHz	Energy deposition	SAR in W/kg
10 GHz – 300 GHZ	Surface tissue heating	Power density W/m2

SAR = Specific energy Absorption Rate
A= Area
H = field strength

Interaction of electromagnetic fields with biological systems

A major determinant for the induction of current or heat (energy) in a biological or non-biological system is frequency. The unit of deposition is current density (A/m^2) which depends on the field strength (H in A/m), the frequency and the body length. Exposure to ELF does not result in a deposition of energy in the body, whereas exposure to RF and microwaves, (such as 900 MHz and 1800 GMS-radiation etc.) does. The measure of the energy deposition or absorption in the body is the SAR. The energy of all electric, magnetic and electromagnetic fields is orders of magnitudes below that of ionising radiation.

Whereas ionising radiation produces biochemical effects such as breaking covalent chemical bonds, generation of ions and other reactive chemical species, the primary consequence of the interaction of electromagnetic fields with biological systems is likely to be the induction of currents. These may invoke the formation of electric dipoles and/or the reorientation of dipoles already present. With cellular and animal systems no consistent relationship has been found between effects and either time varying or varying field strength at frequencies below 100 kHz and current density at or below 10 mA/m^2. At these levels of exposure, indeed, heat deriving from absorption of electromagnetic energy is well below that due to normal metabolic processes.

Austin Bradford's Hill criteria for causal inference

Most epidemiological studies on the effects of EMF on humans are observational in nature, which renders problematic the assessment of causality. In a classic essay (2), Austin Bradford Hill laid down a series of criteria useful in drawing a conclusion as to whether a relationship between an alleged cause and an effect expresses causation or merely an association. With the exception of the first criterion, none of the others is a *sine qua non*. The hypothesis of causation become stronger as the number of fulfilled criteria increases. The criteria are:

- Strength of the association, commonly expressed in terms of relative risk, *i.e.* the factor by which the probability of developing the disease is increased in the exposed over the non exposed population groups. An indicator useful in [illegible]ble risk, *i.e.*

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the proportion of cases caused by the exposure (either among the exposed or the general population).

- Consistency of results between independently performed studies.

- Specificity of the association (although it has become obvious that the rule "one cause – one effect" is hardly applicable for conditions with a multifactorial aetiology).

- Temporal relationship (exposure must precede the effect, taking into account the latent period of the condition).

- Biological gradient, *i.e.* a dose-response effect.

- Biological plausibility, *i.e.* whether it is reasonable to postulate that the cause acts through a mechanism which corresponds to biological knowledge of the adverse effects of the agent.

- Coherence of the cause-to-effect interpretation with generally known facts on the natural history and biology of the disease.

- Reproduction of the condition experimentally (either in animals or in man).

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Radiofrequencies and microwaves (RF)

As stated above these are emitted from sources such as visual display units, television sets, AM radio, induction heaters, mobile phones, etc. The primary literature reviews of effects used for the preparation of the present report were the "Stewart Report" (3) published in 2000 and Elwood's review (4) of the epidemiological studies, which was published in 1999 and later extended to early 2001 in order to identify an exposure standard for Australia (5). To the knowledge of the CSTEE, no additional relevant findings have been reported subsequently. The CSTEE did not identify any major reason for dissent from these reviews with regard to either exhaustiveness of reported scientific observations or the interpretation of scientific findings.

Particular attention was given to the sections regarding the biological end points specifically mentioned in the questions asked to the CSTEE, *i.e.* effects on the immune and circulatory system, on the nervous system, on the general behaviour of exposed people as well as experimental and epidemiological studies investigating carcinogenic risks. Conclusions reached by the CSTEE on each of these areas are summarised below:

1. Immune system: thermal levels of RF exposure elicit both stimulatory and inhibitory responses in components of the immune system. These effects were generally found to be transitory, returning to normal levels following termination of exposure. No consistent effects of low level RF exposure have been reported on blood forming and circulating blood cells or on immune responses.

2. Heart and blood pressure: With the exception of a well designed but small study (which therefore requires confirmation in larger and independent investigations) reporting early effects on blood pressure in volunteers exposed to a conventional GSM digital mobile phone position close to the head, available findings provide no consistent evidence of an effect of mobile phones on the heart and circulation.

3. Nervous system: In the absence of heating, evidence for changes in neuronal excitability, neurotransmitter function and innate and learned behaviour, and for changes in the blood-brain barrier has been inconsistent and unconvincing. Extrapolation from laboratory studies in rats to humans is problematic because of the differences in the pattern of RF energy deposition between rodents and humans. Furthermore, in contrast to humans, rats have the capacity to perceive RF as sounds, which is likely to influence their reactivity. Some studies have suggested an effect on membrane proteins, and on the flux of calcium and other ions across the membrane of neurons and EEG rhythms but these are not reproducible.

4. Neurobehavioral effects and effects on driving: Relevance of experimental studies to man is uncertain because of interspecies differences in the perception of intense pulsed RF fields. Studies on the acute effects of mobile phones on human volunteers have shown some neurobehavioral changes (such so-called neurobehavioral effects are mostly reporting of subjective malaise), the mechanism of which might include a localised heating effect. The interaction between electromagnetic fields and drugs has not been adequately investigated. The main effects of the use of mobile phones on driving are attributable to diversion of the attention.

5. Ocular effects: The eye is a potential target organ of RF and microwave energy because it is not protected by the bone. Electric activity is part of the retina function and therefore objects placed in front of the eye may act as "heat sink" for thermal effects [illegible] make up the bulk of the lens have a limited capacity for repair following insult.

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The literature on the ocular effects of microwaves in laboratory animals (including monkeys and rabbits) is extensive, but experimental designs are difficult to reproduce and results are still controversial. Marked interspecies differences have been noticed. Lens cataracts has been produced after exposure to very high frequencies, but it is not clear whether or not the effect is due to thermal changes. Thus, the relevance of current knowledge to human risk, in the absence of thermal effect, is very limited.

6. Observations in humans regarding health outcomes other than cancer: No consistent evidence of effects on humans has yet been derived from formal epidemiological studies. This cannot be taken to mean that RF and microwaves do not pose any hazard to human health. Most formal epidemiological studies have focussed on the occurrence of cancer.

Among people exposed to radiowaves or otherwise exposed to electromagnetic fields, there have been case reports or reports of small series of cases of subjective symptoms (fatigue, stress, sleep disturbances, depression, burning sensations, rashes, muscular pain, ear, nose, and throat problems, as well as digestive disorders etc.) in individuals that have been characterised as "hypersensitive". The symptoms described seem to affect a limited number of persons but as yet there are no reliable estimates of the frequency of its occurrence. Almost nothing is known on the role of conditions of exposure (frequency, concentration, duration etc.). Limited studies on volunteers found no connection between reported symptoms and exposure to electromagnetic fields. It is therefore very difficult to ascertain whether these are true effects.

7. Genotoxicity: An overview of *in vitro* genotoxicity data, subjected to a weight-of-evidence evaluation (6) concluded that there are no strong indications that electromagnetic fields between 30 MHz and 300 GHz cause DNA damage. Where effects were found, they were attributable to hyperthermia. Despite minor inconsistencies in the literature, it is concluded that, *in vivo* and *in vitro* experiments on the induction of *micronuclei*, SCE or chromosomal aberrations did not detect any effect. Cell transformation assays of radiofrequency field exposure are difficult to interpret because of technical difficulties. There have been reports of DNA fragmentation and on effects on nucleic acid synthesis, which could be relevant to malignancy, but these have not been confirmed independently and are subject to much controversy. The possible interaction between electromagnetic fields and physical or chemical mutagenic or carcinogenic agents represents an interesting hypothesis, which has not been yet sufficiently investigated.

8. Experimental carcinogenesis: The possible carcinogenicity of RF has been investigated in a number of experimental systems. Results have been essentially negative. Original observations of a possible promoting effect on mammary carcinogenesis in mice were not confirmed in subsequent studies. An interesting observation is that of Repacholi *et al* (7), who induced a two-fold increase in lymphoma incidence in a strain of lymphoma-prone transgenic mice (E mu-Pim1) following exposure (1 hour daily for up to 18 months) to plane-wave fields of 900 MHz with a pulse repetition frequency of 217 Hz and a pulse width of 0.6 ms (7). As yet, the open literature has not reported any replication of this finding. It is therefore concluded that it provides inadequate evidence of experimental carcinogenicity.

9. Effects on melatonin production: Recent studies on human volunteers and well-designed studies in mice have not provided any evidence of an effect of EMF on this endpoint. There is no support to the hypothesis that a decreased production of melatonin might interfere with mammary carcinogenesis either in women or in animals. Thus, relevance to long-term effects seems negligible.

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10. Epidemiological studies on the association between RF magnetic fields and human cancer: A number of studies which address three circumstances of exposure: the workplace, the residence close to RF emitters and the use of mobile phones have been published. These have been reviewed in the "Stewart's report" (3), by Elwood (5) and by a Working Group assembled by the Canadian Royal Society (8).

Overall, the epidemiological evidence of RF and microwaves does not suggest consistent cancer excesses. Some studies were very large (*e.g.* the "Motorola study" included 200.000 subjects followed up for a total of approximately 2 million person year-risk).

Thus, for the time being, epidemiological studies on the association between cancer and RF do not indicate any need for reconsidering the exposure limits that have been set a few years ago. This is consistent with the lack of evidence of genotoxic effects believed to be associated to the process of carcinogenesis.

Nevertheless, the need for additional epidemiological surveillance is suggested by some limitations of the studies that are currently available: **i.** the relatively short period of observation compared to the potential latent period of long-term effects; **ii.** the use of proxies (*e.g.* distance from putative sources, extent of use of cellular phone, etc) in order to estimate individual exposure which may be unreliable and could artificially lower risk estimates and **iii.** low statistical power of analyses indicating lack of association.

Extremely low frequency fields (ELF)

The major concern regarding ELF derives from recent reports raising the question as to whether 50/60 Hz magnetic fields might induce cancer in man. A comprehensive review of the available literature has been the so-called "Doll's Report"(9) published early in 2001. This has been a major source of information for the CSTEE. In addition, the CSTEE considered in detail the results of two meta-analyses of previous epidemiological investigations designed as case-control studies which were reported in 2000 (10, 11). A "meta-analysis" is an epidemiological tool that contributes to the assessment of overall evidence of a cause-to-effect relationship, utilising investigations from separate studies. It consists in the creation of a single database through the pooling of the original data of the individual studies. An obvious pre-requisite is that individual studies being meta-analysed must be comparable, both in the design and in the assessment of exposure.

Results of one of the two "meta-analyses", which have been presented to the CSTEE, included 9 studies published between 1993 and 1999 in which 50-60 Hz magnetic fields had been measured in the children's houses during the previous 24-48 h or had been evaluated through theoretical calculations. Total numbers of cases and controls were respectively 3247 and 10400. Sensitivity analyses (estimation of relative risks following exclusion of studies carried out in some countries, notably US and Canada) and analyses limited to subgroups of studies carried out in Scandinavian countries) did not materially change the estimates.

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The following conclusions were reached with regard to the two meta-analyses:

- Both meta-analyses estimated a twofold excess risk for leukaemia for children living in households where exposures to ELF were estimated to be higher than 0.4 µT (0.3 µT according to Greenland's meta-analysis);

- In some studies, selection bias may have occurred, leading to an over-representation of children of higher socio-economic status among cases, but there are no reasons to believe that this was a phenomenon common to all studies taken in consideration;

- The exposure category for which such excess risk has been estimated is open-ended. No analyses have been performed using other cut-off points (also because the number of children exposed to more than 0.4 µT is very small). In other words, the shape of the dose-response relationship above 0.4 µT is not known.

- Relative risk estimates for exposures, intermediate between those showing a statistically significant excess and the reference group, were just above 1.

- In most studies included in the meta-analyses carried out in European countries, children *with leukaemia* exposed to extremely low frequency EMF at levels of 0.4 µT and above did not exceed 1% of the population group which was studied. Thus the percentage attributable risk in the population is likely to be less than 1% of the leukaemia cases.

Other potential end-points of ELF-related effects have received less attention, both in humans and in experimental systems. Recent reports conclude respectively that that there is no consistent evidence of genotoxicity (8) or DNA damage (WHO Fact sheet no 263). Also the evidence of effects on the immune system is extremely limited.

In the case of ELF, reports [CSTEE/2000/26-Add.35 -"Electromagnetic hypersensitivity: an environmental illness" - draft WHO Fact Sheet (document has been reviewed and final version will be released shortly)] on possibly hypersensitive individuals require confirmation and do not provide a basis for changes in exposure limits.

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Opinion/Conclusions

Answer to question A:

- The additional information which has become available on carcinogenic and other non-thermal effects of radiofrequency and microwave radiation frequencies in the last years does not justify a revision of exposure limits set by the Commission on the basis of the conclusions of the 1998 opinion of the Steering Scientific Committee. In particular, in humans, no evidence of carcinogenicity in either children or adults has resulted from epidemiological studies (the size of some of which was very large, although the period of observation was not long enough for a definitive statement). A relatively large series of laboratory studies has not provided evidence of genotoxicity. Subjective symptoms affecting some individuals possibly exists, but not enough information is available on: the levels of exposure producing such effect, on the features underlying individual susceptibility, on the possible biological mechanisms *or* the prevalence of susceptible individuals in different populations. Thus, current knowledge is insufficient for the implementation of measures aimed at the identification and protection of a highly sensitive sub-group of the population.

With regard to extremely low frequency electromagnetic fields, the CSTEE reached the following conclusions:

- Combined analyses of the epidemiological studies on the association between exposure to ELF and childhood leukaemia have strengthened the evidence of an association. However, given some inconsistencies in exposure measurements and the absence of other criteria commonly used in assessing causality (particularly a plausible explanation of underlying biological mechanisms, see above), the association does not meet adequate criteria for being considered causal. Thus the overall evidence for 50/60 Hz magnetic fields to produce childhood leukaemia must be regarded as being limited[*] (*).

- The effect, if any, seems to be limited to exposures above 0.4 μT. In European countries, the proportion of children exposed to such levels is less than 1%. Assuming that the risk is doubled among the exposed, in the general population this would roughly correspond to an excess incidence of less than 1% childhood leukaemia. To put this in context, in European countries, the incidence of leukaemia is around 45 per million children (age 0-14) per year.

- Whether changes of recommended exposure limits to 50/60 Hz magnetic fields (12) ought to be recommended on this basis is a problem for risk managers, falling beyond the remit of the CSTEE.

- There is no convincing suggestion of any other carcinogenic effect of ELF on either children or adults. Current information on this respect does not provide clues for reconsidering exposure limits.

- Reports on possibly hypersensitive individuals require confirmation and do not provide a basis for proposing changes in the exposure limits.

[*] (*) This term is used according to the definition given by the International Agency for Research on cancer, i.e. "*A positive association has been observed between exposure to the agent … for which a causal interpretation is considered … to be credible, but chance, bias or confounding could not be ruled out with reasonable confidence*". Indeed the CSTEE is aware that on this basis, IARC has recently evaluated that extremely low frequency magnetic fields are possibly carcinogenic to humans (group 2B) based on the association of [illegible] magnetic fields and increased risk for childhood leukaemia.

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Answer to question B:

- On the basis of the information available to the CSTEE at the time of responding to this opinion request, the committee has insufficient scientific evidence, as to thermal and non thermal effects, to propose alternatives to the technical annex for the Council Recommendation setting up basic restrictions and reference levels limiting the exposure to non-ionising radiation, based on the guidelines published by the International Commission on Non-Ionising Radiation Protection.

Note

The CSTEE will provide subsequently recommendations for research priorities needed in order to fill the critical gaps in present knowledge which stem from the summary review presented here.

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Annex 1

<table>
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<tr><td rowspan="6">3 x 10^{14}

3 x 10^{11}

3 x 10^{8}

3 x 10^{4}

3 x 10^{1}</td><td rowspan="6">NON-IONISING RADIATION</td><td>UV</td><td rowspan="3">STERILIZATION
LASER
LAMPS
THERMAL SOURCES
REMOTE CONTROL</td></tr>
<tr><td>VISIBLE</td></tr>
<tr><td>INFRA-RED</td></tr>
<tr><td rowspan="3">RADIO FREQUENCY</td><td>MICROWAVE</td><td>RADARS
MICROWAVE DIATHERMY
CELL PHONE
MICROWAVE OVEN
RADIO LINKS</td></tr>
<tr><td></td><td>TV AND RADIO BROADCASTS
RADIOFREQUENCY THERAPY
AMATEUR RADIO
RADIOFREQUENCY WELDING
INDUCTION HEATING</td></tr>
<tr><td>LOW FREQUENCY</td><td>METAL DETECTOR
VIDEO DISPLAY UNITS
MAGNETOTHERAPY
DOMESTIC APPLIANCE
POWER LINES
TELEPHONE LINES</td></tr>
<tr><td>0</td><td colspan="2">STATIC FIELDS</td><td>MAGNETIC RESONANCE
ELECTROLYSIS</td></tr>
</table>

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Thursday, November 1, 2018

High exposure to radio frequency radiation associated with cancer in male rats

NTP releases final reports on rat and mouse studies of radio frequency radiation like that used in 2G and 3G cell phone technologies.

The National Toxicology Program (NTP) concluded there is clear evidence that male rats exposed to high levels of radio frequency radiation (RFR) like that used in 2G and 3G cell phones developed cancerous heart tumors, according to final reports released today. There was also some evidence of tumors in the brain and adrenal gland of exposed male rats. For female rats, and male and female mice, the evidence was equivocal as to whether cancers observed were associated with exposure to RFR. The final reports represent the consensus of NTP and a panel of external scientific experts who reviewed the studies in March after draft reports were issued in February.

"The exposures used in the studies cannot be compared directly to the exposure that humans experience when using a cell phone," said John Bucher, Ph.D., NTP senior scientist. "In our studies, rats and mice received radio frequency radiation across their whole bodies. By contrast, people are mostly exposed in specific local tissues close to where they hold the phone. In addition, the exposure levels and durations in our studies were greater than what people experience."

The lowest exposure level used in the studies was equal to the maximum local tissue exposure currently allowed for cell phone users. This power level rarely occurs with typical cell phone use. The highest exposure level in the studies was four times higher than the maximum power level permitted.

"We believe that the link between radio frequency radiation and tumors in male rats is real, and the external experts agreed," said Bucher.

The $30 million NTP studies took more than 10 years to complete and are the most comprehensive assessment, to date, of health effects in animals exposed to RFR with modulations used in 2G and 3G cell phones. 2G and 3G networks were standard when the studies were designed and are still used for phone calls and texting.

"A major strength of our studies is that we were able to control exactly how much radio frequency radiation the animals received — something that's not possible when studying human cell phone use, which has often relied on questionnaires," said Michael Wyde, Ph.D., lead toxicologist on the studies.

He also noted the unexpected finding of longer lifespans among the exposed male rats. "This may be explained by an observed decrease in chronic kidney problems that are often the cause of death in older rats," Wyde said.

The animals were housed in chambers specifically designed and built for these studies. Exposure to RFR began in the womb for rats and at 5 to 6 weeks old for mice, and continued for up to two years, or most of their natural lifetime. The RFR exposure was intermittent, 10 minutes on and 10 minutes off, totaling about nine hours each day. RFR levels ranged from 1.5-6 watts per kilogram in rats, and 2.5-10 watts per kilogram in mice.

These studies did not investigate the types of RFR used for Wi-Fi or 5G networks.

"5G is an emerging technology that hasn't really been defined yet. From what we currently understand, it likely differs dramatically from what we studied," said Wyde.

For future studies, NTP is building smaller RFR exposure chambers that will make it easier to evaluate newer telecommunications technologies in weeks or months, rather than years. These studies will focus on developing measurable physical indicators, or biomarkers, of potential effects from RFR. These may include changes in metrics like DNA damage in exposed tissues, which can be detected much sooner than cancer.

The U.S. Food and Drug Administration nominated cell phone RFR for study by NTP because of widespread public use of cell phones and limited knowledge about potential health effects from long-term exposure. NTP will provide the results of these studies to FDA and the Federal Communications Commission, who will review the information as they continue to monitor new research on the potential effects of RFR.

NTP uses four categories to summarize the evidence that a substance may cause cancer:

- Clear evidence (highest)
- Some evidence
- Equivocal evidence
- No evidence (lowest)

More information on the categories is available at https://ntp.niehs.nih.gov/results/pubs/longterm/defs/index.html.

About the National Toxicology Program (NTP)*: NTP is a federal, interagency program headquartered at NIEHS, whose goal is to safeguard the public by identifying substances in the environment that may affect human health. For more information about NTP and its programs, visit https://ntp.niehs.nih.gov.*

About the National Institute of Environmental Health Sciences (NIEHS): NIEHS supports research to understand the effects of the environment on human health and is part of NIH. For more information on environmental health topics, visit www.niehs.nih.gov. Subscribe to one or more of the NIEHS news lists to stay current on NIEHS news, press releases, grant opportunities, training, events, and publications.

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Electromagnetic Biology and Medicine ›

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Articles

Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations

Zothansiama, Mary Zosangzuali, Miriam Lalramdinpuii & **Ganesh Chandra Jagetia**

Pages 295-305 | Received 27 Apr 2017, Accepted 30 Jun 2017, Published online: 04 Aug 2017

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ABSTRACT

Radiofrequency radiations (RFRs) emitted by mobile phone base stations have raised concerns on its adverse impact on humans residing in the vicinity of mobile phone base stations. Therefore, the present study was envisaged to evaluate the effect of RFR on the DNA damage and antioxidant status in cultured human peripheral blood lymphocytes (HPBLs) of individuals residing in the [illegible] base

stations and comparing it with healthy controls. The study groups matched for various demographic data including age, gender, dietary pattern, smoking habit, alcohol consumption, duration of mobile phone use and average daily mobile phone use. The RF power density of the exposed individuals was significantly higher ($p < 0.0001$) when compared to the control group. The HPBLs were cultured and the DNA damage was assessed by cytokinesis blocked micronucleus (MN) assay in the binucleate lymphocytes. The analyses of data from the exposed group ($n = 40$), residing within a perimeter of 80 m of mobile base stations, showed significantly ($p < 0.0001$) higher frequency of micronuclei when compared to the control group, residing 300 m away from the mobile base station/s. The analysis of various antioxidants in the plasma of exposed individuals revealed a significant attrition in glutathione (GSH) concentration ($p < 0.01$), activities of catalase (CAT) ($p < 0.001$) and superoxide dismutase (SOD) ($p < 0.001$) and rise in lipid peroxidation (LOO) when compared to controls. Multiple linear regression analyses revealed a significant association among reduced GSH concentration ($p < 0.05$), CAT ($p < 0.001$) and SOD ($p < 0.001$) activities and elevated MN frequency ($p < 0.001$) and LOO ($p < 0.001$) with increasing RF power density.

KEYWORDS: Antioxidants, genotoxicity, humans, micronucleus, power density

Additional information

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Declaration of interest

The authors report no declarations of interest.

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RESEARCH ARTICLE

Towards predicting intracellular radiofrequency radiation effects

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Abstract

Recent experiments have reported an effect of weak radiofrequency magnetic fields in the MHz-range on the concentrations of reactive oxygen species (ROS) in living cells. Since the energy that could possibly be deposited by the radiation is orders of magnitude smaller than the energy of molecular thermal motion, it was suggested that the effect was caused by the interaction of RF magnetic fields with transient radical pairs within the cells, affecting the ROS formation rates through the radical pair mechanism. It is, however, at present not entirely clear how to predict RF magnetic field effects at certain field frequency and intensity in nanoscale biomolecular systems. We suggest a possible recipe for interpreting the radiofrequency effects in cells by presenting a general workflow for calculation of the reactive perturbations inside a cell as a function of RF magnetic field strength and frequency. To justify the workflow, we discuss the effects of radiofrequency magnetic fields on generic spin systems to particularly illustrate how the reactive radicals could be affected by specific parameters of the experiment. We finally argue that the suggested workflow can be used to predict effects of radiofrequency magnetic fields on radical pairs in biological cells, which is specially important for wireless recharging technologies where one has to know of any harmful effects that exposure to such radiation might cause.

Introduction

Weak radiofrequency (RF) magnetic fields in the MHz-range was shown to influence the concentrations of reactive oxygen species (ROS) in living cells [1–4]. Remarkably, the energy that could possibly be deposited by such radiation is orders of magnitude smaller than the energy of molecular thermal motion. A plausible explanation to the observed effect relies on the interaction of RF magnetic fields with transient radicals within the cells, affecting the ROS formation rates through the radical pair mechanism [5–9]. Prediction of the RF magnetic field effects in biomolecular systems is, however, not straightforward, as it relies on multiple interlinked scales ranging from electrons to the whole cell. This gap in our understanding of RF field effects on biological systems is, however, important and needs special attention because wireless charging has already been commercialized in various sectors such as portable

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Competing interests: The authors have declared that no competing interests exist.

consumer electronics [10] and manufacturing facilities [11]. While the World's first wireless charging standard "Qi" launched by the Wireless Power Consortium focuses on short-range wireless charging which has no danger of human exposure to electromagnetic radiation, mid-range wireless charging (with possible human exposure to electromagnetic radiation) has been suggested recently by a group of companies through the AirFuel Alliance.

A cell contains a vast amount of different components interacting in a myriad of ways, and it is, therefore, no simple task to identify the molecular processes that can be affected by RF magnetic fields. Since radicals could possibly exhibit a sufficiently strong interaction with the weak RF magnetic fields [1, 2, 6, 12–16], the search can be somewhat limited by focusing on molecular intracellular processes involving radicals. Radicals inside a cell may be created in pairs in a coherent state far from thermal equilibrium, and the relaxation pathway towards thermal equilibrium can be altered by weak external magnetic fields [5, 7–9, 17–19]. Due to the high reactivity of radicals, various reaction pathways with radical involvement will normally be available, and external magnetic fields would thus modulate the corresponding reaction probabilities [5–9, 20]. The external magnetic RF fields would, therefore, lead to a difference in the relative amounts of intracellular reaction products that in turn would affect cellular functioning. The effect is expected to be dependent on the strength of the external magnetic fields, as well as their polarization and oscillation frequency.

Examples of radicals interacting with RF magnetic fields are known. For example, in previous studies a radical pair with flavin adenine dinucleotide (FAD) and superoxide $O_2^{\bullet -}$, $[FAD^{\bullet -} \ldots O_2^{\bullet -}]$, was suggested to be responsible for an observed effect of RF magnetic fields in human ubilical vein endothelial cells [1, 2], or to be involved in avian magnetoreception [21, 22]. Another example is the cytochrome bc1 complex [23–27], which can be found in the mitochondrial membranes and is responsible for proton transport across the membrane as part of the respiratory chain. A recent study indicated that superoxide may be generated as a side reaction in the cytochrome bc1 complex [24, 25], and it is not unlikely that the $O_2^{\bullet -}$ production rate as well as its chance to escape the reaction sites within the protein complex might be affected by RF magnetic fields.

Theoretical description of weak radiofrequency magnetic field effects in biological systems is not new, and several methods that address radical pair spin dynamics have been developed [12, 13, 28–32]. Common to all of these methods is, that they require a specification of a radical pair Hamiltonian, which describes how spins of the unpaired electrons interact with external magnetic fields, the internal magnetic fields of the molecular environment, and with each other. To describe the majority of the radical pair processes, it is often a good approximation to assume the Hamiltonian time-independent [5, 9, 19], which is however not directly possible once an oscillating RF field is present. The burden of dealing with the time-dependent Hamiltonian can, however, be avoided when using the so-called rotating reference frame method [13, 28, 32] which permits rewriting the equations describing radical pair spin dynamics in a time-independent form. Nevertheless, the method has some limitations, as for example it only applies to circularly polarized single-frequency RF magnetic fields. Other methods that do not possess this specific constraint are, for example, based on perturbation theory [29, 30], the so-called Floquet theory [31], or using the γ-COMPUTE algorithm which exploits the periodicity of the RF field oscillations [12, 33]; the latter methods are, however, subject to different limitations and approximations.

The present investigation aims to establish a general workflow for studying the impact of RF fields on subcellular compartments. In order to illustrate how one should determine some of the key ingredients of the workflow, the rotating reference frame approach is employed due to its simplicity, making the subject more accessible to researchers without a magnetic

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resonance or spin dynamics background. It should be emphasized, however, that more sophisticated methods such as the γ-COMPUTE algorithm [12, 33] exists and, in principle, allows for a more realistic treatment of intracellular spin systems. Since it is at present not known for any given cell type which radicals would display the largest response to RF magnetic fields, the workflow is justified through examples of generic models of radical pair systems, that are aimed to serve as a foundation for studying RF effects in biological systems of varied complexity, that could be found in real biological environments. The models are essentially used to illuminate how various molecular features of a radical pair affect its response to RF magnetic fields. In particular, we consider how a radical pair system responds to RF magnetic fields for (i) different magnetic interactions within the radical pair described through the so-called hyperfine interactions; (ii) different chemical processes initiated from the radical pair, described through specific reaction rate constants; (iii) different strengths of exchange interaction between the two unpaired electrons. Some of the earlier studies [13, 28, 32] have already addressed these questions for different model systems, but we wish to extend the analysis and discuss the implications of moving from just a simple model system of a radical pair to a more complete description that also involves the cellular scale. Moreover, we aim to deliver a general recipe of how RF magnetic field effects in cells measured in laboratory can be interpreted through computational modelling of the underlying biophysical mechanisms. The performed analysis is aimed at biologists and biochemists interested in RF intracellular effects and seeks to provide a consistent explanation of the underlying physics that could possibly be involved in the observed phenomena.

Workflow for interpreting RF field effects in cells

Interpretation of RF field effects in real biological systems involves a significant effort, but the workflow outlined in Fig 1 breaks it down into smaller manageable tasks, which are discussed in detail below. All steps in this workflow are essentially relying on a computational approach which should be closely coupled to experiment in terms of defining the variable parameters of RF magnetic fields and of the key observables.

Radical pair reaction rate constants

Intracellular RF effects depend strongly on the rate constants, associated with the reactions that involve radical pairs. These rate constants determine the fate of the radical pair in terms of possible reaction products and allow estimating the radical pair lifetime. Radical pairs can undergo different processes, where several generic schemes that permit establishing the rate constants rather accurately are reviewed below.

Diffusion rates. Some radical pair processes, in particular the backreaction which regenerates the state prior to formation of a non-equilibrium radical pair, can only happen while the radicals are in close proximity. Therefore, some radical pair processes can be suppressed if one of the radicals is able to diffuse away, and thus escape from the other possible radical pair reaction outcomes. The escape rate constant, k_e, is related to the binding time τ_b of the two radicals in a radical pair as $k_e = 1/\tau_b$. This rate constant can be obtained from molecular dynamics (MD) simulations, where the radical pair and its biological environment have been studied in the state prior to generation of the radical pair, and in a configuration with the radical pair created. Several statistically independent MD simulations of the radical pair state can thus reveal the average binding time, τ_b. An example of binding time determination using this approach can be found in an earlier investigation [34].

Electron transfer rates. Electron transfer reactions are often associated with radical pair dynamics, as radical pairs are often created or abolished through electron transfer. Charge

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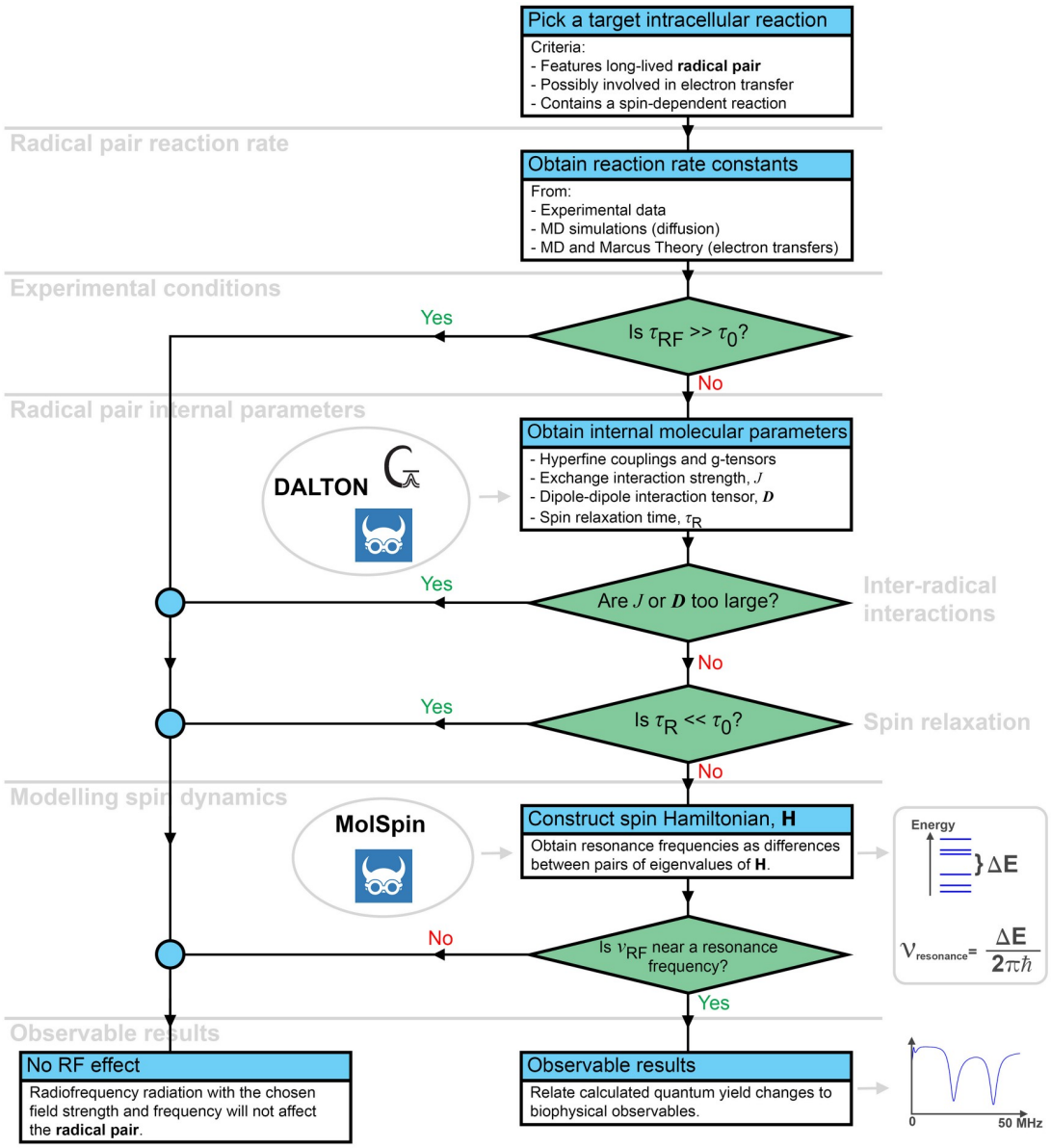


Fig 1. An overview of the workflow to interpret intracellular RF field effects. Three characteristic times are important to expect any possible RF field effects in an intracellular radical pair system: τ_0 is the lifetime of the radical pair; τ_{RF} is the characteristic time of RF magnetic field action on the radical pair, defined in Eq (2); and τ_R the spin relaxation time. ν_{RF} is the frequency of the RF field. The steps of the workflow are discussed in the sections of text indicated on the left side of the figure.

https://doi.org/10.1371/journal.pone.0213286.g001

recombination reactions can often be described by the Marcus theory [35–37], which states that the rate constant of an electron transfer event is given by:

$$k = \frac{2\pi}{\hbar}\frac{|V_{ab}|^2}{\sqrt{4\pi\lambda k_B T}}\exp\left(-\frac{(\Delta G_{ET}+\lambda)^2}{4\pi\lambda k_B T}\right). \quad (1)$$

Here V_{ab} is the transition matrix element between the two states involved in the charge transfer reaction, k_B the Boltzmann constant, ΔG_{ET} is the associated free energy change, and λ is the so-called reorganization energy which describes an additional free energy change linked

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to the conformational changes caused by the electron transfer [35, 38]. Both ΔG_{ET} and λ can be calculated from MD simulations [23, 39], and the transition matrix element can be deduced from quantum chemistry calculations of the radical pair system before and after the electron transfer.

Note that Marcus theory only holds in the adiabatic approximation, where the atomic nuclei can be assumed static relative to the electronic motion. Other methods must be employed for non-adiabatic electron transfers [40].

Radical pair lifetime. The lifetime of a radical pair is a crucial characteristic for RF field effects to emerge. The lifetime, τ_0, is defined as the characteristic time where both radicals of the radical pair experience coherent behaviour and can usually be deduced from the fastest spin-independent process associated with the radical pair (for example radical escape diffusion, discussed above); such an estimate delivers a lower bound for the radical pair lifetime, $\tau_0 = 1/k$ for the rate constant k.

If the fastest process in a radical pair is spin-dependent and occurs with a rate constant k_i, the initial state of the radical pair becomes important; if this process can happen from the initial state of the radical pair, the corresponding radical pair lifetime is approximated by $\tau_0 \approx 1/k_i$. On the other hand, the radical pair interconversion rate, k_{mix}, becomes important as the singet-triplet interconversion leads to radical pair conversion into a spin state with a fast decay route characterized by the rate constant k_i. For radical pairs, where the singlet-triplet interconversion is limiting the fast spin-dependent process, the radical pair lifetime is approximated by $\tau_0 \approx 1/k_{\mathrm{mix}}$.

The radical pair lifetime thus often depends on the radical pair interconversion rate, k_{mix}, which is normally not known upfront since it is mainly determined by the internal parameters of the radical pair such as the hyperfine interactions. As the typical hyperfine interactions are on the order of 1 mT [7, 19, 41], one expects k_{mix} to be about $\frac{g\mu_B}{2\pi\hbar} \cdot 1\ \mathrm{mT} \approx 30\mu s^{-1}$, which can be used as an order of magnitude guess for the lifetime of a typical radical pair if no other information is available.

Experimental conditions

One should next consider the experimental conditions which define the external magnetic fields. The strength and direction of any static magnetic field needs to be determined, as well as the strength, frequency, and polarization of the RF magnetic field.

The characteristic interaction time, τ_{RF}, of the RF magnetic fields with the radical pair, can be determined once the strength of the RF magnetic field is known, and is estimated as:

$$\tau_{RF} = \frac{2\pi\hbar}{g\mu_B B_1}\,. \tag{2}$$

Here g is the isotropic Landé g-factor which is approximately 2 for organic radicals, μ_B is the Bohr magneton, and B_1 is the RF magnetic field strength. Note that τ_{RF} depends only on the field strength of the RF magnetic field, B_1, but not on its oscillation frequency or polarization. If the interaction time is much larger than the lifetime of the radical pair, $\tau_{RF} \gg \tau_0$, the RF magnetic field will not have sufficient time to interact with the radical pair before it decays and, therefore, any effect of the RF magnetic field on the radical pair can be readily excluded, as also schematically depicted in Fig 1.

Radical pair internal parameters

The internal parameters describe the interactions within each radical pair, and knowledge of those can sometimes be enough to exclude the possibility of RF magnetic field effects on the

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biochemical system, as illustrated in Fig 1. The most important parameters describing internal interactions in the radical pairs are the so-called hyperfine couplings, describing the interaction between the unpaired electrons of the radical pairs and any nearby magnetic atomic nuclei, which are present in most radicals. The hyperfine interaction is often decomposed into the spin-dipole interaction, which provides the anisotropic part of the hyperfine interaction, and the Fermi Contact term which is isotropic. Most standard quantum chemistry software packages like Gaussian [42] or DALTON [43] are able to calculate these two components of the hyperfine interactions.

Inter-radical interactions. The two unpaired electrons of the radical pair may interact with each other through the exchange interaction [44–46], $\mathbf{H}_{ex}$, or magnetic dipole-dipole interaction [45, 46], $\mathbf{H}_{dd}$, which have the following generic form:

$$\mathbf{H}_{ex} = -2J(\mathbf{r})\,\mathbf{S}_1 \cdot \mathbf{S}_2, \tag{3}$$

$$\mathbf{H}_{dd} = \frac{g_1 g_2 \mu_0 \mu_B^2}{4\pi}\left(\frac{3(\mathbf{S}_1 \cdot \mathbf{r})(\mathbf{r} \cdot \mathbf{S}_2)}{|\mathbf{r}|^5} - \frac{\mathbf{S}_1 \cdot \mathbf{S}_2}{|\mathbf{r}|^3}\right) = \mathbf{S}_1 \cdot \mathbf{D}(\mathbf{r}) \cdot \mathbf{S}_2\,. \tag{4}$$

Here $J(\mathbf{r})$ is the strength of the exchange interaction, $\mathbf{D}(\mathbf{r})$ the magnetic dipole-dipole interaction tensor, $\mathbf{r}$ the vector going from one radical to the other, $\mathbf{S}_1$ and $\mathbf{S}_2$ are the electron spin operators, and g_1 and g_2 are the g-factors of the two radicals. Since the unpaired electrons of the two radicals are not located at a specific point, integration over their wavefunctions is necessary in order to obtain accurate J and $\mathbf{D}$ parameters. The effect of J and $\mathbf{D}$ is mainly to suppress singlet-triplet interconversion in the radical pairs, which in turn can render the radical pairs immune to RF magnetic field effects, as highlighted in Fig 1. Both interactions strongly depend on the interradical distance r and, therefore, significant variations of J and $\mathbf{D}$ may occur for unconstrained radical pairs. Variation of J and $\mathbf{D}$ is furthermore a source of spin relaxation.

Spin relaxation. Most of the interactions in a radical pair are not static, but depend on time due to the atomic thermal motions. Instead of trying to solve the spin dynamics equations with time-dependent internal interactions, the associated effects can be accounted for through the Redfield theory [18, 45, 47, 48], as was for example done earlier [18, 48]. Accurate accounting for spin relaxation can be complicated, and sometimes it is sufficient to estimate the spin relaxation time, τ_R, which describes the time at which the spin system will reach thermal equilibrium due to relaxation effects. If the relaxation time is much shorter than the expected lifetime of the radical pair, i.e. $\tau_R \ll \tau_0$, the radical pair will reach thermal equilibrium quickly, and will not be able to respond to RF magnetic fields as indicated in Fig 1. If, on the other hand, the relaxation time is much longer than the lifetime of the radical pair, relaxation becomes irrelevant and can be ignored.

Modelling spin dynamics

Once the magnetic and kinetic properties of a radical pair are established it is possible to describe the underlying spin dynamics. A simple initial analysis can provide important insights into the spin system: the eigenvalues of the radical pair spin Hamiltonian, in the absence of the RF magnetic field can be obtained. The difference between any two eigenvalues, ΔE_{ij}, corresponds to a resonance frequency in the spin system and, therefore, the calculated eigenvalues provide a complete spectrum of possible resonance frequencies in the studied radical pair, see Fig 1. Not all of the resonance frequencies, however, will affect the quantum yield of the radical pair reaction. This simple analysis can thus immediately exclude any RF magnetic field effect

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of certain frequencies, that are significantly different from the deduced resonance frequencies, since they would not be able to affect the quantum yield at all. For organic radicals one typically expects multiple resonance frequencies within the 1-50 MHz range due to the hyperfine interactions of the radicals.

For the calculation of the quantum yield change as a function of RF frequency, one can for example use the MolSpin [49] software package, either directly or through the intuitive interface in VIKING [50], which is easy to use and well suited for such calculations.

Observable results

The quantum yields delivered from the spin dynamical calculations can finally be used to qualitatively judge about the relative amount of reaction products obtained from the various reaction pathways associated with the radical pair. Comparing the quantum yields with and without the presence of a RF field, one can thus conclude on the impact of RF magnetic fields on the relative amount of reaction products inside a cell and ultimately suggest if any noticable effects (cell lifetime, growth rate, etc.) are expected due to the presence of a certain radical pair and its involvement in one of the aforementioned processes.

Employing the workflow for generic model systems

To employ the generic workflow in Fig 1, it is illuminating to consider simple generic radical pair models. An example of a simple radical pair model is illustrated in Fig 2A, consisting of two magnetic nuclei (red arrows) and two unpaired electrons (blue arrows), such that each radical has a single magnetic nucleus. The unpaired electrons in the radical pair posses a property called spin [44], which permits them to be affected by external magnetic fields, such as RF magnetic fields. The external magnetic fields, as well as other magnetic interactions of the unpaired electronic spins, result in the singlet-triplet mixing of the radical pair, which is an interconversion between two different types of quantum mechanical states that the spins of the unpaired electrons can reside in, called singlet and triplet states, and occuring with a characteristic rate constant k_{mix}. More details about the quantum states of a radical pair can be found in the Supporting Information (SI). The significance of the singlet and triplet states is illustrated in Fig 2B, and note also the presence of two spin-dependent processes occuring with rate constants k_S and k_T from the singlet and triplet state, respectively. These processes could, for

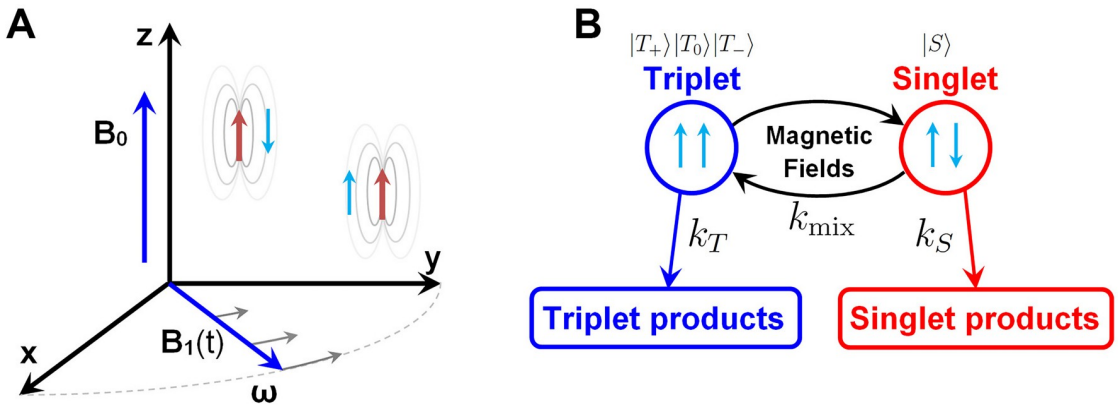


Fig 2. Overview of the simple radical pair model. A: The static magnetic field $\mathbf{B}_0$ points along the z-axis, and the RF field $\mathbf{B}_1(t)$ acts in the xy-plane. The unpaired electrons are each localized around the magnetic nuclei. **B**: Magnetic interactions in the system induces singlet-triplet mixing within the radical pair with a characteristic rate constant k_{mix}. Chemical reactions can occur with rate constants k_S and k_T from radical pairs in the singlet and triplet state, respectively, limiting the lifetime τ_0 of the radical pair.

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example, be electron transfer processes, and will (possibly together with k_{mix}) determine the lifetime of the radical pair, τ_0. The oversimplified radical pair model system in Fig 2 is expected to be more complex in reality and include more nuclei [15, 48, 51], and, therefore, more local magnetic interactions, that will add a specific signature to how a radical pair will respond to external magnetic fields. A more complex model including more magnetic nuclei is, therefore, also considered below. The minimal model, however, is supposed to illuminate in an intuitive fashion the principal effects that are expected to arise in a radical pair system, once it is subject to RF magnetic fields.

Measuring RF field effects in an experiment

The RF magnetic fields could affect cellular dynamics in various ways, such as for example the cell growth or cell death rate. The RF magnetic field influence depends on the underlying subcellular structures and chemical processes on the molecular scale, some of which are involved in radical production. The produced radicals can appear crucial for the functioning of molecular systems [6], or become unfortunate side products as for example the superoxide produced in the bc1 complex [24, 25]. Radicals, and radical pairs in particular, can be created during vital cellular processes, and the spin dynamics of these radicals may determine the outcome of chemical processes in which they participate. In the cytochrome bc1 complex, for example, the radical spin dynamics could possibly affect the probability for $O_2^{\bullet -}$ to leave the complex without recombining back to O_2, thus changing the superoxide concentration within the cell and disturbing the normal operation of the bc1 complex, which rely on intrinsic electron transfers.

To make the proposed approach less abstract, we would like to consider a possible experimental setup, where RF field effects can be observed, and the suggested workflow would turn out to be useful in interpreting observables. For the sake of simplicity it will be assumed that in a staged experiment every cell contains the same number of radical pairs that is affected by RF magnetic fields. Introducing a varying number of radical pairs in different cells does not change the outcomes of the modelling conceptually, and should be accounted for by averaging over an ensemble of cells. Each radical pair leads to different chemical reactions that are initiated from the singlet and triplet states, leading to the so-called singlet and triplet yields; such singlet and triplet yields could for example be superoxide recombining to form O_2 and superoxide escaping the bc1 complex, respectively.

To quantify the action of the magnetic field, it is important to define a coordinate frame used to describe the radical pairs as illustrated in Fig 2A. The most intuitive choice of the coordinate frame is the laboratory frame, illustrated in Fig 3; assuming we have an experimental setup where some cells are put in a Petri dish, and subject to the static and oscillating magnetic fields B_0 and B_1, respectively. The static homogeneous magnetic field could then be applied in a direction perpendicular to the Petri dish, and thereby determine the z-axis; the plane of the Petri dish would then correspond to the xy-plane.

The radical pairs are assumed to be floating freely inside the cells, such that they would feature all possible orientations of the corresponding magnetic moments. Changing the orientation of the cell does not change the internal interactions within the cell, but it does have an effect on interactions with external entities, such as the static external magnetic field, as well as the RF magnetic fields. The experiment is thus expected to be performed on an ensemble of radical pairs, which include all possible orientations of the radical pairs relatively to the external magnetic fields. Averaging over all radical pair orientations is straightforward when all internal interactions in the radical pair, such as e.g. the internal magnetic hyperfine interactions, are isotropic, since in that case the spin dynamics of the radical pair become independent of the external magnetic field direction. Normally, however, hyperfine interactions are

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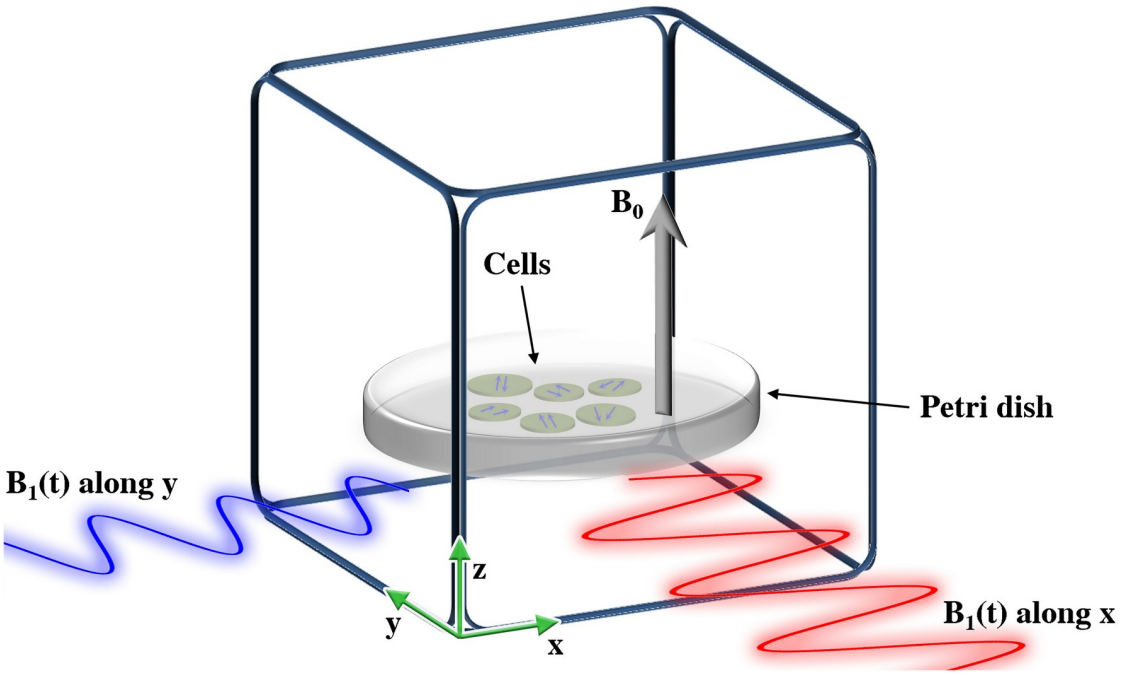


Fig 3. The laboratory coordinate frame. An artistic representation of a Petri dish with an ensemble of cells, and a magnetic field, B_0, in the direction perpendicular to the plane of the Petri dish. The Petri dish is surrounded by rectangular coils that can produce an oscillating magnetic field B_1 along any of the three axes in the laboratory frame. Thus an RF magnetic field rotating in the plane of the Petri dish could be produced, cf. Fig 2A. The orientation of each cells, and hence also of any radical inside the cells, is random, which dictates that any orientational dependent property of the radical pairs should be averaged over all the possible radical orientations.

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anisotropic, but unless the radicals are constrained in some way, rotational diffusion of the radicals will smear away the anisotropies. This happens if the characteristic time for rotational diffusion, the rotational correlation time τ_{rot}, is significantly smaller than the characteristic time scale for the spin dynamics, i.e. the time scale for the singlet-triplet mixing $1/k_{mix} = \tau_{mix}$, see Fig 2B. Typical rotational correlation times for free organic radicals are on the order of $\tau_{rot} = 1$ ps [45], while the time scale of the processes associated with spin dynamics are of ns to μs duration, as shown below. The huge difference in the characteristic values of τ_{rot} and τ_{mix} suggests that all the hyperfine interactions in a typical unconstrained intracellular radical pair can be considered as isotropic to a good approximation [7, 8]. The situation is more complicated for constrained radical pairs, where one has to take the anisotropy into account.

Model details

In order to characterize an ensemble of radical pairs, one should first consider how a single radical pair is described. The results of such a description are the so-called quantum yields, which determine the probability for reaction pathways for the single radical pair. Since most of the radical pairs in an experiment are expected to be similarly prepared, they are assumed to be spawned in the same quantum state, and experience the same internal interactions as the molecular structures of the radical pairs are thought identical. The calculated probabilities for the various reaction products in a single radical pair could then be generalized for every radical pair in the experimental system. There are two potential problems with this approach: (i) the radical pairs in the experimental setup have different orientation relative to external static and RF magnetic fields, and (ii) the inherent randomness of the thermal motion present in the

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radicals will lead to different molecular motions for each of the radical pairs in the ensemble. The first problem is solved by averaging the yield obtained for a single radical pair over all possible orientations of this radical pair. The second problem can be handled through the Redfield theory [18, 45, 47, 48], which has been developed to take spin relaxation into account.

For the description of a single radical pair, one must first account for all the interactions with the magnetic nuclei within the radicals. Such intrinsic magnetic fields of the nuclei are described by the hyperfine interactions which in the present study are assumed to be isotropic, following the arguments above. The strength of the isotropic hyperfine interaction between an unpaired electron of a radical and a magnetic nucleus is characterized by the hyperfine coupling. Since the simple model radical pair shown in Fig 2A has two magnetic nuclei, the hyperfine coupling a_1 is a parameter that permits altering the magnetic properties of the first nucleus, while the hyperfine coupling of the other nucleus, $a_2 = 1$ mT, is kept constant in all calculations. The values for the hyperfine coupling are chosen such that they represent the common order of magnitude for hyperfine couplings for magnetic nuclei [7, 19, 41], and the hyperfine interactions are assumed to be isotropic due to rotational diffusion of the radicals as explained above. Each nucleus in the studied simple radical pair, Fig 2A, is assumed to have a spin quantum number of 1/2, and the Hamiltonian describing the hyperfine interactions of the unpaired electronic spins with the nuclei reads as:

$$\mathbf{H}_{HF} = g\mu_B(a_1\mathbf{S}_1 \cdot \mathbf{I}_1 + a_2\mathbf{S}_2 \cdot \mathbf{I}_2)\,. \tag{5}$$

Here $\mathbf{S}_1$ and $\mathbf{S}_2$ are the electronic spin operators for the two unpaired electrons, and likewise $\mathbf{I}_1$ and $\mathbf{I}_2$ are the two nuclear spin operators. The product $\mathbf{S}_1 \cdot \mathbf{S}_2$ is defined as $\mathbf{S}_1 \cdot \mathbf{I}_1 = \mathbf{S}_{1x}\mathbf{I}_{1x} + \mathbf{S}_{1y}\mathbf{I}_{1y} + \mathbf{S}_{1z}\mathbf{I}_{1z}$ and similarly for $\mathbf{S}_2 \cdot \mathbf{I}_2$ [44, 52, 53]. The radical pair system is assumed to be exposed to the static magnetic field $\mathbf{B}_0$, which points along the z-axis in the laboratory coordinate frame, see Figs 2 and 3, as well as the time-dependent magnetic RF field $\mathbf{B}_1(t)$. The interaction between the electronic spins and both of these magnetic fields is described by the Zeeman Hamiltonian, as

$$\mathbf{H}_Z(t,\Omega) = g\mu_B(\mathbf{R}(\Omega)\mathbf{S}_1 + \mathbf{R}(\Omega)\mathbf{S}_2) \cdot [B_0\,\hat{\mathbf{z}} + B_1\,(\hat{\mathbf{x}}\cos(\omega t + \phi) + \hat{\mathbf{y}}\sin(\omega t + \phi))], \tag{6}$$

where $\hat{\mathbf{x}}$, $\hat{\mathbf{y}}$ and $\hat{\mathbf{z}}$ are the unit vectors pointing along the x-, y- and z-axes, respectively, ω is the angular frequency of the RF magnetic field, B_1 is the RF magnetic field strength, and ϕ is the phase of the RF magnetic field. $\mathbf{R}(\Omega)$ is a standard 3×3 rotation matrix (defined in the SI), where Ω denotes the orientation of the radical pair relative to the laboratory reference frame illustrated in Fig 3. The rotation matrix is necessary for all interactions between internal entities, such as the electronic spins or magnetic nuclei, and external entities, such as the static and RF magnetic fields, since $\mathbf{R}(\Omega)$ is the matrix that transforms the spin operators from the molecular reference frame to the laboratory reference frame; this ensures that the calculation results are independent of the choice of the reference frame. Note that the rotation matrix was not necessary in Eq (5) since only internal entities were involved there.

The nuclear Zeeman term describing the interaction between the external magnetic field and the nuclear spins is neglected in Eq (6), as it is 2-3 orders of magnitude smaller than the electronic Zeeman term due to the magnetic moment of an electron and nuclei being inversely proportional to their respective masses.

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The Zeeman Hamiltonian in Eq (6) may look rather complicated, and it is therefore instructive to write the static and RF contributions explicitly:

$$\begin{aligned}\mathbf{H}_{Z,B_0}(t,\Omega) &= g\mu_B B_0\left(R_{zx}(\mathbf{S}_{1x}+\mathbf{S}_{2x})+R_{zy}(\mathbf{S}_{1y}+\mathbf{S}_{2y})+R_{zz}(\mathbf{S}_{1z}+\mathbf{S}_{2z})\right),\\ \mathbf{H}_{Z,B_1}(t,\Omega) &= g\mu_B B_1[(R_{xx}(\mathbf{S}_{1x}+\mathbf{S}_{2x})+R_{xy}(\mathbf{S}_{1y}+\mathbf{S}_{2y})+R_{xz}(\mathbf{S}_{1z}+\mathbf{S}_{2z}))\cos(\omega t+\phi)\\ &\quad +(R_{yx}(\mathbf{S}_{1x}+\mathbf{S}_{2x})+R_{yy}(\mathbf{S}_{1y}+\mathbf{S}_{2y})+R_{yz}(\mathbf{S}_{1z}+\mathbf{S}_{2z}))\sin(\omega t+\phi)]\,.\end{aligned} \tag{7}$$

Here R_{ij} are the components of the rotation matrix, $\mathbf{R}(\Omega)$, where the orientation Ω has been omitted for clarity. In the special case where the molecular reference frame is the same as the laboratory reference frame, the rotation matrix becomes the identity operator, where $R_{xx} = R_{yy} = R_{zz} = 1$, while all other components are zero. In this case Eq (7) reads as:

$$\begin{aligned}\mathbf{H}_{Z,B_0}(t,\Omega) &= g\mu_B B_0\left(\mathbf{S}_{1z}+\mathbf{S}_{2z}\right),\\ \mathbf{H}_{Z,B_1}(t,\Omega) &= g\mu_B B_1[(\mathbf{S}_{1x}+\mathbf{S}_{2x})\cos(\omega t+\phi)+(\mathbf{S}_{1y}+\mathbf{S}_{2y})\sin(\omega t+\phi)]\,.\end{aligned} \tag{8}$$

This simple case only holds when all internal interactions are isotropic, as discussed below, while Eqs (6) and (7) are more general.

The two unpaired electrons in the radical pair are assumed to have oppositely aligned spins initially, i.e. assume the radicals to be created in the coherent singlet state, denoted as $|S\rangle$. This singlet state is not an eigenstate of the hyperfine Hamiltonian, and is a superposition of the different quantum states which evolve differently over time. Thus the radical pair will alternate between the singlet state $|S\rangle$ and the three triplet states $|T_0\rangle$, $|T_+\rangle$ and $|T_-\rangle$ with a characteristic rate k_{mix}, see Fig 2B, and this dynamics could be affected by RF magnetic fields once the field frequency matches the energy difference between any two quantum states of the radical pair, see Fig 1. A more detailed explanation of singlet and triplet states, and why they are mixed by the Hamiltonian operator, is given in the SI.

In addition to the singlet-triplet mixing of the radical pair, the radicals are expected to participate in chemical reactions within the cell. These reactions depend on the spin state of the radical pair, and it is, therefore, generically assumed that different reactions happen from the singlet and the triplet states [54], leading to the distinct reaction rate constants k_S and k_T, respectively, as illustrated in Fig 1B.

The dynamics of the radical pair can be described in terms of the density operator, $\rho(t, \Omega)$, and its time evolution is described by the Liouville-von Neumann equation [9, 15, 52, 55–58]:

$$\frac{\partial\rho(t,\Omega)}{\partial t} = -\frac{i}{\hbar}[\mathbf{H}(t,\Omega),\rho(t,\Omega)]_- - \frac{k_S}{2}[\mathbf{P}_S,\rho(t,\Omega)]_+ - \frac{k_T}{2}[\mathbf{P}_T,\rho(t,\Omega)]_+\,. \tag{9}$$

Here $[A, B]_\mp = AB \mp BA$ denote the commutator and anti-commutator, while $\mathbf{P}_S = \frac{1}{4}\mathbf{1} - \mathbf{S}_1\cdot\mathbf{S}_2$ and $\mathbf{P}_T = \frac{3}{4}\mathbf{1} + \mathbf{S}_1\cdot\mathbf{S}_2$ are the singlet and triplet projection operators, respectively. The last two terms in Eq (9) describe the chemical reactions [20], while the rest of Eq (9) is a reformulation of the Schrödinger equation in the density operator formalism [9, 15, 45, 48, 52, 55, 56]. All details about the dynamics of the system and the RF magnetic field are stored in the Hamiltonian operator, $\mathbf{H}(t, \Omega) = \mathbf{H}_{HF} + \mathbf{H}_Z(t, \Omega)$, and it is the hyperfine interaction $\mathbf{H}_{HF}$, Eq (5), that is responsible for the singlet-triplet mixing between the different spin states of the radical pair. The static and RF magnetic fields in turn affect the mixing rates of the spin states. Note that solution of Eq (9) in its general form becomes difficult due to the time-dependent Hamiltonian, $\mathbf{H}(t, \Omega)$, and special methods have been developed to handle such cases—the simplest of these is probably the rotating reference frame approach [13, 28, 32].

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The probability for the radical pair to reside in a specific spin state determines the corresponding quantum yield of an associated reaction, and read as [59, 60]:

$$\phi_S(t,\Omega) = \mathrm{Tr}\left[\mathbf{P}_S\rho(t,\Omega)\right]. \tag{10}$$

Specifically, this is the probability of finding a radical pair in the singlet state at the time instance t [9, 15, 48, 52, 56], and $\phi_T = \mathrm{Tr}[\mathbf{P}_T\rho(t,\Omega)]$ defines the probability to observe the triplet state. The total singlet quantum yield, i.e. the probability of forming the singlet products from a radical pair, see Fig 2B, is then given by:

$$\Phi_S(\Omega) = \int_0^\infty k_S\phi_S\, dt\,. \tag{11}$$

Likewise the total triplet quantum yield, $\Phi_T(\Omega)$, can be defined in terms of the time integral of the triplet fraction, i.e. $\Phi_T(\Omega) = \int_0^\infty k_T\phi_T\, dt$. The quantum yields $\Phi_S(\Omega)$ and $\Phi_T(\Omega)$ thus provide the probability that the radical pair ends up as the singlet or the triplet product, respectively.

Once the quantum yields for a single radical pair are obtained, one should consider the ensemble of radical pairs. Since the radical pairs in the ensemble will have different orientations, Ω, one should average the quantum yields over all possible orientations in order to obtain the ensemble average:

$$\langle\Phi_S\rangle = \frac{1}{8\pi^2}\int\int_0^\infty k_S\phi_S\, dt\, d\Omega\,. \tag{12}$$

Here the prefactor of $\frac{1}{8\pi^2}$ is a normalization constant. A reference frame can be described by three Euler angles, α, β, and γ. The ensemble average in Eq (12) may therefore be be written as:

$$\langle\Phi_S\rangle = \frac{1}{8\pi^2}\int_0^{2\pi}\int_0^{2\pi}\int_0^{\pi}\int_0^\infty k_S\phi_S\, dt\, \sin(\beta) d\beta\, d\alpha\, d\gamma\,. \tag{13}$$

If the density operator, $\rho(t,\Omega)$ in Eq (10), is independent of the orientation of the radicals due to e.g. rotational diffusion, Eq (13) simplifies to:

$$\langle\Phi_S\rangle = \int_0^\infty k_S\phi_S\, dt\,. \tag{14}$$

Note, however, that this simplification is not possible for anisoptropic hyperfine interactions (i.e. if the radicals are constrained), or once other anisotropic interactions such as the magnetic dipole-dipole interaction are present, which may be significant when the radicals are located close to each other. The generic model systems studied here only have isotropic internal interactions and so Eq (14) holds.

The ensemble average of the quantum yield determines the fraction of radical pairs reacting through a particular reaction pathway; in the generic model system described in Fig 2B it describes the fraction of radical pairs that end up as singlet and triplet products, respectively. If N_{RPs} denotes the number of radical pairs within a cell, and N_{cells} the total number of cells in an experiment, the total yields can, therefore, be defined as:

$$\overline{\langle\Phi_S\rangle} = \mathcal{N}\langle\Phi_S\rangle, \qquad \overline{\langle\Phi_T\rangle} = \mathcal{N}\langle\Phi_T\rangle, \qquad \mathcal{N} = N_{\mathrm{RPs}}N_{\mathrm{cells}}\,. \tag{15}$$

Thus the average total yields $\overline{\langle\Phi_S\rangle}$ and $\overline{\langle\Phi_T\rangle}$, or the ratio $\overline{\langle\Phi_S\rangle}/\overline{\langle\Phi_T\rangle}$, are the quantities that can be measured experimentally [59, 60] if intracellular reactions that rely on radical pair dynamics are somewhat known. It is thus only the RF field effects that causes a change in these

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average total yields, and hence the average quantum yields, that are becoming noticeable on the cellular scale. Since the exact number of radicals $\mathcal{N}$ is normally not known, it is more common to instead consider the fractions:

$$\frac{\overline{\langle\Phi_S\rangle}}{\overline{\langle\Phi_S\rangle}+\overline{\langle\Phi_T\rangle}}=\langle\Phi_S\rangle,\qquad \frac{\overline{\langle\Phi_T\rangle}}{\overline{\langle\Phi_S\rangle}+\overline{\langle\Phi_T\rangle}}=\langle\Phi_T\rangle, \tag{16}$$

which can be compared with experimentally measured fractions of the various reaction products.

Results of model calculations

Quantifying radical pair response to RF fields

Evaluating the probability of forming the singlet products of the radical pair reaction with and without the presence of a RF magnetic field, and by subtracting one from another, one obtains an action spectrum as shown in Fig 4A. This spectrum describes specifically the change of the ensemble averaged singlet quantum yield in the model radical pair system, and is mathematically defined as:

$$\Delta\langle\Phi_S\rangle=\langle\widetilde{\Phi_S}\rangle-\langle\Phi_S\rangle_0\,. \tag{17}$$

Here $\langle\widetilde{\Phi_S}\rangle$ is the average of singlet products describing the ensemble of radical pairs in the presence of an RF magnetic field, while $\langle\Phi_S\rangle_0$ is the same quantity without the RF contribution, i.e. corresponding to $B_1 = 0$. Thus $\langle\widetilde{\Phi_S}\rangle$ and $\langle\Phi_S\rangle_0$ corresponds to two different experiments: one with a RF magnetic field present and another experiment without, respectively. The difference between the average singlet product yields in the two experiments, $\Delta\langle\Phi_S\rangle$, allows then to quantify the effect of the RF magnetic field. Note that although the definition of $\Delta\langle\Phi_S\rangle$ in Eq (17) makes the singlet product probability difference a function of both B_1 and ω, other parameters such as reaction rate constants and hyperfine couplings still influence the radical pair dynamics, and, therefore, the reaction yield change. The singlet product probability change, $\Delta\langle\Phi_S\rangle$ for this model system, reflects the concentration changes in a chemical species as a result of the RF magnetic field, thus the calculation results are linked to physical

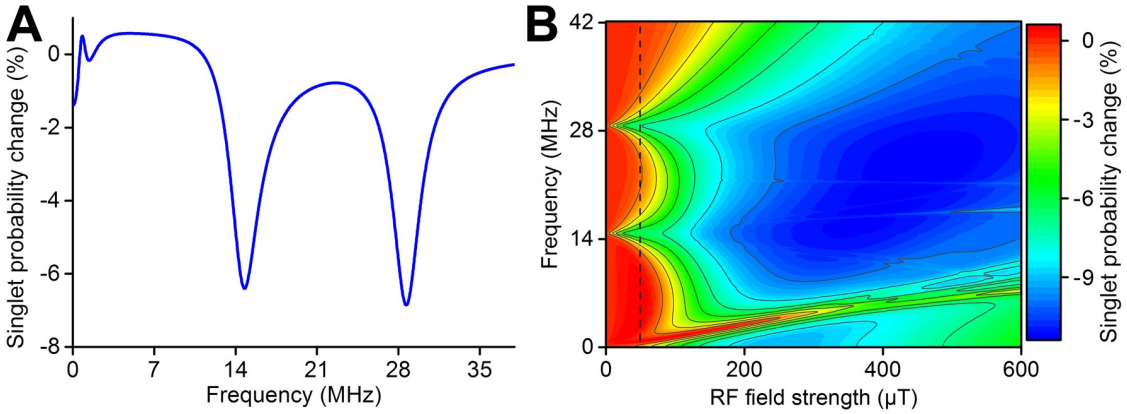


Fig 4. Possible singlet product probability change in the radical pair. A: An action spectrum showing the singlet product probability change, Eq (17), as a function of RF magnetic field frequency, ω, for a specific field strength, $B_1 = 50\ \mu$T, as defined in Eq (6). Note that the yield change is non-zero at zero frequency, since the RF magnetic field corresponds to a static field in this case, i.e. setting $\omega = 0$ in Eq (6). **B**: The singlet product probability change, Eq (17), as a function of both ω and B_1. Note that **A** is the vertical slice of **B** with $B_1 = 50\ \mu$T, as indicated by the dashed line in **B**. All calculations assume $k_S = k_T = 10^6\ \mathrm{s}^{-1}$, $B_0 = 50\ \mu$T and $a_1 = 0.5$ mT.

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observables. It is then possible to obtain action spectra for different combinations of B_1 and ω, as done in Fig 4B for the studied model radical pair system with $k_S = k_T = 10^6$ s^{-1}, $B_0 = 50$ μT and $a_1 = 0.5$ mT, see Fig 2. Note that clear peculiarities are seen in Fig 4B for very weak RF magnetic fields of $B_1 < 100$ μT, while these features disappear as B_1 approaches the strength of the hyperfine interactions in the radical pair which in the considered example are 500-1000 μT. This behaviour is expected to arise because the RF magnetic field induces transitions between spin states at a rate comparable with the rate for coherent mixing of singlet and triplet states governed by the hyperfine interactions, thereby interfering strongly with the coherent spin dynamics in the radical pair.

Influence of the internal magnetic fields

The singlet and triplet states of the radical pair are the so-called eigenstates of the Zeeman interaction with a homogeneous magnetic field along the *z*-axis, and eigenstates of the Hamiltonian do not mix over time. It is, therefore, necessary to include the hyperfine interactions of at least one magnetic nucleus in order to enable any possibility for singlet-triplet mixing, since singlet and triplet states will no longer be eigenstates of the total Hamiltonian in that case. In practice this means that radical pairs without any magnetic nuclei, and therefore no hyperfine interactions, such as a pair of superoxide radicals, would not have any singlet-triplet mixing (unless it is introduced by other means, such as *g*-tensor anisotropy) and, therefore, no RF magnetic field effects would be possible. A single hyperfine coupling on at least one of the two radicals is enough to enable singlet-triplet mixing. The reason that hyperfine interactions are necessary for state mixing is due to the conservation of angular momentum: the singlet and triplet states have different angular momenta by definition, and a conversion between singlet and triplet states can, therefore, only happen if an external angular momentum, such as a nuclear spin, is changed simulatneously, in order to conserve the total angular momentum. RF magnetic fields can also be described in terms of photons, and since photons carry angular momentum, interactions with photons can cause transitions between spin states as well. In the model radical pair system investigated here, each radical has a single magnetic nucleus, and the effect of changing the internal magnetic interactions within the radical pair, i.e. the hyperfine interaction strength of one of these nuclei, through changing a_1, is explored in Fig 5. The

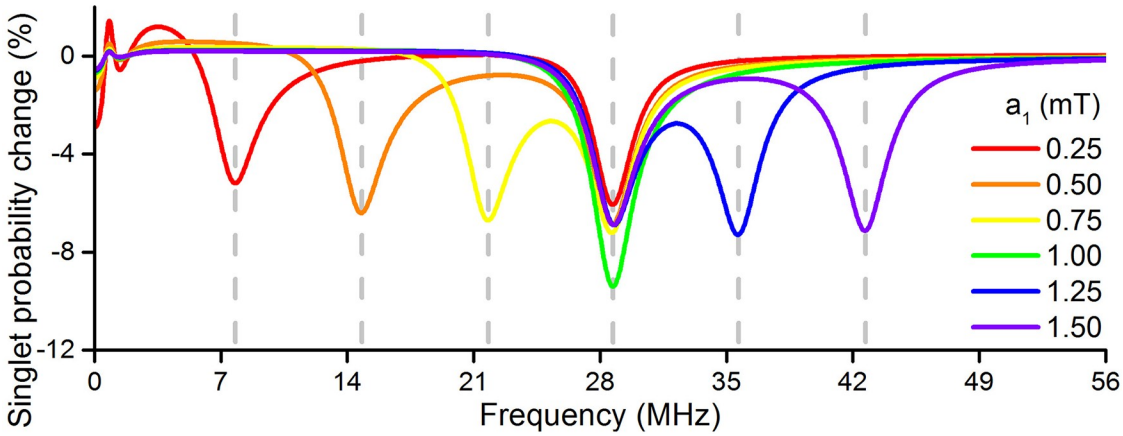


Fig 5. Hyperfine interactions impact the singlet product probability change in the studied model reaction. The strength of the isotropic hyperfine coupling constant a_1 is modified here. Pronounced changes in the singlet probability are always seen in the low-frequency limit, and for $\omega \approx a_1 \cdot 28 \frac{\text{MHz}}{\text{mT}} + 0.7$ MHz. The fixed hyperfine coupling, $\mathbf{a}_2$, gives rise to a singlet probability change around 28.7 MHz and enhances the singlet probability change at 28.7 MHz when $a_1 = 1.00$ mT. $k_S = k_T = 10^6$ s^{-1}, $B_0 = 50$ μT and $B_1 = 50$ μT are assumed in all calculations.

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obtained change in the singlet product probability can be understood by rewriting the hyperfine interaction for the first radical, as:

$$\mathbf{H}_{HF}^{(1)} = g\mu_B a_1 \mathbf{S}_1 \cdot \mathbf{I}_1 = \frac{g\mu_B a_1}{2}\left(\mathbf{Q}_1^2 - \mathbf{S}_1^2 - \mathbf{I}_1^2\right), \tag{18}$$

where $\mathbf{S}_1^2$ and $\mathbf{I}_1^2$ are the total angular momentum operators of the electron and nucleus on the first radical, respectively, both having an eigenvalue of $\frac{3}{4}\hbar^2$. $\mathbf{Q}_1^2 = (\mathbf{S}_1 + \mathbf{I}_1)^2$ is the total spin angular momentum of the first radical consisting of an unpaired electron and a magnetic nucleus; the allowed eigenvalues of $\mathbf{Q}_1^2$ are $0\hbar^2$ and $2\hbar^2$. Thus the possible energy states of the first radical are split by the hyperfine interaction in Eq (18), such that one state has the energy $E_1 = -\frac{3}{4}g\mu_B a_1$, corresponding to the eigenvalue $0\hbar^2$ of $\mathbf{Q}^2$, and three states have the energy $E_2 = \frac{1}{4}g\mu_B a_1$, corresponding to eigenvalue $2\hbar^2$ of $\mathbf{Q}^2$. The transition frequency between these energy states is therefore:

$$\nu = \frac{E_2 - E_1}{2\pi\hbar} + \Delta\nu = \frac{g\mu_B}{2\pi\hbar}a_1 + \Delta\nu \approx 28\frac{\text{MHz}}{\text{mT}}a_1 + \Delta\nu, \tag{19}$$

where $\Delta\nu$ is a contribution from the static external magnetic field, which is needed because only the hyperfine interactions were included in E_1 and E_2 while the Zeeman interaction also impacts on the energy difference between the possible states in the radical; $\Delta\nu$ is approximately 0.7 MHz at $B_0 = 50\ \mu$T. Note that the form of Eq (19) only holds when the static magnetic field is weak compared to the hyperfine interactions, such that it only contributes the small perturbation $\Delta\nu$; a more rigorous treatment of the impact of the static external magnetic field on the transition frequencies is much more involved. The correspondence between transition frequency and the isotropic hyperfine coupling manifests itself in Fig 5: for $a_1 = 0.25$ mT one observes a large change in the singlet yield at $0.25 \cdot 28$ MHz + 0.7 MHz = 7.7 MHz, for $a_1 = 0.75$ mT at 21.7 MHz, and for $a_1 = 1.50$ mT at 42.7 MHz, as indicated by the dashed lines in Fig 5. For all values of a_1, the probability of forming the singlet product additionally have a large change at 28.7 MHz. This additional feature is caused by the second radical, which has a magnetic nucleus with a fixed isotropic hyperfine coupling of 1 mT.

The simple correspondence between hyperfine interactions and the frequency-dependence of the singlet yield change become more complicated when multiple magnetic nuclei reside on the same radical, due to second-order interactions where nuclei may interact with each other through the hyperfine interactions with the unpaired electron. It should nevertheless be clear from Fig 5 that the hyperfine interactions in a radical pair are crucial in determining whether an RF magnetic field might influence a radical pair reaction, and therefore the most important of the internal molecular parameters to be obtained.

The effect of exchange and dipole-dipole interaction

Including the exchange interaction, Eq (3), between the radicals of a radical pair mainly results in a less significant response to the RF magnetic field. A strong exchange interaction, i.e. a large value of J, supresses the singlet-triplet mixing in the radical pair, which in the simple model radical pair leads to a very high singlet yield. This effect of the exchange interaction is illustrated in Fig 6 as a function of

$$\eta = -\frac{2J}{g\mu_B}, \tag{20}$$

instead of J, to allow easier comparison with the hyperfine interactions.

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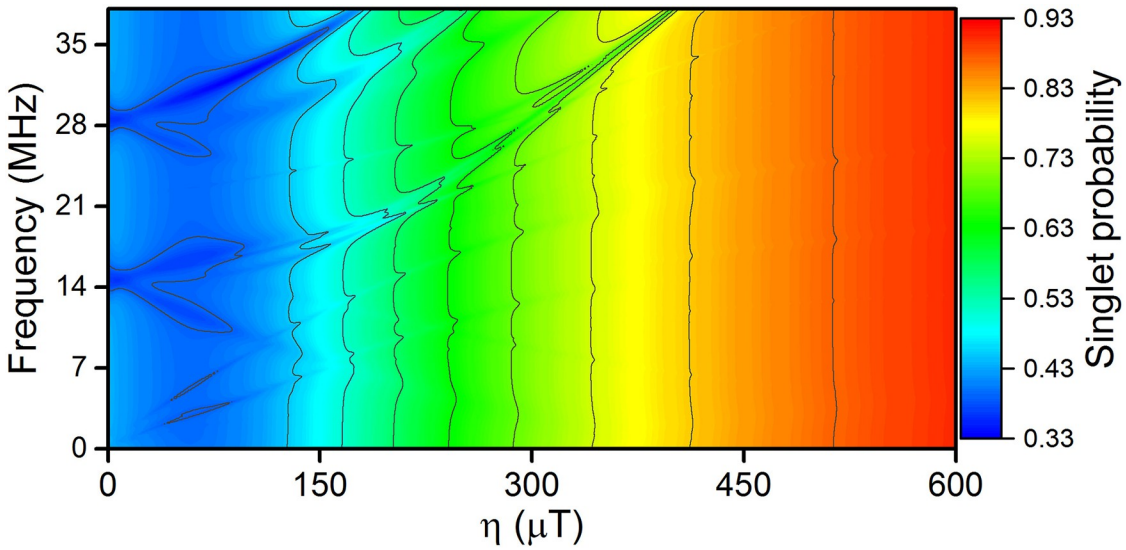


Fig 6. The exchange interaction. The exchange interaction is defiend in Eq (3), but $\eta = -\frac{2J}{g\mu_B}$ is used instead of J for better comparison with the hyperfine interaction strength. For values of η comparable with the hyperfine coupling $a_1 = 500\ \mu$T the singlet-triplet mixing of the radical pair is supressed, leaving the radical pair largely in its initial singlet state.

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The magnetic dipole-dipole interaction between the radicals, Eq (4), has a similar effect to the exchange interaction, with the tensor **D** playing the role of the interaction strength in a similar fashion as J for the exchange interaction. The main difference between these two inter-radical interactions is the tensorial nature of **D** which allows for an anisotropic interaction, but ultimately they both just suppress singlet-triplet mixing and hence the RF magnetic field effects. Thus, as depicted in the workflow diagram in Fig 1, there will be no RF magnetic field effect if J or **D** is too large, as illustrated in Fig 6, i.e. the peculiarities in the singlet probability vanish when η reaches the same order of magnitude as the hyperfine interactions.

Radical pair lifetime

Whether an RF magnetic field has an impact on the radical pair highly depends on how much time the RF field affects the system, as well as the intensity of the RF field. This is also emphasized in the workflow in Fig 1, which indicate that no RF magnetic field effect is expected once $\tau_{RF} \gg \tau_0$. Here τ_{RF} is defined in Eq (2) while the radical pair lifetime τ_0 depends on the reaction rate constants, k_S and k_T. In all the model calculations carried out so far, it is assumed that $k_S = k_T = k$, i.e. that there is only a spin-independent reaction with rate constant k, leading to a radical pair lifetime of $\tau_0 = 1/k$.

Fig 7 illustrates that the most prominent RF magnetic field effects on the singlet yield requires a lifetime of the radical pair in the range of 100 ns—100 μs. These lifetimes are characteristic for an RF field of 50 μT intensity, and τ_{RF} would be somewhat different for e.g. a 5 μT RF field since such a weaker RF magnetic field would require more time to influence the radical pair dynamics.

The singlet yield tends towards a value of 0.25 as τ_0 increases, whereas high rate constants result in very high singlet yields. For example, a singlet product probability of about 0.65 was obtained for $k = 100\ \mu s^{-1}$, since the radical pair is initially assumed to be generated in the singlet state and the probability for it to react chemically before being converted to the triplet state is high. In general this happens when the time scale for singlet-triplet mixing in a radical pair becomes much longer than its lifetime, $\tau_{mix} \gg \tau_0$, i.e. singlet-triplet mixing takes too long

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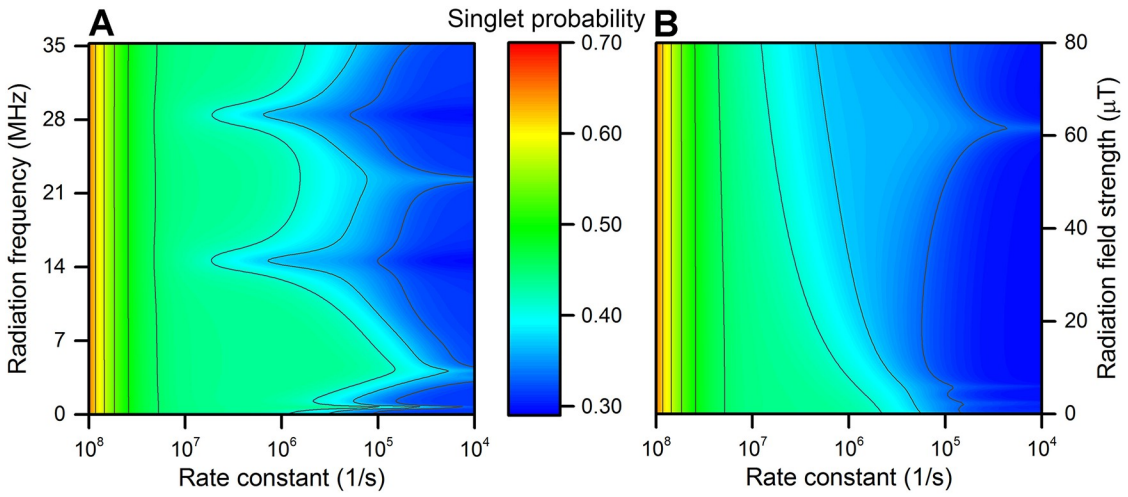


Fig 7. Singlet product probability dependence on k (τ_0) and B_1 (τ_{RF}). The singlet product probability is calculated assuming spin-independent kinetics, i.e. $k = k_S = k_T$. **A**: The dependence of the reaction probability on RF frequency and reaction rate constant, with $B_1 = 50\ \mu$T and therefore $\tau_{RF} = 714$ ns. **B**: The dependence of the reaction probability on RF field intensity and reaction rate constant, with $\omega = 14.4$ MHz corresponding to the significant singlet yield change seen in **A** and Fig 4A. The calculations assume $B_0 = 50\ \mu$T and $a_1 = 0.5$ mT.

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for it to happen before most of the system has already chemically reacted, as is seen in Fig 7 for rate constants $k > 10^7\ \mathrm{s}^{-1}$.

Modelling a more complex radical pair

As stated earlier, the hyperfine couplings in a radical pair has typically a more profound influence on the RF magnetic field response than any of the other internal molecular parameters, provided J and $\mathbf{D}$ are not too large or $\tau_{RF} \gg \tau_0$ to prevent any RF magnetic field effects in the first place. Thus it is instructive to see how a radical pair with more hyperfine interactions can be studied. Since it has been previously suggested that RF effects in a $[\mathrm{FAD}^{\bullet-} \ldots \mathrm{O}_2^{\bullet-}]$ radical pair might lead to increased intracellular superoxide levels [1, 2, 4], this particular system will be considered. It should thus be noted that while the superoxide radical has no hyperfine interactions, the $\mathrm{FAD}^{\bullet-}$ radical contains (i) many nuclei on the same radical; (ii) nitrogen nuclei with a spin of 1; (iii) sets of magnetically equivalent nuclei, e.g. the three H8 methyl protons.

The full $\mathrm{FAD}^{\bullet-}$ radical contains 15 magnetic nuclei (4 nitrogens and 11 protons), and such a high number of magnetic nuclei can be difficult to handle computationally. Luckily it normally suffices to consider only a subset of the magnetic nuclei, since the magnetic nuclei with the smallest hyperfine couplings only would contribute smaller perturbations to the action spectrum. Thus the 8 magnetic nuclei with the largest hyperfine couplings would make up a representative model of the $\mathrm{FAD}^{\bullet-}$ radical.

The radical pair is assumed to be produced in the singlet state, and assume that a reaction to form H_2O_2 may happen only from the singlet state, while superoxide radicals in a triplet state might escape without forming H_2O_2; thus singlet (H_2O_2) and triplet (superoxide) products are defined for this radical pair example. In an experiment, the measured amounts of H_2O_2 and superoxide provides the quantities $\overline{\langle\Phi_S\rangle}$ and $\overline{\langle\Phi_T\rangle}$, respectively, and Eq (16) provides the fractions for these two products, $\langle\Phi_S\rangle$ and $\langle\Phi_T\rangle$. If the experiment is performed twice, with and without a RF magnetic field, the average singlet yield change, $\Delta\langle\Phi_S\rangle$, can then be obtained; it is simply the change in the amount of H_2O_2 produced in the experiment with RF magnetic

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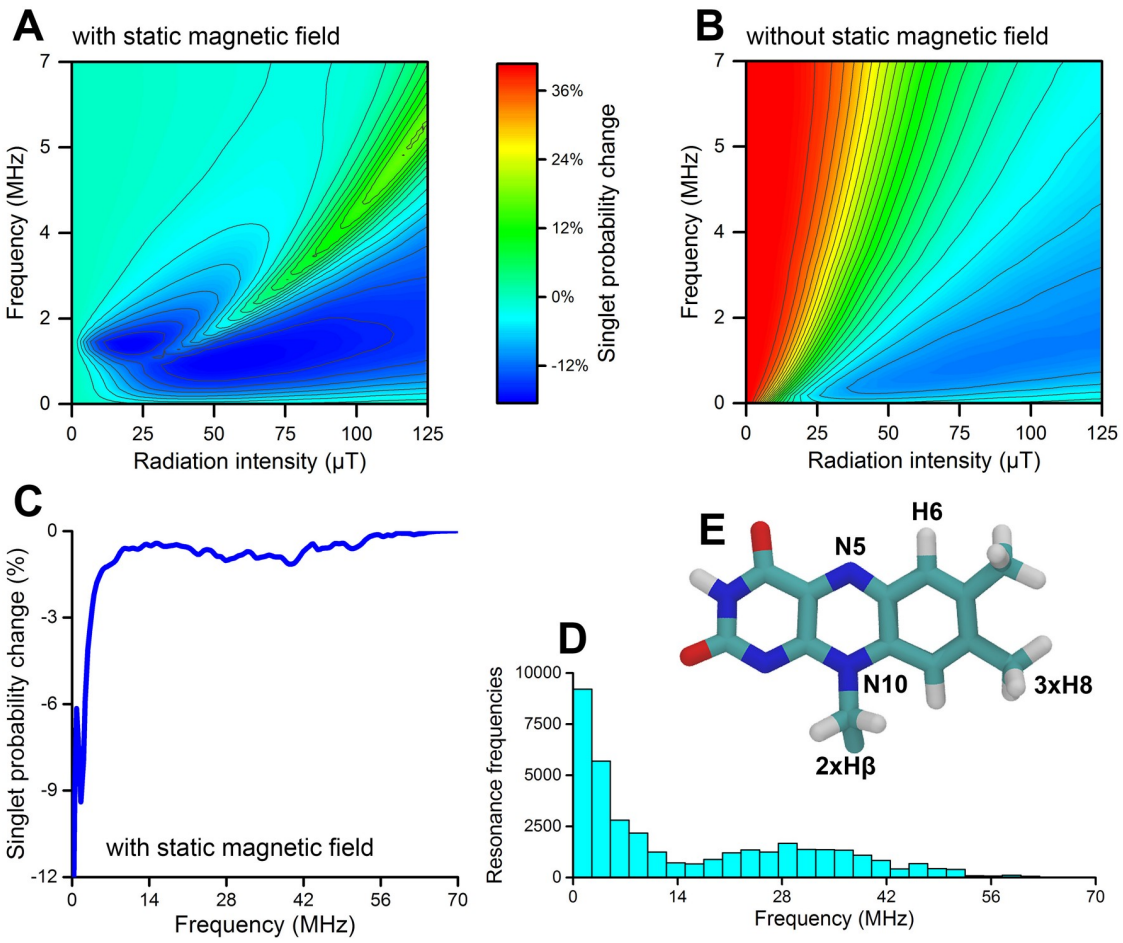


Fig 8. Characterization of RF effects in the $[FAD^{\bullet -} \ldots O_2^{\bullet -}]$ radical pair. A-C: The singlet product probability change was calculated for a model including 8 isotropic hyperfine interactions on $FAD^{\bullet -}$ and none on $O_2^{\bullet -}$, with (**A** and **C**) or without (**B**) a static external magnetic field of $B_0 = 50\ \mu T$ along the z-axis. All calculations assumed $k_S = k_T = 1\ \mu s^{-1}$. Once the static external magnetic field is present, significant singlet probability changes are only seen for RF frequencies below 7 MHz as illustrated in **C**. **D**: The resonance frequencies of the system calculated from the eigenvalues of the spin Hamiltonian. **E**: The nuclei N5, N10, H6, 3 × H8 and 2 × Hβ on FAD were used.

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fields, compared to the experiment without RF magnetic fields, and this is exactly the quantity that was computed in Fig 8A–8C.

The presence of even a weak static magnetic field may have a significant effect on the quantum yields, as illustrated by Fig 8A and 8B; the static magnetic field changes the energy levels of the spin states in the radical pair, thereby changing the resonance frequencies of the spin system. For a complex radical like $FAD^{\bullet -}$, which has many hyperfine interactions, this Zeeman-splitting of the energy levels by a static magnetic field is unlikely to be significant. For superoxide, on the other hand, one of the simplest possible radicals, void of any hyperfine interactions, a notable effect would be expected: in the absence of any coupling between the two unpaired electrons (that is, no exchange or magnetic dipole-dipole interaction), the unpaired electron in the superoxide radical can be considered a "free electron". Such free electrons are known to undergo Larmor precession in a static magnetic field [44], with the precession frequency given by 1.4 MHz in a static magnetic field of 50 μT. Since the main difference between Fig 8A and 8B are seen near 1.4 MHz, this Zeeman-resonance in superoxide seems to be the main cause of the static field effect.

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With the more complex model system defined, it would be straightforward to calculate the action of the RF magnetic field as in Fig 4, and the results of such calculations are shown in Fig 8A–8C. Such a comprehensive analysis may not be necessary, particularly if one is interested in RF magnetic fields with a specific frequency ν_{RF}; a simple analysis of the radical pair system can determine its acceptable resonance frequencies, and unless ν_{RF} is close to any of these frequencies there can be no effect of the RF magnetic field, as illustrated in Fig 1. The resonance frequencies are obtained from the eigenvalues of the spin Hamiltonian for the radical pair system, as the difference between any pair of its eigenvalues. For a Hamiltonian with n eigenvalues there will thus be $n(n-1)$ resonance frequencies, where n may potentially be a rather large number, being determined by the type and number of magnetic nuclei in the radicals. A histogram of the number of resonance frequencies would, therefore, be a simple way to represent them, as is illustrated in Fig 8D for the $FAD^{\bullet-}$ radical. Note that there is a certain similarity between Fig 8C and 8D as each peculiarity in Fig 8C is caused by excitation of specific resonance frequencies. In particular, there is a significant change in the singlet product probability at low frequencies, which is expected since any resonance frequency is calculated as the difference between two energy levels: the largest resonance frequency just above 50 MHz is only about a factor of 2 larger than the largest resonance frequency in the two-nucleus systems studied previously, while the number of energy levels (spin states) has increased from 16 (two electronic spins and two spin-1/2 nuclei) to 6528 (two electronic spins, 6 protons and 2 nitrogen nuclei). The energy levels must therefore be packed much closer to each other, which means that the energy difference between a pair of energy levels will in many cases be very small, leading to a small resonance frequency. As seen in Fig 5, singlet yield change as a function of the oscillation frequency of the RF magnetic field follows a Lorentzian distribution centered around a specific resonance frequency. In other words, not only does the resonance frequencies affect radical pairs, but oscillation frequencies near a given resonance frequency might also have an effect, although the effect is smaller for frequencies further away from a resonance frequency, as dictated by the Lorentzian distribution. The full-width at half-maximum (FWHM) of the Lorentzian distribution depends on the lifetime of the radical pair, and the effect is, therefore, known as lifetime broadening [61]. Due to lifetime broadening, RF magnetic fields of any frequency below a few MHz, dependending on the radical pair lifetime, will, therefore, significantly affect the singlet product probability. This may be considered a general feature of radical pairs with many hyperfine interactions, with the radical pair lifetime being the crucial parameter due to the lifetime broadening.

Discussion

Determining whether radical pairs residing in a biological environment are susceptible to RF magnetic field effects is no simple matter, but the presented workflow outlines the steps necessary to produce a realistic computational model of ensembles of such radical pairs, as well as the interpretation of calculation results in terms of physical observables. Such a computational approach has the predictive power necessary to evaluate the possible health effects of RF magnetic fields.

The Liouville-von Neumann equation allows to describe the dynamics of ensembles of transient intracellular radical pairs, and permits predicting their response to external RF magnetic fields. Note that only the magnetic aspect of the electromagnetic radiation has been considered here; electric fields do not directly interact with spins, except for the nuclear quadrupole interaction for nuclei with a spin of at least 1, and any indirect effects by e.g. a displacement in the electronic density would be negligible compared to the magnetic interactions. The calculation examples in the present study employed the rotating reference frame approach to establish the

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characteristic change of the radical pair singlet product probability, which would characterize such a response. This theoretical description was chosen due to its simplicity, which served well to demonstrate many features of RF magnetic field responses in model radical pair ensembles.

The change in the probability of the singlet product caused by an RF magnetic field has been shown in model calculations and previous studies [13, 28, 32, 51] to depend on the structure of the molecular system hosting the radical pair, described mainly through the hyperfine interactions. The generic two-nuclei model displayed a very simple relationship between the peculiarities in the singlet yield change and the RF magnetic field frequency, and similar relationships may also be found for more realistic models containing more magnetic nuclei, although they would be much more complex due to the larger number of nuclear spin states as illustrated for the $[FAD^{\bullet -} \ldots O_2^{\bullet -}]$ radical pair. The computations predict that for significant RF field-induced effects to happen within the 1-50 MHz range with RF field strengths below 100 μT, the recombination and chemical reactions of the radical pair should occur with rate constants in the interval of 10^4-10^7 s^{-1}. Although the present investigation focuses on a simplified model system, these limits on the rate constants are expected not to be much different for a more realistic radical pair system since they depend on the time scale for singlet-triplet mixing, which in turn depends on the strength of the hyperfine interactions; even though the hyperfine interactions in a real molecular system could be larger than those of the studied model system, they are expected to be of the same order of magnitude. It should be noted, however, that the rate constants for chemical reactions involving singlet and triplet states are in general not equal, since recombination may happen either only from the singlet state or only from the triplet state [54]. Although different reaction rate constants for singlet and triplet were not explored in the present study, it is already supported by the formalism described above, see e.g. Eq (9).

The workflow described here represents a general framework that can be applied to many different physical systems, not even limited to radical pairs. In fact many complexes involving metal ions would posses a number of unpaired electrons, which could take the role of one of the radicals in a radical pair, the main difference being the spin quantum number. The main challenge that remains in order to explain the observed RF magnetic field effects in cells is, therefore, to find cellular processes that could be affected, and design experiments to obtain the magnitude of any RF field effects. Theoretical calculations as those presented here can both aid in explaining observed effects of RF fields, and make predictions about frequency ranges that deserve experimental investigation in order to observe an effect.

Supporting information

S1 Fig. The three Euler angles α, β and γ. First a rotation about the z-axis by angle α is performed, then a rotation about the initial x-axis by the angle β, and finally a rotation about the z-axis by the angle γ.
(PDF)

S1 File. Spin systems and mixing of states. The summary provides a short introduction to the essential concepts of spin dynamics used in the paper.
(PDF)

S2 File. Rotation matrices. The basic concepts of rotation matrices that describe transformation from the molecular frame of reference to the laboratory frame.
(PDF)

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Long-Term, Low-Level Microwave Irradiation of Rats

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Our goal was to investigate effects of long-term exposure to pulsed microwave radiation. The major emphasis was to expose a large sample of experimental animals throughout their lifetimes and to monitor them for effects on general health and longevity.

An exposure facility was developed that enabled 200 rats to be maintained under specific-pathogen-free (SPF) conditions while housed individually in circularly-polarized waveguides. The exposure facility consisted of two rooms, each containing 50 active waveguides and 50 waveguides for sham (control) exposures. The experimental rats were exposed to 2,450-MHz pulsed microwaves at 800 pps with a 10-μs pulse width. The pulsed microwaves were square-wave modulated at 8-Hz. Whole body calorimetry, thermographic analysis, and power-meter analysis indicated that microwaves delivered at 0.144 W to each exposure waveguide resulted in an average specific absorption rate (SAR) that ranged from 0.4 W/kg for a 200-g rat to 0.15 W/kg for an 800-g rat.

Two hundred male, Sprague-Dawley rats were assigned in equal numbers to radiation-exposure and sham-exposure conditions. Exposure began at 8 weeks of age and continued daily, 21.5 h/day, for 25 months. Animals were bled at regular intervals and blood samples were analyzed for serum chemistries, hematological values, protein electrophoretic patterns, thyroxine, and plasma corticosterone levels. In addition to daily measures of body mass, food and water consumption by all animals, O_2 consumption and CO_2 production were periodically measured in a sub-sample (N=18) of each group. Activity was assessed in an open-field apparatus at regular intervals throughout the study. After 13 months, 10 rats from each group were euthanized to test for immunological competence and to permit whole-body analysis, as well as gross and histopathological examinations. At the end of 25 months, the survivors (11 sham-exposed and 12 radiation-exposed rats) were euthanized for similar analyses. The other 157 animals were examined histopathologically when they died spontaneously or were terminated *in extremis*.

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Statistical analyses by parametric and non-parametric tests of 155 parameters were negative overall for effects on general health, longevity, cause of death, or lesions associated with aging and benign neoplasia. Positive findings of effects on corticosterone level and immune system at 13 months exposure were not confirmed in a follow-up study of 20 exposed and 20 control rats. Differences in O_2 consumption and CO_2 production were found in young rats. A statistically significant increase of primary malignancies in exposed rats vs. incidence in controls is a provocative finding, but the biological significance of this effect in the absence of truncated longevity is conjectural. The positive findings need independent experimental evaluation. Overall, the results indicate that there were no definitive biological effects in rats chronically exposed to RF radiation at 2,450 MHz.
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Key words: SAR, longevity, health, tumor incidence

INTRODUCTION

Advances in dosimetry, and a better understanding of energy absorption by biological tissues, have eliminated many concerns regarding effects of radio-frequency electromagnetic radiation [Tyler, 1975; Elder and Cahill, 1984; NCRP, 1986; Polk and Postow, 1986; Lin, 1989; Gandhi, 1990]. Despite this lessening of concern for low-level, acute exposures, lack of data on long-term, low-level radiation has fueled public and scientific concerns. In this context, officials of the United States Air Force sought to support research in this area to provide data for use in the development of environmental impact studies for present and planned Air Force systems.

The goal of the project was to investigate effects on health of long-term exposure to low-level, pulsed microwave radiation. The approach was to expose a large population of experimental animals to microwave radiation throughout most of their lifetimes and to monitor them for effects on general health and longevity.

Although the initial impetus for the study was the question of environmental impact of the Air Force PAVE PAWS system, early on it was decided not to study a replica of the PAVE PAWS emissions, but to create a generalized level of radiation that would provide whole-body exposure based on the maximum of permissible absorption [ANSI C95.1-1982, 1983; IEEE C95.1–1991,1992] at the resonant frequency in human beings (0.4 W/kg), as scaled to the proportions of the experimental animal of choice.

Following a period of pilot studies and training of technicians, exposures to microwaves commenced on September 1, 1980, and concluded September 27, 1982. The 100 experimental and 100 sham-exposed animals underwent the longest near-continuous exposure ever completed. The findings were reported in a series of 9 Air Force technical reports, which are available through the National Technical Information Service (Springfield, Virginia). Interested readers should refer to the technical reports for details [Guy et al., 1983a, b, 1985; Chou et al, 1983; Johnson et al., 1983, 1984; Kunz et al., 1983, 1984, 1985].

METHODOLOGY

Experimental Design

Exposure criteria. Much of the past work on chronic exposure of large numbers of text animals has been based on anechoic chambers, metal capacitor plates, or

resonant cavities. With these methods, the energy coupled to each animal is a function of the group size, group orientation, and the orientation of each animal within the group, as well as of the presence and location of water and food dispensers. Because estimates of energy absorption are uncertain, quantitative extrapolation of biological results from laboratory animals to human beings is virtually impossible. In addition, the cost in time and resources of even simple experiments involving chronic exposures of animal populations in large anechoic chambers is prohibitive.

For this study, we chose a system of cylindrical, wire-mesh waveguides to expose a large number of animals to a common source while independently maintaining relatively constant and quantifiable coupling of electromagnetic energy to each animal regardless of position, posture, or movement [Guy and Chou, 1977; Guy et al., 1979]. The system, which consists of a number of independent waveguides, allows individual animals to be continuously exposed under normal laboratory conditions while living unrestrained and with continuous access to food and water.

A frequency of 2450 MHz was selected so each rat would have approximately the same size-to-wavelength ratio as a human being exposed at 450 MHz, the frequency near which PAVE PAWS operates. The initial consideration was to produce the same average SAR in test animals as predicted for man exposed to a 1-mW/cm^2, 450-MHz RF field. To simulate radar exposure, pulse modulation was used (10 μs pulse, 800 pps). In addition to the pulse modulation, we decided to square-wave modulate the microwaves. The inclusion of square-wave modulation was prompted by the evidence of altered movement of Ca^{++} ions in chicken and cat brains exposed to ELF-modulated RF fields [Adey, 1981]. Because the demonstrated effects are most pronounced when the modulation frequencies correspond to the dominant EEG frequency, we selected a modulation frequency of 8 Hz because it is at the peak of the rat's hippocampal theta rhythm [Coenen, 1975].

Rationale of biological assessment. Not only were reported biological effects from low-level microwaves selected as end points (e.g., alterations of hematopoietic, immunologic, and specific blood chemistry indices), but assays for effects on general health, metabolism, and life span were also included (references listed in later sections). In addition, end points were considered that could be assessed without seriously compromising the health of the animal, the value of concurrent measurements, or the power of the statistical evaluations on the chosen end points. Only male rats were used to minimize statistical variation, i.e., to avoid the hormonal variations characteristic of female rats. Use of female rats would have required a substantial increase in the number of animals. A total of 155 parameters was studied. The end points selected are shown in Table 1. Due to space limitations, details of rationale and methods of biological assessments cannot be provided here. The original NTIS reports should be consulted.

Statistical considerations. For any failure-time end point, such as time to death, time to cancer diagnosis, or time to some specified change in animal mass or blood chemistry, an initial sample size of 100 in each group was calculated to be sufficient for detection, at the .05 significance level, of a 50% increase (or 33% reduction) in instantaneous failure rate with a probability (power) of 90%. For any normally distributed end point (including transformations on failure-time variables), a sample size of 100 per group permits the detection, at the .05 level of significance, of a difference between groups of 40% of one standard deviation, with a power of 90%. Adjustment for a differential effect due to the altered experimental procedure for

TABLE 1. Endpoints Selected to Study the Effects of Long-Term, Low-Level RF Exposure on Rats

Category	Parameters	No.
Behavior	Open field behavior (activity, quadrant change, urination, defecation)	4
Corticosterone	Serum corticosterone	1
Immunology	Mitogen stimulation (PHA,LPS,ConA,PWM,PPD), B-cell, T-cell, %CRPC, total CRPC, plaque	10
Hematology	WBC, RBC, HCT, Hgb, MCV, MCH, MCHC, neutrophils, lymphocytes, eosinophil, monocytes	11
Blood chemistry	Glucose, BUN, creatinine, Na, K, Cl, CO_2, uric acid, total bilirubin, direct bilirubin, Ca, phosphorus, alkaline phosphatase, LDH, SGOT, SGPT, cholesterol, triglycerides, total protein, albumin, globulin	21
Protein electrophoresis	Albumin fraction, alpha-1 and 2 fractions, beta fraction, gamma fraction	4
Thyroxine	Thyroxine	1
Urinalysis	Urine observation	1
Metabolism	Body mass, food consumption, water consumption, O_2 consumption, CO_2 production, respiratory quotient, metabolism quotient	7
Total body analysis	Body mass, moisture, protein nitrogen, crude fat, nonprotein nitrogen, total ash, mineral contents (aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, phosphate, potassium, selenium, silver, sodium, strontium, tin, titanium, vanadium), fatty acids (palmitic, palmitoleic, stearic, oleic, linoleic, linolenic)	39
Organ mass	Heart, brain, liver, kidneys, testicles, adrenals	9
Histopathology	All tissues and organs	46
Longevity	Survival days	1
Total		155

the subset of 36 rats subjected to metabolic rate measurements had very little effect on the power calculations made, nor did adjustment for an interim euthanasia of 20 animals.

Differences between the two groups on single measurements were assessed by Student's t tests, in some cases after transformation to improve the normality of the data. Reported P values must be considered in the light of the multiple end points analyzed. Logical groupings of variables were compared across groups of the multivariate Hotelling's T^2 statistic.

Differences in tumor prevalence or incidence were assessed with time-adjusted analyses. The occurrence of neoplastic and non-neoplastic lesions was recorded along with the age of the animal and whether the animal had died spontaneously or was euthanatized. Survival curves of the exposed and sham-exposed animals were estimated by product-limit estimates [Kaplan and Meier, 1958] and compared by the log-rank statistic [Mantel, 1966]. The histopathological data were grouped with respect to age, at 6-month intervals, and the data were divided into neoplastic and non-neoplastic diagnoses. The incidence of neoplastic or non-neoplastic lesions was given as the proportion of the number of animals bearing such lesions at a specific anatomic site (numerator) to the number of animals examined pathologically (denominator). For tissues that required gross observation for detection of lesions (i.e., skin or subcutaneous tumors), for lesions that appeared at several sites (i.e., multiple

lymphomas), or for tissues that were examined histologically only when lesions were detected grossly, the denominator consisted of the number of animals necropsied in that experimental group.

The analysis of the lesions involved a 4-way table with factors of age at death, treatment condition, mode of death (terminated or spontaneous), and organ. The tables were then collapsed with respect to individual organs. From these tables, the Mantel-Haenszel estimate of the odds ratio was computed, and the chi-square statistic was used to test whether the odds ratio was significantly different from unity [Mantel and Haenszel, 1959]. This statistic reflects the difference in prevalence of lesions, over time, between the exposed and sham-exposed animals, and is appropriate if the lesions are "incidental" (do not affect the animal's survival). The time to a malignant lesion was also analyzed with survival-analysis techniques, as would be appropriate if lesions were fatal. If an animal had malignant lesions, its time-to-tumor was taken as its survival time. If there were no malignant lesions present, the time-to-tumor was considered censored (i.e., the time to appearance of a tumor is assumed to be longer than the time to death). The log-rank statistic was used to compare the times to tumor of the exposed animals with those of the sham-exposed animals [McKnight and Crowley, 1984].

Final protocol. During the first year of the study, the rats were bled from the orbital artery every 6 weeks, with the first bleeding during the 7th week of exposure. In addition to the hematological and serum-chemistry evaluation of blood collected during the first bleeding, corticosterone levels were determined in all samples having adequate amounts of serum. In subsequent bleedings, corticosterone and thyroxine levels were determined only quarterly, whereas the hematology and serum chemistry were evaluated for each sample (every 6 weeks). This frequency of bleeding was considered sufficient to detect the onset of most degenerative or disease states that would occur during the lives of the individual rats without unduly stressing the animals. Every 3 months a urinalysis was done on all rats, the first during the fourth week of exposure. This frequency of biochemical evaluations increased the opportunity to detect subclinical abnormalities and to follow their pathophysiological course. Open-field assessment was conducted every 6 weeks.

During the second year of the study, the frequency of bleeding was reduced to 12-week intervals, and the corticosterone analysis was eliminated except just prior to euthanasia of remaining animals at the end of the 2 years; urinalysis was done every 2 weeks, and open-field analysis was conducted quarterly.

Facilities

Animal facility. To maintain the colony of rats used in this study in the healthiest possible state, free of chronic disease and other problems common to rats, two specific-pathogen-free (SPF) rooms in the Division of Animal Medicine were acquired (Fig. 1). Access to the clean hall is via a shower room, through which all personnel must pass to shower and don autoclaved garments. A walk-in autoclave connected the cage-washing facility with the clean hallway so that, once washed, all materials entering the clean hall must have passed through autoclaving before being returned to the animal rooms. All soiled cages and waste collectors left the clean rooms via the dirty hallway and were then taken to the cage-washing facility.

Each alcove housed 20 waveguides mounted on four horizontal shelves, five waveguides per shelf. The exposure and sham-exposure waveguides were randomly

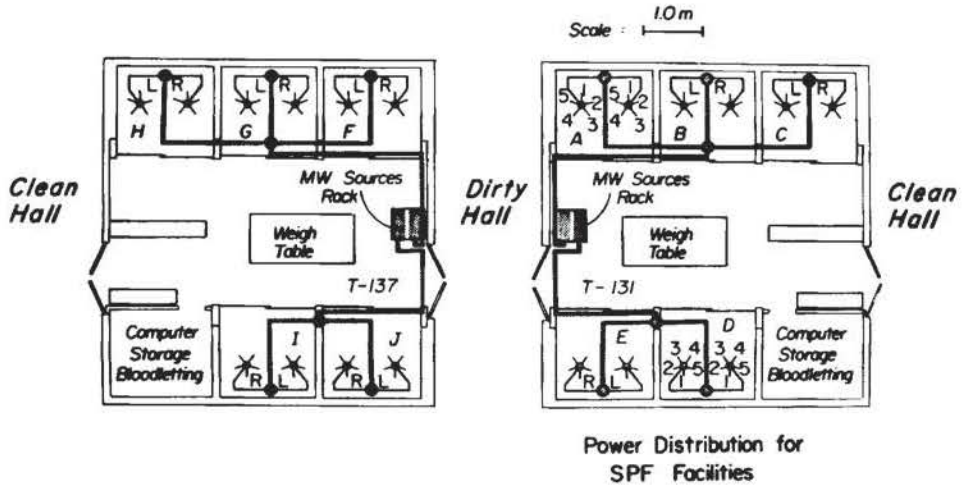


Fig 1. Top view of exposure rooms (T-131 and T-137) with alcove designations and associated exposure-cell identification system.

arranged, except that only sham-exposure waveguides could be in the center position because of a sliding-glass-door operation. One of the alcoves in each room was equipped as a metabolism alcove, in which O_2 consumption and CO_2 production were measured. The sixth alcove in each room was partitioned off as a procedures area that was used for bleeding and as housing for the main data-collection computer and miscellaneous supplies.

In the SPF rooms the airflow rate was programmed for 22 exchanges each hour, to maintain positive-pressure flow. Over the course of the project, ambient temperatures were balanced between the workspaces and alcoves to maintain a fairly constant 21±1°C environment in the facility. Humidity was in the range of 30–70%. Sound-pressure measurements indicated an average level in the central workspace of approximately 60 dBA (relative to 20 $\mu N/cm^2$) and alcove levels that were 6 to 10 dBA lower, depending on position within the alcove. Light-intensity measurements during the light cycle (0700–1900) indicated a 13-lux average workspace level and 6-lux average alcove level.

Microwave exposure system. As shown in Figure 2, when an animal housed in a plastic cage was exposed in the circular waveguide to microwaves fed into the terminal (P_{IN}), some energy (P_A) was absorbed by the animal, some (P_W) was absorbed by the walls of the chamber, some was reflected in the form of both right-hand (P_{RR}) and left-hand (P_{RL}) circularly polarized waves that couple back to the probes on the feed section of the waveguide, and some (P_{TA} and P_{TB}) were absorbed at the termination terminals. The reflected component P_{RR} was measured as CP_{RR} at the reflecting arm of the bidirectional coupler, which was placed between the source and the input probe (C is the coupling coefficient of the bidirectional coupler). The reflected component P_{RL} was measured directly at the other terminal of the transmitting transducer. The power level of the incident energy launching the right-hand circularly polarized waves was measured (as CP_{IN}) at the incident-wave terminal of the coupler. The power level of energy transmitted beyond the animal was measured at the terminals (P_{TA} and P_{TB}) of the termination transducer. The sum

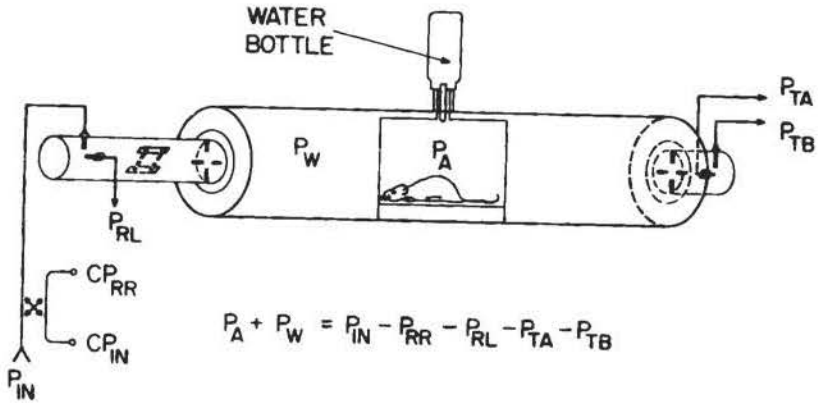


Fig. 2. The exposure chamber was a circularly polarized waveguide operating at 2,450 MHz. A rat, housed inside a plastic cage, was exposed in the 20.3-cm diameter wire-mesh tube. A circular polarizer, at the left end, converted the linearly-polarized TE_{11} mode to the circularly-polarized TE_{11} mode. Tuning stubs inside the polarizer matched the impedance of the propagating modes. Transmitted microwaves were terminated in the transducer at the right side of the tube.

of power levels of energy absorbed by the animal and the chamber walls can be obtained from the equation in Figure 2.

The water bottle in each waveguide was electrically decoupled from the animal by two concentric 1/4-wavelength choke sections so that the tip of the water nozzle had an extremely high impedance, virtually preventing conduction currents between it and any contacting object. The theory of the waveguide operation has been described elsewhere [Guy et al., 1979].

Microwave generation and distribution. Each exposure room was equipped with two 2,450-MHz pulsed microwave sources (Epsco, model PG5KB, Trenton, NJ), each source capable of providing an average output power of 20 W and a peak power of 5 kW. These generators were controlled by a microprocessor to deliver repetitive pulse trains as shown in Figure 3.

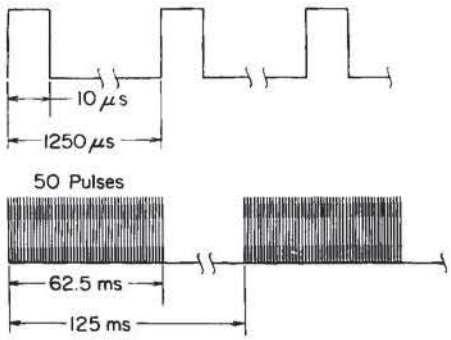


Fig. 3. Modulation characteristics of the microwave pulses: 8 groups per second, 50 10-μs-wide pulses per group, with a repetition rate of 800 pps. The period was 125 ms; with pulse onsets separated by 1.25-ms intervals. This is the equivalent of an 800-pps source square-wave modulated at 8 Hz.

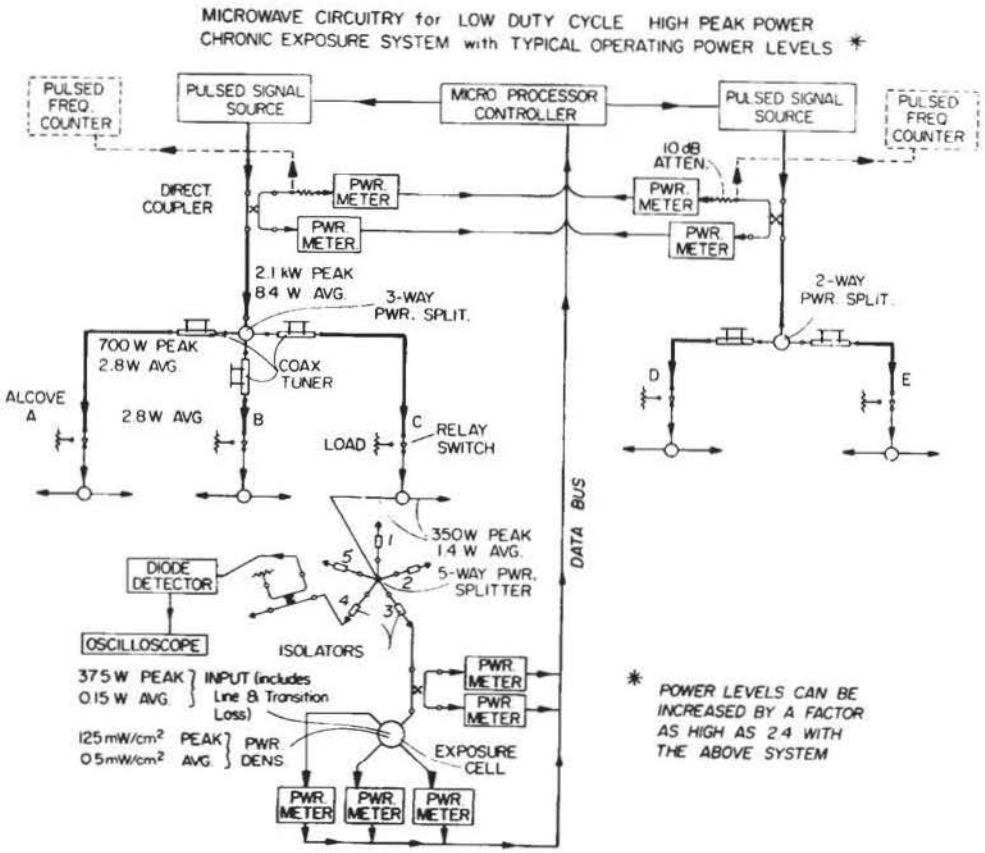


Fig. 4. Schematic of the microwave-distribution system in room T-131. The microwave energy was divided by means of low-loss coaxial cable via a 3-way splitter. Then the microwaves were fed through a single-pole double-throw (SPDT) coaxial relay to a 2-way splitter. Microwaves from each arm of the 2-way splitter were fed to a 5-way splitter; thus, the power-level of microwave radiation was again equally divided and transmitted through isolators to the two groups of five active exposure waveguides in each alcove. The distribution system of the second generator in each room was similar except that the microwaves were initially split in two ways to energize two alcoves. Power levels of forward and reflected energy at each generator output terminal was measured and recorded through a directional coupler and digital power meters interfaced with a microprocessor.

The microwaves from one generator in each equipment rack were transmitted to three alcoves (Fig. 4). The power levels of input, reflected, and transmitted energy associated with one exposure waveguide per room were monitored to obtain a recording of the average absorption loss of the waveguide-rat assembly; the average SAR could be calculated from the known waveguide loss and the mass of the rat. Each room contained a total of nine power meters, two each for the incident and reflected energy at each generator and five for the incident, reflected, and transmitted energy at the multiple terminals of the respective waveguides. The average SAR in the experimental animal was determined from the power meters. Throughout the chronic study, the monitoring system was connected each day to a different exposure waveguide so that every waveguide was monitored 1 day every 50

days over the course of the experiment. There was insignificant down time due to microwave power failure. Spare generators were available for this rare occurrence.

Dosimetry

Dosimetry studies conducted in preparation for this experiment were directed toward determining the power level for each waveguide that would best simulate with rats the exposure of man to an RF field. To determine the conditions necessary for simulating such exposure, the relation between the input power and the average and distributed SAR in the body of an exposed rat living in the exposure waveguide had to be quantified.

A microprocessor-controlled, twin-well calorimetry system was developed to measure the average SAR in rat carcasses. The average SARs for live exposed rats over the first year of exposure are shown in Figure 5. The results show that the SARs calculated from the data on the live animals are very close to but slightly less than the values calculated from measurements on rat carcasses. The results of this study have been published by Chou et al. [1984]

To best simulate the exposure of human beings, from child to adult, to radiation at the maximal levels allowed by ANSI C95.1-1982 [1982], the input power level for each alcove cluster was set so that the average input power was 0.144 W, which resulted in an initial average SAR of 0.4 W/kg in young rats of 200-g body mass.

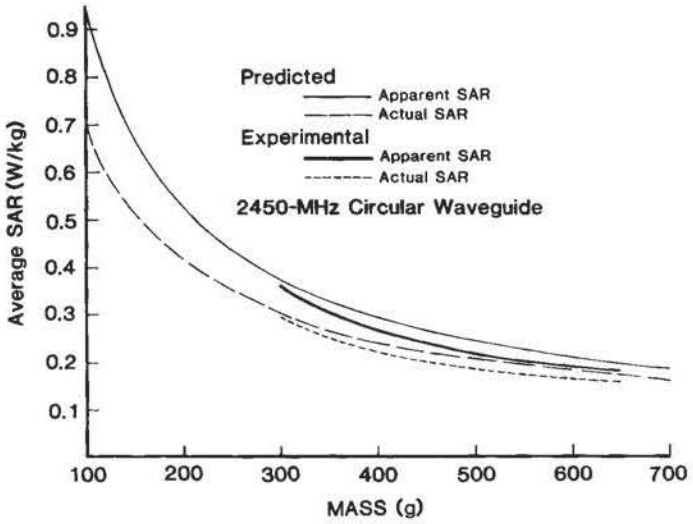


Fig. 5. Average SAR values measured for rat carcasses (Predicted) compared with average SAR values measured for free-roaming exposed rats (Experimental); SARs were averaged over weekly periods during first-year chronic exposure (input power 0.144 W to the waveguide). The predicted actual SAR was measured calorimetrically on rat carcasses of various body masses; bodies were exposed in five orientations in the waveguide: center, far corner, side, transverse, and diagonal positions. Predicted apparent SAR was measured by power meters on rat carcasses. Experimental apparent SAR was measured by power meters in live rats. Assuming that a live rat would spend equal time in each of the five orientations, the experimental actual SAR data were calculated from the apparent SAR and correction factors. The correction factors were the ratios between actual SAR and apparent SAR measured on rat carcasses.

Experimental Animals and Exposure Regimen

Two hundred male, Cesarean-derived, barrier-reared, Sprague-Dawley rats were obtained at 3 weeks of age from Camm Laboratory (Wayne, New Jersey): the rats were randomly assigned to exposure and control groups. Exposure began at 8 weeks of age, 21.5 h/day, 7 days a week, for 25 months. Maintenance procedures were done between 8 A.M. and 12 A.M. to minimize circadian-rhythm effects. The two and one-half hours off-time was used for cage cleaning, measurements of body mass, food and water consumption, blood letting, and other biological procedures.

Biological Assessment

Behavior testing. Behavior is a valuable end point for assessing neurological effects of exposure to microwaves [Lovely et al., 1977; cf. Shandala et al., 1979]. Constraints of both design and logistics, however, made selection of appropriate tests for this project a difficult task. Tests should not jeopardize the health of the animals or the reliability of data obtained from other measures. A test protocol must not entail differential treatment of an animal based on its performance (e.g., shock intensity or reward magnitude) and thereby produce secondary effects as artifacts that must be distinguished from any primary (microwave) effect. In addition, all testing must be performed within the SPF environment and in such a manner so as not to interfere with the normal daily maintenance procedures or exposure protocols.

The risk of physical harm to the animals eliminated many standard behavioral tests, so we chose a simple behavioral test based on quantification of a naturally-occurring behavior. Open-field or exploratory behavior has long been used as a sensitive endpoint in pharmacology and teratology, and it is accepted as a measure of general arousal or anxiety [Walsh and Cummins, 1976]. In addition, East European researchers have used the open-field test extensively in biological studies of microwaves [Shandala et al., 1979].

The open-field test is not the most impressive of the behavioral tests considered; however it is simple in nature and does not rely on elaborate or time-consuming training procedures or shock-motivated performance, and it can be routinely administered by laboratory personnel under the rigid SPF protocol.

An open-field apparatus with infrared-light-emitting sensors was used. This apparatus provided a readout of both motion activity and the coordinates in the field. The latter information was used to indicate an animal's field position in one of the possible quadrants. In addition, at the end of each test session the apparatus was inspected for urination and defecation.

Evaluation of the immune system. Alterations in the immune system due to microwave exposure have been reported and disputed in the literature [cf., e.g., Mayers and Habeshaw, 1973; Czerski et al., 1974; Huang et al., 1977; and Wiktor-Jedrzejczak et al., 1977]. The conflicting results justified an assay of immunocompetence in this study. The immune-system evaluation consisted of several basic tests that were designed to detect immunological effects that might result from exposure to RF fields:

a. Blood lymphocyte evaluation of the numbers of B- and T-cell, antigen-positive lymphocytes, and complement-receptor-bearing lymphocytes.

b. Spleen lymphocyte evaluation for response to the following mitogens: phytohemagglutinin (PHA), concanavalin A (ConA), pokeweed mitogen (PWM), lipopolysaccharide (LPS), and purified protein derivative of tuberculin (PPD).

c. Direct plaque-forming cell assay (with spleen cells) and serum-antibody titration of exposed rats immunized with the T-dependent antigen sheep red-blood cells (SRBC).

The following immunological tests were performed at the 13-month interim euthanasia of 10 animals from each treatment group, and after 25 months of exposure with the final euthanasia of 10 animals from each group; response of splenic lymphocytes to various mitogens, plaque-forming ability, complement-receptor formation, and enumeration of B- and T-cells.

Blood sampling for corticosterone and health profile. Pituitary-adrenal axis activity as indexed by plasma corticosterone levels has long been interpreted as an indicator of general arousal, i.e., alerting borne of anxiety, fear, or stress. If long-term exposure to pulsed RF fields disrupts normal physiological functions or is psychologically disturbing to the animal, an increased basal level of corticosterone can be expected [Lotz and Michaelson, 1978]. The endocrine system can provide evidence of summation of multiple, otherwise subthreshold, effects. Individual corticosterone data are of value for correlation with results from individual animals or subpopulations that might exhibit abnormal indices of blood chemistry or a high incidence of tumors, and also as a measure of a possible nonspecific microwave effect.

The research protocol required the rapid collection of blood from all test animals in a 2-h period per day over 4 days for each blood sampling. The collection procedure was designed to be as rapid and atraumatic as possible. To prevent artifactual elevation of corticosterone, blood samples for serum corticosterone were drawn within 2 min after a rat was removed from its cage [Zimmermann and Crutchlow, 1967; Davidson et al., 1968]. The animals were rapidly anesthetized by a mixture of halothane, nitrous oxide, and oxygen; blood samples were drawn by the relatively atraumatic retro-orbital technique. Alternate eyes were sampled for blood in successive samplings so as to minimize ocular damage. A single blood sample, 1.8 to 2.0 ml, was taken at each session for all determinations.

Metabolism. An important consideration in performing the long-term exposure of rats is that the nominal 0.4-W/kg average SAR, initially is about 5% of the average metabolic rate of an active, young 200-g rat and about 10% of its resting rate. This SAR may be as high as 15% of the average metabolic rate of a lethargic, old, 600-g rat and 25% of its resting rate. The decision was, therefore, made to use a constant power density, which resulted in a declining SAR as the animals matured.

Exposure to microwave radiation for long periods could have different consequences for longevity, either life-shortening or life-lengthening, depending on the energy-budgeting option [Sacher and Duffy, 1978]. Therefore, given the importance of the metabolic versus extrinsic-budget question, the protocol provided the following animal measurements:

a. Daily-lifetime body mass measures, i.e., growth.
b. Daily-lifetime food and water consumption.
c. 24-h cycles of oxygen consumption and carbon dioxide production, measured at regular intervals throughout the life span.
d. Periodic assessment of thyroxine level.
e. Periodic assessment of urine production.
f. Total-body analysis at spontaneous death or termination.

Despite the importance of direct metabolic measurements through respiratory gas-exchange analysis, two factors precluded their application to all 200 animals:

(1) physical as well as financial constraints made it impossible to instrument all 200 waveguides, and (2) rotating all animals through a few instrumented waveguides would have an associated animal-transfer-management risk and a subsequent loss of data. In addition, were such a mass rotation attempted, the need to allow each animal a minimum of 2 days in the instrumented waveguide to adapt to the new environment would have led to a rotation schedule allowing data to be obtained, at most, twice a year from an animal, which would have been too infrequent. Therefore, we selected a subset of the exposed and control samples for rotation through waveguides adapted for the measurement of oxygen consumption and carbon dioxide production. This procedure did not result in loss of overall statistical power, and it produced more frequent measures on the specific animals involved. Given the modular arrangement of the rooms, 36 animals (18 exposed and 18 sham-exposed) were measured for respiratory gas exchange.

Histopathology. As part of a general health screen at time of animal procurement, 10 rats, 21 days old, received gross and histopathological examination. After 13 months, 10 exposed and 10 sham-exposed rats were randomly-selected and euthanatized for examination; at 25 months, the surviving 12 exposed rats and 11 sham-exposed rats were euthanatized and examined. The other 157 animals were examined when they died spontaneously or were terminated *in extremis* during the study.

A pathologist (L.L.K.), without knowing the identity of the rats, provided evaluative data to the technical personnel of the Bioelectromagnetics Research Laboratory, who were responsible for computer entry and quality control. Statisticians then evaluated the data, and the final results were reviewed by the pathologist for appropriate interpretative comments.

The occurrence of neoplastic and non-neoplastic lesions was recorded along with the age and the cause of death of each animal, whether the animal was euthanatized or had died spontaneously. The data on pathology were collected to permit comparison of survival curves of exposed and sham-exposed animals, age-associated lesions, and incidence of tumor metastases, as well as the number of lesions per rat.

RESULTS

Behavioral Evaluations

Figure 6 shows data from the 14 sessions of open-field assessment; except for the first test session, 2 years of exposure to the low-level, pulsed-microwave radiation did not lead to significant behavior alterations as measured by activity, defecation, or urination. During the first test session, the general activity level of the exposed animals was significantly lower ($t = -2.24$, $P = .026$, $df = 195$), by approximately 9%, than that of the sham-exposed animals. The open-field activity pattern during the course of this study resembles that normally observed as a function of age and experience, and it apparently was not affected by a lifetime of exposure to the low-level pulsed microwaves (Hotelling's T^2 statistic $F = 8.73$, $P = .40$, $df = 8,168$).

Plasma Corticosterone

Analysis of the data obtained during the five sampling periods (Fig. 7) indicates that serum corticosterone levels were not dramatically altered in either the

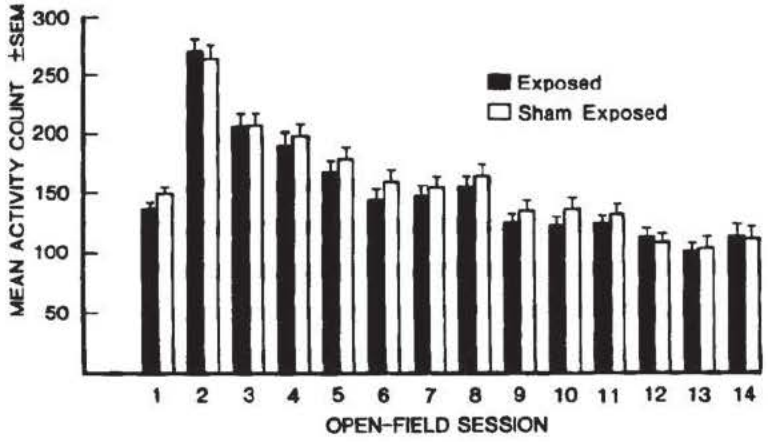


Fig. 6. Comparison by treatment group of mean levels of activity throughout the 14 open-field assessment sessions.

exposed or sham-exposed rats. The multivariate statistical analyses of the data ($F = 1.38$, $P = .24$, df = 5,133) indicate that no overall effects of microwave radiation were measurable by levels of serum corticosterone.

When the serum corticosterone values of exposed and sham-exposed animals were compared for each session, a t test indicated that exposed animals had relatively elevated serum corticosterone levels at the time of the first sampling session ($t = 2.06$, $P = .04$, df = 154), and that sham-exposed animals had elevated levels at the time of the third session ($t = -2.25$, $P = .026$, df = 161). Exposed and sham-exposed animals had comparable levels of corticosterone on all other regular sampling sessions.

The finding of elevated corticosterone was tested in a follow-up study [Chou et al., 1986]. Two groups of 20 animals each were exposed for 6 and 12 months, respectively, under the same exposure parameters as in the original study. An equal

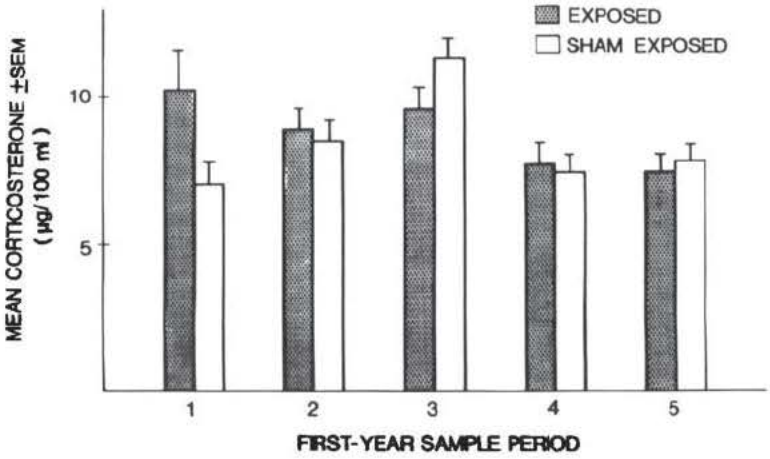


Fig. 7. Comparison of mean corticosterone levels from five quarterly determinations during the first year of the project.

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number of sham-exposed rats served as controls. Corticosterone measured at 6 weeks, 6 months and 12 months did not show any statistically significant differences ($P > .05$) between 20 control and 20 exposed rats.

Immunological Competence

When compared with sham-exposed rats after 13 months of exposure (Fig. 8), exposed animals had a significant increase in both splenic B-cells ($t = 3.76$, $P = .002$, $df = 16$) and T-cells ($t = 3.48$, $P = .003$, $df = 16$). This apparent general stimulation of the lymphoid system in exposed animals was not detected in the animals after 25 months of exposure: Comparison of exposed and sham-exposed rats at euthanasia of survivors did not reveal any significant differences in the percentage or total numbers of B and T cells per spleen.

No significant differences were seen between exposed and sham-exposed rats in the percentage of complement-receptor-positive cells in the spleen at either the interim or final euthanasia. These findings indicate no difference between the treatment groups for lymphocyte maturation.

The plaque assay performed on exposed animals immunized with SRBC in the 13-month exposure rats exhibited a slight but statistically insignificant increase in plaques per spleen relative to the sham-exposed. This difference reversed after 25 months when exposed animals showed a slightly lower and statistically insignificant number of plaques per spleen. This assay indicated no statistically significant alteration of the reticuloendothelial system, which first processes antibodies in the presence of T-cells, because the SRBC antigen is T-cell dependent.

The mitogen-stimulation studies following 13 months of exposure revealed significant differences between groups in their responses to various B- and T-cell specific mitogens. The radiated animals had a nonsignificant increase in response to PHA but a significant increase in response to LPS (mean of 6.06 vs. 3.67, $t = 2.35$, $P = .032$) and PWM (mean of 6.41 vs. 4.61, $t = 2.43$, $P = .027$). As compared with sham-exposed animals, exposed animals also had a significantly increased response to ConA (mean of 17.0 vs. 10.7, $t = 2.65$, $P = .018$) and a decreased response to PPD (mean of 2.74 vs. 6.98, $t = -2.65$, $P = .018$). These results indicate a selective effect of exposure on the lymphoreticular system's response to mitoge-

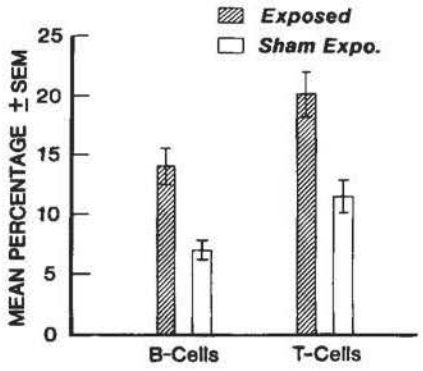


Fig. 8. Mean percentages of B-cells and T-cells within culture population of splenic lymphocytes for exposed and sham-exposed groups.

nic stimulation. Mitogen-response data were not available from the 25-month exposure studies because the lymphocyte cultures failed to grow.

In a follow-up study [Chou et al., 1986], no significant differences between 20 exposed and 20 sham-exposed rats were observed in the proliferation of thymocytes to ConA, PHA, and PWM after 6- and 12-months of RF exposure. The same lack of differences was found for splenocytes stimulated by LPS, PHA, PPD, ConA, and PWM. Flow cytometry revealed no group alterations in the number and frequency of B- and T-cells. However, after 12 months of exposure, a reduction in cell surface expression of Thy 1.1 (T-cell related) surface antigen, and a reduction in the mean cell-surface density of s-Ig (B-cell related) on small lymphocytes in spleen were observed. The stimulatory effect observed in the original study was not confirmed.

General Health Profile

In an attempt to detect and document any effects on the general health of the exposed animals, the following biochemical and hematological parameters were monitored: serum chemistry components, hematological constituents, protein electrophoretic patterns and fractions, and thyroxine levels. Multivariate analyses with Hotelling's T^2 statistic on a truncated data set (outliers removed) indicated no overall

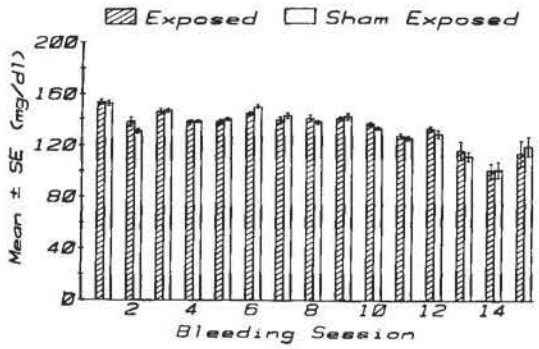


Fig. 9. Comparison of serum glucose for exposed and sham-exposed animals for 15 sampling sessions.

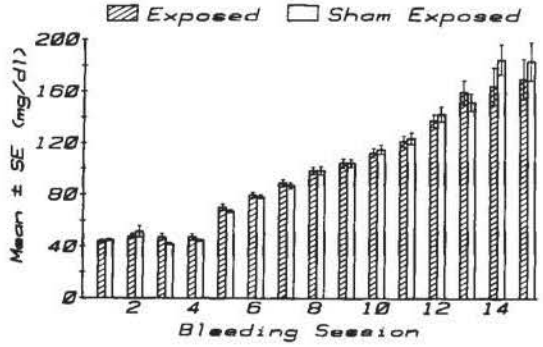


Fig. 10. Comparison of serum cholesterol levels of exposed and sham-exposed animals from 15 sampling sessions.

differences among all parameters between exposed and sham-exposed samples. Figures 9 and 10 present two representative examples of glucose and cholesterol levels from 36 sets of data. Individual *t* tests of all parameters across all 15 sampling sessions indicated a significant reduction in the absolute eosinophil counts of exposed rats during session 2, and marginally significant reductions in absolute neutrophil count during sessions 2 and 3. None of the other comparisons was significant. Therefore, these findings indicate that after the 25-month exposure no consistent effects were produced in bone-marrow erythropoietic cells or in the juxtaglomerular apparatus of the kidney and its production of erythropoietins.

Twenty-one serum chemical constituents were measured in serum samples collected during all 15 sampling sessions. The serum-chemistry tests were sensitive enough to detect population changes due to aging. Statistical analysis of the data by Student's *t* tests did not indicate any differences between exposed and sham-exposed animals.

Electrophoresis of the serum proteins revealed no significant changes in the electrophoretic patterns and absolute protein fractions between the population groups. Both groups showed a gradual decrease in the albumin/globulin ratio with increasing age, and the overall level of globulin fractions observed in these barrier-sustained animals was lower than that reported in conventional-colony animals. The microwave exposure had no apparent effect on the functioning of various organ systems that contributed to serum-protein concentrations.

Thyroxine levels did not differ significantly between exposed and sham-exposed animals (Fig. 11). Thus, exposure had no effect on the hypothalamic-pituitary-thyroid feedback mechanism. The absolute level of serum thyroxine developed to a maximum in young animals and decreased gradually as they aged. The correlation of this age-related decrease in thyroxine levels with increasing cholesterol (Fig. 10) and triglyceride levels in both test and sham groups shows it to be a reliable indicator of metabolic activity in the rat.

The major conclusion that can be reached from the evaluations of hematology, serum chemistry, protein electrophoretic patterns and fractions, and thyroxine levels is that any significant variations of the parameters observed during the lifetime of the exposed animals were to be expected as a function of aging.

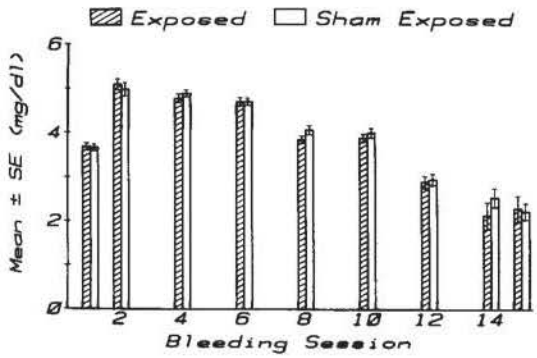


Fig. 11. Comparison of thyroxine data for exposed and sham-exposed animals for blood sampling sessions for which analysis was made.

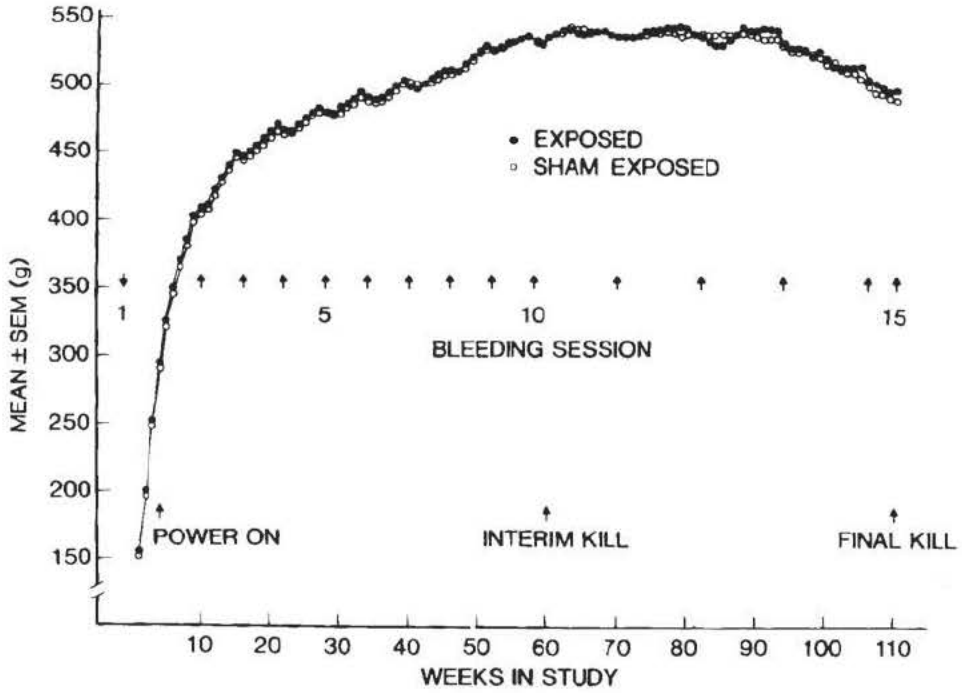


Fig. 12. Mean weekly body mass throughout 25-month study. Arrows indicate periodic bleeding sessions as well as other significant events during the course of the study.

Metabolism

Body mass and consumption of food and water. Growth curves for microwave-exposed and sham-exposed animals throughout this study (Fig. 12) are in general agreement with those reported for the Sprague-Dawley rat [Berg, 1960; Masoro, 1980]. The asymptotic body mass was somewhat lower than expected, possibly because of a periodic "stunting" effect coincident with the start of the regular blood-sampling sessions.

The average daily food intake of approximately 25 to 26 g is higher than that usually reported for the rat [Brobeck, 1948; Hamilton, 1967; Jakubczak, 1976] and indicated by the feed manufacturer (12 to 15 g/day). These food-intake norms, however, are for animals housed in a standard animal facility maintained at a higher ambient temperature (25 °C). The amount of food eaten by the animals in our facility, which was maintained at 21 ± 1 °C, is in agreement with that reported for animals housed at lower ambient temperatures [Brobeck, 1948; Hamilton, 1967; Jakubczak, 1976] and in other studies in our laboratory that had used the waveguide apparatus [Lovely et al., 1977]. Throughout the 25 months, no overall differences were observed between treatment groups in either food or water consumption.

The similarity in overall patterns of growth, food and water consumption, and body-mass loss and recovery in exposed and sham-exposed samples indicates that no effects of microwave irradiation were apparent in these measures of long-term energy balance.

Total body analysis. With one exception, the combined analyses of organ mass, general carcass composition, fatty-acid profile, and mineral content provided no evidence that metabolic processes were adversely affected in the animals exposed for 13 or 25 months to microwave radiation. A highly significant elevation of adrenal mass was indicated by the 75% increase observed for exposed rats as compared with sham-exposed animals. However, when the animals with benign tumors in the adrenal gland were separated from those without tumors, the difference became insignificant. For animals with tumors, the adrenal mass was significantly higher in the exposed group than in the sham group. This analysis indicated that the increase in adrenal mass was related to the tumors and was independent of the metabolic processes in the rats. The mean adrenal mass in exposed animals without tumors was slightly larger, but statistically insignificant, as compared with that of the sham-exposed rats. This increase in mass was attributed to one animal with a hyperplastic adrenal cortex, which was secondary to a pituitary tumor.

O_2 consumption and CO_2 production. Differences between exposed and sham-exposed rats occurred in O_2 consumption and CO_2 production in younger rats (body mass 300–400 g) but not in the more mature animals (17–24 months old, body mass 550–600 g). The average hourly O_2 consumption for the young rats during the nocturnal period (1900–0600 lights off) was significantly different between the treatment conditions (Hotelling T^2 statistic, $F = 2.29$, $P = 0.025$, df = 11,44). Although individual t tests of hourly CO_2 productions of the young animals did not show consistent significant difference between treatment groups, the Hotelling T^2 statistic was significant during the diurnal (1300–1900 lights on) period ($F = 2.73$, $P = .023$, df = 6,49) and even more significant during the night time hours ($F = 2.91$, $P = .006$, df = 11,44). The effects observed in the young animals were less pronounced during the second round (36 days later) of measurements. On an hour-to-hour basis, the mature animals' metabolic measures appeared less variable than those of the young. The young animals demonstrated more marked responses to the lights-off condition and generally higher levels on each measure during the night time hours, i.e., the active portion of the rats' circadian cycle. This apparent synchronization of metabolic activity with the light-dark cycle has been noted by others investigating the variation of activity, food and water consumption, and energy balance patterns as a function of photoperiod [Zucker, 1971; Besch and Woods, 1977].

Gross Pathological and Histopathological Evaluation

Longevity. Product-limit estimates and log-rank statistics were used to estimate and compare survival curves of exposed and sham-exposed animals (Fig. 13). Evaluation of the curves revealed that the median survival time was 688 days for exposed animals and 663 days for the sham-exposed. Despite subtle differences in the survival curves in the early and late stages of the study, statistical analysis indicated no significant differences during any phase of the life span of the animals. Statistical evaluation indicated no association between a specific cause of death and treatment condition; however, for cause of death due to urinary tract blockage (9 in exposed group and 19 in sham group), there is some indication that survival times were longer in the exposed animals.

Histopathology. Parasitic, bacterial, mycoplasmal, and viral agents were monitored during the 25-month period. A low-level (15%) infestation of the colony with pinworms, *Syphacia muris*, occurred but no histological lesions were attributed to these nematodes. The microflora of the animals was altered over the course of the experiment by the sporadic occurrence of *Proteus* sp. (*mirabilis, rettgeri,* and

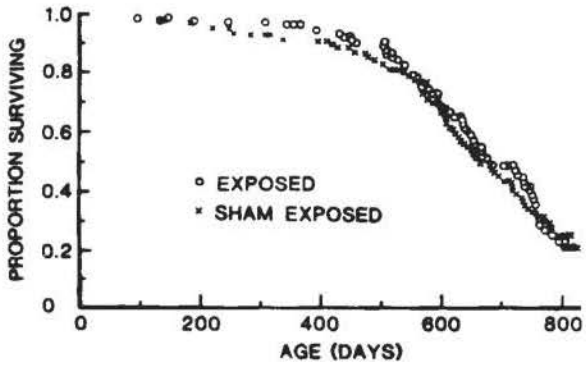


Fig. 13. Survival data for microwave-exposed and sham-exposed animals throughout the 25-month study.

vulgaris), *Staphylococcus epidermidis*, *Neisseria* sp., *Escherichia coli*, and *Klebsiella* sp. These intestinal flora became opportunistic organisms in the few cases of preputial adenitis and wound infections that occurred. *Mycoplasma* sp. was not isolated, either by culture or serology, and serological monitoring failed to reveal any significant elevations in titers of any of the common rodent viruses. There were no underlying diseases that complicated or produced erroneous results in the gross or histopathological evaluations of the experimental animals.

The histopathology data were grouped with respect to the animal's age, at 6-month intervals, and the data were divided into neoplastic and non-neoplastic diagnoses. The documentation of morphological lesions showed 2,184 pathological changes in the 200 animals examined. The non-neoplastic lesions comprised 1,992 of the observed changes, with 217 unique combinations of organs and lesions. The neoplastic lesions accounted for 192 of the observations, with 83 unique combinations of organs and types of neoplasms.

Chronic glomerulonephropathy was the most frequent cause of death and one of the most consistently encountered non-neoplastic lesions. Statistical analysis (Mantel-Haenszel estimate and chi-square statistics) indicated that glomerulonephropathy was less frequently observed in the exposed than in the sham-exposed animals ($\underline{P} = .04$, df = 1). Analysis of the other non-neoplastic lesions did not indicate that the specific lesions were more likely in either treatment condition. To detect a progressive development of the chronic glomerulonephropathy, the severity of the lesions was also evaluated. This analysis revealed no significant differences between the treatment condition and the severity of non-neoplastic lesions.

The neoplastic lesions were identified as benign or malignant, with the malignant lesions classified as primary or metastatic. A summary of these combinations is presented in Table 2, which indicates the total number of primary and metastatic malignancies and benign lesions observed in both exposed and sham-exposed animals. The incidence of neoplastic lesions corresponds with that normally reported for the Sprague-Dawley rats: Only two tumors were present in rats younger than 12 months, and tumor incidence rapidly increased after 18 months of age [MacKenzie and Garner, 1973; Altman et al., 1985]. The endocrine system had the highest incidence of neoplasia in the aging rats, as is expected in this animal. The incidence of benign pheochromocytoma of the adrenal medulla was much higher in the exposed group than in the controls (7 out of 100 vs. 1 out of 100). However, Fisher's exact test did not show a statistically significant effect ($\underline{P} = .065$).

TABLE 2. Neoplastic Lesions Per Organ System

Organ	Lesions	Exposed			Sham-exposed		
		B	P	M	B	P	M
Adrenal	Adenoma	0	0	0	1	0	0
	Carcinoma	0	0	0	0	1	0
	Cortical adenoma	10	0	0	10	0	0
	Cortical carcinoma	0	3	0	0	0	0
	Myelomonocytic leukemia	0	0	0	0	0	1
	Malignant lymphoma	0	0	1	0	0	0
	Pheochromocytoma	7	0	0	1	0	0
Blood vessel	Hemangiosarcoma	0	1	0	0	0	0
Bone marrow	Leukemia	0	0	0	0	0	1
	Myelomonocytic leukemia	0	0	1	0	0	1
	Malignant lymphoma	0	1	0	0	0	0
Brain	Myelomonocytic leukemia	0	0	0	0	0	1
	Malignant lymphoma	0	0	2	0	0	0
Cervical	Myelomonocytic leukemia	0	0	0	0	0	1
Lymph node	Lymphocytic lymphoma	0	0	0	0	1	0
	Malignant lymphoma	0	0	0	0	0	1
Colon	Malignant lymphoma	0	0	1	0	0	0
Duodenum	Myelomonocytic leukemia	0	0	1	0	0	0
	Malignant lymphoma	0	0	1	0	0	0
	Squamous cell carcinoma	0	0	1	0	0	0
Edipidymis	Squamous cell carcinoma	0	0	1	0	0	0
Eye	Leukemia	0	0	0	0	0	1
Heart	Myelomonocytic leukemia	0	0	1	0	0	1
	Malignant lymphoma	0	0	1	0	0	0
	Neurinoma	1	0	0	2	0	0
Kidney	Leukemia	0	0	0	0	0	1
	Myelomonocytic leukemia	0	0	1	0	0	1
	Malignant lymphoma	0	0	1	0	0	0
	Nephroblastoma	1	0	0	1	0	0
Liver	Adenoma	2	0	0	0	0	0
	Carcinoma	0	0	0	0	1	0
	Hepatocellular adenoma	1	0	0	0	0	0
	Leukemia	0	0	0	0	0	1
	Myelomonocytic leukemia	0	0	2	0	0	1
	Malignant lymphoma	0	0	1	0	0	1
	Squamous cell carcinoma	0	0	1	0	0	0
Lung	Leukemia	0	0	0	0	0	1
	Myelomonocytic leukemia	0	0	1	0	0	0
	Malignant lymphoma	0	0	1	0	0	0
Lymph node	Myelomonocytic leukemia	0	1	2	0	1	0
	Malignant lymphoma	0	0	1	0	0	0
	Transitional cell carcinoma	0	0	1	0	0	0
Mesentery	Transitional cell carcinoma	0	0	1	0	0	0
Nasal cavity	Leukemia	0	0	0	0	0	1
Pancreas	Adenoma	0	0	0	1	0	0
	Islet-cell adenoma	1	0	0	1	0	0

Continued

TABLE 2. Continued.

Organ	Lesions	Exposed			Sham-exposed		
		B	P	M	B	P	M
Pancreas	Squamous cell carcinoma	0	0	1	0	0	0
Parathyroid	Malignant lymphoma	0	0	1	0	0	0
Parotid SG	Myelomonocytic leukemia	0	0	1	0	0	0
Peritoneum	Liposarcoma	0	1	0	0	0	0
Pituitary	Adenoma	17	0	0	21	0	0
	Carcinoma	0	2	0	0	0	0
Preputial gland	Malignant lymphoma	0	0	1	0	0	0
Skeletal muscle	Myelomonocytic leukemia	0	0	1	0	0	0
Skin	Auditory sebaceous sq carcinoma	0	1	0	0	0	0
	Basal cell carcinoma	0	1	0	0	0	0
	Basal cell tumor	1	0	0	0	0	0
	Keratoacanthoma	1	0	0	1	0	0
	Malignant lymphoma	0	0	1	0	0	0
	Pilomatricoma	1	0	0	0	0	0
	Sebaceous adenoma	2	0	0	0	0	0
Spleen	Myelomonocytic leukemia	0	0	1	0	0	1
	Malignant lymphoma	0	0	1	0	0	0
Stomach	Malignant lymphoma	0	0	1	0	0	0
	Squamous cell carcinoma	0	1	0	0	0	0
	Squamous cell papilloma	3	0	0	4	0	0
SubQ tissue	Fibroma	1	0	0	0	0	0
	Fibrosarcoma	0	1	0	0	0	0
	Lipoma	1	0	0	0	0	0
	Neurinoma	0	0	0	1	0	0
Testes	Benign interstistial cell tumor	1	0	0	0	0	0
	Squamous cell carcinoma	0	0	1	0	0	0
Thymus	Myelomonocytic leukemia	0	1	0	0	0	0
	Lymphocytic lymphoma	0	1	0	0	0	0
	Malignant lymphoma	0	0	0	0	1	0
Thyroid	Adenoma C-cell	10	0	0	9	0	0
	Carcinoma C-cell	0	2	0	0	0	0
	Leukemia	0	0	0	0	0	1
	Malignant lymphoma	0	0	1	0	0	0
Ureter	Malignant lymphoma	0	0	1	0	0	0
Urin/bladder	Transitional cell carcinoma	0	1	0	0	0	0
	Transitional cell papilloma	1	0	0	0	0	0
Zymbal's gland	Leukemia	0	0	0	0	0	1
Total		62	18	36	53	5	18

This table lists neoplastic lesions found per organ system. These lesions may be benign (B), a primary malignancy (P), or a metastatic malignancy (M) arising from a primary malignancy in another organ system (i.e., a malignant neoplasm may occur as a metastatic malignancy in many organs of a single animal, but as a primary malignancy in only one organ system of an animal).

The low incidence of neoplasia with no significant increase in any specific organ or tissue required the data to be collapsed and evaluated with respect to occurrence per se of neoplasms, with no attention given to the site or organ of occurrence. For benign lesions, as shown in Table 3, the Mantel-Haenszel (M-H) estimate of the odds ratio was 1.04. The chi-square statistic, which tests whether the relative risk is 1, was .001 ($P = .97$, df = 1); therefore, we found no evidence that either group had an excess of benign lesions. For total neoplastic incidence including benign and malignant lesions, statistical evaluation revealed no significant difference between the exposed and sham-exposed groups ($\chi^2 = 0.32$, $P > .05$).

A similar set of tables was prepared for primary malignant neoplastic lesions and is presented in Table 4. When all age categories for the primary malignant lesions were considered, the M-H estimate of the odds ratio was 4.27 and the chi-square statistic was 7.66 ($P = .006$, df = 1). With the first three age categories combined and the analysis repeated, the M-H statistic was 4.38 and the chi-square statistic was 7.9 ($P = .005$, df = 1). When the first four age categories were collapsed (leaving two categories: 1–24 and 25–30 mo), the M-H statistic was 4.47 and the chi-square was 6.97 ($P = .008$, df = 1). When age at death was ignored completely, the M-H estimate of the relative risk was 4.46 and the chi-square was 8.00 ($P = .005$, df = 1). It is interesting that the estimate of the odds ratio and the chi-square statistic are both insensitive to the way the data were grouped with respect to age at death.

A survival-type analysis also was done with time of death as a surrogate for time to tumor development if a primary malignant lesion were present. If no primary malignant lesions were found, time to tumor was considered censored at the time to death. From that analysis, the log-rank statistic is 7.63 with a P value of .006. This analysis indicates that the primary tumors occurred earlier in exposed rats than in sham-exposed animals.

DISCUSSION

We investigated the effects on health of long-term exposure to low-level, pulsed, microwave radiation. Among the 155 parameters studied, most of them showed no

TABLE 3. Incidence of Benign Neoplasms at Death

Age	Benign neoplasms	No. of animals	
		Exposed	Sham
Age considered (mo)			
1–6	Yes	0	0
	No	3	3
7–12	Yes	0	3
	No	5	5
13–18	Yes	1	5
	No	24	18
19–24	Yes	16	11
	No	19	24
25–30	Yes	22	19
	No	10	12
Age not considered			
	Yes	39	38
	No	61	62

TABLE 4. Incidence of Primary Malignant Lesions at Death

Age	Primary malignant lesions	No. of animals	
		Exposed	Sham
Age considered (mo)			
1–6	Yes	0	0
	No	3	3
7–12	Yes	0	0
	No	5	8
13–18	Yes	2	2
	No	23	21
19–24	Yes	9	1
	No	26	34
25–30	Yes	7	2
	No	25	29
Age not considered			
	Yes	18	5
	No	82	95

significant differences associated with exposure during the 25-month period. However, a few parameters showed positive effects. There was a statistically significant increase in the mean of the serum corticosterone level in exposed rats at the time of the first blood sampling, and there was a significantly lower level at the third session of measurement as compared with sham-exposed animals. The other significant effects involved the immune response of the rats at 13 months of exposure and the O_2/CO_2 metabolism in young rats.

The early finding of elevated corticosterone levels was not found in the later sessions of the 25-months study. The failure to repeat may be due to maturational differences, to the decreasing SAR as animals grew, or to a combination of the two. The lack of a significant difference in the total number of B and T cells in the terminal-euthanasia animals of the original study may also be the result of aging, the onset of immunosenescence, or the declining SARs. The role of a decreased SAR in animals across time should be considered if a similar study is conducted. One could avoid this problem by increasing the power level to keep the SAR constant.

A follow-up study was conducted to confirm both corticosterone and immune system effects [Chou et al., 1986]. Neither effect was confirmed in two groups of 20 animals each exposed for 6 and 12 months, respectively, under the same exposure condition as the original study. An equal number of sham-exposed animals served as controls. The sample size of 20 animals per group was chosen to have good statistical power (80%) to detect the same magnitude of differences observed in the original study. The failure to confirm indicates that the original findings are not robust.

The lack of discernible differences in O_2 consumption and CO_2 production in the mature animals at this level of microwave exposure is in agreement with the results of Phillips et al. [1975]. They exposed male adult rats to various intensities of 2,450-MHz microwaves. Animals receiving 27 cal/min (~ 2W) showed no difference from controls. The microwave exposure in our study resulted in an energy deposition of 1.5–2.0 cal/min (144 mW) throughout the lifetime of the animal,

well below levels employed by Phillips et al. Under the ambient environmental conditions of temperature, humidity, and airflow, the rate of energy deposition used in our study was not sufficient to produce robust changes in the metabolism of the mature rat exposed to microwave irradiation. Changes in the O_2 consumption and CO_2 production were observed in young, exposed animals—and these changes were more pronounced during the first round of the measurements—are consistent with the fact that the rate of energy absorption in our waveguide apparatus decreases with increasing body mass. Due to the fast growth rate of the rats (Fig. 12), the animals were subjected to higher SARs only during the first month.

The incidence of benign pheochromocytome of the adrenal medulla was higher but not statistically significantly so in the exposed group. However, we note that the incidence of this tumor in the exposed group does not exceed the incidence of tumors reported in the literature for this strain of rat housed under specific pathogen-free conditions [Anver et al., 1982]. Strict comparisons of these data with those from other laboratories cannot be made, however, because the animals were not subjected to parallel conditions. A reference control—large numbers of untreated rats except for observation of longevity and post-mortem analysis—would be desirable in future studies.

The finding of a near fourfold increase of primary malignancies in the exposed animals is provocative. These data cannot be considered as an artifact because different statistical analyses led to similar results. Although the overall difference in numbers of primary malignancies is statistically significant, the biological significance of this difference is open to question. First, detection of this difference required the collapsing of sparse data without regard for the specific type of malignancy or tissue of origin. Also, when the incidence of the specific primary malignancies in exposed animals was compared with specific tumor incidence reported in the literature, the exposed animals had an incidence similar to that of untreated control rats of the same strain maintained under similar SPF conditions. It is important to note that no single type of primary malignancy was enhanced in the exposed animals. From the standpoint of carcinogenesis and under the assumption that the initiation process is similar for both benign and malignant tumors, benign neoplasms have considerable significance. That treatment groups showed no difference in incidence of benign tumors is an important element in defining the promotion and induction potential of microwave radiation for carcinogenesis.

Morphologically, carcinogenesis proceeds through transitory or progressive states of growth, including hyperplasia and/or dysplasia, benign neoplasia, and finally overt malignant neoplasia. This morphological continuum, which often, but not always occurs, is the basis for grading systems and staging systems in common usage in medical pathology. Although the exact cause of cancer remains illusive, there is considerable morphological and biochemical evidence that neoplasms in humans and animals progress through a series of stages and ultimately become completely autonomous, invade surrounding tissue, and metastasize widely. Although there are readily recognizable histopathologic differences between the cancer cell and the normal cell, the biochemical differences, especially relating to the molecular biology of DNA and RNA synthesis, protein and polypeptide synthesis, enzyme activity, and membrane receptions to ultrastructural and cellular components is far from being completely understood [Busch, 1974, 1979].

The incidence of benign pheochromocytomas of the adrenal medulla was higher in the exposed group than in the controls; however, no other single type of tumor was significantly increased by the treatment, even though the primary malignancies of all types is significantly elevated in the exposed group. In considering this issue, one perspective to keep in mind is that, with the induction of cancer by a carcinogen, tissue-specific effects are usually induced, so that an agent is not usually considered carcinogenic unless it induces a significant response in any one tissue. The U.S. Environmental Protection Agency Guidelines for carcinogenicity risk assessment states, "A statistically significant excess of tumors of all types in the aggregate, in the absence of a statistically significant increase of any individual tumor type, should be regarded as minimal evidence of carcinogenic action unless there are persuasive reasons to the contrary" [U.S. EPA, 1986].

The combining of malignant tumors from all sites for statistical comparison of incidence in the exposed and control groups is questionable as to its biological relevance. A major factor that one must consider is the different response found in this study from what is expected in a chemical carcinogenesis study. There was no discernible induction of benign tumors in the organs that were apparently developing malignant neoplasms. Considering that the majority of the 155 parameters evaluated showed no differences, and especially that longevity was not affected, the biological significance of the increased primary malignancies is unknown. Chance variations may be the reason for difference in numbers of malignancies [Ward, 1983].

Scientists of the Georgia Institute of Technology have performed a complementary study, also supported by the Air Force; 200 rats were exposed to 435-MHz fields in circular, parallel-plate waveguides, 22 hr/day for 6 months. No significant differences in blood-borne end points were found [Toler et al., 1988]. To explore the possibility of RF-induced tumor initiation or promotion, the Georgia Tech group exposed a large population (200 exposed and 200 sham-exposed) of mammary-tumor-prone mice to 435 MHz fields for 21 months. This study was specifically designed to examine the effects of low-level, pulsed RF fields on cell growth and differentiation, unlike our project which was designed to study effects on general health and longevity. Their experiment is completed and the data are being analyzed. It will be interesting to compare their results with ours.

CONCLUSIONS

Microwave exposure of 100 male rats (and 100 sham-exposed controls) at SARs of 0.4 to 0.2 W/kg (pulsed, 2,450-MHz circularly-polarized microwaves at 21.5 h/day, for 25 months) showed no biologically significant effects on general health, serum chemistry, hematological profiles, longevity, cause of death, and lesions associated with aging and benign neoplasia. Statistically significant effects were found in corticosterone levels and immunological parameters at 13 months exposure, but these findings were not confirmed in a follow-up study. O_2 consumption and CO_2 production were lower in exposed young rats. These effects were not observed in mature rats. The findings of an excess of primary malignancies in exposed animals is provocative. However, when this single finding is considered in light of other parameters, it is conjectural whether the statistical difference reflects a true biological influence. The overall results indicate that there are no defintive, biologi-

cally significant effects on rats chronically exposed to this form of microwave irradiation. Positive findings need further independent experimental evaluation.

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Mobile Phone Base Station Tower Settings Adjacent to School Buildings: Impact on Students' Cognitive Health

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Abstract

The use of mobile phones has remarkably increased and become a basic need of daily life. Increasing subscriptions of mobile phones boost the installation of mobile phone base station towers (MPBSTs) in crowded commercial and residential areas including near school buildings. This study investigated the impact of exposure to radiofrequency electromagnetic field (RF-EMF) radiation generated by MPBSTs on cognitive functions. Two hundred and seventeen volunteer male students aged between 13 and 16 registered from two different intermediate schools: 124 students were from School 1 and 93 students were from School 2. The MPBSTs were located within 200 m from the school buildings. In School 1, RF-EMF was 2.010 μW/cm^2 with a frequency of 925 MHz and in School 2, RF-EMF was 10.021 μW/cm^2 with a frequency of 925 MHz. Students were exposed to EMFR for 6 hr a day, 5 days a week for a total period of 2 years. The Narda Safety Test Solution device SRM-3006 was used to measure RF-EMF in both schools, and cognitive functions tasks were measured by the Cambridge Neuropsychological Test Automated Battery (CANTAB). Significant impairment in Motor Screening Task (MOT; $p = .03$) and Spatial Working Memory (SWM) task ($p = .04$) was identified among the group of students who were exposed to high RF-EMF produced by MPBSTs. High exposure to RF-EMF produced by MPBSTs was associated with delayed fine and gross motor skills, spatial working memory, and attention in school adolescents compared to students who were exposed to low RF-EMF.

Keywords

Electromagnetic Field Radiation, Mobile Phones Base Station Tower, Cognitive function

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In recent years, tremendous developments in mobile phones have revolutionized the telecom industry by making telecommunication faster, economical, and more convenient (D'Silva, Swer, Anbalagan, & Bhargavan, 2014). With the introduction of new applications and multifunctional technology in mobile phones, the telecom industry is appealing to both youth and adults. The usage of mobile phones has dramatically increased, which is considered as a basic tool in daily life (Al-Khlaiwi & Meo, 2004). Worldwide, the number of subscriptions of mobile phones is about 7.52 billion. This number is more than the worldwide population, as many users own more than one mobile phone (World Bank, 2018). The extensive usage of cellular phones has led to the growing installation of mobile phone base station towers (MPBSTs) in crowded commercial and residential areas, which raises community concerns (Buckus et al., 2017; Meo et al., 2015; Wiedemann, Freudenstein, F., Böhmert, Wiart, & Croft, 2017; Zhang et al., 2017; Figure 1).

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Figure 1. Mobile phone base station tower located in a residential area.

Source: Photo taken by a coauthor.

MPBSTs are mainly installed on tall trees, water tanks, or tall commercial and residential buildings to provide the best possible network services (Meo et al., 2015). Mobile phones communicate with nearby MPBSTs mainly through EMF radiofrequency waves operating at the frequencies of 1.8–2.2 GHz for digital systems and 400–900 MHz for analogue systems (Buckus et al., 2017). The EMFs absorbed by MPBSTs are based on the properties of the absorbing tissue, antenna position, magnetic field frequency, the power emitted, and distance of their placement (Wiedemann et al., 2017). Exposure to RF-EMF has several effects on human health including fatigue, tension, headache, sleep disturbance (Al-Khlaiwi & Meo, 2004), physiological and psychological problems (Deniz et al., 2017), hearing and vision complaints (Meo & Al-Drees, 2005), risk of type 2 diabetes mellitus (Meo et al., 2015), and cancer (Moulder, Foster, Erdreich, & McNamee, 2005).

Extensive fixing of MPBSTs in densely populated commercial, residential areas, and school buildings has started community concerns about adverse effects on human health (Meo et al., 2015), mainly brain function (Saikhedkar et al., 2014). Therefore, this study explored the association of exposure to radio frequency electromagnetic field radiation (RF-EMFR) generated by MPBSTs on cognitive function amongst school-going adolescents.

Methods

Study Design and Participants

Students were recruited based on their apparently healthy status, voluntary participation, same gender, age, height, weight, ethnicity, and from homogenous educational, socioeconomic, and residential backgrounds. Initially, 300 students (150 from School 1 and 150 from School 2) were registered. A detailed clinical history was obtained to consider whether the students should be included or not. After clinical history, finally 217 were selected:124 students from School 1 and 93 from School 2. The age of School 1 group was 13–16 years (mean age 14.25 ± 0.98) and that of School 2 group was 13–16 years (mean age 14.10 ± 1.01). The study was piloted as permitted by the Institutional Review Board, College of Medicine King Saud University, Riyadh, Saudi Arabia (Ref # E-16-2124). Written consent was obtained from the students and or their parents.

Exclusion Criteria

Students with clinical histories of blood disease, anemia, diabetes mellitus, obesity, asthma, seizures, malignancy, and those who smoked tobacco were excluded from the study. Known cases of anxiety, vision problems, attention deficit, skeletal muscle disorders, physical disability, those on sedatives, and those with sleep disturbance history were also excluded from the study (Meo, Bashir, Almubarak, Alsubaie, & Almutawa, 2017; Timothy, Durazzo, Meyerhoff, & Nixon, 2010). Students whose residence was near the high transmission lines or MPBST were also excluded (Meo et al., 2015). Students who frequently used and kept cordless phones and Wi-Fi routers in their bedrooms were also excluded from the study (Meo et al., 2015).

Radiofrequency Field Exposure

Two different intermediate schools were selected; both had MPBSTs situated nearby and were operational for

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Table 1. Anthropometric Variables of Students in Both Schools.

Parameters	School 1 (n = 124) RF-EMF: 2.010 μW/cm^2	School 2 (n = 93) RF-EMF: 10.021 μW/cm^2	p value
Age (years)	14.25 ± 0.98	14.10 ± 1.01	.29
Height (m)	1.61 ± 0.08	1.61 ± 0.09	.95
Weight (kg)	56.13 ± 16.55	59.11 ± 16.91	.19
BMI (kg/m^2)	21.25 ± 5.03	22.40 ± 5.16	.09

Note. Values are expressed in mean ± *SD*. RF-EMF = radio frequency electromagnetic field; *SD* = standard deviation.

about 3 years. The source of RF-EMF around the schools was visually checked by two coauthors to exclude the presence of any other source of RF-EMF, overhead power lines, or high transmission electricity lines in the surrounding area. RF-EMFR measurements were done in three different sites of the classrooms (center and two corners), twice a day before and after recording the test parameters during the study period in a similar research methodology approach used by (Meo et al., 2015).

The Narda Safety Test Solution SRM-3006 was used to measure the RF-EMF. In School 1, the RF-EMF was 2.010 μW/cm^2 and in School 2 it was 10.021 μW/cm^2 at a frequency of 925 MHz; students were exposed to RF-EMFR for 6 hr daily, 5 days a week (Meo et al., 2015) for a total period of 2 years.

Neuropsychological Tests Procedure

Cognitive function was tested using the Cambridge Neuropsychological Test Automated Battery (CANTAB) research suite 6.0.37. Measurements were recorded at a fixed time of the day (9:00–11:00 am) to minimize the physiological diurnal variations. Each subject was tested in two tasks; the total time required to complete the tasks was about 15–20 min. Sitting well on a chair, with a flat touch screen in front, students were asked to complete the tasks by stirring the screen with the index finger of the dominant hand. There was a distance of 25 cm between the participant and the screen.

Motor Screening Task

The Motor Screening Task (MOT) is a simple reaction time test; it measures the psychomotor functions, speed, and accuracy. The MOT is an essential test of fine and gross motor skills appraised in a visuomotor accuracy-tracking task (Geertsen et al., 2016). It is vital for global understanding abilities, mainly the attention and information on the sensorimotor function or comprehension (Cercel et al., 2014). It provides a general assessment of sensorimotor deficits or lack of comprehension and measures the person's response time to a visual stimulus. Fine and gross motor skills are highly essential in managing the routine activities in everyday life; these skills are linked to objective performance with higher cognitive functions (Geertsen et al., 2016).

Spatial Working Memory Task

The Spatial Working Memory (SWM) task is a test of memory retention and visuospatial information (Deniz et al., 2017). This test is essential to measure the working memory for spatial stimuli and requires the subject to use prompt reminding information to work toward the objective. A number of boxes appear each time, the task requires the participant to press the boxes until he finds the token inside each one; the token moves from one box to another and never appears in any box twice. Elimination by the subject is required until the token is found in each box.

Statistical Analysis

Statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS for Windows, version 21.0). Independent t-test was used to compare the differences in the mean values of the two quantitative variables. The effect size was measured using Cohen's d formula, and statistical significance was set at $p < .05$.

Results

In School 1, students were exposed to RF-EMF produced by MPBSTs at 2.010 μW/cm^2 at a frequency of 925 MHz for 6 hr a day, 5 days a week. Although in School 2, students were exposed to RF-EMF of 10.021 μW/cm^2 at a frequency of 925 MHz for 6 hr a day, 5 days a week for a total period of 2 years (Table 2). In School 1 group, students' age range was 13–16 years (mean age 14.25 ± 0.98), while in School 2, it was 13–16 years (14.10 ± 1.01; Table 1) .

MOT and SWM tasks were recorded; the MOT results are expressed as the standard score of mean latency (MOT ML). There was a statistically significant impairment in the MOT ML (806.99 ± 136.28 vs. 849.53 ± 160.14; $p = .036$) and SWM task (37.29 ± 3.14 vs. 36.40 ± 3.22; $p = .043$) among students who were exposed to

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Table 2. Comparison of the Cognitive Function Between Students Who Were Exposed to RF-EMF at 2.010 μW/cm^2 Versus Students Who Were Exposed to RF-EMF Generated by MPBSTs at 10.021 μW/cm^2.

Parameters	School 1 (n = 124) RF-EMF: 2.010 μW/cm^2	School 2 (n = 93) RF-EMF: 10.021 μW/cm^2	p value
MOT mean latency	806.99 ± 136.28	849.53 ± 160.14	.03
SWM strategy	37.29 ± 3.14	36.40 ± 3.22	.04

Note. Values are expressed in mean ± *SD*. Cohen's *d* for MOT mean latency is 0.28 and for SWM strategy is 0.27. MOT = Motor Screening Task; SWM = Spatial Working Memory; RF-EMF = radio frequency electromagnetic field; *SD* = standard deviation.

high RF-EMFR generated by MPBSTs (School 2) compared to students who were exposed to low levels of RF-EMFR (School 1; Table 2). Cohen's *d* for MOT ML was 0.28 and for SWM strategy was .27; it shows small effect of RF-EMF produced by MPBSTs on cognitive function impairment.

Discussion

The RF-EMF radiations are the waves emitted from MPBSTs. The occurrence of RF-EMFR changes rapidly with distance and they scattered in different directions toward the ground (Buckus et al., 2017). The RF-EMFR carry non-ionizing radiations, known to have biological effects on human health (Hardell, Carlberg, & Hedendahl, 2018). The present study identified a decrease in fine and gross motor skills, spatial working memory, and attention among school children who had been exposed to high RF-EMF compared to students who had been exposed to low RF-EMF.

Singh et al. (2016) investigated the RF-EMFR generated by MPBSTs and its impact on the public health of people who lived close to the MPBSTs. The authors reported that majority of the subjects who were living adjacent to the MPBSTs complained about cardiovascular and nervous system associated clinical symptoms including headache, sleep disturbances, dizziness, difficulties in concentration, and high blood pressure, when compared to the control subjects.

In agreement with present study findings, researchers established a link between high exposure to RF-EMF and cognitive function (Calvente et al., 2016). The study outcome demonstrates a positive link between exposure to RF-EMF and decline in cognitive function. Children who were exposed to high levels of RF-EMF had lower cognitive scores for verbal expression and comprehension in comparison to those living in areas with lower exposure. They also identified that exposure to RF-EMFR has a negative impact on cognitive and behavioral development in children. Similarly, Thomas et al. (2010) reported a significant decrease in response time in adolescents who were involved in using mobile phones for long durations.

Contradictory to present study findings, Malek, Rani, Rahim, and Omar (2015), Haarala, Björnberg, Ek, Laine, Revonsuo, and Koivisto (2003), and Riddervold et al. (2008) reported no impact of RF-EMF exposure generated from MPBSTs on human cognitive function. The most probable reason for this contradiction is the determination of acute effect in a very limited time period. However, in the current study, the students were exposed to 6 hr a day, 5 days a week for a total period of 2 years.

Abdel-Rassoul et al. (2007) performed a study on inhabitants living near the MPBSTs. The exposed people experienced a considerable increase in neuropsychiatric symptoms including headache, dizziness, sleep disturbance, depressive feelings, and memory changes compared to those in the control group. The exposed inhabitants exhibited a decreased performance in attention and short-term memory tests. Silva, Barros, Almeida, and Rêgo (2015) demonstrated an association between anxiety and depression in individuals who live 100–200 m closer to MPBSTs compared to subjects living 300 m away from MPBSTs. Augner and Hacker (2009) reported that closer the distance to the MPBSTs, greater the radiation and higher the percentage of somatization, anxiety, and phobic nervousness in individuals living near MPBSTs. Kalafatakis, Bekiaridis-Moschou, Gkioka, and Tsolaki (2017) identified that mobile phone use has a significant negative impact on the working memory performance of people. The current study findings are in agreement with the results found by Abdel-Rassoul et al. (2007) and Kalafatakis et al. (2017).

Saikhedkar et al. (2014) determined the effects of mobile phone radiation on cognitive performances mainly on learning and memory. Their study findings indicate significant changes in behavior and poor learning in the exposed group as compared to the control group. These study findings agree with the present study findings that high exposure to RF-EMF produced by MPBSTs is associated with a decline in the fine and gross motor skills and spatial working memory and attention in the school adolescents who had been exposed to high RF-EMF compared to the students who had been exposed to low RF-EMF.

The potential reasons behind cognitive functions impairment in subjects exposed to RF-EMF radiation

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from MPBSTs are sleep disturbances, behavioral problems (Hardell et al., 2018), reduced regional cerebral blood flow (Hossman & Herman, 2003; Huber et al., 2002), myelin sheath damage (Kim, Yu, et al., 2017), and neuronal function impairment (Kim, Kim, et al., 2017). RF-EMF radiation may result in these mechanisms associated with neurological functioning resulting in cognitive impairment.

Strengths and Limitations

We took considerable efforts to adjust the relevant confounding factors; still there might be some residual confounding. This study has a relatively reasonable sample size, well-established research methodology, exclusion criteria, reliable tools used to measure the RF-EMFR, and minimized confounding factors (Meo et al., 2015). The recruitment of the male gender only is the limitation of this study due to the rules and regulations in Saudi Arabia that do not allow co-education systems in schools or universities. Students whose residences were adjacent to high power lines or MPBSTs and students who commonly used and kept cordless phones and Wi-Fi devices in their bedrooms were excluded from the study. There may be chances of exposure to RF-EMF generated from other sources such as television, remote devices, and wireless networks.

Conclusions

Despite the limitation of this cross-sectional study, it is identified that high exposure to RF-EMF produced by MPBSTs is associated with a decrease in fine and gross motor skills and spatial working memory and attention in school adolescents compared to students who had been exposed to low RF-EMF. This study provides cognizance to society and stakeholders in health care about the health hazards of RF-EMF produced from MPBSTs. No one can deny the facilities that are being provided by the telecommunication industry, but it is believed that nothing should be compromised over health. MPBSTs must be installed away from thickly populated residential zones particularly in or near the school buildings or there must be some system to shield human beings from RF-EMFR.

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Non-thermal Biological Effects of Microwaves

Igor Belyaev

List of Abbreviations - Anomalous viscosity time dependence (AVTD); blood-brain barrier (BBB); catalase (CAT); Digital Enhanced (former European) Cordless Telecommunications (DECT); circularly polarized (CP); continuous wave (CW); Digital Advanced Mobile Phone System (DAMPS); discontinuous transmission (DTX); electroencephalographic (EEG); electromagnetic field (EMF); embryonic stem (ES) cells; ethidium bromide (EtBr); extremely low frequency (ELF); Gaussian Minimum Shift Keying (GMSK); Ginkgo biloba (Gb); Global System for Mobile Communication (GSM); glutathione peroxidase (GSH-Px); International Commission for Non-Ionizing Radiation Protection (ICNIRP); linearly polarized (LP); malondialdehyde (MDA); micronucleus (MN) assay; microwaves (MWs); N-acetyl-beta-d-glucosaminidase (NAG); nitric oxide (NO); non-thermal (NT); ornithine decarboxylase (ODC); phorbol ester 12-myristate 13-acetate (PMA); phosphorylated H2AX histone (γ-H2AX); power density (PD); regional cerebral blood flow (rCBF); Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP); specific absorption rate (SAR); static magnetic field (SMF); superoxide dismutase (SOD); Time Division Multiple Access (TDMA); tumor suppressor p53 binding protein 1 (53BP1); ultraviolet (UV); Universal Mobile Telecommunications System (UMTS).

Abstract **- The aim of this paper is to overview the diverse biological effects of non-thermal microwaves (NT MWs) and complex dependence of these effects on various physical and biological parameters. Besides dependencies on frequency and modulation, the available data suggest dependencies of the NT MW effects on intermittence and coherence time of exposure, polarization, static magnetic filed, electromagnetic stray field, genotype, gender, physiological and individual factors, cell density during of exposure and indicate that duration of exposure may be not less important than power density (PD) for the NT MW effects. Further evaluation of these dependencies are needed for understanding the mechanisms by which NT MWs affect biological systems, planning in vivo and epidemiological studies, developing medical treatments, setting safety standards, and minimizing the adverse effects of MWs from mobile communication.**

Key words **- non-thermal effects of microwaves, mobile (cellular) phones.**

I. Introduction

Electromagnetic exposures vary in many parameters: power (specific absorption rate, incident power density), wavelength/frequency, near field - far field, polarization (linear, circular) continues wave (CW) and pulsed fields (pulse repetition rate, pulse width or duty cycle, pulse shape, pulse to average power, etc.), modulation (amplitude, frequency, phase, complex), static magnetic field (SMF) and electromagnetic stray field at the place of exposure, overall duration and intermittence of exposure (continuous, interrupted), acute and chronic exposures. With increased absorption of energy, so-called thermal effects of microwaves (MWs) are usually observed that deal with MW-induced heating. Specific absorption rate (SAR) or power density (PD) is a main determinate for the thermal MW effects. Many other physical parameters of exposure may be important for so-called non-thermal (NT) biological effects, which are induced by MWs at intensities well below any heating [1-11]. An important question is how these physical parameters should be taken into account in safety standards.

Most often, the current safety standards are based on the thermal effects of MWs obtained in short-term (acute) exposures. In some countries, such as Russia, the NT MW effects, especially those induced during prolonged (chronic) exposures, are accepted and taken into account for establishment of the national safety standards [10-12]. It should be stressed, that in contrast to the ICNIRP (International Commission for Non-Ionizing Radiation Protection) safety standards [13], which are based on the acute thermal effects of MWs, the standards adopted by the Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP) are based on the experimental data from chronic (up to 4 month) exposures of animals to MWs at various physical parameters including intensity, frequency and modulation, which were performed in the former Soviet Union and Russia [10-12]. Since establishment of the current safety standards, the situation with exposure of general population to MWs has been changed significantly. Nowadays, most part of population is chronically exposed to MW signals from various sources including mobile phones and base stations. These exposures are characterized by low intensities, varieties of signals, and long-term durations of exposure that are comparable with a lifespan. So far, the "dose" (accumulated absorbed energy that is measured in radiobiology as the dose rate multiplied by the exposure time) is not adopted for the MW exposures and SAR or PD is usually used for the guidelines. To what degree SAR/PD can be applied to the nowadays NT MW chronic exposures is not known and the current state of research demands reevaluation of the safety standards [12].

There are two main approaches to treat numerous data regarding the NT MW effects. The first one is based on the consideration of these effects dependent on various physical parameters and biological variables as has consistently been described in many experimental studies and will be partially reviewed in this paper. The second approach is based on neglecting or minimizing the experimentally observed NT MW effects based on the current state of theoretical physical science that is insufficient for comprehensive explanation of the NT MWs effects. As a result of such various treatments of

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the experimental data, the safety standards significantly, up to 1000 times, vary between countries.

The literature on the NT MW effects is very broad and this paper is not intended to be a comprehensive review of this literature. There are four lines of evidence for the NT MW effects: (1) altered cell responses in laboratory *in vitro* studies and results of chronic exposures *in vivo* studies [3, 11] (this review); (2) results of medical application of NT MWs in the former Soviet Union countries [4, 7, 14, 15]; (3) hypersensitivity to electromagnetic fields (EMFs); (4) epidemiological studies suggesting increased risks of brain tumors, acoustic neuroma and T-cell lymphoma for the mobile phone users [16-18]. In this review, we will focus on the studies showing a complex dependence of the NT MW effects on various parameters.

II. Experimental Studies

Examples of diverse *in vitro* biological effects of NT MWs in the frequency range as used in mobile communication and at intensities below ICNIRP restrictions are given in Table 1.

The first data on the NT effects of MWs in so-called millimeter range (wavelength 1-10 mm in vacuum) was obtained by Vilenskaya and co-authors [19] and Devyatkov [20]. Important regularities of the NT MW effects such as "resonance-type" dependence on frequency and "effective intensity windows", were found in these studies as previously reviewed [2, 7-9, 21-23]. The first investigations of the NT MW effects at lower frequency ranges were performed by Blackman and colleagues [24-26] and Adey with colleagues [27, 28]. Theses groups found dependence of the NT MW effects on modulation. Since that time, other groups have confirmed the main findings of these pioneering studies as will be reviewed below.

III. Frequency Windows

Effects of NT MWs on repair of radiation-induced DNA breaks in *E. coli* K12 AB1157 were studied by the method of anomalous viscosity time dependence (AVTD) [29]. The AVTD method is a sensitive technique to detect changes in conformation of nucleoids induced by both genotoxic and stress factors [30-35]. Significant inhibition of DNA repair was found when X-irradiated cells were exposed to MWs within the frequency ranges of 51.62-51.84 GHz and 41.25-41.50 GHz. The effects were observed within two "frequency windows" displaying a pronounced resonance character in each with the resonance frequencies of 51.755 GHz and 41.32 GHz, respectively [29, 36]. These MW effects could not be explained by heating.

The resonance frequency of 51.755 GHz was stable within the error of measurements, $\pm$1 MHz, as PD decreased from $3\cdot10^{-3}$ to 10^{-19} W/cm^2 [30, 36]. However, the half-width of the resonance decreased from 100 MHz to 3 MHz. This sharp narrowing of the 51.755 GHz resonance was followed by an emergence of new resonances, 51.675$\pm$0.001, 51.805$\pm$0.002, and 51.835$\pm$0.005 GHz, as PD decreased from $3\cdot10^{-3}$ to 10^{-7} W/cm^2 [30, 37]. The half-widths of all these resonances including the main one, 51.755$\pm$0.001 GHz, were about 10 MHz at the PD of 10^{-10} W/cm^2. These data were interpreted as a splitting of the main resonance 51.755 GHz in the MW field [30]. The MW effects were studied at different PDs and several frequencies around the resonance frequency of 51.675 GHz. This resonance frequency was found to be stable, $\pm$1 MHz, within the PD range of 10^{-18} - 10^{-8} W/cm^2. Along with disappearance of the 51.675 GHz resonance response at the sub-thermal PD of 10^{-6} - 10^{-3} W/cm^2, a new resonance effect arose at 51.688$\pm$0.002 GHz [37]. This resonance frequency was also stable within the PD range studied. Taken together, these data strongly suggested a sharp rearrangement of frequency spectra of MW action, which was induced by the sub-thermal MWs. The half-widths of three resonances studied depended on PD, changing either from 2-3 MHz to 16-17 MHz (51.675 GHz and 51.668 GHz resonances) or from 2-3 MHz to 100 MHz (51.755 GHz resonance) [30, 37]. These data indicated that different dependencies of half-width on PD might be expected at various resonance frequencies.

Significant narrowing in resonance response was found when studying the growth rate in yeast cells [38] and chromatin conformation in thymocytes of rats [39]. In the Gründler's study, the half-width decreased from 16 MHz to 4 MHz as PD decreased from 10^{-2} to 10^{-12} W/cm^2 [38].

The results of these studies with different cell types indicate that narrowing of the resonance upon decrease in PD is one of the general regularities in cell response to NT MWs. This regularity suggests that many coupled oscillators are involved non-linearly in the response of living cells to NT MWs as has been predicted by Fröhlich [40].

Gapeev and co-authors studied effects of MW exposure on the respiratory burst induced by calcium ionophore A23187 and phorbol ester 12-myristate 13-acetate (PMA) in the peritoneal neutrophils of mice [41]. MWs at the PD of 50 μW/cm^2 inhibited the respiratory burst. MW effect depended on frequency and was maximal at the frequency of 41.95 GHz.

Based on the extrapolation from the data obtained in the extremely high frequency range (30-300 GHz), the values for half-width of resonances at the frequency range of mobile phones (0.9–2 GHz) were estimated to be 1-10 MHz [35]. Effects of GSM (Global System for Mobile Communication) MWs on chromatin conformation and 53BP1 (tumor suppressor p53 binding protein 1)/γ-H2AX (phosphorylated H2AX histone) DNA repair foci in human lymphocytes were studied in this frequency range [33-35]. Dependence of these MW effects on carrier frequency was observed [33, 35]. This dependence was recently replicated in independent set of experiments with lymphocytes from twenty persons in total [33, 42].

Tkalec and colleagues exposed duckweed (*Lemna minor L.*) to MWs at the frequencies of 400, 900, and 1900 MHz [43]. The growth of plants exposed for 2 h to the 23 V/m electric field of 900 MHz significantly decreased in comparison with the control, while an electric field of the same strength but at 400 MHz did not have such effect. A modulated field at 900 MHz strongly inhibited the growth, while at 400 MHz modulation did not influence the growth significantly. At both frequencies, a longer exposure mostly decreased the growth and the highest electric field (390 V/m) strongly inhibited the

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growth. Exposure of plants to lower field strength (10 V/m) for 14 h caused significant decrease at 400 and 1900 MHz while 900 MHz did not influence the growth. Peroxidase activity in exposed plants varied, depending on the exposure characteristics. Observed changes were mostly small, except in plants exposed for 2 h to 41 V/m at 900 MHz where a significant increase (41%) was found. Authors concluded that MWs might influence plant growth and, to some extent, peroxidase activity. However, the effects of MWs strongly depended on the characteristics of the field exposure such as frequency and modulation.

IV. Power Windows

It was found that the NT MW effects are observed within specific PD "windows" [20]. This type of PD dependence for the MW effects was observed in several following studies as previously reviewed [7-9, 21-23].

The data obtained in experiments with *E coli* cells and rat thymocytes provided new evidence for this type of PD dependence [30, 37, 39, 44]. Window-like PD dependences of the MW effects were observed at different resonance frequencies. The most striking PD window was found at the resonance frequency of 51.755 GHz [30]. When exposing *E. coli* cells at the cell density of $4 \cdot 10^8$ cell/ml, the effect reached saturation at the PD of 10^{-18}-10^{-17} W/cm^2 and did not change up to PD of 10^{-3} W/cm^2. In these experiments, the direct measurements of PD below 10^{-7} W/cm^2 were not available and lower PDs were obtained using calibrated attenuators. Therefore, some uncertainty in the evaluation of the lowest PDs was possible. The background MW radiation in this frequency range has been estimated as 10^{-21}-10^{-19} W/m^2/Hz [45]. Based on the experimentally determined half-width of the 51.755 GHz resonance, 1 MHz [30], the background PD was estimated as 10^{-19}-10^{-17} W/cm^2 within the 51.755 GHz resonance. The resonance MW effects on *E. coli* cells were observed at PD very close to the estimated background value [30, 37, 46-48]. The data suggested that the PD dependence of MW effect at specific resonance frequencies might have a threshold comparable with the background level.

Dependence of the MW effect on PD at one of the resonance frequencies, 51.675 GHz, had the shape of "window" in the PD range from 10^{-18} to 10^{-8} W/cm^2 [37]. It is interesting, that no MW effect was observed at sub-thermal and thermal PDs at this resonance frequency. This type of PD dependence clearly indicated non-thermal mechanism of the MW effects observed. The position of the PD window varied between different resonance frequencies and depended on cell density during exposure of cells [37].

Despite some uncertainty in the evaluation of PD at the levels below 10^{-7} W/cm^2 in the referred studies the data indicated that MWs at frequencies within specific frequency windows ("resonances") result in biological effects at very low intensities comparable with intensities from base stations and other MW sources used in mobile communication.

V. Duration of Exposure and Time after Exposure

Bozhanova with co-authors reported that the effect of cellular synchronization induced by NT MWs depended on duration of exposure and PD [49]. The dependence on duration of exposure fitted to exponential function. The important observation was that the decrease in PD could be compensated by the increase in the duration of exposure in order to achieve the same synchronization of cells.

Kwee and Raskmark analyzed effects of MW at 960 MHz and various SARs, 0.021, 0.21, and 2.1 mW/kg on proliferation of human epithelial amnion cells [50]. These authors reported linear correlations between exposure time to MW at 0.021 and 2.1 mW/kg and the MW-induced changes in cell proliferation albeit no such clear correlation was seen at 0.21 mW/kg.

MW exposure of *E. coli* cells and rat thymocytes at PDs of 10^{-5}-10^{-3} W/cm^2 resulted in significant changes in chromatin conformation if exposure was performed at resonance frequencies during 5-10 min [29, 39, 51]. Decreasing of PD by orders of magnitude down to 10^{-14}-10^{-17} W/cm^2 could be compensated by several-fold increasing of exposure time to 20-40 min in order to achieve the same changes in chromatin conformation [47]. The duration of exposure should be longer, more than 1 h, to achieve the same effect at the lowest estimated PD of 10^{-19} W/cm^2 [47]. Therefore, decreasing of PD by orders of magnitude could be compensated by several-fold increasing of exposure time and duration of exposure to NT MWs may have significantly larger role than PD.

The MW effects on *E. coli* cells depended also on the post-exposure time [46-48]. This dependence had an initial phase of increase about 100 min post-exposure followed by the phase, which was close to a plateau, around 100 min. A trend to decrease in effect was observed at longer times up to 300 min [46, 48].

Significant MW-induced changes in chromatin conformation were observed when rat thymocytes were analyzed in-between 30-60 min after exposure to MWs [39]. This effect nearly disappeared if the cells were incubated more than 80 min between exposure and analysis.

In recent studies, human lymphocytes from peripheral blood of healthy and hypersensitive to EMF persons were exposed to MWs from the GSM mobile phones [33, 34]. MWs induced changes in chromatin conformation similar to those induced by heat shock, which remained up to 24 h after exposure. It was found in the same and following studies that GSM MWs at the carrier frequency of 915 MHz and UMTS (Universal Mobile Telecommunications System) MWs at the 1947.4 MHz (middle channel) inhibited formation of the 53BP1/γ-H2AX DNA repair foci and these adverse effects remained during 72 h after 1-h exposure [33, 42].

The data suggested that there is a time window for observation of the MW effects, which may be dependent on endpoint measured, cell type, duration and PD of exposure.

VI. Intermittence and Coherence Time of Exposure

Diem and colleagues exposed cultured human diploid fibroblasts and cultured rat granulosa cells to intermittent and continuous MWs (1800 MHz; SAR 1.2 or 2 W/kg; different modulations; during 4, 16 and 24 h; intermittent 5 min on/10 min off or continuous wave) [52]. Comet assay was applied to analyze DNA single- and double-strand breaks. MW-induced effects occurred after 16 h exposure in both cell types and after different mobile-phone modulations. The intermittent exposure showed a stronger effect than continuous exposure.

MW exposure of L929 fibroblasts was performed by the group of Litovitz [53]. MWs at 915 MHz modulated at 55, 60, or 65 Hz approximately doubled ornithine decarboxylase (ODC) activity after 8 h. Switching the modulation frequency from 55 to 65 Hz at coherence times of 1.0 s or less abolished enhancement, while times of 10 s or longer provided full enhancement. These results suggested that the microwave coherence effects are remarkably similar to those observed previously with extremely low frequency (ELF) magnetic fields by the same authors.

VII. Polarization

The effects of circularly polarized (CP) MWs were studied in *E. coli* cells at the frequencies from two frequency windows (resonances) that were identified using linearly polarized (LP) MWs, 51.62-51.84 GHz and 41.25-41.50 GHz. At the resonance frequency of 51.76 GHz, right-handed CP MWs inhibited repair of X-ray-induced DNA damages [36, 51]. In contrast to right-handed polarization, left-handed CP MWs had virtually no effect on the DNA repair, while the efficiency of LP MWs was in-between of two circular polarizations. Inversion in effectiveness of circular polarizations was observed at another resonance frequency, 41.32 GHz. In contrast to the frequency of 51.76 GHz, left-handed CP MWs at 41.32 GHz significantly inhibited DNA repair, while right polarization was almost ineffective. MWs of the same CP affected cells at several frequencies tested within each resonance, other CP being always ineffective [36, 44, 51]. Therefore, specific sign of effective CP, either left- or right-, was the attribute of each resonance. Two different types of installations, based on either spiral waveguides [51] or quarter-wave mica plates [36, 37, 44, 54, 55], were used to study the dependences of the MW effects on polarization. Similar results were observed regardless the way of producing the MWs of different polarizations.

Pre-irradiation of *E. coli* cells to X-rays inverted the sign of effective polarization [36, 44]. This inversion was observed for two different resonances, 41.32 and 51.76 GHz. Neither resonance frequencies, nor half-widths of the resonance changed during the inversions in effective CPs. The effects of left- and right-handed CP MWs become the same at 50 cGy [36]. At this dose, about one single stranded DNA break per haploid genome was induced and this dose was too low to damage significantly any cellular structure except for DNA. It is known that a nucleoid in *E. coli* cells consists of the supercoiled DNA-domains. X-ray-induced DNA breaks result in relaxation of the DNA-domains. It is believed that the majority of DNA in living cells has a right-handed helicity (B-form) but a minor part, in order of 1 %, may alternate from the B-form in the form of left-handed helix (Z-form). Supercoiling is connected with transitions between right B-form to left Z-form in these DNA sequences. The data suggested that difference in biological effects of polarized MWs might be connected with DNA helicity and supercoiling of DNA-domains.

Supercoiling of DNA-domains is changed during cell cycle because of transcription, replication, repair, and recombination. It can also be changed by means of DNA-specific intercalators such as ethidium bromide (EtBr). EtBr changes supercoiling and facilitates the transition of DNA sequences from Z-form to B-form. Preincubation of *E. coli* AB1157 cells with EtBr inverted the effective polarization at the resonance frequency of 51.755 GHz and right-handed MWs became more effective than left polarization [54]. EtBr changed the supercoiling of DNA-domains starting at a concentration of 1 μg/ml as measured with the AVTD in different cell types including *E. coli* [30, 32, 56]. The data provided further evidence that DNA may be a target for the NT MW effects.

Investigations of NT MW effects at 15 resonances in *E. coli* cells and 2 resonances in Wistar rat thymocytes provided evidence that one of two circular polarizations is always more effective than another one [36, 37, 39, 44, 46, 51, 54, 55, 57, 58]. These data are summarized in Table 2. In all experiments, the effect of linear polarized MWs was in-between of effects of two circular polarizations.

Obviously, the difference in effects of right- and left polarizations could not be explained by heating or by mechanism dealing with “hot-spots” due to unequal SAR distribution. The data about the difference in effects of differently polarized MWs, the inversion of effective circular polarization between resonances and after irradiation of cells with X-rays and incubation with EtBr provided strong evidence for the non-thermal mechanisms of MW effects. These data indicated either an asymmetrical nature of the target for the NT MW effects, which is presumably chromosomal DNA [36], or an existence of selection rules on helicity if quantum-mechanical approach is applied [44].

VIII. Modulation

There is experimental evidence for the role of modulation in the diverse biological effects of NT MW both *in vitro* and *in vivo* [28, 41, 59-68]. Examples include different types of modulation such as amplitude-, speech and phase modulations. Amplitude modulation at 16 Hz but not 60 Hz or 100 Hz modulated MW, 450 MHz, increased activity of ODC [63]. Speech-modulated 835 MHz MWs produced no effect on ODC as compared to typical signal from a TDMA (Time Division Multiple Access) digital cellular phone [60]. Phase-modulated GSM-1800 MWs (Gaussian Minimum Shift Keying, GMSK) at 1.748 GHz, induced micronuclei in human lymphocytes while CW MWs did not [64].

In the study by Gapeev and co-authors, stimulation of the respiratory burst was observed in the peritoneal neutrophils of

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mice upon modulation of MWs at 41.95 GHz, 50 μW/cm^2 , with the frequency of 1 Hz [41]. Only this modulation out of four tested (0.1, 1, 16, and 50 Hz) resulted in stimulation of the respiratory burst.

Huber with coauthors investigated effects of MWs similar to those used in mobile communication, a "base-station-like" and a "handset-like" signal (10 g tissue-averaged spatial peak-specific absorption rate of 1 W/kg for both conditions), on waking regional cerebral blood flow (rCBF) in 12 healthy young men [65]. The effect depended on the spectral power in the amplitude modulation of the carrier frequency such that only "handset-like" MW exposure with its stronger low-frequency components but not the "base-station-like" MW exposure affected rCBF. This finding supported previous observations of these authors [66] that pulse modulation of MWs is necessary to induce changes in the waking and sleep EEG, and substantiated the notion that pulse modulation is crucial for MW-induced alterations in brain physiology.

Markkanen and colleagues exposed cdc48-mutated *Saccharomyces cerevisiae* yeast cells to 900 or 872 MHz MWs, with or without exposure to ultraviolet (UV) radiation, and analyzed apoptosis [67]. Amplitude modulated (217 pulses per second) MWs significantly enhanced UV induced apoptosis in cells, but no effect was observed in cells exposed to unmodulated fields at the identical time-average SAR of 0.4 W/kg that was lower than the ICNIRP safety standards.

Persson with colleagues studied effects of MWs of 915 MHz as CW and pulse-modulated with different pulse power and at various time intervals on permeability of the blood-brain barrier (BBB) in Fischer 344 rats [68]. Albumin and fibrinogen were demonstrated immunochemically and classified as normal versus pathological leakage. The CW-pulse power varied from 0.001 W to 10 W and the exposure time from 2 min to 960 min. The frequency of pathological rats significantly increased in all exposed rats. Grouping the exposed animals according to the level or specific absorption energy (J/kg) gave significant difference in all levels above 1.5 J/kg. The exposure was 915 MHz MWs either pulse modulated at 217 Hz with 0.57 ms pulse width, at 50 Hz with 6.6 ms pulse width, or CW. The frequency of pathological rats was significantly higher in MW-exposed groups than in controls and the frequency of pathological rats after exposure to pulsed radiation was significantly less than after exposure to CW.

Significant amount of *in vivo* studies under varying parameters of exposure (intensity, frequency, exposure time, modulation, intermittence) have been performed in Russia/Soviet Union and published in Russian. Retrospective analysis of 52 Russian/Soviet *in vivo* studies with animals (mice, rats, rabbits, guinea pigs) on chronic exposure to MWs has recently been published [11]. In these studies, various endpoints were measured up to 4 month of chronic exposure including analysis of: weight of animal body, histological analysis and weight of tissues, central nervous system, arterial pressure, blood and hormonal status, immune system, metabolism and enzymatic activity, reproductive system, teratogenic and genetic effects. Based on their analysis, the authors concluded that: "exposure to modulated MWs resulted in bioeffects, which can be different from the bioeffects induced by CW MWs; exposure to modulated MWs at low intensities (non-thermal levels) could result in development of unfavorable effects; direction and amplitude of the biological response to non-thermal MW, both *in vitro* and *in vivo*, depended on type of modulation; often, but not always, modulated MWs resulted in more pronounced bioeffects than CW MW; the role of modulation was more pronounced at lower intensity levels".

One review of the Russian/Soviet studies is available in English [14]. These authors conclude that "a number of good-quality studies have convincingly demonstrated significant bioeffects of pulsed MWs. Modulation often was the factor that determined the biological response to irradiation, and reactions to pulsed and CW emissions at equal time-averaged intensities in many cases were substantially different".

In conclusion, significant amount of *in vitro* and *in vivo* studies from different research groups clearly indicated dependence of the NT MW effects on modulation.

IX. Electromagnetic Environment

Hypothetically, background EMF might be of importance for the MW effects. This hypothesis is based on the experimental observations that SMF, ELF magnetic fields, and MWs at low intensities induced similar effects in cells under specific conditions of exposure [1, 34, 69-71]. Despite very little has been done for mechanistic explanation of such effects, there are attempts to consider the effects of EMFs in a wide frequency range in the frames of the same physical models [72-76].

Litovitz and colleagues found that the ELF magnetic noise inhibited the effects of MWs on ODC in L929 cells [61]. The ODC enhancement was found to decrease exponentially as a function of the noise root mean square amplitude. With 60 Hz amplitude-modulated MWs, complete inhibition was obtained with noise levels at or above 2 μT. With the DAMPS (Digital Advanced Mobile Phone System) cellular phone MWs, complete inhibition occurred with noise levels at or above 5 μT. Further studies by the same group revealed that the superposition of ELF noise inhibited hypoxia de-protection caused by long term repeated exposures of chick embryos to MWs [77].

Ushakov with co-authors exposed *E. coli* cells to MWs at the PD of 10^{-10} W/cm^2 and the frequencies of 51.675, 51.755 and 51.835 GHz [55]. In this study, cells were exposed to MWs at various values of SMF: 22, 49, 61, or 90 μT. The authors observed dependence of the MW effects on SMF during MW exposure.

If confirmed, the observations on dependence of the NT MW effects on SMF and ELF stray field would be of significant interest for further development of physical theory for the NT MW effects and development of mobile communication with minimized health risks.

X. Cell-to-cell Interaction in Response to MWs

The effects of NT MWs at the resonance frequency of 51.755 GHz on conformation of nucleoids in *E. coli* cells

were analyzed in dependence on cell density during exposure [47]. The per-cell-normalized effect of MWs increased by a factor of 4.7±0.5 on average as cell density increased by one order of magnitude, from $4 \cdot 10^7$ to $4 \cdot 10^8$ cell/ml. These data suggested a co-operative nature of cell response to MWs, which is based on cell-to-cell interaction during exposure. This suggestion was in line with the observed partial synchronization of cells after exposure to MWs.

The co-operative nature of cell response to MW at the resonance frequency of 51.755 GHz was confirmed in further studies with *E. coli* cells [30, 37, 48]. In addition, dependence of the per-cell-normalized effect on cell density was found for two other resonances, 51.675 GHz and 51.688 GHz. These data suggested that the dependence on the cell density during exposure is a general attribute of the resonance response of *E. coli* cells to NT MWs. At the cell density of $4 \cdot 10^8$ cells/ml, the average intercellular distance was approximately 13 μm that is 10 times higher than the linear dimensions of *E. coli* cells [47, 48]. Therefore, no direct physical contact seemed to be involved in the cell-to-cell interaction. Two mechanisms, biochemical and electromagnetic, were considered to account for the co-operative nature in the resonance response to weak EMF in wide frequency range including ELF, MWs and ionizing radiation [47, 78, 79]. The first one, biochemical, is based on release of secondary chemical messengers (ions, radicals, or molecules) by those cells, which were directly targeted. Via diffusion, these messengers can induce response in other cells. The second mechanism, electromagnetic, is based on reemission of secondary photons. According to this mechanism, reemitted photons can induce response in other cells if the intercellular distance is shorter than the length of photon absorption. Our experimental data on MW effects fitted better to the electromagnetic mechanism but a combination of two mechanisms was also possible [47, 48]. In particular, radicals with prolonged lifetimes might be involved in the observed cell-to-cell communication during response to EMF [80].

The absorption length of photons with the frequencies of 10^{12}-10^{13} Hz corresponds to the intracellular distance at the cell density of $5 \cdot 10^8$ cell/ml, at which saturation in the dependences of the EMF effects on the cell density was observed [47, 48, 80, 81]. Such photons may be involved in cell-to-cell communication according to the electromagnetic mechanism and in agreement with the prediction of Fröhlich that biosystems support coherent excitations within frequency range of 10^{11}-10^{12} Hz [40]. From this point of view, cell suspension may respond to NT MWs as a whole. In this case, the number of the exposed cells should be large enough to facilitate cell-to-cell communication during the responses to MWs at specific parameters of exposure such as frequency, modulation, and polarization. Interestingly, the cell density for saturation of both MW and ELF effects was about $5 \cdot 10^8$ cell/ml that is close to cell densities in soft tissues of eukaryotes [48, 80]. Such density of cells in the tissues may be important for regulation of living systems by electromagnetic cell-to-cell communication. Cellular membranes and DNA have been considered as possible sources of coherent excitations and photons, which may be involved in electromagnetic cell-to-cell communication [30, 40, 80].

PD dependences of the MW effect at the 51.755 GHz resonance frequency were considerably different between two cell densities, $4 \cdot 10^7$ cells/ml and $4 \cdot 10^8$ cells/ml [30]. However, the resonance frequency of 51.755 GHz did not shift with the changes in cell density. The half-width of the 51.755 GHz resonance did not depend on cell density either. Contrary to the 51.755 GHz resonance response, the half-width of the 51.675 GHz resonance depended on cell density [37]. The data suggested that intracellular interaction during the NT MW exposures at some specific frequencies might affect sub-cellular targets for NT MWs. This target is presumably chromosomal DNA that is organized in the DNA-domains [36, 58, 72].

In all studies concerning dependence of the MW effects on cell density, the cells occupied a negligible part of the exposed volume and could not change the absorption of MWs even at the highest cell densities [30, 37, 47, 48]. Striking difference in the cell responses at various cell densities provided further evidence for non-thermal mechanism of the observed MW effects.

Significant MW effect on synchronization of *Saccharomyces carlsbergensis* yeast cells were observed by Golant and co-authors [82]. Exposure to MWs at 30 μW/cm^2 and 46 GHz induced synchronization as measured by cell density and bud formation. Authors assumed that MWs induced cell-to-cell interaction resulting in the observed synchronization.

XI. Genetic Background

We studied effects of MWs on *E. coli* cells of three isogenic strains with different length of chromosomal DNA [58]. Bacterial chromosomal DNA in N99 wild type cells was lengthened by inserting DNA from λ and $\lambda imm^{434} bio^{10}$ phages. Lysogenic strains N99(λ) and N99(λ,$\lambda imm^{434} bio^{10}$) obtained were used for MW exposure along with the wild type N99 strain. The response of each strain was studied at 10-17 frequencies inside frequency ranges of 41.24-41.37 GHz and 51.69-51.795 GHz. Clear resonance responses to MWs at 10^{-10} W/cm^2 were observed for each strain in both frequency ranges. Significant shifts of both resonance frequencies were found between strains (Table 3). The shifted resonances had the same amplitude and half-width as for N99 cells [58]. Upon shifting, no changes in effective circular polarization within each shifted resonance were observed (Table 3). The shifts in resonance frequencies could not be explained by activity of additional genes inserted with the phage DNA. On the other hand, the theoretical consideration based on oscillations of the DNA-domains regarding a whole nucleoid provided a good correlation between the increasing in the DNA length and the shifts in resonances [58].

A detailed analysis of MW effects on *E. coli* AB1157 cells at 10^{-10} W/cm^2 and various frequencies revealed the resonance frequency of 51.755±0.001 GHz [30]. This value was statistically significantly different from the resonance frequency of 51.765±0.002 in response of *E. coli* N99 cells to MWs in the same frequency range [30]. It should be noted

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that both strains, AB1157 and N99, are considered as wild type strains. Nevertheless, these strains are different in their genotypes by several specific gene markers [29, 83]. These data suggested that strains of different origin, even being considered as wild type strains, might have different resonance responses to NT MWs.

Stagg with colleagues exposed tissue cultures of transformed and normal rat glial cells to packet-modulated MWs (TDMA that conforms to the North American digital cellular telephone standard) at 836.55 MHz [84]. Results from the DNA synthesis assays differed for these two cell types. Sham-exposed and MW-exposed cultures of primary rat glial cells showed no significant differences for either log-phase or serum-starved condition. C6 glioma cells exposed to MWs at 5.9 μW/g SAR (0.9 mW/cm^2) exhibited small (20-40 %) but significant increases in 38 % of [^{3}H]-thymidine incorporation experiments.

Repacholi with co-authors chronically exposed wild-type mice and E mu-Pim1 transgenic mice, which are moderately predisposed to develop lymphoma spontaneously, to plane-wave pulse-modulated MWs at 900 MHz with a pulse repetition frequency of 217 Hz and a pulse width of 0.6 ms [85]. Incident power densities were 2.6-13 W/m^2 and SARs were 0.008-4.2 W/kg, averaging 0.13-1.4 W/kg. The lymphoma risk was found to be significantly higher in the exposed transgenic mice. No effects were seen in the wild type mice.

Markkanen with colleagues found that MWs affected the UV-induced apoptosis in *Saccharomyces cerevisiae* yeast cells KFy437 (cdc48-mutant) but did not modify apoptosis in KFy417 (wild-type) cells [67].

Czyz with colleagues exposed pluripotent embryonic stem (ES) cells of wild-type and deficient for the tumor suppressor p53 to pulse modulated GSM MWs at 1.71 GHz [86]. Two dominant GSM modulation schemes (GSM-217 and GSM-Talk), which generate temporal changes between GSM-Basic (active during talking phases) and GSM-DTX (discontinuous transmission, which is active during listening phases thus simulating a typical conversation), were applied to the cells at and below the ICNIRP safety standards. GSM-217 MWs induced a significant upregulation of mRNA levels of the heat shock protein, hsp70 of p53-deficient ES cells differentiating in vitro, paralleled by a low and transient increase of c-jun, c-myc, and p21 levels in p53-deficient, but not in wild-type cells. Theses data substantiated the notion that the genetic background determines cellular responses to GSM MWs.

XII. Gender-related and Individual Differences

There are studies indicating that MWs may exert a gender-related influence on brain activity [87, 88]. Papageorgiou with co-authors investigated the gender-related influence of MWs, similar to that emitted by GSM900 mobile phones, on brain activity [87]. Baseline electroencephalographic (EEG) energy of males was greater than that of females, while exposure to MWs decreased EEG energy of males and increased that of females. Memory performance was invariant to MW exposure and gender influences. Smythe and Costall reported the effects of mobile phone exposure on short- and long-term memory in male and female subjects [88]. The results showed that males exposed to an active phone made fewer spatial errors than those exposed to an active phone condition, while females were largely unaffected. These results further indicated that mobile phone exposure has functional consequences for human subjects, and these effects appear to be sex-dependent.

We analyzed effects of GSM MWs on chromatin conformation in human lymphocytes from peripheral blood [35]. The MW effects varied between individuals. 30-min exposure to MWs at 900 and 905 MHz resulted in statistically significant condensation of chromatin in lymphocytes from one out three tested donors. This condensation was similar to effects of heat shock within the temperature window of 40-44^{0}C. Stronger effects of MWs were found following 1-h exposure. In replicated experiments, cells from 4 out 5 donors responded to 905 MHz. Statistically significant response to 915 MHz was observed in cells from one out five donors. Dependent on donor, condensation, 3 donors, or decondensation, 1 donor, of chromatin was found in response to 1-h exposure. The effects of MWs correlated statistically significantly with the effects of heat shock and the initial state of chromatin before exposure.

Significant individual variations in effects of GSM and UMTS MWs on chromatin conformation and 53BP1/γ-H2AX DNA repair foci in human lymphocytes were observed in further studies [33, 34, 42]. Despite some trends to different response between lymphocytes from hypersensitive to EMF subjects and matched healthy controls [34], these differences were not statistically significant between groups [33, 34, 42]. Significant variations in response of cells were observed in both hypersensitive and control groups of subjects. These studies provided unequivocal evidence that GSM and UMTS MWs induce adverse effects in lymphocytes from hypersensitive subjects. One cannot exclude that compensatory reactions are less efficient in the hypersensitive providing stronger connection of reactions to NT MWs at the cellular level with symptoms of hypersensitivity.

Zotti-Martelli with colleagues exposed peripheral blood lymphocytes from nine different healthy donors for 60, 120 and 180 min to CW MWs with a frequency of 1800 MHz and PDs of 5, 10, and 20 mW/cm^2 and analyzed DNA damage using micronucleus (MN) assay [89]. Both spontaneous and induced MN frequencies varied in a highly significant way among donors, and a statistically significant increase of MN, although rather low, was observed dependent on exposure time and PD. Authors concluded that MWs are able to induce MN in short-time exposures to medium PD fields. The data analysis highlighted a wide inter-individual variability in the response, which was replicated in further experiments.

XIII. Physiological Variables

The importance of physiological variables, which may include all conditions of cell culture growth such as aeration, the composition of the growth and exposure media has been previously reviewed [8].

In our investigations, *E. coli* cells were exposed to CP or LP MWs (100 μW/cm^2) at the resonance frequencies of 41.32

GHz and 51.76 GHz [46, 47]. Both value and direction of the MW effects strongly depended on the phase of culture growth. At logarithmic phase of growth, MWs resulted in condensation of nucleoids. In contrast, MW exposure decondensed nucleoids in cells if exposure was performed at the stationary phase of growth. It is known, that the state of nucleoid condensation depends on cell activity. In stationary cells nucleoids are more condensed compared to logarithmic cells that divide actively. We concluded that MWs are able either stimulate or inhibit activity of the cells in dependence on stage of growth, stationary or logarithmic, respectively. Higher variability in effects was observed for logarithmic phase and effects were more stable for the stationary phase that is characterized by partial synchronization of cells [46, 47]. There was no effect at all if cells were exposed at the end of the logarithmic phase where the MW effects changed their direction from inhibition to stimulation [47]. Another peculiarity was observed at the very beginning of the logarithmic stage, where the condensation of chromatin induced by MWs was very weak. The AVTD data were confirmed by the electrophoretic analysis of proteins bound to DNA [46]. The main feature of the effect in the stationary phase was a decrease in the quantity of several unidentified DNA-bound proteins with molecular weights of 61, 59, 56, 26, and 15 kDa. In contrast, the main trend was an increase in some proteins, 61, 56, 51 and 43 kDa after exposure at the logarithmic phase. The decrease or increase in the level of proteins bound to DNA correlated with the observed changes in the state of nucleoids, decondensation or condensation, respectively.

The MW effects was studied both at stationary and logarithmic phase of growth during exposure to MWs in the PD range of 10^{-18} to $3 \cdot 10^{-3}$ W/cm^2 at various cell densities [48]. Relatively weak response to MWs was observed in exponentially growing cells. Partially synchronized stationary cells were more sensitive, especially at the cell densities above 10^8 cell/ml. The data suggested that the co-operative responses of cells to MWs vary in dependence on phase of growth.

Recent data by Ushakov and colleagues indicated that the MW effects on *E. coli* cells depended on concentration of oxygen in the cell suspension during exposure [55]. This dependence might suggest that oxygen concentration should be indicated in order to improve reproducibility in replication studies.

XIV. Antioxidants and Radical Scavengers Inhibit Effects of MWs

Lai and Singh described effects of MWs on the rat brain cells as measured using a microgel electrophoresis assay [90]. These effects were significantly blocked by treatment of rats either with the spin-trap compound N-tert-butyl-α-phenylnitrone or with melatonin that is potent free radical scavenger and antioxidant [91]. These data suggested that radicals might be involved in the effects of MWs. Other groups confirmed this suggestion in further studies.

Oktem with colleagues exposed rats to MWs from GSM900 mobile phone with and without melatonin treatment [92]. Malondialdehyde (MDA), an index of lipid peroxidation, and urine N-acetyl-beta-d-glucosaminidase (NAG), a marker of renal tubular damage, were used as markers of oxidative stress-induced renal impairment. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate the changes of antioxidant status. In the MW-exposed group, while tissue MDA and urine NAG levels increased, SOD, CAT, and GSH-Px activities were reduced. Melatonin treatment inhibited these effects. The authors concluded that melatonin might exhibit a protective effect on mobile phone-induced renal impairment in rats.

Ozguner with colleagues exposed Wistar-Albino rats to MWs from GSM900 mobile phone with and without melatonin and analyzed histopathologic changes in skin [93]. MW induced increase in thickness of stratum corneum, atrophy of epidermis, papillamatosis, basal cell proliferation, granular cell layer (hypergranulosis) in epidermis and capillary proliferation. Impairment in collagen tissue distribution and separation of collagen bundles in dermis were all observed in exposed animals as compared to the control group. Most of these changes, except hypergranulosis, were prevented with melatonin treatment. The authors concluded that exposure to GSM900 MWs emitted by mobile phones caused mild skin changes and melatonin treatment could reduce these changes.

Ayata et al. analyzed the effects of 900 MHz MWs with and without melatonin on fibrosis, lipid peroxidation, and anti-oxidant enzymes in rat skin [94]. The levels of MDA and hydroxypyroline and the activities of SOD, GSH-Px, and CAT were. MDA and hydroxyproline levels and activities of CAT and GSH-Px were increased significantly in the exposed group without melatonin and decreased significantly in the exposed group with melatonin. SOD activity was decreased significantly in the exposed group and this decrease was not prevented by the melatonin treatment. The authors assumed that the rats irradiated with MWs suffer from increased fibrosis and lipid peroxidation and that melatonin can reduce the fibrosis and lipid peroxidation caused by MWs.

Ilhan with co-authors investigated oxidative damage in brain tissue of rats exposed to GSM900 MWs with and without pretreatment with Ginkgo biloba (Gb) [95]. MWs induced oxidative damage measured as: (i) increase in MDA and nitric oxide (NO) levels in brain tissue, (ii) decrease in brain SOD and GSH-Px activities and (iii) increase in brain xanthine oxidase and adenosine deaminase activities. These MW effects were prevented by the Gb treatment. Furthermore, Gb prevented the MW-induced cellular injury in brain tissue revealed histopathologically. Authors concluded that reactive oxygen species may play a role in adverse effects of GSM900 MWs and Gb prevents the MW-induced oxidative stress by affecting antioxidant enzymes activity in brain tissue.

XV. Summary of Experimental Studies

Numerous experimental data have provided strong evidence for NT MW effects and have also indicated several regularities in these effects: dependence of frequency within

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specific frequency windows of "resonance-type"; dependence on modulation and polarization; dependence on intensity within specific intensity windows including super-low PDs comparable with intensities from base stations/masts; narrowing of the frequency windows with decrease in intensity; high sensitivity of the NT MW effects to the duration of exposure; dependence on cell density that suggests cell-to-cell interaction during response to NT MWs; dependence on physiological conditions during exposure and a potential of radical scavengers/antioxidants to minimize the MW effects; genomic differences can influence response to NT MWs; there are not yet confirmed observations that oxygen concentration, SMF and EMF stray field during exposure may be of importance for the effects of NT MWs.

XVI. Replication Studies

Obviously, not taking into account the dependences the NT MW effects on a number of physical parameters and biological variables may result in misleading conclusions regarding the reproducibility of the NT MW effects. Especially important might be the observations that NT MWs could inhibit or stimulate the same functions dependent on conditions of exposure [2]. Under different conditions of exposure, MWs either increased or decreased the growth rate of yeast cells [8], the radiation-induced damages in mice [96], the respiratory burst in neutrophils of mice [41], the condensation of nucleoids in *E coli* cells [46, 47] and human lymphocytes [35]. Potentially bi-directional effects of MWs should be taken into account in replication studies.

Despite of considerable body of studies with NT MWs in biology, only a few studies were performed to replicate the original data on the NT MW effects. It should be noted, that these "replications" are usually not comparable with the original studies because of either missing description of important parameters of exposure or significant differences in these parameters between original study and replication.

One well-known attempt to replicate the results of Gründler was the study by Gos and co-authors [97]. No MW effects were observed in this study. However, the deviations from the Gründler's protocol might be a simple reason for poor reproducibility. For example, synchronized cells were used in studies of Gründler. Contrary to the Gründler's original protocol, Gos used exponentially growing cells. If the MW effects in yeast cells are dependent on stage of growth, cell density and intercellular interactions as it has been described for *E. coli* cells [30, 37, 46, 47], no response should be expected in the logarithmic phase of growth. Gos and colleagues used *S. cerevisiae* strain with the auxotrophy mutations for leucine and uracil. Gründler used the wild type strain. It might suggest another cause for the deviations between the data of Gründler and Gos. Despite orientation of SMF in respect to electric and magnetic components of MWs was the same, the values of SMF were different. The stray ELF field was 120 nT in the study by Gos, that is higher than usually observed background fields, < 50 nT. The spectral characteristics of the background fields, which were described only in the study by Gos, might be also different. In addition, the conditions of cell cultivation might vary between studies; for example, the data on oxygen concentration in media used in both studies is not available.

Amount of already known physical and biological variables that are important for reproducibility of the NT MW effects seem to be far beyond the limits of usually controlled parameters in biological experiments. The knowledge of some of these variables is based on consistent findings following from experimental studies of different research groups. Further evaluation of variables that are important for the NT MW effects would benefit from the developing of the physical and molecular biological models for the MW effects.

Most reviews of the experimental studies do not include analysis of various biological variables and physical parameters when comparing the data on NT MW effects from different studies. As result, misleading conclusion is often made that MWs at NT levels produce no "reproducible" effects. Bearing in mind the importance of several critical physical and biological variables for reproducibility of the MW effects and based on the available replication studies, we would suggest the next analogy in response to the claims that there are no reproducible NT MW effects. These claims would be similar to a situation if one would use a TV-set with a wrong broadcasting system, for example PAL/SECAM in U.S. or NTSC in Europe, and based on seeing nothing would conclude that there is no stable TV broadcasting in U.S./Europe.

XVII. Possible Mechanisms

The fundamental question is how MWs at so low intensities affect living systems? Most probably, the physical mechanisms of the NT MW effects must be based on quantum-mechanical approach and physics of non-equilibrium and nonlinear systems [40, 73, 98-100].

Analyzing theoretically our experimental data on the MW effects at super-low intensities we concluded that these effects should be considered using quantum-mechanical approach [47]. Reanalysis of our data by Binhi resulted to the same conclusion [73]. This is in line with the fundamental quantum-mechanical mechanism that has been suggested by Fröhlich [40]. Our data indicated also that chromosomal DNA is a target for interaction with MWs [36, 54, 58].

The length of genomic DNA is much longer than the dimension of surrounding compartment. For example, there is about 1.8 m of DNA in a human genome that is compacted in interaction with other compounds such as proteins, RNA and ions to fit into a nucleus with a characteristic diameter of 5-10 mμ. Importantly, concentration of DNA in the nuclei is higher than in crystallization solutions for DNA, 50-100 mM versus 10-30 mM DNA, respectively. Whether DNA is organized in nuclei as a liquid crystal remains to be investigated. However, it is clear that DNA in a living cell cannot be considered as an aqueous solution of DNA molecules in a thermodynamic equilibrium.

The quantum-mechanical physical model for primary interaction of MWs with DNA has been proposed [101]. We hypothesized that genomic DNA contain two different codes [78]. The first one is well-known genetic triplet code for coding the genes. The second one is a "physical code" that

determine the spectrum of natural oscillations in chromosomal DNA including electromagnetic, mechanical and acoustic oscillations, which are hypothetically responsible for regulation of gene expression at different stages of ontogenesis and for genomic rearrangements in evolution [78]. The physical model describing these coupled oscillations in chromosomal DNA has been proposed [58]. This model helps to resolve so-called C-paradox that addresses the issue of a genome size, so-called C-value. Only few percent of DNA encodes genes in almost all eukaryotic genomes. The same amount of DNA is involved in regulation of gene expression by known biochemical mechanisms. The function of the rest of DNA, which does not depend on complexity of eukaryotic species and is represented by noncoding repetitive DNA sequences, is not understood in molecular biology providing a basement for hypotheses such as "junk DNA". The function of this major part of genomic DNA became clear given that the whole genomic DNA is responsible for the creation of the natural spectrum of oscillations that is hypothetically a main characteristic of each biological species [78].

XVIII. Were the Real Signals used in Mobile Communication Tested for Adverse Effects?

Based on available experimental data, it is believed that both beneficial and adverse health effects can be induced by NT MWs dependent on conditions of exposure [2-5, 7, 11, 14-16]. In contrast to thermal effects of MWs that can be described solely by SAR/PD, several other parameters are important for the NT MW effects.

Multiple sources of mobile communication result in chronic exposure of significant part of general population to MWs at the non-thermal levels. Therefore, the ICNIRP safety standards, which are based on thermal effects in acute exposures cannot protect from the chronic exposures to NT MW from mobile communication [13].

Most of the real signals that are in use in mobile communication have not been tested so far. Very little research has been done with real signals and for durations and intermittences of exposure that are relevant to chronic exposures from mobile communication. In some studies, so-called "mobile communication-like" signals were investigated that in fact were different from the real exposures in such important aspects as intensity, carrier frequency, modulation, polarization, duration and intermittence. How relevant such studies to evaluation of adverse health effects from MWs of mobile communication is not known. For example, GSM users are exposed to MWs at different carrier frequencies during their talks. There are 124 different channels/frequencies, which are used in Europe for GSM900. They differ by 0.2 MHz in the frequency range from 890 MHz to 915 MHz. Mobile phone users are supplied by various frequencies from base stations depending on number of connected users. The base station can change the frequency during the same talk. GSM uses GMSK modulation (Gaussian Minimum Shift Keying). Contrary to GSM phones, UMTS mobile phones of the 3rd generation (3G) use essentially QPSK (Quadrature Phase Shift Keying) modulation and irradiate wide-band signals with the bandwidth of 5 MHz. UMTS MWs may hypothetically result in a higher biological effect because of eventual "effective" frequency windows within the bands.

We tested some of the real signals from GSM900 and UMTS mobile phones. Frequency-dependent effects of GSM MWs on the DNA repair 53BP1/γ-H2AX foci and chromatin conformation in human lymphocytes were observed in replicated studies [33, 34, 42]. UMTS MWs induced significant adverse effects in human lymphocytes stronger or the same as effects of heat shock at 41-43^{o}C and GSM MWs at the carrier frequency of 915 MHz [42]. The results obtained were in line with our hypothesis that UMTS MWs may affect cells more efficiently than GSM MWs because of the nature of signal.

XIX. Urgent Needs and Further Perspectives

At present, new situation arose when significant part of general population is exposed chronically (much longer than previously investigated durations of exposures) to NT MWs from different types of mobile communication including GSM and UMTS/3G phones and base stations, WLAN (Wireless Local Area Networks), WPAN (Wireless Personal Area Networks such as Bluetooth), DECT (Digital Enhanced (former European) Cordless Telecommunications) wireless phones. It should be anticipated that some part of population, such as children, pregnant women and groups of hypersensitive persons could be especially sensitive to the NT MW exposures. It is becoming more and more clear that the SAR concept that has been widely adopted for safety standards may not be useful alone for the evaluation of health risks from MWs of mobile communication. How the role of other exposure parameters such as frequency, modulation, polarization, duration, and intermittence of exposure should be taken into account is an urgent question to solve. Solving this question would greatly benefit from the knowledge of the physical mechanisms of the NT MW effects. The understanding of mechanisms for the NT MW effects is far away from comprehensive. Many questions remain to be addressed such as whether resonance effects of MWs depend on electromagnetic noise and SMF during exposure.

Besides fundamental importance, the development of comprehensive mechanisms is socially important for two main reasons. The first one is development of new medical treatment modalities using MWs. The second reason is accumulating evidence for adverse health effects of the NT MWs [3, 11]. So far, most laboratory and epidemiological studies did not control important features of the NT MW effects as described above and therefore, only limited conclusion regarding health effects of MWs from mobile communication can be drawn from these studies.

It should be noted that one group of epidemiologists with a long-lasting experience in studying relationship between mobile phone usage and cancer risk have consistently been concerned regarding importance of various MW signals and exposure durations [18, 102-104]. The group of Hardell was the first epidemiologic group in attempting to study separately the MW signals from cordless phones, analogue phones and

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digital phones. As a rule, analogue phones had the highest association with the cancer risk. Cordless phones were associated with the risk for brain tumors, acoustic neuroma, and T-cell lymphoma stronger or in the same degree as digital and analogue phones despite significantly lower SAR values were produced by cordless phones [16, 18, 103, 104]. This important result can be considered as an independent conformation, at the epidemiological level, of the observations from specially designed *in vitro* and *in vivo* studies that the NT MW effects depend not solely on SAR/PD but also on other parameters. It should be also noted that epidemiological data are controversial and methodological differences are a subject of debates between various research groups [16, 105]. However, the approach of the Hardell's group is more valid from the mechanistic point of view and this should be taken into account when comparing with results with other groups that ignore or minimize the complex dependencies of the NT MW effects on several parameters/variables [105].

The data about the effects of MWs at super low intensities and significant role of duration of exposure in these effects along with the data showing that adverse effects of NT MWs from GSM/UMTS mobile phones depend on carrier frequency and type of the MW signal suggest that MWs from base-stations/masts can also produce adverse effects at prolonged durations of exposure and encourage the mechanistic *in vitro* studies using real signals from base stations/masts. Further investigations with human primary cells under well controlled conditions of exposure, including all important parameters as described above, are urgently needed to elucidate possible adverse effects of MW signals that are currently used in wireless communication, especially in new technologies such as UMTS mobile telephony.

The dependence of adverse effects of NT MWs from GSM/UMTS mobile phones on carrier frequency and type of signal should be taken into account in settings of safety standards and in planning of *in vivo* and epidemiological studies. One important conclusion stemming from the available *in vitro* and *in vivo* studies is that epidemiological studies should not be given priority before proper design of these studies will be available as based on mechanistic understanding of the NT MW effects. This conclusion is based on two principle arguments. First, it is almost impossible to select control unexposed groups because whole population in many countries is exposed to wide range of MW signals from various sources such as mobile phones and base stations/masts of various kinds, WLAN, WPAN, DECT wireless phones and given that duration of exposure (must be at least 10 years for cancer latency period) may be more important for the adverse health effects of NT MWs than PD/SAR. Second, the adverse effects of "detrimental" signals are masked because people are exposed to various signals/frequencies including non-effective or even hypothetically beneficial. From this point of view, current epidemiological studies are either inconclusive, if results are negative, or underestimate significantly the hazard of using specific signals, if results are positive.

The joining of efforts of scientific groups within national or international programs is needed for mechanistic studies of the NT MW effects. To be based on the available science regarding biological action of NT MWs, this joining should involve scientists having long-lasting experience in studying the NT MW effects. Otherwise, misleading conclusions or inconclusive results may be expected.

RNCNIRP proposed that guidelines for NT MWs should be further developed by studies based on the next priorities [12]: (1) Acute and chronic bioeffects of real MW signals as currently in use (GSM, UMTS/3G phones and base stations…) should be tested in experiments with primary human cells and animals; (2) Studies with volunteers under controlled conditions of chronic exposures. Complains by phone users cannot be used for objective evaluation of health effects from mobile phones. There is a need for correlation of these complains with the data obtained in studies using the objective criteria. The data from the acute exposures of volunteers have very limited value because possible accumulation of effects during real chronic exposures is not evaluated. (3) Development of reliable and relevant methods to control personal exposures. (4) Epidemiological investigations of the postponed adverse health effects on various functions of organism and diseases including neurodegenerative diseases and cancer.

Because NT MWs affect not only brain cells, but also blood cells [33-35, 64], skin and fibroblasts [52, 53, 93, 106], stem cells [86, 107], reproductive organs and sperm quality [108-110] the using of hands-free cannot minimize all adverse health effects. Possibilities to minimize the adverse effects of NT MWs using various biophysical and biochemical approaches should be studied.

Identification of those signals and frequency channels/bands for mobile communication, which do not affect human cells, is needed as a high priority task for the development of safe mobile communication.

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TABLE1

EXAMPLES OF DIVERSE BIOLOGICAL EFFECTS OF NT MWS IN THE FREQUENCY RANGE AS USED IN MOBILE COMMUNICATION

Objects	Effects	Reference
Preloaded synaptosomes	Changes in calcium efflux	[28]
Reuber H35 hepatoma cells	Ornithine decarboxylase (ODC)	[63]
Rat brain cells	DNA breaks as measured with comet assay	[91]
AMA human epithelial cells	Cell proliferation	[111]
Human lymphocytes	53BP1/γ-H2AX DNA repair foci	[33]
Human lymphocytes	Changes in chromatin conformation similar to stress	[35]
Fisher rats	Nerve cell damage	[112]
Healthy young men	Regional cerebral blood flow	[65]
Soil nematode Caenorhabditis elegans	Stress response	[113]
Human peripheral blood cultures	Micronucleus frequency	[64]
Embryonic stem (ES) cells	Gene expression	[86]
Human diploid fibroblasts	DNA single- and double-strand breaks	[52]
Peritoneal neutrophils of mice	Respiratory burst induced by calcium ionophore A23187 and phorbol ester 12-myristate 13-acetate (PMA)	[41]
L929 fibroblasts	Ornithine decarboxylase (ODC)	[61]
Fisher rats	Blood-brain barrier permeability	[68]
Human epithelial amnion cells	Heat shock proteins	[114]
Chick forebrain tissue	Efflux of calcium ions	[115]
Mouse embryonic stem cells	Transient increase of DNA double-strand breaks	[107]
Saccharomyces cerevisiae yeast cells KFy437	Enhanced UV induced apoptosis	[67]

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TABLE 2

SUMMARY OF THE POLARIZATION STUDIES. NT MWS AFFECTED NUCLEOIDS IN *E. COLI* CELLS AND WISTAR RAT THYMOCYTES WITHIN SPECIFIC FREQUENCY WINDOWS (RESONANCES). EACH RESONANCE WAS CHARACTERIZED BY A SPECIFIC CP (RIGHT- OR LEFT-HANDED) THAT WAS EFFECTIVE, WHILE ANOTHER CP WAS NOT.

Cells	Resonance frequency, GHz	Effective circular polarization
E. coli K12 N99(λ,λ*imm*^{434}*bio*^{10})	41.277±0.002	Right-handed
Wistar rat thymocytes	41.303±0.001	Right-handed
E. coli K12 N99(λ)	41.305±0.001	Right-handed
E. coli K12 AB1157	41.32±0.01	Right-handed
E. coli K12 N99	41.324±0.001	Right-handed
Wistar rat thymocytes	41.61±0.01	Left-handed
E. coli K12 AB1157	51.425±0.001	Left-handed
E. coli K12 AB1157	51.575±0.001	Right-handed
E. coli K12 AB1157	51.675±0.001	Left-handed
E. coli K12 N99(λ,λ*imm*^{434}*bio*^{10})	51.723±0.001	Left-handed
E. coli K12 N99(λ)	51.740±0.001	Left-handed
E. coli K12 AB1157	51.755±0.001	Left-handed
E. coli K12 N99	51.765±0.002	Left-handed
E. coli K12 AB1157	51.805±0.002	Right-handed
E. coli K12 AB1157	51.835±0.005	Left-handed
E. coli K12 AB1157	51.857±0.001	Left-handed
E. coli K12 AB1157	51.955±0.001	Right-handed

TABLE 3

GENOMIC DIFFERENCES INFLUENCED RESPONSE OF CELLS TO MWS. EXPERIMENTALLY DETERMINED RESONANCE FREQUENCIES, EFFECTIVE CP, AND SHIFTS BETWEEN RESONANCES FOR THREE *E. COLI* STRAINS, N99, N99(λ), AND N99(λ,λ*i*P^{434}P*BIO10*), WHICH WERE ISOGENIC BUT DIFFERENT IN THE LENGTH OF GENOME.

Frequency band	*E. coli* strain and genome length, Mb:	N99 4.20	N99(λ) 4.249	N99(λ,λ*i*^{434}*bio10*) 4.286
41.240-41.370 GHz	Resonance frequency, GHz:	41.324±0.001	41.305±0.001	41.277±0.002
	Effective circular polarization:	Right-handed	Right-handed	Right-handed
	Shift in respect to N99, MHz:	0	19±2	47±4
51.690-51.795 GHz	Resonance frequency, GHz:	51.765±0.002	51.740±0.001	51.723±0.001 GHz
	Effective circular polarization:	Left-handed	Left-handed	Left-handed
	Shift in respect to N99, MHz:	0	25±3	42±3

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INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY

ENVIRONMENTAL HEALTH CRITERIA 16

RADIOFREQUENCY AND MICROWAVES

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While every effort has been made to present information in the criteria documents as accurately as possible without unduly delaying their publication, mistakes might have occurred and are likely to occur in the future. In the interest of all users of the environmental health criteria documents, readers are kindly requested to communicate any errors found to the Division of Environmental Health, World Health Organization, Geneva, Switzerland, in order that they may be included in corrigenda which will appear in subsequent volumes.

In addition, experts in any particular field dealt with in the criteria documents are kindly requested to make available to the WHO Secretariat any important published information that may have inadvertently been omitted and which may change the evaluation of health risks from exposure to the environmental agent under examination, so that the information may be considered in the event of updating and re-evaluation of the conclusions contained in the criteria documents.

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THE INTERNATIONAL SYSTEM OF UNITS (SI) COMMONLY USED IN ELECTROMAGNETICS

Name of Dimension of Quantity	Symbol for quantity	SI unit and symbol
Admittance	Y	siemens (S)
Area. surface	S	square metre (m^2)
Attenuation	A	1 (Non-SI unit is the dB)
Attenuation coefficient	alpha	reciprocal metre (1/m)
Capacitance	C	farad (F)
Charge	Q	coulomb (C)
Charge, volume density of	q	coulomb per cubic metre (C/m^3)
Conductance, electric	G	siemens (S)
Conductivity	Â	siemens per metre (S/m)

Current	I	ampere (A)
Current density	J	ampere per square metre (A/m^2)
Dielectric polarization	P ($P = D - epsilon_o E$)	coulomb per square metre (C/m^2)
Dipole moment (electric)	p	coulomb œ metre (C œ m)
Dipole moment (magnetic)	j	weber metre (Wb œ m)
Electric field strength	K	volt per metre (V/m)
Electric flux	phi	coulomb (C)
Electric flux density	D	coulomb per square metre (C/m^3)
Electric polarization	D_1	coulomb per square metre (C/m^2)
Electric potential	V	volt (V)
Electric susceptibility	chie ($chie = epsilon_r - 1$)	(see glossary)
Energy or work	E	joule (J)
Energy density	w	joule per cubic metre (J/m^3)
Frequency	f	hertz (Hz)
Impedance	Z	ohm (OMEGA)
Impedance, characteristic	Z_o	ohm (OMEGA)
Inductance, mutual	M	henry (H)

(Cont'd)

Name of Dimension of Quantity	Symbol for quantity	SI unit and symbol
Length	I	metre (m)
Magnetic field strength	H	ampere per metre (A/m)
Magnetic flux	PHI	weber (Wb)
Magnetic flux density	B	tesla (T)
Magnetic polarization	B_1	tesla (T)
Permeability	μ	henry per metre (H/m)
Relative permeability	$μ_r$ ($μr = μ/μ_o$)	(see glossary)
Permittivity	epsilon	farad per metre (F/m)
Phase coefficient	ß	radian per metre (rad/m)
Power	P	watt (w)
Power gain	G ($G = 10 \log (P_2/P_1)$)	1 (Non-SI unit is the dB)
Poynting vector	S	watt per square metre (W/m^2)
Propagation coefficient	gamma (gamma = alpha + jß) where alpha = attenuation coefficient and ß = phase coefficient	Units for alpha and ß given separately
Radiant intensity	I	watt per steradian (W/sr)
Reactance	X	ohm (OMEGA)
Wavelength	lambda	metre (m)

[a] The SI units for non-ionizing radiation have not been completely developed. Terms used in the text but not defined in this table can be found in the glossary at the end of the document.

ENVIRONMENTAL HEALTH CRITERIA FOR RADIOFREQUENCY AND MICROWAVES

A Joint WHO/IRPA Task Group on Environmental Health Criteria for Radiofrequency and Microwaves met in Geneva from 18-22 December 1978. Dr B. H. Dieterich, Director, Division of Environmental Health, opened the meeting on behalf of the Director-General. The Task Group reviewed and revised the draft criteria document, made an evaluation of the health risks of exposure to radiofrequency and microwaves, and considered rationales for the development of exposure limits.

In November 1971, the WHO Regional Office for Europe convened a Working Group meeting in The Hague which recommended, *inter alia,* that the protection of man from microwave radiation hazards should be considered a priority activity in the field of non-ionizing radiation protection. To implement these recommendations, the Regional Office decided to prepare the manual on "Non-Ionizing Radiation Protection", which will include a chapter on microwave radiation (WHO, 1981).

In 1973, a symposium, sponsored by WHO and the Governments of Poland and the USA, was held in Warsaw, on the biological effects and health hazards of microwave radiation. This symposium provided one of the first opportunities for an international exchange of quite diverse opinions on the effects of microwaves. Recommendations adopted by the symposium included the promotion and coordination, at an international level, of research on the biological effects of microwaves, and the development of a non-ionizing programme by an international agency (Czerski et al., 1974a).

The International Radiation Protection Association (IRPA) became responsible for these activities by forming a Working Group on Non-Ionizing Radiation at its meeting in Washington, DC, in 1974. This Working Group later became the International Non-Ionizing Radiation

Committee (IRPA/INIRC) at the IRPA meeting in Paris in 1977 (IRPA, 1977).

Two WHO Collaborating Centres, the National Research Institute of Mother and Child, Warsaw (for Biological Effects of Non-Ionizing Radiation) and the Bureau of Radiological Health, Rockville (for the Standardization of Non-Ionizing Radiation) cooperated with the IRPA/INIRC in initiating the preparation of the criteria document. The final draft was prepared as a result of several working group meetings, taking into account comments received from the national focal points for the WHO Environmental Health Criteria Programme in Australia, Canada, Japan, Netherlands, New Zealand, Poland, Sweden, the United Kingdom, and the USA as well as from the United Nations Environment Programme, the United Nations Industrial Development Organization, the International Labour Organisation, the Food and Agriculture Organization of the United Nations, the United Nations Educational, Scientific and Cultural Organization, and the International Atomic Energy Agency. The collaboration of these

national institutions and international organizations is gratefully acknowledged. Without their assistance this document could not have been completed. In particular, the Secretariat wishes to thank Professor P. Czerski, Mrs A. Duchêne, Mr F. Harlen, Dr M. Repacholi, and Dr M. Shore for their help in the final scientific editing of the document.

The document is based primarily on original publications listed in the reference section. Additional information was obtained from a number of general reviews, monographs and proceedings of symposia including: Gordon, 1966; Presman, 1968; Petrov, ed., 1970; Silverman et al., ed., 1970; Marha et al., 1971; Michaelson, 1977; Minin, 1974; Dumanski et al., 1975; Tyler, ed., 1975; Baranski & Czerski, 1976; Glaser & Brown, 1976; Glaser et al., 1976, 1977; IVA Committee, 1976; Johnson et al., 1976; Johnson & Shore, ed., 1977; Justesen & Guy, 1977; Hazzard, ed., 1977; Serdjuk, 1977; Taylor & Cheung, ed., 1977; National Health and Welfare, Canada, 1977, 1978; Durney et al., 1978.

Modern advances in science and technology change man's environment, introducing new factors which besides their intended beneficial uses may also have untoward side effects. Both the general public and health authorities are aware of the dangers of pollution by chemicals, ionizing radiation, and noise, and of the need to take appropriate steps for effective control. The increasing use of electrical and electronic devices, including the rapid growth of telecommunication systems (e.g., satellite systems), radiobroadcasting, television transmitters, and radar installations has increased the possibility of human exposure to electromagnetic energy and, at the same time, concern about possible health effects.

This document provides information on the physical aspects of electromagnetic fields and radiowaves in the frequency range of 100 kHz-300 GHz, which has been arbitrarily subdivided according to the traditional approach into microwaves (300 MHz to 300 GHz) and radiofrequencies (100 kHz to 300 MHz). A brief survey of man-made sources is presented. It is known that electromagnetic energy in this frequency range interacts with biological systems and a summary of knowledge on biological effects and health aspects has been included in the document. In a few countries, concern about occupational and public health aspects has led to the development of radiation protection guides and the establishment of exposure limits. Several countries are considering the introduction of recommendations or legislation concerned with protection against the untoward effects of non-ionizing energy in this frequency range. In others, the tendency is to revise existing standards and to adopt less divergent exposure limits. It is hoped that this criteria document may provide useful information for the development of national protection measures against non-ionizing radiation.

Details of the WHO Environmental Health Criteria Programme, including some of the terms frequently used in the documents, can be found in the introduction to the environmental health criteria document on mercury (Environmental Health Criteria 1 - Mercury, World Health Organization, Geneva, 1976), now available as a reprint.

1. SUMMARY AND RECOMMENDATIONS FOR FURTHER STUDIES

1.1 Summary

1.1.1 Physical characteristics in relation to biological effects

Microwave and radiofrequency (RF) radiation constitute part of the whole electromagnetic spectrum. This document is concerned with frequencies lying between 10^5 and 3×10^{11} Hz (100 kHz and 300 GHz). The term radiofrequency refers to the range 100 kHz-300 MHz (3 km to 1 m wavelength in air) and microwaves to the frequency range of 300 MHz-300 GHz (1 m to 1 mm wavelength in air).

Exposure conditions in the microwave range are usually described in terms of "power density" and are reported in most studies in watts per square metre, or milliwatts or microwatts per square centimetre (W/m^2, mW/cm^2, $\mu W/cm^2$). However, close to microwave and RF

sources with longer wavelengths, the values of both the electric (V/m) and magnetic (A/m) field strengths provide a more appropriate description of the radiation. Exposure conditions can be altered considerably by the presence of objects, the degree of perturbation depending on their size, shape, orientation in the field, and electrical properties. Very complex field distributions can occur, both inside and outside biological systems exposed to microwaves and RF. Refraction of the radiation within these systems can focus the transmitted radiation resulting in markedly nonuniform fields and energy deposition. Different energy absorption rates may result in thermal gradients causing biological effects that may be generated locally, difficult to predict, and perhaps unique.

When electromagnetic radiation passes from one medium to another, it can be reflected, refracted, transmitted, or absorbed, depending on the biological system and the frequency of the radiation. Absorbed microwave and RF energy can be converted to other forms of energy and cause interference with the functioning of the living system. Most of this energy is converted into heat. However, not all microwave and RF radiation effects can be explained in terms of the biophysical mechanisms of energy absorption and conversion to heat. It has been demonstrated both theoretically and experimentally that other types of energy conversion are possible. Interactions at the microscopic level leading to perturbations in complex macromolecular biological systems (cell membranes, subcellular structures) have been postulated. Biological phenomena caused by such perturbations are expected to show a resonant frequency dependence.

1.1.2 Sources and control of exposure

General population exposure from man-made sources of microwave and RF radiation now exceeds that from natural sources by many orders of magnitude. The rapid proliferation of such sources and the substantial increase in radiation levels is likely to produce "electromagnetic pollution". Major man-made sources include: radar installations, broadcasting and television networks, and telecommunication equipment. In industrial, commercial, and home equipment, notably those where energy is applied for heating purposes such as plastic sealing, welding, drying, cooking, and defrosting, there may be extraneous emission (leakage) of microwave or RF radiation.

The problem of this extraneous radiation or pollution from sources of 100 kHz-300 GHz electromagnetic waves varies from country to country, depending on the degree of industrialization. Radiation emitted from high power sources such as broadcasting and telecommunication networks propagates over large distances and may even cover the whole circumference of the globe. With the increasing use of transmitter/receivers by sea and air traffic, and the necessity for ground-based radar control, increased levels of environmental electromagnetic radiation may constitute a problem in many countries.

Problems of pollution range from electromagnetic interference, particularly in relation to the operation of health services, to direct risks to the health of individuals.

1.1.3 Biological effects in experimental animals

When sufficient microwave and RF radiation is absorbed and converted into heat there is a consequent rise in temperature in the organism. Injuries that have been studied in animals have resulted from exposure to high levels of radiation and have varied from local lesions and necrosis to gross thermal stress from hyperthermia. Death from hyperthermia was found to occur following exposure to power densities of a few tens of mW/cm^2 to several hundreds of mW/cm^2, depending mainly on the size of the animal and the radiation frequency. Recently, there has been a much wider appreciation of the consequences of nonuniform energy deposition (as described in sections 6:3 and 7.1). Lesions have been found in the internal organs of animals exposed for prolonged periods during which there was no significant rise in rectal temperature. Furthermore, such animals did not show any overt signs of distress.

Acute exposures may cause injury to the eye. The cornea and crystalline lens are particularly susceptible to injury within the frequency range of 1-300 GHz. The cornea is at greatest risk between 10 and 300 GHz and the crystalline lens from 1 to 10 GHz. For short-term[a] exposures, the cataractogenic incident power density levels lie within the range of 150-200 mW/cm^2. Cataract formation induced by a 1-h exposure can take as long as 10-14 days to develop. The formation of retinal lesions is also possible.

It has been demonstrated that low-level,[b] long-term[a] exposure may induce effects in the nervous, haematopoietic, and immunocompetent cell systems of animals. Such effects have been reported in small animals (rodents) exposed to incident power density levels as low as 0.1-1.0 mW/cm^2. The reported effects on the nervous system include behavioural, bioelectrical, metabolic, and structural (at the cellular and subcellular levels) changes. Erythrocyte production and haemaglobin synthesis may be impaired and immunological reactivity changed. All these effects may influence the susceptibility of animals

to other environmental factors. For example medium level, long-term exposure increases the sensitivity of animals to neurotropic drugs, particularly those inducing convulsions. Thermal mechanisms seem wholly inadequate to account for the results of studies indicating that cerebral tissue, exposed to weak electromagnetic fields, responds only over a limited range of intensities and modulation frequencies of the RF carrier field. There appears to be evidence for both amplitude and modulation frequency windows, outside which effects are not observed.

Genetic effects, effects on development, and teratogenic effects have been observed in animals and plants. Numerous reports have indicated that at sufficiently high intensities, microwave and RF exposure may induce chromosomal aberrations, and also disturbances in somatic cell division (mitosis), germ cell maturation (meiosis), and spermatogenesis (section 7.7). The intensity levels required to produce these effects seem to indicate that a thermal mechanism may be responsible. Existing information on the influence of microwave and RF exposure on the transmission and expression of hereditary traits is, however, insufficient. No threshold levels or dose-effect relationships can be established at present.

1.1.4 Power density ranges in relation to health effects

During the 1973 Warsaw International Symposium on biological effects and health hazards of microwave radiation, it was agreed that microwave power densities could be divided into ranges. The following is an abridged version of this agreement:

Microwave densities may be divided into the following 3 ranges:

(a) High power densities, generally greater than 10 mW/cm^2, at which distinct thermal effects (see Glossary) predominate;

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[a] See Glossary.

[b] In this document, the ranges for low, medium, and high level exposures are approximately those agreed by the Warsaw symposium (section 1.1.4).

(b) Medium power densities, between 1-10 mW/cm^2, where weak but noticeable thermal effects exist; and

(c) Low power densities, below 1 mW/cm^2, where thermal effects are improbable, or at least do not predominate.

The boundaries indicated for these ranges are arbitrary and depend on numerous factors, such as animal size, threshold of warmth sensation, frequency, and pulsing. The introduction of the intermediate range of subtle effects calls attention to the need for additional research, aimed at clarification of the underlying mechanisms.

It should be noted that the classification applied to the microwave region (300 MHz-300 GHz). A similar classification was not determined for the RF region (100 kHz-300 MHz).

1.1.5 Exposure effects in man

The meagre evidence available on exposure effects in man has been obtained from incidents of accidental acute over-exposure to microwaves and RF. Not enough attention has been given to the conduct of epidemiological investigations. In some human studies, which have been conducted on people exposed occupationally, subjective symptoms have been reported.

A considerable number of people in many countries have received microwave and RF diathermy treatment at power levels of several tens of watts for a duration of about 20 min daily over a period of some weeks.

Adverse effects have not been adequately investigated among diathermy patients. This is a group of people exposed to microwaves and RF who can be readily identified and such studies should be carried out, as they may yield considerable information concerning exposure effects in man.

1.1.6 Health risk evaluation as a basis for exposure limits

Theoretical considerations, experimental animal studies, and limited human occupational exposure data constitute the basis for the establishment of health protection standards. It should be noted that, in some countries, microwave and RF health protection standards have recently been changed and that there is a tendency to adopt less divergent exposure limits in comparison with those proposed two decades ago.

In establishing health protection standards, different approaches and philosophies have been adopted.

A highly conservative approach would be to keep exposure limits close to natural background levels. However, this is not technically feasible. A reasonable risk-benefit analysis has to be considered.

More data on the relationship between biological and health effects and the frequency and mode of generation of the radiation, particularly in complex modulations, are needed.

In the case of pulse modulation, peak power density may be a factor which should be considered in setting exposure limits. However, it is not possible to propose a limit of peak power density from the information available at present.

1.2 Recommendations for Further Studies, Exposure Limits, and Protective Measures

1.2.1 General recommendations

The basic biophysical mechanisms of interaction of microwaves and RF with living systems still need clarification and further studies.

Work on both theoretical and experimental dosimetry, the calculation and measurement of fields and of energy deposited within simulated or actual biological systems, should be continued and refined.

Results of animal studies are difficult to extrapolate to man, and these studies alone do not constitute a satisfactory basis for the establishment of health protection criteria. They should, therefore, be supplemented by appropriate epidemiological studies in man.

The existing data on power, amplitude, and frequency "windows" seem to warrant continued investigations.

The effects of chronic exposure on sensitivity to convulsant and other drugs are potentially useful and may have a direct bearing on the development of exposure standards.

Long-term, low-level exposures combined with such stresses as high ambient temperature and humidity should be investigated.

There is little published information on dose-effect relationships; reports tend to be limited to whether effects are observed at one particular level of exposure rather than over a range. More dose-related information, even covering small subject areas, would be valuable.

Investigations on the genetic effects and effects on development of microwave and RF radiation should have priority.

Attention should be given to investigating the different sensitivities to microwave/RF exposure of subgroups within the general population.

National and international agreements on exposure limits, ways and means of controlling this type of environmental pollution, and concerted efforts to implement such agreements are needed.

1.2.2 Measurement techniques

There is a continuing need for the development of microwave/RF measuring instruments that: (a) give direct readings of electric or magnetic field strength, or power density; (b) are robust; (c) are portable, light-weight, and battery-operated; and (d) are sensitive and can be used over a wide frequency range.

The problem of the design of personal dosimeters also remains to be solved.

1.2.3 Safety procedures

Computation techniques or methods that predict the distribution of fields close to deliberate high-power emitters (in the near field) are needed.

Emphasis should be placed on the development of technology to ensure containment and limitation of radiation to the deliberately exposed object, as well as the reduction of leakage emission from devices.

Personal protective devices should be used only as a last resort.

Adequate medical surveillance of occupationally-exposed persons should be provided.

Once exposure limits have been set, safety guidelines or codes of practice concerning safe use and installation design should be developed as soon as possible.

1.2.4 Biological investigations

Reports of experimental work should contain sufficient information

describing the exposure conditions to allow an estimation not only of the total absorbed energy but also, as far as possible, of the distribution of the energy deposited within the irradiated biological system.

Systematic investigation of the effects of microwave/RF exposure at all levels of biological organization are to be encouraged. This includes effects at the molecular level on subcellular components;

cells, viruses, and bacteria; organs and tissues; and whole animals. Particular attention should be paid to: (a) long-term, low-level exposures and possible delayed effects; (b) the possibility of differences in sensitivity of various body organs and systems, where specific effects in various animal species are being considered; and (c) the influence of microwave/RF exposure on the course of various diseases, including any possible increase in sensitivity to microwaves/RF that may result because of the disease state.

1.2.5 Epidemiological investigations

Epidemiological studies should be carried out in a careful manner, paying attention to the relationship between exposure to microwaves/RF and other environmental factors occurring in the place of work and to the health status of the investigated group. Specific biological endpoints should be selected and adequate examination methods used for such studies. Conventional medical examinations will not provide sufficient information.

Studies should be carried out on (a) workers occupationally exposed to microwave/RF sources; (b) patients treated with microwave and RF diathermy; and (c) groups within the general population living near high-power microwave/RF sources.

A distinction should be made between occupational and public health protection standards.

1.2.6 Exposure limits and emission standards

1.2.6.1 Occupational exposure limits

The occupationally-exposed population consists of healthy adults exposed under controlled conditions, who are aware of the occupational risk. The exposure of this population should be monitored.

It is possible to indicate exposure limits from available information on biological effects, health effects, and risk evaluation. For occupational exposure, values within the range 0.1-1 mW/cm^2 include a high enough safety factor to allow continuous exposure to any part of the frequency range over the whole working day. Higher exposures may be permissible over part of the frequency range and for intermittent or occasional exposures. Special considerations may be indicated in the case of pregnant women.

1.2.6.2 Exposure limits for the general population

The general population includes persons of different age groups and different states of health, including pregnant women. The possibility that the developing fetus could be particularly susceptible to microwave/RF exposure deserves special consideration.

Exposure of the general population should be kept as low as readily achievable and exposure limits should generally be lower than those for occupational exposure.

1.2.6.3 Emission standards

Emission standards for equipment should be derived from, and be lower than exposure limits, where this can reasonably be achieved. A class of equipment may be considered safe and exempt from regulations, if hazardous levels of radiation exposure cannot originate from such a source.

1.2.6.4 Implementation of standards

The implementation of microwave and RF occupational and public health protection standards necessitates: the allocation of responsibility for measurements of radiation intensity and interpretation of results; and the establishment of detailed radiation protection safety codes and guides for safe use, which indicate, where appropriate, ways and means of reducing exposure.

1.2.6.5 Other protective measures

Prevention of health hazards related to microwave and RF radiation also necessitates the establishment of rules for the prevention of interference with medical electronic equipment and devices such as cardiac pacemakers, prevention of detonation of electroexplosive devices, and prevention of fires and explosions due to the ignition of flammable material (vapours) by sparks originating from induced fields.

1.2.6.6 Studies related to the establishment of limits

Studies of the frequency and modulation dependence of biological and health effects are of prime importance. The results of such investigations may make it possible to modify the rationales of present day standards and to identify frequencies at which exposure limits should be lower or higher than those suggested in section 11.

2. MAGNITUDE OF EXPOSURE TO MICROWAVE AND RF RADIATION AND SOURCES OF CONCERN

Electromagnetic fields and RF radiation occur naturally over a very wide range of frequencies. The ionosphere very effectively shields the earth's biosphere from radiations of this type originating in space. Electromagnetic fields and radiation of high intensity may be generated by natural electrical phenomena such as those accompanying thunderstorms.

However, in the frequency range of 100 kHz to 300 GHz, the intensity of natural fields and radiation is low. Exposure of the urban population in the USA to man-made microwave sources was found by Janes (1979) to vary from a very low value to as high as 100 $\mu W/cm^2$. The median exposure to the total microwave flux from external sources for this population was calculated to be 0.005 $\mu W/cm^2$. Osepchuk (1979) has calculated the background exposure from the sun, integrated up to 300 GHz to be 1.4×10^{-5} $\mu W/cm^2$. These values can be put in better perspective by noting that the integrated microwave/RF flux emitted from the human body has been calculated by Justesen (1979) to be up to 0.5 $\mu W/cm^2$.

The proliferation of man-made sources of energy in the 100 kHz-300 GHz range has only occurred over the last few decades. From the point of view of biological evolution, this energy constitutes a very recent physical factor in the environment. Observations of biological effects from exposure to microwaves gave rise to concern in the early 1940s. On the basis of special research programmes, radiation protection guides recommending exposure limits were developed in the 1950s in the USSR and the USA. Thereafter, several industrialized countries introduced recommendations and/or legislation on microwave and RF health protection. It should be noted, however, that exposure limits vary widely, and are the subject of many discussions and much controversy.

Although concern about microwave and RF effects and possible hazards arose first in highly developed countries, the problem is universal. Developing countries are rapidly establishing telecommunications, broadcasting systems, and other sources of electromagnetic energy. Electromagnetic waves emitted in particular countries may propagate around the globe. A report from the USA (Office of Telecommunications Policy, 1974) states: "Unless adequate monitoring programs and methods of control are instituted in the near future, man may soon enter an era of energy pollution comparable to that of chemical pollution of today."

The urgent need for international agreement on maximum exposure limits and international programmes for the containment of electromagnetic pollution has been stressed at international meetings (Czerski et al., 1974a). Prevention of potential hazards is a more efficient and economical way of achieving control than belated efforts to reduce existing levels.

3. PROPERTIES OF MICROWAVE AND RADIOFREQUENCY (RF) RADIATION

Radiowaves in the frequency range 100 kHz-300 GHz are non-ionizing electromagnetic radiation, and can be described in terms of time-varying electric and magnetic fields moving though space in wavelike patterns, as represented in Fig. 1.

The wavelength (the distance between corresponding points of successive waves) and the frequency (the number of waves that pass a given point in 1 second) are related and determine the characteristics of electromagnetic radiation. The shorter the wavelength, the higher the frequency. At a given frequency, the wavelength depends on the velocity of propagation and therefore, will also depend on the properties of the medium through which the radiation passes. The wavelength normally quoted is that in a vacuum or air, the difference being insignificant. However, the wavelength can change significantly when the wave passes through other media. The linking parameter with frequency is the velocity of light (3×10^8 m/second in air). The velocity decreases and the wavelengths become correspondingly shorter, when microwaves and RF radiation enter biological media, especially those containing a large proportion of water.

Another related property of electromagnetic waves is the photon energy, which increases linearly as the frequency increases. Fig. 2 shows the spectrum of electromagnetic radiation ranging from highly energetic ionizing radiation with extremely high frequencies and short wavelengths to the less energetic non-ionizing radiation with the much lower frequencies and longer wavelengths of radio-frequencies.

Conventionally a photon energy of 12eV, corresponding to a

wavelength of 100 nm, is taken as the dividing line between ionizing and non-ionizing radiation. This is in the vacuum region of the ultraviolet spectrum. Microwave and RF radiations are much less energetic. Their energy per photon corresponds to 1.25×10^{-3} eV at 300 GHz and 4.1×10^{-10} eV at 100 kHz, and is much too low to cause ionization.

3.1 Units of Radiation

When microwave or RF radiation is absorbed in a medium, the most obvious effect is heating. The radiation intensity can be determined calorimetrically. In SI terminology, it is known as the irradiance and is expressed in W/m^2. Traditionally, however, the term "power density" has been and continues to be used for this part of the frequency range, and will be used in this document with the more commonly reported units of mW/cm^2 and $\mu W/cm^2$.

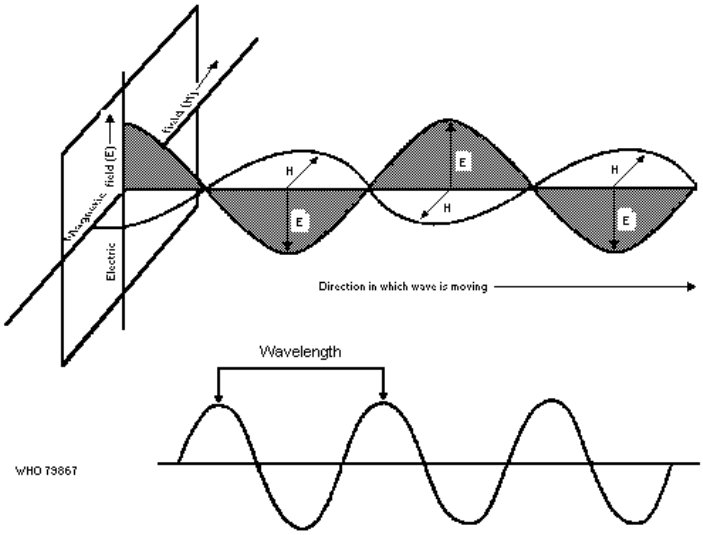


Fig. 1. An electromagnetic monochromatic wave. Electromagnetic waves consist of electrical and magnetic forces which move in consistent wave-like patterns at right angles to one another.

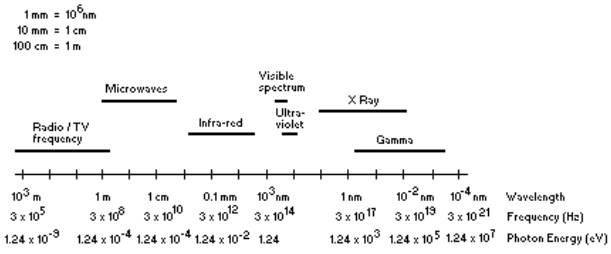


Fig. 2. The spectrum of electromagnetic radiation.

The associated electric and magnetic field strengths *(E* and *H)* can be equally valid expressions of radiant energy flow. When these are stated in V/m and A/m, respectively, their product yields VA/m^2. At distances greater than about one wavelength from the source, *E* and *H* are in phase and VA/m^2 may be expressed as W/m^2. Ideally, at a distance sufficiently remote from the source of radiation that it can be regarded as a point source, an inverse square law of power density with distance applies, the ratio *E/H* is 120 pi, i.e., 377OMEGA. The power density can, therefore, be derived from $E^2/377$ or from $H^2 \times 377$. Where *E* and *H* are expressed in V/m and A/m (Table 1), this is referred to as plane-wave or far-field conditions and to obtain a measure of the radiated power density, only the *E* field or the *H* field need be measured. Most instruments used for measuring power density measure the *E* field, because this technique is more versatile and presents fewer practical problems. *H* field detectors have been devised for a limited range of frequencies. Instruments combining both types of detection are possible, in principle, but would be most difficult to construct.

Table 1. Comparison of power densities in the more commonly used units for free-space, far-field conditions

W/m^2	mW/cm^2	$\mu W/cm^2$	V/m	A/m

10^{-2}	10^{-3}	1	2	5×10^{-3}
10^{-1}	10^{-2}	10	6	1.5×10^{-2}
1	10^{-1}	10^{2}	2×10	5×10^{-2}
10	1	10^{3}	6×10	1.5×10^{-1}
10^{2}	10	10^{4}	2×10^{2}	5×10^{-1}
10^{3}	10^{2}	10^{5}	6×10^{2}	1.5
10^{4}	10^{3}	10^{6}	2×10^{3}	5

The distance beyond which far-field conditions apply is usually taken as being 2 a^{2}/lambda, where a is the maximum dimension of the source (antenna) and lambda is the wavelength. The radiated "near field" includes distances of less than 2 a^{2}/lambda, where the inverse square law with distance does not apply and the impedance in space (the ratio E/H) may differ from 377OMEGA. Close to the source, at distances less than lambda, reactive components of E and H become progressively more important. Instruments, calibrated in units of power density but based on the measurement of E, for instance, will become increasingly inaccurate at close range. The instruments make valid measurements of the E fields, but their scale indications in terms of power density no longer apply. These and allied considerations are also discussed in section 4.3.2.

3.2 Other Physical Considerations

A detailed analysis and interpretation of the perturbing effects of objects placed in the path of microwave or radiofrequency beams requires the solution of Maxwell's field equations[a] for the appropriate boundary conditions. However, an important insight can be obtained by comparison with the shorter wavelength visible radiation, to which the same equations apply. The general laws of geometrical and physical optics remain valid: particularly the latter because of the wavelengths involved and because deliberate generators of microwaves and RF emit coherent radiation, i.e., the wave fronts are regular and radiated over a narrow band of frequencies at any one time. Radiation

[a] A set of four fundamental equations that describe all electric and magnetic fields. Their solution for real materials requires knowledge of the macroscopic electrical and magnetic properties of the materials.

reflected into the path of the incident beam will form standing waves and, at a distance of a few wavelengths, diffraction effects can cause additive and subtractive interference. Both effects have been convincingly demonstrated by Beischer & Reno (1977) at 1 GHz with man as the perturbing influence. Diffraction and internal reflections can also take place when radiation penetrates heterogeneous materials such as body tissues, leading to markedly nonuniform internal fields and energy deposition. As in geometric optics, the combination of a high refractive index and convex body contours behaves like a strong convex lens focusing the penetrating radiation. Absorption and internal scattering will limit the extent of these effects. Without the absorption of energy to initiate some change, there cannot be any biological effects.

Direct radiation is usually polarized, i.e., the E and H fields are oriented parallel to particular orthogonal planes or rotate in an ordered fashion. The plane of polarization of the reflected radiation will, thus, be changed complicating the measurement of the combined beams and investigation of the biological effects. Orientation with respect to the plane of polarization is important in some measuring instruments and in the distribution and total energy absorption in animals and in man. In some radar applications, typical equipment may emit pulses of 1 microsecond (µs) with a pause between pulses of 1 millisecond (ms). This constitutes a factor of 10^{3} in the values of instantaneous power radiated and deposited, and of 30 in the electric fields, compared with continuous wave (cw) generation at the same average power. Thus, instruments to be used in pulsed fields must have a wider dynamic range and more robust burn-out characteristics.

4. SOURCES AND CONDITIONS OF EXPOSURE

4.1 Natural Background Sources

Microwave and RF radiation occurs naturally, but the intensity of natural radiation in the range of 100 kHz-300 GHz is very low in comparison with the overall intensity of man-made radiation in this range, as shown in Fig. 3. The intensity of natural fields is mostly due to atmospheric electricity, which is static and has an electric field intensity of about 100 V/m (IVA Committee, 1976). This is known as the earth's electric and magnetic field. Radio emissions of the sun and stars, which are equivalent to about 10 pW/cm^{2} in the range of 100 kHz to 300 GHz also contribute to natural radiation. Local disturbances leading to increased field intensities occur during thunderstorms. Electromagnetic fields with a very wide frequency range

are created (atmospheric noise) with a maximum field intensity at about 10 kHz (Minin, 1974; IVA Committee, 1976).

Artificial microwave and RF radiation constitutes a very recent environmental factor, dating back only a few decades. Depending on the frequency range, exposure from man-made sources of microwave and RF radiation may be many orders of magnitude higher than that from natural radiation and man as a species has had no opportunity to adapt to microwave and RF radiation at such environmental levels (Presman, 1968).

There exists a great diversity of man-made sources, both in respect of power output and the power densities that are generated, and the frequency range in which the sources operate. According to the use of the source, different segments of the general population are exposed in different ways. There are obvious differences, depending on the development of the country, between the average exposure of the general population, the exposure of inhabitants of urban industrialized areas, and the exposure of inhabitants of rural areas. There is also a risk of exposure to microwaves and RF in some occupations. In view of this, the discussion of man-made sources must include a description of exposure situations.

4.2 Man-Made Sources

Any appliance that generates electricity or is driven by an electric current generates electromagnetic fields. These propagate through space in the form of electromagnetic waves. Man-made microwave and RF sources may be broadly divided into 2 classes, i.e., deliberate emitters, and sources of unintentional, incidental radiation.

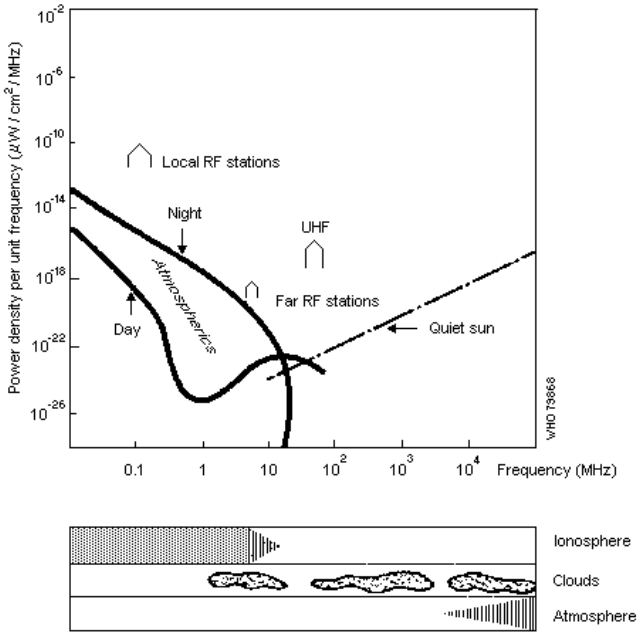


Fig. 3. Comparison of natural background and man-made RF and microwave radiation (From: Minin, 1974).

4.2.1 Deliberate emitters

Deliberate emitters generally have a radiating element (antenna) designed to emit electromagnetic waves into the surrounding environment in a specified manner. The frequency, direction of propagation, and the point of origin are determined by the intended use of the equipment. Because of physical laws, and, in spite of the degree of perfection of the design of a deliberate emitter, some unintentional leakage, or stray radiation is always generated. This should be taken into account when evaluating a deliberate emitter as a radiation source.

Unintentional radiation may occur in the form of broad-band noise or may be generated as discrete harmonics. In some instances, it is generated by sources that emit radiation outside the microwave and RF ranges. For example, while the intentional radiation of fluorescent light tubes lies in the visible light range, such tubes also generate very low levels of microwave and RF white noise (Mumford, 1949).

Typical deliberate emitters include radiobroadcasting and television stations, radar installations, and electronic wireless communication systems. These sources can be classified in different ways and classifications may vary from country to country depending on attitudes towards possible environmental and health effects. When classified according to the nominal power output or the effective

radiated power (ERP), such emitters may be divided into high, medium, and low power sources. Radar systems used for tracking and guiding purposes, as well as sources used in satellite systems are among the most powerful. It was reported in 1974 in the USA, that there were 20 nonpulsed unclassified sources with average effective radiated power (ERP) ranging from 5 GW to 31.6 GW and one experimental source with an average ERP of 3.2 TW (3.2×10^{12}W) (Hankin, 1974). All these sources were used in conjunction with satellite systems. A further 144 sources had an average ERP of 1 MW or more. The twenty most powerful unclassified pulsed (radar) sources had average ERPs between 8.7 MW and 840 MW and peak ERPs ranging from 35.4 GW to 2.8 TW; 229 unclassified pulsed sources had peak ERPs of 10 GW or more. This may be compared with television or amplitude modulation (AM) broadcasting stations in which the power of the transmitters is of the order of tens of kW (usually about 50 kW) or radio telephones (walkietalkies), in which ERPs may be of the order of a few watts or less.

Another approach towards classification of sources is to examine the configuration of the radiated fields and their propagation in space. Directional radiating elements (antennae) generating intense focused beams and multidirectional, variously polarized antennae may be used. Taking into account the power of the transmitter and the type of the radiating element, the magnitude of distances (or zones) at which various intensities of radiation (power densities on strength of E or H fields) occur can be computed. In this case, the

classification of sources also depends on arbitrarily chosen levels of radiation intensity. This approach may be useful in the siting of sources and in establishing "safe", "hazardous", and "danger" zones around a source.

Deliberate emitters may be also classified according to the mode of generation. Microwaves and RF may be generated continuously or in pulses and both continuous and pulsed wave generators may operate for long periods (up to 24 h per day) or short intermittent periods. The generated radiosignal may be frequency, amplitude, or pulse-modulated. Sources with moving directional antennae and sources generating mobile narrow beams may illuminate a point in space intermittently with a time-varying intensity ranging from zero to extremely high, at pulse peak power. Because of these complexities and since a point in space may be illuminated by radiation originating from several sources, the determination of the total or average quantity of energy delivered at this point during a period of time, may be difficult and may necessitate the use of sophisticated equipment and advanced computing methods.

Evaluations of the intensity of microwave and RF radiation generated by deliberate emitters have been published in the USA (Smith & Brown, 1971; Tell, 1972; US Environmental Protection Agency, 1973; Tell & Nelson, 1974a; Tell et al., 1974; Hankin et al, 1976; Stuchly, 1977; Tell & Janes, 1977; Tell & Mantiply, 1978). Fig. 4-7 illustrate the number of sources operating in the frequency range 10 kHz-300 GHz and capable of producing power densities equal to or greater than 10 mW/cm^2, 1 mW/cm^2, 0.1 mW/cm^2, and 0.01 mW/cm^2. These data should be compared with data in Tables 2-6.

Table 2 presents anticipated characteristics of satellite communications systems, which are among the most powerful sources of continuous wave radiations (100 W/m^2, 10 W/m^2, 1 W/m^2, and 0.1 W/m^2). Table 3 presents characteristics of pulsed wave, high power generators, and Tables 4 and 5 include characteristics of on-board aircraft and marine radars, respectively. Table 6 shows the characteristics of some North American broadcasting transmitters, the electric field intensity, and the equivalent power density at ground level at a distance of one mile from the transmitter tower. Fig. 8 presents power density versus distance for a television transmitter. In this context, it should be stressed that according to data of the US Environmental Protection Agency (Tell, 1972; Hankin et al., 1976; Tell & Mantiply, 1978) and the US Bureau of Radiological Health (Smith & Brown, 1971), broadcasting stations are "significant sources of RF exposure" (Tell & Janes, 1977). In view of the increasing popularity of mobile (portable or mounted on vehicles) transmitters for personal use, field intensities in the vicinity of antennae of these citizen band (CB) transmitters may be of concern in some countries from the point of view of population exposure (Neuksman, 1978; Ruggera, 1979).

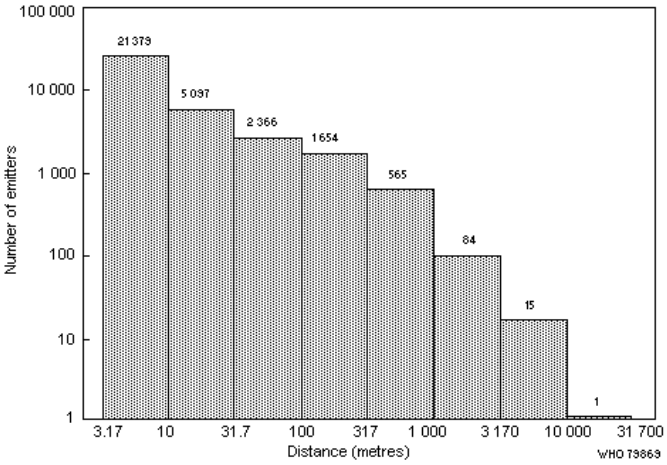


Fig. 4. Microwave sources in the USA in 1973, capable of producing a power density equal to or greater than 10 mW/cm^2 (From: National Health and Welfare, Canada (1977) based on Rowe et al., 1973).

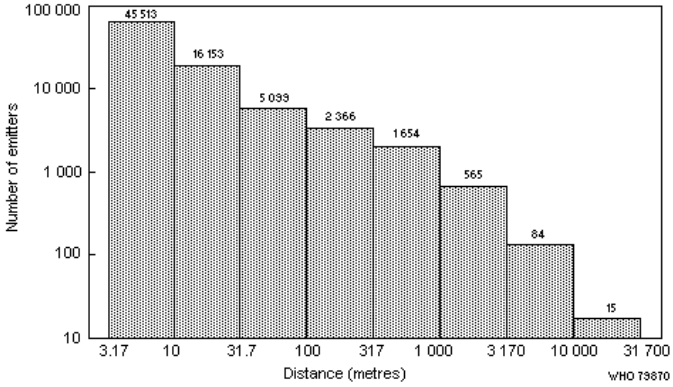


Fig. 5. Microwave sources in the USA in 1973, capable of producing a power density equal to or greater than 1 mW / cm^2 (From: National Fealth and Welfare, Canada (1977) based on Rowe et al., 1973).

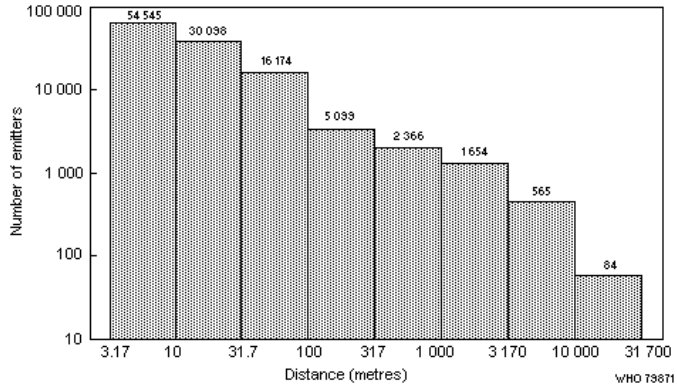


Fig. 6. Microwave sources in the USA in 1973, capable of producing a power density equal to or greater than 0.1 mW / cm^2 (From: National Fealth and Welfare, Canada (1977) based on Rowe et al., 1973).

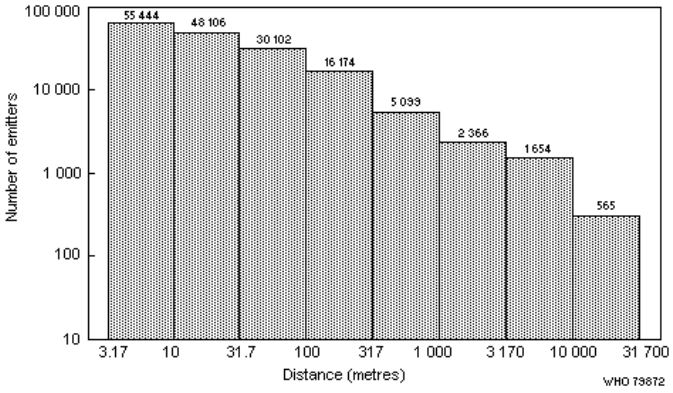


Fig. 7. Microwave sources in the USA in 1973, capable of producing a power density equal to or greater than 0.01 mW / cm ^{2} (From: National Health and Welfare, Canada (1977) based on Rowe et al., 1973).

Table 2. Anticipated characteristics of selected satellite communication systems[a]

System	f(GHz)	P_{av}(kW)	P_{max}(mW/cm^2)	Distance in km from antenna for power densities of 0.1 mW/cm^2	1 mW/cm2	10 mW/cm^2
LET	8.1	2.5	30.4	0.246	0.78	2.46
AN/TSC-54	8.1	8	50.8	0.46	1.45	4.58
AN/FSC-9	8.1	20	7.6	6.23	19.7	62.3
Intensat	6.25	5	0.73	--	--	12.3
Goldstone Venus	2.38	450	97.3	4.16	13.2	41.6
Goldstone Mars	2.38	450	16.8	9.68	33.4	106

[a] From: National Health and Welfare, Canada (1977) based on Hankin et al. (1976).

Table 3. Anticipated characteristics of typical high peak power radars[a]

System	f(GHz)	P(kW)	P_{max}(mW/cm^2)	Distance in km from antenna for power densities of 10 mW/cm^2	1 mW/cm^2	0.1 mW/cm^2
Acquisition radar FPN -- 40	9.0	0.18	12.8	0.028	0.111	0.351
Acquisition radar ARSR	1.335	20	111	0.147	0.465	1.47
Tracking radar Hawk Hi Power	9.8	4.7	800	0.108	0.344	1.08
Tracking radar no. 1	2.85	12	34.2	9.392	1.24	3.93
Tracking radar no. 2	1.30	150	55.7	1.75	5.52	17.5

[a] From: National Health and Welfare, Canada (1977) based on Hankin et al. (1976).

Table 4. Experimental data for typical on-board aircraft radars[a]

Radar system	Aircraft	f(GHz)	Power average (w)	Power density max. (mw/cm^2)	Approximate distance from radome in m for power density of 10 mW/cm^2	1 mW/cm^2
WP 103	BAC 111	9.375	26	20	3	11
AVQ 20	Convair	9.375	16	10	2	11
AVQ 50	Convair 580	9.375	16	26	2	11
AVQ 20	DC-9	9.375	28	15	4	13

[a] From: National Health and Welfare, Canada (1977) based on Tell & Nelson (1974a).

Table 5. Power density in the vicinity of on-board marine radars (non-rotating antennae)[a]

System	f(GHz)	Peak (kW)	Power Average (w)	Distance from antenna (m)	Average power density (μW/cm2)	
Decca 101	9.445	3	3.25	25.5	6.8	7.5 ± 5.4
Decca 202	9.445	3	1.5	45.7	3.6	5.1 ± 4.6
Decca RM316	9.41	10	5	103.6	3.7	5.9 ± 5.0
Kelvin-Hughes 17	9.445	3	2.75	103.6	0.6	1.4
Konel KRA 221	9.375	10	4.8	45.7	9.2	6.1 ± 4.5

[a] From: National Health and Welfare, Canada (1977), based on Peak at al. (1975).

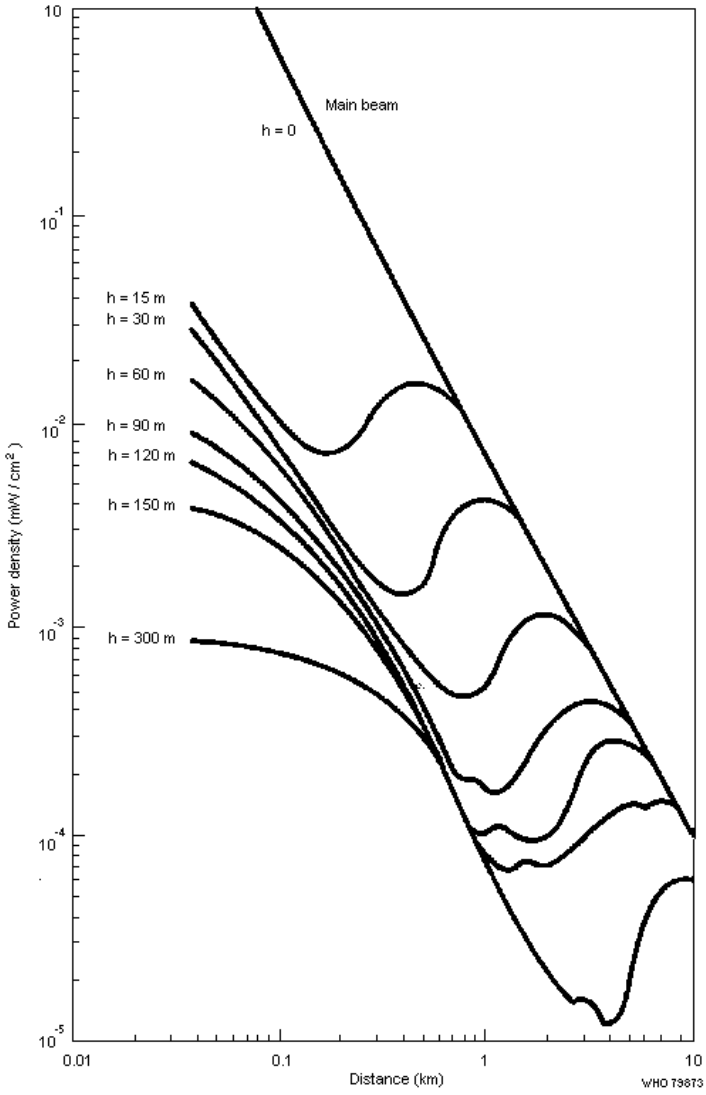


Fig. 8. Power density versus distance at various heights for a TV station with ERP equal to 1 mW / cm^2 (From: National Health and Welfare, Canada, 1977).

Table 6. Parameters of broadcasting transmitters[a]

Service	Frequency (MHz)	Maximum ERP (kW)	Tower Height (m)	Field intensity (mV/m)	Power density (μW/cm^2)
FM Radio	88--108	100	152	1023	2.78
VHF-TV, ch. 2--6	54--88	100	305	807	1.73
VHF-TV, ch. 7--13	174--216	316	305	191	0.1
UHF-TV	470--890	5000	305	380	0.38

[a] From: National Health and Welfare, Canada (1977), based on Tell (1972).

Medical microwave and RF equipment (chiefly medical diathermy) is a particular class of deliberate emitters designed and used for the irradiation of human subjects to obtain beneficial effects. In this case, the intended human exposure is carried out under professional supervision and constitutes part of medical practice. The contribution of medical uses to the general population exposure is difficult to evaluate and varies from country to country. A survey in Pinellas County (Florida, USA) revealed that among a population of 500 000 persons, 7037 individuals received 45 000 microwave or shortwave diathermy treatments of various durations and exposure levels (Remark, 1971). It should be pointed out that the county has a large population of retired people.

Although individual patients may absorb large quantities of energy, the exposure is limited to selected body areas and limited in time. However, medical microwave and RF equipment is also a source of unintentional radiation (Bassen et al, 1979) and during irradiation sessions, considerable scattering of electromagnetic fields may occur (Witters & Kantor, 1978; Bassen et al., 1979). Thus, particular attention should be paid to limiting exposure to the areas intended and to avoiding additional radiation doses to the patient from adjacent sources (other diathermy equipment). The occupational exposure of personnel operating the equipment should also be limited. The unintentional exposure of both patient and personnel usually involves the whole body.

4.2.2 Sources of unintentional radiation

Electrical and electronic, industrial or commercial equipment and consumer products in which, by design, the electromagnetic energy is contained within a restricted area, but into which objects to be processed are introduced, can all be sources of unintentional radiation. Any energy (radiation) emanating outside the area represents an energy loss. However, complete containment of electromagnetic energy is not always technically feasible. A typical example of a source of unintentional or leakage radiation is the microwave oven for commercial or home use. The microwave energy should be totally contained in the oven's cavity and used for heating (cooking) food. Leakage of microwaves does not serve any purpose and, if excessive, may represent a hazard to the user.

Microwave and RF equipment is used in many industries for such processes as melting, welding, drying, gluing, plastic processing, and sterilization. Surveys of dielectric radiofrequency heaters in Canada (Stuchly et al., 1980; National Health and Welfare, Canada, 1980) have shown that these heaters are used predominantly for plastic sealing and wood gluing, and operate at frequencies between 4 and 51 MHz with output powers in the range of 0.5-90 kW. Operators of some of these devices were exposed to fields with equivalent power densities exceeding 10 mW/cm^2. Most industries use electrical and electronic equipment (NIOSH, 1973). Table 7 represents various uses of microwave and RF generating equipment within certain frequency bands. Table 8 shows frequencies allocated for industrial, scientific, and medical uses (ISM bands) and Table 9, the frequencies allocated for these purposes in the USA and the USSR.

Unintentional exposure to microwave and RF radiations from deliberate emitters occurs universally. The results of a series of investigations by the US Environmental Protection Agency (section 4.2.1) indicate that urban populations in highly industrialized countries may be exposed to overall intensities of the order of $\mu W/cm^2$ (Gordon, 1966; Marha et al., 1971; Minin, 1974; Dumanski et al., 1975; Baranski & Czerski, 1976; Johnson et al., 1976; IVA Committee, 1976; National Health and Welfare, Canada, 1977, 1978; Durney et al., 1978). Inhabitants of high buildings in the vicinity of the rooftop antennae of broadcasting and television stations may be exposed to levels ranging from a few hundred µW to a few mW per cm^2. According to Tell & Mantiply (1978), 50% of the urban population of the USA is exposed to less than 0.005 mW/cm^2, 95% to less than 0.01 mW/cm^2, and 99% to less than 0.1 mW/cm^2.

Table 7. Selected examples of the typical uses of equipment generating radiofrequency and microwave radiation

Frequency	Use	Occupational exposure
Below 3 MHz	Metallurgy: eddy current melting, tempering; broadcasting, radiocommunications, radio-navigation.	Metal workers; radiotransmitter personnel.
3--30 MHz	Many industries such as the car, wood, chemical, and food industries for heating, drying, welding, gluing, polymerization, and sterilization of dielectrics; agriculture; food	Various factory workers, e.g., furniture veneering operators, plastic sealer operators, drug & food sterilizers, car industry workers; medical personnel; broadcasting transmi

	processing; medicine; radio-astronomy; broadcasting.	television personnel.
30--300 MHz	Many industries as above; medicine; broadcasting, television, air traffic control, radar radionavigation.	Various factory workers, as above; medical personnel; broadcasting transmitter and television personnel.
300--3000 MHz	TV, radar (troposcatter and meteorological); microwave point-to-point; telecommunication telemetry; medicine; microwave ovens; food industry; plastic preheating.	Microwave testers; diathermy and microwave diathermy operators and maintenance workers; medical personnel; broadcasting transmitter and television personnel; electronic engineers and technician: air crews; missile launchers; radar mechanics and operators and maintenance workers.
3--30 GHz	Altimeters; air- and ship-borne radar; navigation; satellite communication microwave point-to-point.	Scientists including physicists; microwave development workers; radar operators; marine and coastguard personnel; sailors, fishermen and persons working on board ships.
30-300 GHz	Radiometeorology; space research; nuclear physics and techniques; radio spectroscopy.	Scientists including physicists; microwave development workers; radar operators.

Table 8. Designation and use of microwave and RF Bands

Letter designation of microwave frequency bands		Some industrial, scientific, and medical (ISM) frequency bands, (not applicable in all countries)
Band	Frequency -- MHZ	
L	1100-- 1700	13.56 MHz ± 6.78 kHz
LS	1700-- 2600	27.12 MHz ± 160 kHz
S	2600-- 3950	40.68 MHz ± 20 kHz
C	3950-- 5850	433 MHz ± 15 MHz
XN	5850-- 8200	915 MHz ± 25 MHz
X	8200--12 400	2450 MHz ± 50 MHz
Ku	12 400--18 000	5800 MHz ± 75 MHz
K	18 000--26 500	22 125 MHz ± 125 MHz
Ka	26 500--40 000	

General population exposure may be considered as long-term, very low-level, intermittent exposure for 24 h per day (or for major portions of the day) to a very wide range of microwave and RF radiation frequencies.

4.3 Estimating Exposure Levels

4.3.1 Far-field exposure

Estimates of far-field exposures are necessary before powerful and complex installations are constructed. The subject is discussed at length by Minin (1974), who not only considers factors connected with equipment and the local topography but also gives information on methods of screening. Whenever possible, estimates of radiation fields should be made before detailed surveys of potentially hazardous exposures are carried out. Mumford (1961) gives approximate formulae for some radar antennae; additional information can be obtained from textbooks and monographs (Kulinkovskaja, 1970; ANSI, 1973; US Department of Commerce, 1976; National Health and Welfare, Canada, 1977; Krylov & Jucenkova, 1979). This procedure is necessary not only to select a suitable survey instrument but also to determine if potentially hazardous exposure of the operator could occur, if the instrument were faulty. Unlike instruments for ionizing radiation, there are no sources readily available for checking the calibration of the instrument.

Table 9. Radiofrequency and microwave band designations

Band designations					
USA	USSR				
(a) Radiofrequency bands					
Low frequency	(LF) Long	VCh	10^4-10^3 m	30-3 kHz	radionavigation; radio beacon AM broadcast.

Medium frequency (MF)	Medium	(HF)	10^3-10^2 m	0.3-3 MHz	marine radiotelephone; AM broadcasting.
High frequency	(HF) Short	UHF	10^2-10 m	3-30 MHz	amateur radio; citizens band in the USA. etc.; world-wide broadcasting; medical diathermy; RF sealers, welders, heaters; short-wave diathermy.
Very high frequency (VHF)	Ultra-short (metre)		10-1 m	30-300 MHz	Frequence modulated (FM) broadcasting; television; air traffic control; radionavigation.
(b) Microwave bands					
Ultra high frequency (UHF)	Decimetre	Super HF		0.3-3 GHz	microwave diathermy; television; microwave point-to-point; microwave ovens & heaters; telemetry; tropo scatter & meteorological radar.

Table 9 (Cont'd)

Band designations

USA	USSR				
Super high frequency (SHF)	Centimetre	(SHF)	10-1 cm	3-30 GHz	satellite communication; air-borne weather radar; altimeters; shipborne navigational radar; microwave point-to-point; amateur radio.
Extra high frequency (EHF)	Millimetre		1-0.1 cm	30 GHz-300 GHz	cloud detection radar.

In the far field on the antenna axis, power density (P_d) can be calculated from the formula:

$$P_d = GP_t/4\pi d^2 = A_eP/\lambda^2 d^2$$

where G is the far-field gain, P_t is the power delivered to the antenna (W), d is the distance from the antenna (m), lambda is the wavelength (m) and A_e is the effective area of the antenna (m^2). G, the far-field gain of the antenna, represents the ratio of the observed power density, on axis, to the power density from a point source having the same output power and emitting equally in all directions.

4.3.2 Near-field exposure

When the distance is not great compared with the antenna dimensions, the power density tends to vary inversely with d instead of d^2 (as in the far field), and may display interference patterns. Radiations from different parts of the antenna, having the same wavelength, combine in various phases. For parabolic antennae, the maximum power density (P_d) expected in the radiated near field can be estimated from:

$$P_d = 4 P_t/A_e$$

where P_t is the transmitted power and A_e is the effective area of the antenna. This expression will generally overestimate the power density. A fuller discussion of this relationship is provided by Hansen (1976) and Hankin et al. (1976).

Effects of ground reflections could increase P_d by a factor of 4 or even more if focusing effects are present. These predicted values of maximum power density should be within ±3 dB (i.e., within a factor of the true maxima for most horn antennae and circular reflector antennae). However, different antenna illumination functions may produce near-field power densities that may be higher than those predicted. It should be recognized that the equation is only suitable for obtaining approximate power densities to use as a rough guide. More precise values require careful measurements (Bowman, 1970, 1974; Ruggera, 1977).

In the case of low frequencies or large aperture antennae, the existence of potentially hazardous reactive near fields becomes relevant. These electric and magnetic fields are calculable only with reference to the geometry of the specific antenna and source. For

instance, exact equations for the electric and magnetic fields generated by a small electric dipole contain terms in lambda/ d, lambda/ d^2, and lambda/ d^3. When d is much smaller than lambda, the lambda/ d^3 terms predominate and this is referred to as the reactive near field. Objects within this region may couple with the source and extract energy. When lambda/ d approaches 1, all terms contribute and this is sometimes called the intermediate field. When lambda/ d is substantially less than 1, the conditions are those of the far field.

4.4 Facilities for Controlled Exposure

Controlled exposure facilities are required for the calibration of instruments used in measuring power density, for the exposure of experimental animals in the study of effects, and for the exposure of phantoms (models) and carcasses in studies on absorbed energy and its distribution. The unrepeatability of much of the early biological work has been ascribed to the inadequacy of exposure facilities. Large gradients in field intensities are very undesirable and preferred methods make use of either far-field exposures carried out under conditions in which reflections are reduced to a minimum (e.g., in anechoic chambers), or using guided wave techniques. The basic premise is that known exposure conditions can be established by a combination of measurement and calculation. Except in laboratories with a responsibility for maintaining primary standards, it is probably preferable to use the far-field or guided wave methods to obtain suitable exposure conditions, and to measure the radiation field using an instrument that has been calibrated at a primary laboratory.

The methods of instrument calibration have been described in detail by Engen (1973), Baird (1974), and Bassen & Herman (1977) and are summarized in the following section. The principles apply equally to animal exposure.

4.4.1 Free space standard field method

There are several variations of this method, but the objective is always to establish a known calibration field in free space. The most common experimental arrangement is shown in Fig. 9. As discussed in section 4.3.1, the power density (P_d) at a point on the transmitting antenna is given by:

$$P_d = GP_t/4\pi d^2$$

where P_t is the power delivered to the transmitting antenna, G is the effective gain of the transmitting antenna, and d is the distance from the antenna. The gain is normally determined in advance, and P_t and d are measured as part of the regular calibration procedure.

The most convenient method of determining P_t is by sampling forward or incident and reflected powers. The incident power P_i and the reflected power P_r are monitored, and P_t is obtained from the relation $P_t = P_i - P_r$. The high quality, broadband equipment available together with methods for its use in

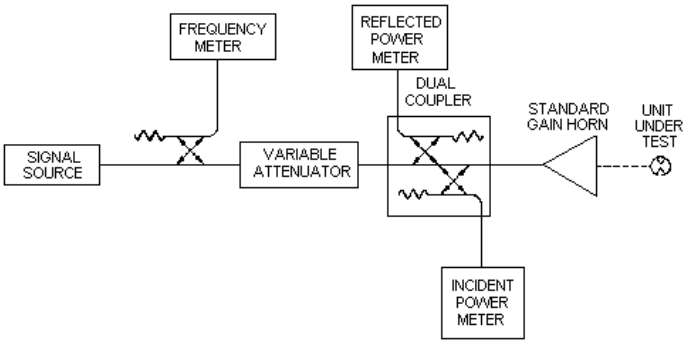


Fig. 9. Diagram of the basic experimental arrangement required for the free space standard field method.

determining P_i are described in Bramall (1971), Engen (1971), Aslan (1972), and Bowman (1976). The methods cited are for calibrating power meters, but the same techniques can be applied for the calibration of antennae, if corrections are made for mismatch effects, including those from animal exposure.

The principal sources of error in the free space method are multipath interference and uncertainties in the determination of gain. Multipath effects have often been overlooked, but every calibrating facility will have some reflections associated with the walls, equipment, and probe support structure. These reflections may cause the field in the calibrating region to be significantly different from that predicted. Even high-quality anechoic chambers are not perfect

and should be evaluated, if the greatest accuracy is desired. Calibration errors due to multipath effects can be reduced by observing the probe response as a function of position and averaging the results. This is sometimes referred to as the multiple position averaging technique and useful discussions of the method can be found in Bowman (1974), Bassen & Herman (1977), Swicord & Cheung (1977), and Swicord et al. (1977).

4.4.2 Guided wave methods

The fields inside a waveguide can be accurately calculated and, in some cases, are sufficiently uniform to be considered for calibration purposes (Hudson, 1966; Hudson & Saulsbury, 1971). The main advantage of such a system is that it requires considerably less power and space. One disadvantage is that the maximum transverse dimension of a rectangular waveguide must be less than the free space wavelength of the highest calibration frequency, in order to avoid higher order modes which result in complicated field distributions. Thus, the method is generally used for frequencies below 2.6 GHz, since the device being calibrated must be small compared with the guide dimension.

The probe to be calibrated is usually inserted into the wave-guide through a hole in the side wall and positioned in the centre of the guide, where the field in most nearly uniform. It is difficult to estimate the total uncertainty of this method, because the field intensity will be modified by the size and nature of the probe being calibrated. A careful error analysis of this problem has not been completed, but it appears that, if the maximum probe dimension is less than one third of the smaller waveguide dimension, the total uncertainty should not exceed ± 1 dB (22%). Woods (1969) described a system which operated from 400 to 600 MHz with an estimated uncertainty in the field intensity of ± 0.5 dB (12%). Later results at 2450 MHz have been reported by Aslan (1972) with claims of higher accuracy.

Other types of guided wave structures can be used reliably to establish uniform fields for calibration purposes in the RF frequency range below about 500 MHz, where free space techniques become difficult and standard waveguides are unavailable or inconvenient. The two most commonly used structures are the parallel plane line and the Transverse Electromagnetic Mode (TEM) cell (Crawford, 1974). Both structures can be used to produce transverse electromagnetic waves with the same wave impedance (377OMEGA) as a plane wave in free space, a feature which makes them desirable for calibration purposes. Furthermore, the fields can be calculated with sufficient accuracy for many calibration purposes.

A basic TEM cell is illustrated in Fig. 10. The principal advantage of this structure over the parallel plane line is that the TEM cell is fully shielded, thus eliminating extraneous radiation that may interfere with electronic equipment. The basic unit is a section of two conductor transmission lines. As shown in the figure, the main body of the cell consists of a rectangular outer conductor and a flat centre conductor located midway between the top and bottom walls. The field intensity in the centre of the cell can be quite uniform, and the wave impedance throughout the cell is very close to the free space wave impedance. It is mainly because of these features that this type of cell is used for calibrations.

The dimensions of such a cell are adjusted according to the desired upper frequency limit.

4.4.3 Standard probe method

A stable and reliable probe, which has been accurately calibrated by one of the previously described techniques, a "transfer standard", is used to measure the field intensity over a particular region in space (or in a guided system) produced by an arbitrary transmitting antenna. The probe to be calibrated is then placed in the same location in the field and the meter reading compared with the known value of the field. The only requirements are that the transmitter should generate a field which has the desired magnitude, is constant in time, and is sufficiently uniform over the calibrating region. Accuracies of about ± 0.5 dB (12%) should be attainable. This method is the simplest, and may ultimately prove to be the best method of calibrating hazard meters for general field use Baird (1974). The advantages of this method are its convenience, reliability, and simplicity. Potential sources of error, when using the transfer standard to calibrate another probe, are the possible differences in the receiving patterns of the two probes, especially in the near fields of a source of radiation, and the errors due to scattering from probes under test.

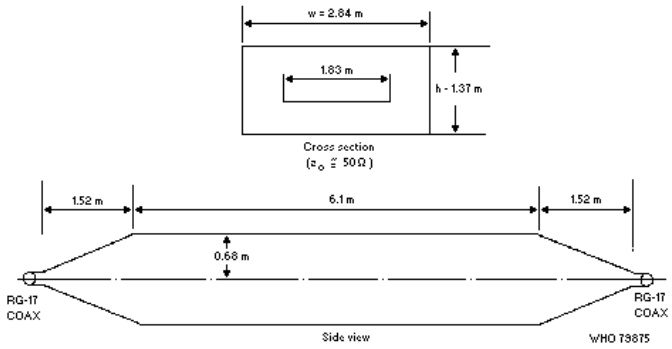


Fig. 10. A type of TEM transmission cell used at the US National Bureau of Standards for calibrating hazard meters and for measuring the susceptibility of electronic equipment to EM fields. Such cells can also be used as exposure chambers for studying biological effects. This cell was designed for an upper frequency limit of about 500 MHz.

5. MEASURING INSTRUMENTS

5.1 General Principles

Most power density instruments are composed of 3 basic parts: the sensor, connecting leads, and meter unit. This configuration reduces perturbation of the field in the immediate vicinity of the sensor to a minimum and, in surveys of potentially hazardous equipment, may help in reducing the exposure of the operator. Neither leads nor meter unit should respond to the radiation being measured or serious error can ensue. The instrument should respond only to microwave and RF fields and not, for instance, to light and infrared radiation, or to static and low-frequency electric and magnetic fields. Comparatively few instruments are likely to meet these requirements in full.

The basic principles of instrument calibration with the uncertainties associated with the different methods have already been discussed in section 4.4. The same accuracy cannot be expected or achieved when using the meters for making practical measurements in surveys because: (a) hazard meters are usually calibrated in nominally plane-wave fields, which are seldom encountered in practice, and the sensor may not respond in the same way to non-planar fields; and (b) in most calibration methods, only the sensor (probe) is exposed to the field, while, in practice, the complete system, including the indicating unit and connecting cable, is immersed in the field. Even when these do not respond to the radiation, the radiation fields will be perturbed by their presence and that of the operator. If good measurement procedures are followed, accuracies of 2 dB can be achieved.

5.2 Types of Instruments in Common Use

5.2.1 Diode rectifier

In these instruments, small antennae terminate in single or multiple diodes. Multiple diodes and antenna elements arranged in suitable configurations can be used to sum all electric field components enabling measurements to be made, irrespective of polarization and direction of incidence. Three orthogonal elements are necessary and sufficient for such an isotropic instrument.

Some units, now in use, employ a single diode combined with a short dipole or small loop antenna. The sensitivity of these instruments changes with their orientation, with respect to the plane of polarization of the *E* or *H* field. They must, therefore, be oriented so that the maximum value can be read -- a process that can be tedious and time-consuming. Such instruments are, however, useful for identifying and measuring individual field components.

An orthogonal dipole array or multiple diodes and dipoles arranged in a single plane will respond well to all signals polarized in the plane of the array, but not to components polarized at wide angles to the array. Such units must also be oriented to obtain the maximum field readings.

All these instruments are basically power density sensitive in the far field, that is, at low levels, the rectified voltages are proportional to the square of the *E* field (i.e., to the power density). When adapted to broadband operation, the upper frequency range is, at present, about 18 GHz. The corresponding low frequency limit is about 0.5 MHz.

Diode characteristics depend directly on ambient temperature and variations in output with ambient temperature may be in the order of tenths of a dB (several percent) per degree Celsius. Diode units may also be modulation sensitive, with errors in reading dependent on the

form of modulation.

5.2.2 Bolometer

In bolometric instruments, the microwave/RF currents cause heating and induce a change in some physical property, most commonly the resistance of a thermistor. A measure of the power density would then be the resulting imbalance of a bridge circuit containing the thermistor. For small deviations from balance, the bridge output is proportional to the temperature of the thermistor and therefore to the square of the electric field, i.e., to the RF power dissipated in the thermistor. The thermistors used have a positive temperature coefficient. Thus, this type of instrument can withstand large overloads without damage. As the power density increases, the resistance of the element increases, causing a mismatch condition and the power absorbed by the thermistor is also inversely proportional to its resistance. Both effects limit the power absorbed by the element. These units may exhibit drift in the zero reading and loss in sensitivity caused by changes in ambient temperatures.

5.2.3 Thermocouple

The detection elements in thermocouple-type radiation monitors are generally thin-film type thermocouples. The films perform the simultaneous functions of lossy antenna element and temperature detector. The output from the thermocouple is proportional to the square of the electric field and the units are relatively independent of ambient temperature (Bassen et al., 1977). Hot and cold junctions of the thermocouple are in extremely close proximity and very stable. Variation in sensitivity is of the order of 0.1% per°C. The use of small, thin, resistive films provides very broad bandwidth. More detailed discussions of these, and other types of instruments, can be found in Aslan (1972), Bowman (1976), Eggert & Goltz (1976), and Eggert et al. (1979).

6. MICROWAVE AND RF ENERGY ABSORPTION IN BIOLOGICAL SYSTEMS

Electric and magnetic fields are induced within a biological system exposed to microwave or RF energy. To understand the resulting biological effects, it is necessary to determine the induced field strength at various internal points of the system. Knowing the electrical and geometrical characteristics of the irradiated object and the external exposure conditions, it is possible, in principle, to calculate the rate at which energy is absorbed throughout the interior of the irradiated object.

The magnitude of interior and exterior scattered and reflected fields depends on many factors: the frequency and configuration of the incident field; the electrical properties of the various layers (tissues) of which the irradiated system is composed; the shape, the size relative to wavelength, and the relative orientation of the system. Biological systems are usually of complex exterior and interior geometry, and consist of several layers with various electrical properties (complex permittivity). As a result, the internal energy deposition in biological systems will be nonuniform. Depending on the thermal properties and blood flow of tissues, there can be marked differences in the magnitude and rate of increase in temperature, and thermal gradients can result. A review on the interaction of microwave and RF radiation with living systems has recently been completed by Stuchley (1979).

6.1 Methods of Computation

Methods of computation for predicting internal energy deposition using various approximate mathematical models of human and animal bodies have been developed. These show reasonable agreement with experimental measurements of energy absorption in phantom models and animal carcasses (Guy, 1971, 1974; Johnson & Guy, 1972).

Theoretical analyses have led to the prediction of the resonant absorption of energy in both the whole and parts of the body of human models and animals. The effects of such variables as frequency and polarization of the field, the size and shape of the exposed body, and the surrounding environment, ground plane, and other objects have been evaluated.

Details concerning computational and experimental techniques, data on specific absorption rates within the range of 10 kHz-100 GHz in man and laboratory animals, as well as pertinent reference lists, can be found in the three editions of the "Radiofrequency radiation dosimetry handbook" (Johnson et al., 1976; Durney et al., 1978, 1980). In the most recent edition of the Handbook, several models relevant to exposures in the near-field of the radiation source have been included.

The intensity of the internal electric field or the amount of energy absorbed per unit time per unit mass (the specific absorption rate (SAR)) are both used in radio-frequency and microwave dosimetry. Most frequently used units of SAR are W/kg and mW/g. Further discussion on SAR follows in section 6.3.

6.2 Experimental Methods

Measurements of internal electric fields within dielectric media are possible if a small, insulated dipole array is used. Such a device has been developed in miniature form and used to measure internal microwave fields in phantoms and living animals with uncertainties of less, than 1 dB. The advantage of the implantable electric field probe method over thermal dosimetric techniques is the greater sensitivity of the field probe, allowing the use of microwave and RF sources with much lower power outputs. Thus, the energy deposition can be mapped in a biological body or a scan through a phantom exposed to only moderate levels of microwave or RF energy.

Thermal measurements in phantoms or animal carcasses can yield direct data on SAR. Small thermistor probes with non-perturbing resistive leads, and optical fibre probes with temperature-sensitive sensors using a light source have been developed (Aslan, 1972; Cetas, 1975; Livingston et al., 1975; Bowman 1976; Deficis & Prou, 1976; Bassen et al., 1977). Thermographic cameras used in conjunction with sectioned phantom models or carcasses can record the heat distribution in an entire plane. High intensity exposure fields have to be employed to yield significant increases in temperature.

6.3 Energy Absorption

Biological systems are lossy dielectrics characterized by limited conductivity. The losses originate from the movement of free ions (conduction loss) and molecular rotation (dielectric loss). Thus, electromagnetic waves, propagating through a biological medium, interact with it, and energy transfer occurs. This results in attenuation of the field and an increase in the kinetic energy of the molecules of the medium, i.e., in heating. The degree of attenuation of the field depends on the dielectric properties of the medium, and these change with the frequency of the incident field. The real and imaginary parts of the complex permittivity generally decrease with increasing frequency.

The above statements present, in a simplified form, the classical theory of microwave and RF energy absorption, which was developed by Schwan and his school (Schwan & Piersol, 1954, 1955; Schwan, 1971, 1976). The latest restatement of this approach (Schwan, 1978) may be summarized as follows: "Among the established effects in biological systems the most important is heat development but direct field interactions with membranes, biopolymers, and biological fluids are all possible". All energy deposition, however, takes place because of conduction losses, molecular movements, and biopolymer rotation.

During the last few years, the concept of the specific absorption rate (SAR) has been developed for quantifying microwave and RF effects.

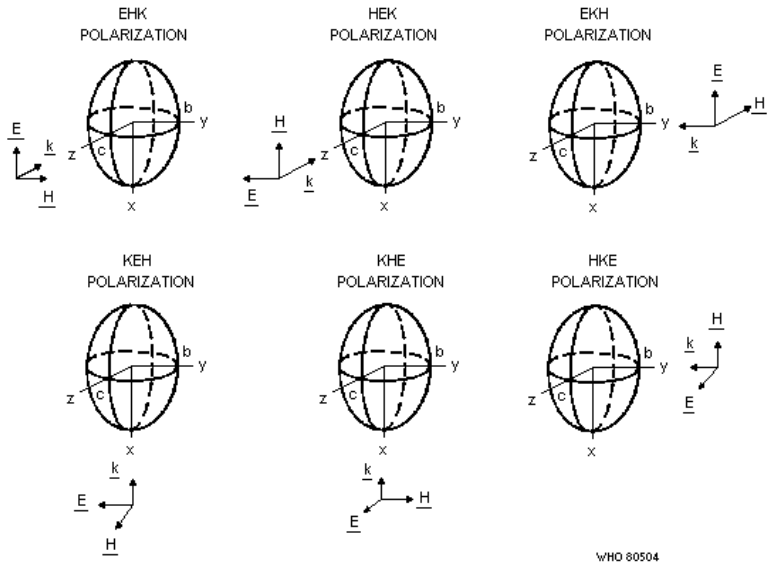
As mentioned earlier, the specific absorption rate is defined as the rate of energy absorption per unit mass of an exposed object. For steady-state sinusoidal fields, the SAR is directly proportional to the tissue conductivity, the square of the electric field, and inversely proportional to the mass density. The relationship is more complex in pulsed or modulated fields, if the intrinsic properties of the medium are non-linear. However, since the SAR is related to the intensity of the internal electric field, this concept can be used independently of the nature of the interaction mechanism responsible for biological effects. This stems from the fact that it is the internal electric field intensity that quantitatively describes the interaction. Nevertheless, it may not be the only factor, e.g., frequency and/or modulation of the radiation field may strongly affect biological effects. Consequently, the nature of the radiation fields should always be considered in addition to the SAR.

The SAR is a measure of the absorbed energy which may or may not all be dissipated as heat. The temperature is a function of the SAR, but it is also a function of the thermal characteristics of the absorber (i.e., the size, shape, thermal conductivity).

The values of the SAR averaged over the whole body and the distribution of the SAR have been estimated theoretically and measured experimentally in models and experimental animals for various exposure conditions. For human subjects, the average SAR for exposures in the far field may reach a peak in the frequency range of 30-200 MHz, depending on various factors associated with the specific exposure situation (Johnson et al., 1976; Durney et al., 1978, 1980). Fig. 11 presents the average SAR in man and experimental animal models at an incident power density of 1 mW/cm^2 in free space (far-field) conditions. The graphs in Fig. 11 (page 46) show the importance of size, frequency, and orientation, while Fig. 12 shows values of average SAR at the resonant frequency for several exposure conditions for models of man and 2 sizes of rats. This mathematical modelling is only possible for greatly simplified models.

In addition to the average SAR, the SAR distribution in many models has been calculated. Much of this work can be found in reports by Shapiro et al. (1971), Lin (1976), Gandhi et al. (1979), Kritikos & Schwan (1979), and is summarized in the latest edition of the

Dosimetry Handbook (Durney et al., 1980).



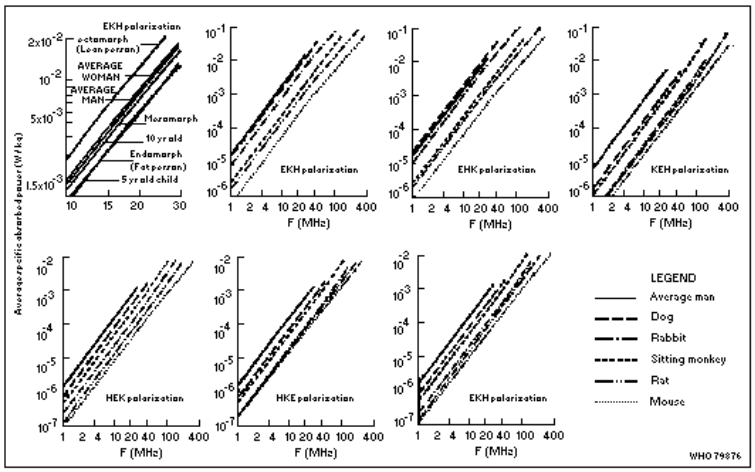


Fig. 11. Average specific absorbed power in ellipsodal models of man and test animals; incident power density 1 mW / cm^2 (From: National Health and Welfare, Canada (1977) based on Rowe et al., 1973).

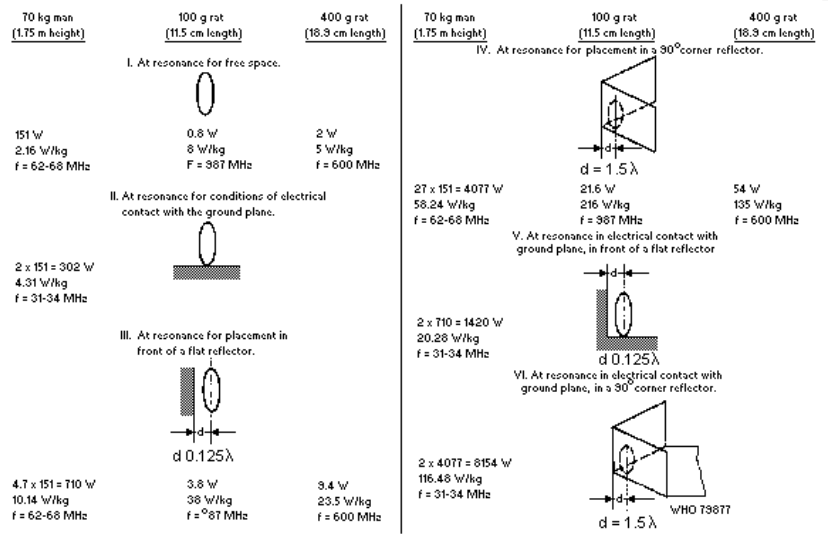


Fig. 12. Specific absorption rates for man and two sizes of rat irradiated with the plane wave of a power density of 10 mW/cm^2 under various conditions (From: National Health and Welfare, Canada (1977) based on Gandhi et al. (1977).

In the absence of adequate knowledge concerning the mechanisms of interactions between microwave energy and biological systems, and in the light of the limitations inherent in the SAR, the following conclusions can be drawn:

(a) SAR alone cannot be used for the extrapolation of effects from one biological system to another, or for the extrapolation of biological effects from one frequency to another.

(b) Curves for exposure which produce equivalent SAR for a given body over the microwave/RF energy spectrum may be used to predict equivalent average heating, provided data concerning heat dissipation indicates equivalent heat dissipation dynamics. Such curves cannot, however, be used as the only basis for predicting biological effects or health risks over the microwave/RF spectrum, since from current knowledge, it is not possible to state that equivalent average energy absorption rate for given radiation frequencies is associated with equivalent biological effects.

6.4 Molecular Absorption

Despite the photon energies, some recent theoretical explanations of experimental observations strongly indicate the possibility of interactions at the molecular level. Proton tunnelling, changes in the conformation of molecules, and cooperative mechanisms have been envisaged (Fröhlich, 1968; Illinger, 1971, 1974; Cleary, 1973, 1978; Rabinowitz, 1973; Grodsky, 1975; Keilmann, 1977).

It has been postulated (Fröhlich, 1968; Rabinowitz, 1973) that microwaves in the frequency region of 60-120 GHz may influence macromolecules in biological systems, altering such functions as cell division, and virus inactivation or activation. Effects on enzyme systems, DNA-protein structures (chromosomes), and cell membranes are possible (Grundler & Keilmann, 1978; Pilla, 1979; USSR Academy of Sciences, 1973). Physical experimental techniques need developing and further studies on biological effects are necessary. Similar mechanisms may be operative at lower frequency ranges (Kaczmarek & Adey, 1974; Adey, 1975; Grodsky, 1975; Bawin & Adey, 1976) and the present status of knowledge about the molecular absorption of microwaves and RF in biological systems has been summarized by Straub (1978) who states:

> "Absorption of non-ionizing electromagnetic (EM) radiation by biologically important molecules can occur by many different mechanisms over the frequency range from several hertz through the millimeter microwave region. The absorption of EM radiation is determined by the bulk dielectric properties of living tissues, cells and biomolecules in solution. However, the existence of diverse and complex molecular structures characteristic of biological systems makes it necessary to consider the details of
>
> absorption and dissipation of EM energy. In addition, the biological function of the molecular species absorbing energy needs to be studied to understand the significance of the EM absorption. Among many possible examples the following five are given: (1) The network of membranous lipid-containing structures within and at the outside limit of cells poses a series of barriers to thermalization of the absorbed radiation. Thus, adiabatic conditions may be maintained in small membrane bound volumes for much longer periods of time than in simple solution.

Large thermal gradients and temperature elevations can result. (2) Subsequent temperature elevation may cause membrane structures or complex protein assemblies to pass through phase transitions, altering their properties. (3) Spatial anisotrophy in the arrangement of large molecular assemblies, as found in mitochondria and ribosomes, results in specialised functions which can he completely changed if some of the molecules are rotated or translated by EM radiation. (4) Quantum effects such as proton tunnelling with resulting isomerization of DNA base pairs may also be influenced by EM radiation. (5) Otherwise random motion of "gates" in excitable channels of nerve membranes may be brought into forced oscillation by EM radiation, with resultant membrane depolarization. Detailed knowledge of structure and function of the biological system thus reveals many perturbations which might be induced by EM absorption, and, conversely, EM radiation can be used to probe biological structures and function."

7. BIOLOGICAL EFFECTS IN EXPERIMENTAL ANIMALS

During the past thirty years, research has been devoted to various aspects of the interactions between microwave and radiofrequency radiation and biological materials. Unfortunately, most experiments have tended to report biological effects as phenomena rather than attempting to establish whether such radiation presents a health risk to man and other biota. In Czechoslovakia, Poland, and the USSR, a continuous research effort made over the last 25-30 years has resulted in numerous research reports and reviews (Presman, 1968; Marha et al., 1971; Baranski & Czerski, 1976). In the past 20-25 years, interest in this field of studies has increased in the USA, first with the establishment of the Tri-service Programme in 1956 and then other programmes in later years.

It is impossible to review the numerous studies (see bibliographies by Glazer et al., 1976; Glazer & Brown, 1976; Glazer et al., 1977) related to the biological effects of microwave radiation and only those most pertinent to the evaluation of potential biological hazards have been cited. Potentially beneficial effects of microwave radiation are outside the scope of this document.

Only limited information is available from studies of human subjects directly exposed occupationally or experimentally to microwave radiation. Most of the data on possible harmful effects are based on studies of separate cells, simple organisms, animals, and models, making it difficult to extrapolate such experimental results to man.

Radiant energy absorption in the living system followed by direct interaction with biophysical or biochemical processes, may be defined as the primary interaction. Changes in the structure and function of a biological system as a result of the primary interaction are considered to be biological effects. Immediate biological effects arising at the site of the primary interaction may induce further indirect changes, both acute and chronic.

The analysis of data on effects requires the consideration of a sequence of events: the physical interaction followed by physiological reactions -- local and generalized, and immediate and delayed biological effects. In addition, frequent activation of adaptive mechanisms may lead to their exhaustion via the classical sequence of events of stress-adaptation-fatigue. Consequently, the effects of single and repeated exposures should be considered separately, even when exposures take place under identical conditions.

For many years, the primary interaction of microwave and RF radiation with living systems was considered almost exclusively in terms of electromagnetic field theory (Schwan, 1976, 1978). It was concluded that the conversion of the absorbed energy into kinetic energy of molecules (i.e., heat) was the only significant mechanism involved. However, there are discrepancies between some empirical observations and the theoretical explanations available (Cleary, 1973; Baranski & Czerski, 1976; Dodge & Glaser, 1977), which indicate that "non-thermal" effects may play some role. Direct interference with bioelectric phenomena (as seen on the electroencephalogram and the electromyogram) and the role of electromagnetic fields in the transmission of biological information was suggested by Presman (1968), but these hypotheses need experimental verification.

Interaction of microwave energy at the molecular level has been postulated to explain the primary interaction between microwaves and parts of living systems such as membranes (Fröhlich, 1968; Adey, 1975; Bawin et al., 1975; Grodsky, 1975; Bawin & Adey, 1976; Grundler & Keilman, 1978; Pilla, 1979).

7.1 Hyperthermia and Gross Thermal Effects

Numerous biological and pathophysiological effects have been attributed to temperature increases in the tissue resulting from absorption of microwave energy. Thermal effects leading to gross injury or death have been studied in a number of experimental animals and are described here. More subtle effects of thermal origin, caused by absorption of microwave energy will be described in later sections

The absorption of microwave energy often results in an increase in temperature. If the rate of increase exceeds the ability of the thermoregulatory system of the organism to dissipate heat, hyperthermia will occur, followed by injuries such as burns, haemorrhage, tissue necrosis (Cleary, 1978), and death. The extent of the damage depends on the thermal sensitivity of the tissue. With partial body exposure, highly vascularized tissues show greater resistance to thermal damage, because of the more efficient heat dissipation. Microwave-induced death in an experimental animal depends not only on the quantity of absorbed energy but also on the rate of absorption, the animals thermoregulatory system, its physiological status, and the environment. Quite different responses to microwave exposure have been observed in various species. Table 10 gives the survival times of various experimental animals following prolonged continuous exposure to microwaves at different frequencies.

Dogs exposed to microwaves at frequencies of 2.86 GHz, 1.28 GHz, and 200 MHz (Michaelson, 1971, 1973) and a power density of 165 mW/cm^2 experienced three distinct phases of hyperthermia. First, the body temperature increased by 1-1.4°C after about 30 min (the extent of the delay depending on the exposure frequency). Second, at thermal equilibrium which lasted about 1 h (longer at lower frequencies), the rectal temperature stabilized at between 40.5°C and 41°C. Finally, the thermoregulatory system could not dissipate the heat rapidly enough, the rectal temperature quickly rose above 41°C, and the animal succumbed. Similar thermal responses have been

Table 10. Power densities and exposure times until thermal death in a number of animal species at various frequencies[a]

Species	Power density mW/cm^2	Exposure time min	Frequency MHz	Rectal temperature increase °C	Reference
dog	350	15	200	5	Addington et al. (1958)
	330	15	200	4	Michaelson (1971)
	220	21	200	4	Addington et el. (1958)
	165	270	22 800	4-6	Ely & Goldman (1956)
rabbit	300	25	2 800	6-7.5	Ely & Goldman (1956)
	165	40	2 800	> 4	Michaelson (1971)
	165	30	200	6-7	Ely et al. (1954)
	100	103	3 000	4-5	Gordon (1966)
rat	400	13-14	10 000	7	Gordon (1966)
	300	15	3 000	8-10	Gordon (1966)
	300	15	24 000	5	Ely & Goldman (1956)
	150	15	2 400	-	Michaelson (1971)
	100	25	3 000	6-7	Gordon (1966)
	100	5-120	mm--dm	-	Gordon (1966)
	80	35	2 400	-	Michaelson (1971)
	80	56	24 000	-	Deichmann (1966)
	50	80	24 000	-	Deichmann (1966)
	40	90	3 000	7	Gordon (1966)
	40	30-180	mm--dm		Gordon (1966)
	30	135	24 000	-	Deichmann (1966)
	10	> 5 h	mm--dm	-	Gordon (1966)
mouse	180	3	24 000		Deichmann (1966)
	150	5	24 000		Michaelson (1971)
	80	13	24 000		Deichmann (1966)
	80	13	24 000		Michaelson (1971)
	50	35	24 000		Deichmann (1966)
	50	35	24 000		Michaelson (1971)
	30	140	24 000		Deichmann (1966)

[a] "Adapted from: Baranski & Czerski (1976).

described for dogs with body weights between 4 and 20 kg. No period of thermal equilibrium was observed in rats and rabbits exposed at the same power density (165 mW/cm^2) (Michaelson, 1973).

Table 11 gives the survival time of rats exposed intermittently to 24 000 MHz microwaves at 300 mW/cm^2. These data provide information on a situation corresponding to exposure to a rotating antenna. This type of intermittent exposure prolongs the survival time of the irradiated animals.

Table 11. Survival time of rats following intermittent exposure to 24 000 MHz microwaves at 300 mW/cm^2 depending on the relationship between duration of exposure period and duration of exposures on-off[a]

Operation period of	Survival time equal to effective

the transmitter (s)		irradiation time (min)
on	off	
60	60	16.5
5	15	28
3	3	40
30	60	39
10	20	65
3	6	95
60	180	28
10	30	76
3	9	110 to 120
30	120	70 to 75
15	60	Over 100

[a] From: Baranski & Czerski (1976) based on Deichmann et al. (1959).

Table 12 provides a summary of data (Baranski & Czerski, 1976) on the mass, body surface, and basal metabolic rate of commonly used experimental animals. These data can be used to compare the experimental results of a microwave-induced thermal load with the animal's ability to dissipate heat (its thermoregulatory system).

Table 12. Mass, body surface and metabolic rate in various experimental animals[a]

	Man	Dog	Rabbit	Monkey	Guineapig	Rat	Mouse
Mass (kg)	65	15.0	3.5	3.2	0.8	0.2	0.02
Body surface (m^2)	1.83	0.85	0.2	0.26	0.071	0.081	0.085
Basal metabolic rate (W/m^2)	45.5	46.0	40.5	30.5	33.7	45.2	26.2

[a] From: Baranski & Czerski (1976).

In the results presented in Table 10, it was generally assumed that the area of the species exposed was approximately one third of the body surface, the incident energy was totally absorbed, the heat dissipation index was 12 $W/m^2/°C$, and that the initial temperature difference between body surface and surrounding air was 10°C.

Environmental conditions can influence the thermal response (Baranski et al., 1963; Michaelson, 1971). At an ambient temperature above normal (40.5°C), the animal's thermoregulatory system can maintain a normal body temperature, but is not able to cope with an additional thermal load produced by microwave exposure. However, at a lower ambient temperature (11°C), after an initial period of adaptation, the microwave radiation does not significantly affect the animal's rectal temperature (Michaelson, 1973).

The influence of environmental conditions on hyperthermia induced by microwave radiation exposure can be summarized as follows: (a) increasing ambient temperatures and humidity enhance thermal stress; and (b) increased air velocity decreases thermal stress.

In a study by McLees & Finch (1973) in which rats were exposed to 24 GHz and 300 mW/cm^2, it was shown that body cover also affected hyperthermia. Animals with and without hair died within 15.5 and 18.5 minutes, respectively, indicating that clothing could be expected to enhance the thermal effects of radiation, unless such clothing shielded from, or reflected microwave energy.

When dogs were anaesthetized using sodium pentobarbital, chlorpromazine, or morphine, impaired thermoregulatory responses and increased susceptibility to radiation thermal stress were observed (McLees & Finch, 1973; Baranski & Czerski, 1976).

Repeated exposure resulted in physiological adaptation via the classical sequence of stress-adaptation-fatigue. Daily exposure of dogs to 1280 MHz microwaves for 6 h per day, 5 days per week, for one month at a power density of 100 mW/cm^2, resulted in an increase in rectal temperature with each exposure during the first week. During the following 3 weeks, temperature increases were moderate, and a progressive reduction in the pre-exposure temperature was observed as the number of exposures increased (Michaelson, 1973). These results have been confirmed for other species (Gordon, 1966; Phillips et al., 1973).

The blood circulation was considered to be an effective system for distribution of the heat generated throughout the body (Michaelson, 1971), and until recently, the thermal effects of microwaves in animals were mainly considered in terms of "volume heating". Guy and

his associates (Guy, 1971, 1974; Johnson & Guy, 1972) using phantom models, developed elegant thermographic techniques and demonstrated convincingly very nonuniform deposition of microwave energy, expected to result in nonuniform deep body heating. In physiological terms, this means that absorbed energy may cause local thermal stimulation or gross effects on different organs depending on the exposure level.

7.2 Effects on the Eye

Studies on the effects of microwave radiation on the eye were carried out as early as 1948 (Richardson et al., 1978). Most animal studies have been conducted on the New Zealand white rabbit because its eye is similar to the human eye.

Investigations to determine cataractogenic radiation levels and lengths of exposure at various frequencies have been conducted in both the far and near fields. In far-field studies, the whole of the body of the animal is exposed but, in some cases, this results in the animal's death. Near-field techniques involve exposing the eye at some distance from the source and permitting air to circulate against the eye, or exposing the eye by direct contact with a source of microwave energy, so that there is no air circulation. The conditions of exposure have a considerable influence not only on the development of cataracts but also on their location in the eye. When air circulation is permitted, the exposure causes opacities to develop in the posterior subcapsular cortex of the lens. Without an air gap, opacities develop in the anterior subcapsular cortex (Carpenter et al., 1974b).

Guy and his colleagues (1975b) have recently determined threshold power density levels and durations of exposure for cataract formation in rabbit eyes with a single exposure to 2.45 GHz near-field radiation. Their results are in good agreement with earlier data obtained by Carpenter and his co-workers (1974b) as shown in Fig. 13. At 2.45 GHz, the maximum temperatures occurred near the posterior

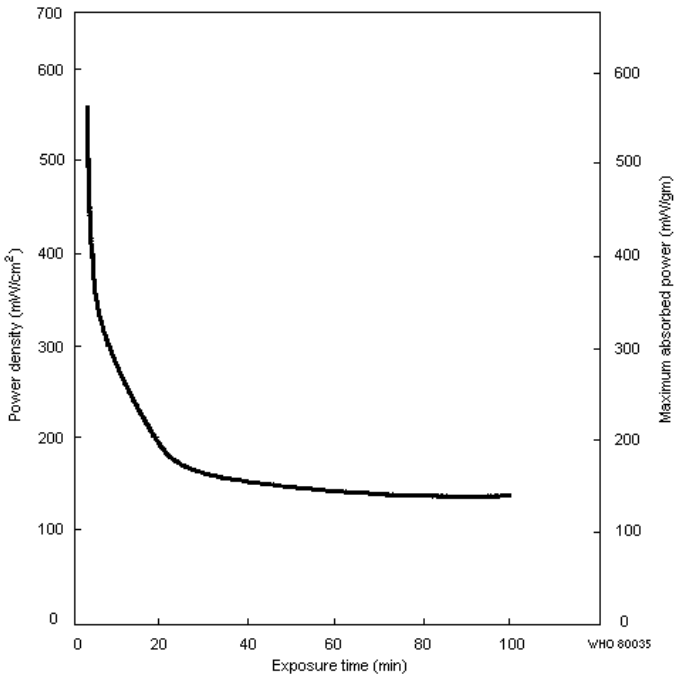


Fig. 13. Threshold time and microwave power density levels for the production of cataracts in rabbits' eyes by single exposure to nearfield 2.45 GHz radiation. From: Guy et al. (1975b).

surface of the lens, and irreversible changes in the lens took place in the posterior cortical area only. Other changes in the exposed eye were found to be transient in nature and disappeared within two days of irradiation. The minimum power density level at which cataracts were formed appeared to be 150 mW/cm^2 for 100 min corresponding to a maximum specific absorption rate in the vitreous body of 138 W/kg. The threshold temperature in the eye for cataract formation was estimated to be about 41°C (Guy et al., 1975b).

To investigate the mechanism by which microwaves produce cataracts at 2.45 GHz, rabbits were subjected to general hyperthermia and local heating of the lens (Kramer et al., 1976). Rabbits, under general hyperthermia, were kept at a temperature above 43°C for 35 minutes. After 4-6 months, the only cataracts observed occurred in eyes damaged by insertion of the temperature probes. The authors concluded that basic differences occur when heating by means of microwave energy and by convective hyperthermia. Eyes irradiated with microwaves show a characteristic temperature gradient, with the highest temperature

behind the lens, whereas in hot bath experiments, the highest temperature occurs at the surface of the cornea. Further high-level microwave exposure raises the eye temperature within minutes, compared with at least 2 h in the hot water bath. Thus, a sharp temperature gradient and a high rate of heating rather than gradual, more uniform heating may be necessary to produce cataracts (Kramer et al., 1976).

In studies to investigate the relative cataractogenic effects of exposure to two frequencies, 2.45 and 10 GHz, a special dielectric lens was used to irradiate the eyes of New Zealand white rabbits, selectively. With a constant power density, exposure to 10 GHz induced a higher intraocular temperature than exposure to 2.45 GHz. However, when the animals were exposed to these frequencies for the same length of time, cataracts were induced at lower power densities at 2.45 GHz than at 10 GHz (Table 13). Although opacities formed in the posterior subcapsular cortex of the lens at both frequencies, their initial appearance and subsequent development differed. Radiation at 2.45 GHz induced posterior cortical banding within 1 or 2 days, followed by the appearance of small granules along or on the horizontal line of the posterior suture. Occasionally small vesicles developed. Some opacities also had a fibrillar, cotton-like appearance, and superficial damage, such as pupillary constriction and hyperaemia of the bulbar and palpebral conjunctiva was observed within 24 hours (Hagan & Carpenter, 1976).

In one of the very few investigations of chronic, low-level exposure of rabbits' eyes (2 mW/cm^2 for 8 h per day, 5 days a week, for 8-17 weeks at 2.45 GHz), ocular changes were not observed up to 3 months after termination of exposure (Ferri & Hagan, 1976).

Table 13. Production of cataracts in the eyes of rabbits by a single 30-min exposure to 2.45 GHz or 10 GHz

	2.45 GHz		10 GHz	
Incident power density (mW/cm^2)	Number of experiments	Development of lens opacities (%)	Number of experiments	Development of lens opacities (%)
275	12	8	--	--
295	12	67	--	--
310	12	58	12	0
325	12	100	--	--
345	2	100	12	50
375	--	--	12	67
410	--	--	11	82
440	--	--	2	100

[a] From: Hagan & Carpenter (1976).

When the cataractogenic power density levels for continuous wave and pulsed radiation were compared at a few frequencies, no differences in the threshold levels for cataractogenesis were found (Carpenter & Van Ummersen (1968); Carpenter (1969); Birenbaum et al. (1969); Williams & Finch (1974); Weiter et al. (1975). The average power density, not the peak power density, appears to be the critical field parameter in cataract induction.

Most authors including Belova (1960), Carpenter et al. (1974b), Paulson (1976), Kramer et al. (1978) and Steward-Dehaan et al. (1979) have tended to relate microwave cataracts to the secondary effects of local temperature increase. The conventional view is that, as the crystalline lens does not have its own blood supply, it is easily overheated with consequent damage to capsular cells and denaturation of the protein in the lens.

Studies have been performed to determine if cataracts can be formed by an accumulation of exposures at subthreshold levels. In one experiment, rabbits' eyes were exposed for 3 min to 2.45 GHz radiation at a power density of 280 mW/cm^2 (5 min exposure was required to induce a cataract after a single exposure). When the 3-min exposure was given once a day for 5 days, the animals developed cataracts. However, if the eyes were exposed under the same conditions, but with a break of 7 days between exposures, cataracts did not develop

(Carpenter, 1969). In an earlier study, rabbits' eyes were exposed to 2.45 GHz at a power density of 80 mW/cm^2 for 60 min daily, for 10 or 15 days (Carpenter & Van Ummersen, 1968). Cataracts appeared 1-6 days after treatment. However, the authors later indicated that the power density measurement was inaccurate and that subsequent measurements showed that the actual power density was greater than 80 mW/cm^2.

Paulsson et al. (1979) studied the eyes of rabbits exposed to 3.1 GHz pulsed (pulse length 1.4 µs, repetition frequency 300 Hz) radiation at an average intensity of 55 mW/cm^2 (1.3 MW/m^2 peak) either to single exposures of 1-1´ h or, after a series of repeated 1-h exposures, for up to 53 h during 100 days. Degenerative changes in the retinal neurons and synaptic boutons, and reactive changes in

glial cells were observed only following the repeated exposures. No evidence was found of increased permeability of the blood-retina barrier.

Effects of millimetre waves (35 and 107 GHz) at power densities ranging from 5 to 60 mW/cm^2 for 15 min-1 h were investigated in rabbit eyes by Rosenthal et al. (1976). Corneal damage and epithelial and stromal injury were observed. Stromal injury appeared at lower power densities (5 mW/cm^2) at a frequency of 107 GHz than at 35 GHz, but it was concluded that keratitis (inflammation of the cornea) was a useful criterion for ocular response to millimetre radiation. Keratitis occurred at lower power densities than those required to produce other ocular effects such as iritis or lenticular injury. The recovery rate from stromal injury depended on the frequency of the radiation and was faster after exposure to 107 GHz.

The following conclusions on the effects of microwave radiation on the eye can be drawn from these and other data from literature reviews:

(a) Above 500 MHz, opacities of the eye may be produced when power densities exceed 150 mW/cm^2, if the duration of exposure is sufficiently long;

(b) Although ocular injury has not been reported at frequencies below 500 MHz, its possibility cannot be excluded;

(c) The frequency of the microwave radiation influences the type and location of the injury to the eye;

(d) Exposure conditions, namely whether in the near field or far field, whole body or selective exposure of the eye, eye exposure with or without an air gap (to provide cooling), and the temperature of the animal's body, all influence the power density and duration of exposure needed to produce eye injury.

(e) Injury to the eye from microwaves appears to be predominantly thermal in nature, temperature gradients within the eye and the rate of heating being two major factors in the stress that leads to injury. Non-thermal effects cannot be excluded but they alone do not appear to be sufficient to produce effects in the eye, although they may provide a necessary mechanism of interaction.

(f) As can be seen in Fig. 13 (p. 55) the threshold curve of power densities versus time to produce eye cataracts is not linear. Exposure of the eye at each frequency seems to require a threshold microwave power density below which even continuous exposure does not produce eye injury. This would appear to exclude the possibility of cataractogenesis caused by low level chronic exposure, and this was confirmed in a recent experiment (Ferri & Hagan, 1976).

(g) Pulsed and continuous wave radiation with the same average power density level seem to possess the same potential for cataract induction. However, effects from pulsed radiation with a small duty factor and high peak power cannot yet be excluded;

(h) Cataracts can be produced by repeated exposures to sub-threshold power density levels. For this cumulative effect to occur, the levels have to be sufficiently high that a slight but persistent injury is not fully repaired before another exposure takes place. However, if the time between exposures is sufficiently long for repair to take place, cumulative damage is not observed.

7.3 Neuroendocrine Effects

Interaction between the endocrine and nervous systems is very important to the functioning of the human body. The hypothalamus within the brain is a control centre involved in the regulation of the autonomic nervous system, including such visceral functions as temperature control within the whole body. This gland, coordinated by the central nervous system (CNS), releases specific factors into the pituitary portal system, which regulate hormones released by the endocrine organs. The endocrine system can be considered as a feedback control system where the hypothalamus, via the pituitary, causes hormones to be secreted by endocrine glands. Once the endocrine hormones have reached a certain level, this information is fed back to the pituitary and hypothalamus, causing a reduction or cessation in hormone secretion. The system's actions are modified by direct neural inputs from higher brain centres and peripheral nerves.

Descriptions of the biochemical and neuroendocrine aspects of exposure to microwaves can be found in recent reviews by Michaelson et al. (1975) and Cleary (1977).

Dogs exposed to 3 GHz microwaves at 10 mW/cm^2 showed a substantial increase (100%-150%) in corticosteroid levels, a decrease in blood potassium, and an increase in blood sodium content (Petrov & Syngajevskaja, 1970). The increase in the corticosteroid levels during and after irradiation may have been an adaptive reaction, since in some animals the adrenocortical function becomes inhibited and sensitivity to microwave radiation increases because of insufficient

release of adrenocorticotropic hormone (ACTH).

Dumanskij & Sandala (1974) found that chronic low-level exposure of rats and rabbits to 3 cm, 12 cm, and 6 m microwaves at 10 μW/cm^2 and below, for 8-12 h per day, for 120 days, reduced cholinesterase and increased 17-ketosteroid levels in the urine during the 60 days following irradiation. A reduced amount of ascorbic acid in the adrenal glands and reduced adrenal gland weight were also observed. Syngajevskaja et al. (1962) exposed dogs and rabbits (162 animals) to decimeter waves at 70 mW/cm^2 for 30 min and reported increases in the ascorbic acid concentration in the adrenals, while exposure at 5 mW/cm^2 for 30 min caused it to decrease. Changes in glucose levels in the blood and variations in liver glycogen content were observed; lactic acid levels were also affected. It has been suggested that a whole body rise in temperature caused by microwave exposure suppresses the hormone-producing functions of the anterior pituitary and adrenals, while exposures not resulting in an increased rectal temperature enhance hormone production (Petrov & Syngajevskaja, 1970).

No significant alterations were observed in growth hormone or thyroxine levels in barbiturate-anaesthetized dogs, cranially exposed to 2.45 GHz microwaves at various power densities (20-80 mW/cm^2) for 1 h (Michaelson et al., 1975). When rats were exposed (whole body) for 1 h to 2.45 GHz microwaves at 9 mW/cm^2 an increase in growth hormones was observed, but at 36 mW/cm^2 exposure, a significant decrease was noted (Syngajevskaja et al., 1962).

The thyroid activity in rats exposed to 2.45 GHz microwaves at 1 mW/cm^2 for 8 h per day for 8 weeks was studied by Milroy & Michaelson (1972). No structural or functional changes were detected, other than those that could be attributed to microwave-induced thermal stress. In contrast, Baranski et al. (1973) reported that rabbits exposed to 10 cm microwaves at 5 mW/cm^2 showed increased thyroid activity. Mikolajczyk (1977) suggested that these differences in results were due to the experimental procedure and conditions rather than the differences in species.

When rats were exposed to 2.45 GHz microwaves at 10, 15, 20, and 25 mW/cm^2 for 4, 16, and 60 h (i.e., 64 h with two 2-h breaks), Parker (1973) found that the iodine-concentrating ability of the thyroid serum, protein-bound iodine levels, and thyroxine increased slightly at 10 mW/cm^2, but decreased at 20 and 25 mW/cm^2 during the 16-h exposure. Exposure at 15 mW/cm^2 for 60 h resulted in a decrease in protein-bound iodine and thyroxine, and a decrease in the ability to concentrate iodine.

When male rats were exposed to 2.87 GHz radiation at 10 mW/cm^2 for 6 h per day, 6 days per week for 6 weeks, there were no significant differences between the average body and organ weights of irradiated and control animals (Mikolajczyk, 1977). Although the levels of growth hormone in the anterior pituitary were the same in both groups of rats, a significantly higher level of luteinizing hormone (LH) was found in the irradiated animals. It was suggested that changes in the LH activity might be due to the influence of microwave exposure on the pituitary, or on hypothalamic function or on both.

Various animal studies in which neuroendocrine effects have been reported following exposure to low intensity fields are summarized in Table 14. Baranski & Czerski (1976) state in their review of endocrine effects that it is extremely difficult to sum up the evidence. All aspects of microwave interactions reported need further investigation concerning both the cause and dose dependence of the effects described and the mechanisms involved. However, it could be stated that:

(a) Microwave radiation induces endocrinological changes that may be due to stimulation of the hypothalamic-hypophyseal system, through thermal interaction at the hypothalamus, or immediately adjacent levels of organization, the pituitary, the particular endocrine gland, or the end-organ.

(b) Since the neuroendocrine system is homeostatic, transient neuroendocrinological changes should not be equated with pathological alterations.

(c) Sufficient data are available to indicate that the response of the neuroendocrine system to microwaves depends on the frequency, power density, the duration of exposure, and the part of the body exposed.

(d) The nonuniform distribution of microwave energy within the body seems to be an important factor affecting the response of the neuroendocrine system.

(e) Several components of the neuroendocrine system are critically sensitive to environmental temperature, thus low-power density, microwave-induced effects could result from sensitivity to small changes in temperature.

(f) From available data, it would seem that direct interaction of microwaves with components of the neuroendocrine system cannot be excluded.

Table 14. Neuroendocrine effects of exposure to low intensity fields[a]

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
10 cm, cw; 0.01, 1, 3, 10, 20 & 150 mW/cm^2; 1 h/day, single or repeated exposures	endocrine gland hormone levels	rats (in vivo)	Increase in gonadotropic tropic hormones followed by decrease 18 h after exposure at 10 Mw/cm^2 or greater intensities; alteration in hypothalamic function governing the follicle-stimulating hormone (FSH) and luteinizing hormone (LH) release from pituitary; no changes in corticosteroid content of adrenals or blood at 10 mW/cm^2 for 15, 30, or 60 min.	Mikolajczyk (1972)
10 cm, cw; 100 mW/cm^2 10 min exposure/ day for 14 days	adrenal alterations	rats (in vivo)	Initial decrease in Sudan III stain-positive lipids, birefringent substances, & ascorbic acid; Increase in all variables during course of exposure return to normal 2 weeks after exposure.	Leites & Skuricina (1961)

Table 14 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
decimetre waves, 40 mW/cm^2; 1-h daily exposure, prolonged duration.	adrenal cortex alterations, serum electrolytes	rats (in vivo)	No effect on serum Na+ or K+; Increase In $Ca+^2$ and $C--^1$ In serum and urine.	Nikogosjan (1962)
15 mW/cm^2; 60 h up to 60 mW/cm^2; up to 2 h	neuroendocrine responses	rats (in vivo)	Transient changes in plasma corticosterone, growth hormone, and thyroid hormone levels (20-30 mW/cm^3 seemed to be the transitional range for stimulation of pituitary -- adrenal activation); noted effects correlated with temperature increases in endocrine gland.	Michaelson et al. (1977) and Lotz & Michaelson (1978)
2.45 GHz, cw; 1 mW/cm^2; continuous exposure, 8 wk; 10 mW/cm^2, 8 h/day for 8 wk	thyroid function	rats (in vivo)	No structural or functional changes other than those attributable to thermal stress.	Milroy & Michaelson (1972)

Table 14 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
2.45 GHz, cw; 15 mW/cm^2 60 h exposure	thyroid function	rats (in vivo)	23% decrease in protein-bound iodine and 55% decrease in serum thyroxine.	Parker (1973)
2.86-2.88 GHz, cw;	survival endocrine	rats time, (in vivo)	Survival time of hypophysectomized	Mikolajczyk (1974)

10-120 mW/cm^2	function		rats increased at 120 mW/cm^2; 2-week habituation before exposure alterations in corticosterone levels; daily exposures at 10 mW/cm^2 for 1 month did not alter gonadotropins (LH and FSH) but single exposures induced detectable alterations.	
10 cm, cw; 5 mW/cm^2 (free field exposure)	carbohydrate metabolism, skeletal muscle metabolism	rabbits (in vivo)	Changes in serum pyruvic and lactic acid; decrease in skeletal muscle glycogen; altered electromyography indicative of changes in muscle metabolism; altered carbohydrate metabolism.	Baranski et al. (1967)

Table 14 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
10 cm, cw; 5 mW/cm^2 repeated exposure	thyroid function	rabbits (in vivo)	Increased radioiodine uptake, histological & electronmicroscopic signs of thyroid hyperfunction.	Baranski et al. (1973)
10 cm, cw; 50-60 mW/cm^2, 4 h/day	adrenal function	rabbits (in vivo)	Decrease 17-hydroxy-corticosteroid in urine, first 20 exposures; return to normal at day 10 due to adaptation; no changes in 17-hydro-xycorticosteroid in urine.	Lenko et al. (1966)
metre & decimetre waves; 70 mW/cm^2; 30 min	endocrine function	dogs, rabbits (in vivo)	Increased adrenal ascorbic acid concentration following 70 mW/cm^2, decrease following 5 mW/cm^2, thermal intensities suppress pituitary & adrenal functions; low-intensity exposure stimulates.	Syngajevskaja et al. (1962)

Table 14 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
1.24 GHz, pw; 360 Hz pulse repetition rate; 2 ms pulse, 50 mW/cm^2; average power; 6 h/day for 6 days	thyroid alterations	dogs (in vivo)	Increased radioiodine uptake 4-25 days after exposure: radio-iodine uptake increased 3-4 years after single 100 mW/cm^2 exposure to 1.28 GHz, pw.	Howland & Michaelson (1959)
2.45 GHz, cw; 20-40 mW/cm^2; 2 h	neuroendocrine responses	dogs (in vivo)	Transient increased mean plasma corticosterone levels, correlated with mean colonic temperature.	Michaelson et al. (1977b)

[a] Adapted from: Cleary (1978).

7.4 Nervous System and Behavioural Effects

Microwave radiation effects on the central nervous system and behaviour have been the subject of most controversy in the whole field

of bioeffects. Czechoslovak, Polish, and Soviet investigations on this subject commenced in the early fifties and have been the source of most of the reports on the effects of microwaves on man. Animal studies and clinical and industrial surveys in Czechoslovakia, Poland, and the USSR have been summarized by Marha et al. (1971), Baranski & Czerski (1976), and Presman (1968), respectively. The basic assertion is that exposure to microwaves at low power densities results in neurasthenic disorders in man. Subjective complaints such as headache, fatigue, weakness, dizziness, moodiness, confusion, and nocturnal insomnia have been reported. In small experimental animals, chronic and repeated exposures at incident power densities of 10 mW/cm^2 or less have been reported to lead to disturbances in conditioned reflexes and to behavioural changes (Kholodov, 1966; Presman, 1968; Petrov et al., 1970; Prey, 1971, 1977; Marha, 1971; Lobonova, 1974; Galoway, 1975; Hunt et al., 1975; Serdjuk, 1977; Cleary, 1978). Studies of microwave/RF exposure effects on conditioned and normal reflexes, as well as on behaviour, were carried out on mice, rats, guineapigs, rabbits, dogs, monkeys and in some instances on birds (Romero-Sierra et al., 1974; Bigu-del-Blanco et al., 1975; Bliss & Heppner, 1977).

Numerous reports of the sensitivity of the human CNS to low level microwave exposure have stimulated interest in the subject with a consequent increase in studies on microwave effects on the animal CNS (Cleary, 1977). Investigations have been conducted at various levels of CNS organization and range from studies of isolated nerves (McRee & Wachtel, 1977) to behavioural studies in primates (De Lorge, 1976, 1979). These studies were established to determine if the effects were thermally-induced or were the result of the direct action of microwave-energy on the CNS. The results of many studies can be explained by the nonuniform distribution of thermal energy and/or thermal gradients, but the results of others such as the increase in calcium efflux from cerebral tissue, due to specific amplitude modulation are difficult to explain on the basis of heating.

Disturbances in the bioelectric function of the chick forebrain with calcium efflux were observed following *in vivo* exposure to 147 MHz radiation, amplitude modulated at 9-20 Hz (Bawin et al., 1975). These effects could not be obtained when the frequency of amplitude modulation was between 6 and 9 Hz or between 20 and 35 Hz. A 20% increase in calcium was also observed by Kaczmarek & Adey (1974) in the cat brain after *in vivo* exposure to 10 ms pulsed radiation at 200 Hz, 20-50 mV/cm^2. Further research is needed since these effects may depend on a direct interaction of electromagnetic fields with the cellular membrane (Grodsky, 1975; Straub, 1978; Kolmitkin et al., 1979).

Blackman et al. (1979) recently confirmed the work of Bawin and Adey and their coworkers, in finding that calcium efflux from brain tissue depended on amplitude modulation frequency and power levels. Increased calcium efflux appeared at amplitude modulation frequencies around 9 Hz, peaked from 11-16 Hz, and disappeared above 20 Hz as shown in Fig. 14. It can be said that a "frequency window" exists for this phenomenon. Calcium efflux appears at 0.5 mW/g, reaches higher values at 0.75 mW/g and decreases at 1.0 mW/g. Thus, it can be said that "power windows" also exist. These may shift with frequency (Blackman et al., 1979).

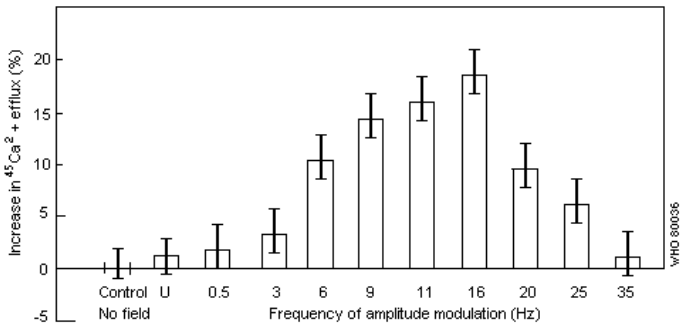


Fig. 14. Effects of amplitude modulated radiofrequency fields (147 MHz) on calcium efflux from isolated forebrain of neonatal chick (From: Bawin et al. (1975).

The electrical activity of the brain, measured by means of an EEG, may be influenced by a wide variety of exposure regimes. Acute single exposures to 40 mW/cm^2 or more, induce transient changes in EEG patterns. Early experimentation in this area has been summed up by Kholodov (1966). Long-term, repeated exposures of dogs, cats, rabbits, rats, frogs, and mice at power densities between 2 and 5 mW/cm^2 were reported to lead to alterations, such as the desynchronization of basal rhythms and later a flattening in EEG tracings (Baranski & Edelwejn, 1968; Bychkov & Dronov, 1974; Bychkov et al., 1974; Gillard et al., 1976). However, these earlier reported effects are questionable since experiments were carried out using EEG electrodes or wires that significantly perturbed the field.

Mice, rats, and rabbits subjected to long-term, low or medium-level (about 1-5 mW/cm^2) exposure were reported to show an increased susceptibility to convulsant drugs (Baranski & Edelwejn, 1968; Servantie et al., 1974, 1975; Krupp, 1977). Detailed analyses of EEG data and results of pharmacological studies indicate that the reticular formation of the midbrain is the structure in which exposure to microwaves and RF may induce effects at low incident power density levels.

The mechanism of changed susceptibility to drugs acting on the nervous system, particularly convulsant drugs, after repeated microwave exposures is unclear. On the other hand, as the action of many drugs is well understood, the phenomenon may serve to clarify mechanisms of action of microwave and RF radiation on the nervous system (Czerski, 1975). The phenomenon has practical implications in the case of the medication of microwave workers.

Structural changes in the nervous tissue of rabbits and hamsters which were demonstrable by electron and light microscopy, were reported following single exposures to 2450 MHz microwaves at power densities of 25-50 mW/cm^2 (Baranski, 1967; Baranski & Edelwejn, 1979; Albert & De Santis, 1975; Albert, 1979). In their study on rabbits subjected to single or repeated exposures to continuous or pulsed microwaves (2950 MHz), Baranski & Edelwejn (1974) did not find any effects on acetylcholinesterase activity after long-term exposure (2 h/day for 3-4 months to 3.5-5 mW/cm^2).

Brain hyperaemia, pyknosis, and vacuolization of nerve cells were observed in rats repeatedly exposed for 75 days to 3- and 10-cm microwaves at high power densities (40-100 mW/cm^2) (Tolgaskaya et al., 1962; Tolgaskaya & Gordon, 1973). These effects were less pronounced following exposures at 10-20 mW/cm^2 and with exposure to 3-cm microwaves compared with 10-cm microwaves at the same power density. The effects were reversible, several days after termination of the experiment.

The blood-brain barrier of rats may be affected by pulsed and continuous wave microwave radiation at 1.2 GHz (Frey et al., 1975). A single exposure of 30 min at an average power density of 0.2 mW/cm^2 pulsed and 2.4 mW/cm^2 continuous wave radiation led to an increase in permeability. In another study on rats, Oscar & Hawkins (1977) found temporary alterations in permeability following single 20-min exposures to 1.3 GHz radiation at power densities of about 1 mW/cm^2 pulsed and 3 mW/cm^2 cw. Many other investigators including Merrit (1977) and Sutton & Carrell (1979) were unable to reproduce these experimental results.

In studies by Wachtel et al. (1975), exposure of individual neurons to 1.5 GHz and 2.45 GHz microwave radiation at a dose rate of approximately 10 mW/g had a marked effect on the firing pattern of Aplysia neurons. Although heating may have been partially responsible, the authors suggest that other factors are needed to explain the effect. Rectification of the applied field in nerve tissue could explain the observed effects.

The threshold power density required to evoke potentials in the brain stem of cats using nonperturbing electrodes was found to be approximately 0.03 mW/cm^2 with a peak of 60 mW/cm^2 for frequencies between 1.2-1.5 GHz (Frey, 1967).

Stverak et al. (1974) found that rats having an inherent predisposition to epileptic seizure after sound stimulation showed reduced sensitivity of this phenomenon following long-term (4 h/day for 10 weeks) exposure to 2850 MHz radiation, pulsed for 10 µs, repetition frequency 769.2 Hz, at an average power density of 30 mW/cm^2.

Behavioural perturbations in rats in the form of work stoppage have been reported by Justesen & King (1970) and Lin et al. (1979). Exposure of hungry unrestrained rats to 2.45 GHz microwaves at a dose rate of approximately 9 mW/g caused stoppage of work for food after 20 min of exposure in a multimode cavity (Justesen & King, 1970). With restrained rats irradiated with near-field radiation at 918 MHz, the threshold dose rate for the effect was 8 mW/g (Lin et al., 1979). It was calculated by Justesen (1978) that an integral dose between 8 and 10 J/g was required for work stoppage in hungry rats, e.g., 23 min exposure to an average power density of 20 mW/cm^2 at 600 MHz (resonant frequency for the rat) or 46 min exposure to the same power density at 400 MHz. The work stoppage was found to be related to the specific absorption rate, suggesting a thermal basis for the effect.

In studies by Moe et al. (1977), rats exposed for 210 h to 918-MHz radiation at 10 mW/cm^2 showed decreased locomotor activity and food intake. This behavioural change could be attributed to thermal loading, even though the animals were not under hyperthermic stress.

The effects on exploratory activity, swimming, and discrimination involving a vigilance task were studied in rats exposed to 2.45 GHz pulsed radiation (Hunt et al., 1975). A dose rate of 6 mW/g caused a

moderate decrease in the level of exploratory activity and swimming speed. The results were attributed to fatigue from thermal overexposure, since the effect on vigilance discrimination was observed to be directly related to induction of and recovery from hyperthermia. Nearly lethal radiation (11 mW/g) initially produced a marked degradation in performance, but the rats returned to the trained level of proficiency after 1 h.

Microwave radiation was found to affect the behaviour of rats conditioned to respond to multiple schedules of reinforcement (Thomas et al., 1975). Exposure for 30 min to 2.86- and 9.6-GHz pulsed radiation, and to 2.45-GHz cw radiation just before experimental sessions at power densities exceeding 5 mW/cm^2 caused significant alterations in behaviour.

Roberti et al. (1975) did not find any difference in the spontaneous motor activity of rats after exposure for periods totalling 408 h to 10.7- and 3-GHz microwaves at power densities ranging from 0.5 to 26 mW/cm^2. Classical Pavlovian methods were used by Svetlova (1962) and Subbota (1972) to investigate reflex and conditioned reflex actions in microwave-irradiated dogs, by determining the time of initiation of saliva secretion following the conditioning stimulus, the latency time, and the number of drops secreted. After lateral exposure to 10-cm microwaves for 2 h at power densities ranging from 1-5 mW/cm^2, the intensity of the response increased on the opposite side, and the latency time was shortened. However, following 70 h of exposure in 35 days (2 h/day), the conditioned responses became identical to those before irradiation showing that a gradual adaptation of the dogs' responses to successive microwave exposures occurred.

Galloway (1975) investigated the effects of 2.45 GHz cw microwave exposure on discrimination and acquisition tasks in trained rhesus monkeys. The heads of the animals were exposed directly with energy deposited at rates ranging from 5 to 25 W (for a 1.2 kg head the resulting average dose rate was between 4 mW/g and 21 mW/g). Before testing, the monkeys were given a dose of 2.5 J/g over 2 min. Convulsions occurred in all animals irradiated at 25 W and in some at 15 W, an integral dose approaching 25 J/g (the dose required to produce convulsions (Justesen, 1978)) was given. It is apparent that hot spots were produced in the monkey's brains to induce this effect. Exposure to 10 W for 5 days, for 40 min per day did not produce any performance deficit, even in animals suffering from skin burns and severe convulsions caused by exposure to high power radiation.

The performance of a vigilance task was investigated in rhesus monkeys after whole body exposure to 2.45 GHz far-field radiation. Behaviour was not disrupted provided that increases in colonic temperature did not exceed 1°C. With a 1-h exposure, the threshold of behavioural disruption was 70 mW/cm^2 (De Lorge, 1976).

Exposure to continuous wave microwave radiation of 1.2 GHz at average power densities of 10-20 mW/cm^2 did not affect skilled motor performance in monkeys even when the animals were positioned for maximum energy deposition in the brains and subjected to three 2-h periods of exposure (Scholl & Allen, 1979).

A number of studies including some of those already discussed and others for comparison are summarized in Table 15. The results obtained by different investigators vary according to exposure conditions and the end-point investigated. Interpretation of these observations is difficult since many observations are either controversial or contradictory. Data tend to be better substantiated at power densities above 5-10 mW/cm^2.

In 1961, Frey reported the sensory effect of "microwave hearing". Man perceives an audible clicking or buzzing sensation on exposure to pulsed radiation at low power densities. He (Frey, 1971) considered that the effect was caused by direct neural stimulation but later studies by Foster & Finch (1974) and Chou et. al., (1977) have strongly indicated that an electromechanical interaction occurs due to thermal expansion. The threshold of microwave hearing is approximately 10 mJ/g per pulse and is independent of the pulse width for pulses of less than 30 microseconds (Guy et al., 1975a). Microwave hearing is now thought to be caused by a small but fast rise in temperature which, by thermal expansion, generates a wave of pressure exciting the cochlea.

To summarize, it can be stated that studies on the effects of microwaves/RF radiation on the nervous system indicate that exposure at low-power densities appears to induce detectable changes in some cases (Cleary, 1977). While there seems to be evidence that, at sufficiently high intensities (above 1-5 mW/cm^2), nonuniform heating of various critical organs takes place in experimental animals, it is not possible at present to exclude other mechanisms. Furthermore, it is difficult to evaluate the significance of microwave-induced behavioural effects because of the general lack of quantitative correlations between thermal effects at low power densities and responses at the physiological or psychological levels of analysis (Cleary, 1977).

Table 15. Neural effects of exposure to low-intensity fields

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
200 Hz; 10 ms pulsed field; 20-50 mV/cm	cerebral Ca^{+2} efflux	cat-direct cortical stimulation (in vivo)	20 % increase in Ca^{+2} efflux from neurons.	Kaczmarek & Adey, (1974)
147 MHz. AM modulated at 6, 9, 11, 16 Hz; 1-2 mW/cm^2 (closed irradiation system)	cerebral Ca^{+2} efflux	chick fore-brain (in vivo)	Increase in Ca +2 from neurons; no change from unmodulated fields; maximum rate of efflux at 11 Hz and alterations in neuron firing patterns at intensity equivalent to 10 mW/cm^2 free field exposure.	Bawin et al. (1975)
ELF fields, 1-75 Hz; 0.5 to 1 V/cm (closed system irradiation)	cerebral Ca^{+2} efflux	isolated chick and cat cerebral tissue (in vivo)	Suppression in Ca^{+2} release from neurons; biphasic intensity & frequency dependence; maximum effect at 6 and 16 Hz; 0.1 and 0.56 V/cm.	Bawin & Adey (1976)
1.5 and 2.45 GHz, cw and pw (closed irradiation system)	electrical activity of individual neurons	aplysia ganglia (in vivo)	Effects attributed to ganglionic warming, but effects not produced by non-radiation heating.	Wachtel et al. (1975)

Table 15 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
2.45 GHz, cw	functional alterations in neuronal elements	spinal cord of cat (in vitro)	Alteration in evoked potentials also produced by non-radiation heating but with change in timing.	Taylor & Ashlemen, (1975)
3 GHz, pw; 5 mW/cm^2; pulse repetition rate 500-600 Hz (free field exposure)	electrical activity of cortical neurons	rat (in vivo)	10-day exposure resulted in synchronization of electronic frequency; synchronization persisted for hours after exposure.	Servantie et al. (1975)
2.45 GHz, cw, 0.3-1500 mW/g, pw; 0.3-2.2 × 1055 mW/g temperature controlled exposure (closed system irradiation)	synaptic transmission; neural function	rabbit vagus nerves, superior cervical ganglia; rat diaphragm muscle (in vitro)	No changes other than those thermally-induced.	Chou & Guy (1975)
3.1 GHz; pw 10-400 W/kg Mean 5 × 10^4 to 2 × 10^6 W/kg peak temperature controlled exposure (free space irradiation)	axonal transport & microtubules	rabbit vagus nerve & brain extracts (in vivo)	No effects.	Paulsson et al. (1977)

Table 15 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
decimeter waves; 0.5 mW/cm^2 (free space irradiation)	neurotransmitter release	rabbit (in vivo)	Decreased acetyl-cholinesterase (ACHE) activity.	Syngajevskaja, et al. (1962)
10 cm. 0.5 mW/cm^2	neurotransmitter	rabbits &	No alteration cau	

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(free space irradiation)	release in brain	guineapigs (in vivo)	by 8-month exposure to 1 mW/cm^2; with 3-h exposure to 3.5 mW/cm^2, no cw effect but pw decreased AChE activity in guineapigs; after 4 months exposure, there was a decrease with cw and an increase with pw; midbrain most affected; lipid & nucleoprotein metabolism altered in rabbit.	
1.6 GHz; 80 mW/cm^2 environmental temperature (free space irradiation)	neurotransmitter release in brain	rats (in vitro)	10-min exposure led to 4 °C rectal temperature rise in irradiated and heated controls; hypothalamic evarternol (nore-pinephrine) decreased in both groups; serotonin decreased in hippocampus of irradiated animals only.	Merrit et al. (1976)

Table 15 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
1.7 GHz, cw; 10 and 25 mW/cm^2 (free space irradiation)	histological alterations in brain	Chinese hamster (in vitro)	30-120 min exposure led to cytopethological effects In hypothalamic and subthalamic neurons; no effect on other brain regions or on glial cells; no repair evident dent 14 days after exposure.	Albert & DeSantis (1975)
960 MHz, cw; 2-10 mW/g (closed system irradiation)	heart rate	isolated turtle heart (in vitro)	Bradycardia due to alteration in neuro-transmitter release; biphasic intensity response.	Tinney et al. (1976)
10.5 cm, cw; 0.5-10 mW/cm^2; temperature-controlled exposure (free space irradiation)	passive and dynamic electric parameters	skeletal muscle, South American frog (in vivo)	Differential effect of microwave exposure on dependent variable time constants; muscle cells of summer frogs more sensitive than those of winter frogs.	Portela et al. (1975)
3 & 10.7 GHz, cw; 0.-526 mW/cm^2 408-h exposure (free field exposure)	behavioural modification (spontaneous motor activity)	rat (in vivo)	No effects on spontaneous motor activity.	Roberti et al. (1975)

Table 15 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
9.4 GHz, pw; 2.3 mW/cm^2 & 0.7 mW/cm^2 average; 2 week exposure (free field exposure)	behavioural modification (free field spontaneous behaviour)	rat (in vivo)	Control results: decrease in locomotor activity, & vigilance: increase in exploratory activity; exposed results: increased exploratory activity (slower than controls); increase then decrease in vigilance, uniform locomotor.	Gillard et al. (1976)
2.45 GHz, pw; 5, 10, 15 mW/cm^2, 30-min exposures (free field exposure)	behavioural modification (fixed consecutive number switching	rat (in vivo)	Dose-dependent increase in the frequency of premature switching alteration (in the perceptio	Thomas et al. (1975)

	frequency)			
2.45 GHz, cw; 4-72 mW/cm^2; 30, 60, 120-min exposures (free field exposures)	behavioural modification (auditory vigilance task)	rhesus monkey (in vivo)	Vigilance performance not affected by exposure.	De Lorge (1976)

Table 15 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
2.45 GHz, cw; 2-min exposure, 5-25 W output (applicator exposure of head)	behavioural modification (discrimination and repeated acquisition)	rhesus monkey (in vivo)	Convulsions induced at 15 and 25 W; irradiation 40 min/ day for 5 days did not produce any behavioural effects at less than 15 W; no low-intensity effects.	Galloway (1975)
9.3 GHz, cw; 0.7-2.8 mW/cm^2, 5-min exposure (free field exposure)	amplitude of cortical brain waves in anaesthseized animals (pentobarbital)	rabbit (in vivo)	Atypical arousal phenomena, 3-12 min after exposure, followed in 3-5 min by longer period of arousal; atypical behaviour.	Goldstein & Sisko (1974)
2.45 and 1.7 GHz, cw & pw; 5-50 mW/cm^2 (free field exposure)	duration of pentobarbital-induced sleeping time	rabbit (in vivo)	Dose-dependent analeptic effect.	Cleary & Wangemann (1976)

Table 15 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
3 GHz, pw; 5 mW/cm^2 (free field exposure)	effects of drugs on CNS	mice (in vivo) rats (in vivo) and (in vitro)	Exposure delayed onset of pentetrazol-induced convulsion during first 15 days of exposure, reduced latency after 15 days; decreased susceptibility to curare-like drugs in in vivo and in vitro systems.	Servantie et al. (1974)
Occupational microwave & RF exposure	CNS drug tolerance (cardiazole)	human subjects (in vivo)	Altered EEG patterns and convulsions in workers with over 3 years microwave exposure (similar results reported in rabbits).	Edelwejn & Baranski (1966) Baranski & Edelwejn (1968)
occupational microwave & RF exposure	CNS functional disorders	human subjects (in vivo)	Transient subjective complaints during first year of exposure; phasic adaptation after 1 year; objective symptoms of neurovegetative disturbances after 5 years of exposure (acrocyanosis, hyper-hydrosis, dermographism, hypotonia tremors.	Petrov (1970)

Table 15 (Cont'd)

Independent variables	Dependent variables	Experimental subject	Results and comments	Reference
3.1 GHz; pw, 55 mW/cm^2, repeated or single 1-h exposure (free space irradiation)	histological alterations in retina	rabbit (in vivo)	Cytopathological effects in the plexiform layers of retina, no effects on photo-receptors; alterations persisted for 3 months after radiation.	Paulsson et al. (1979)

From: Cleary (1978).

7.5 Effects on the Blood Forming and Immunocompetent Cell Systems

Studies have been conducted on the effects of microwave radiation on blood and the immunocompetent system, but the results are frequently contradictory and the reasons for the discrepancies are not always easily identified. For example, in 1962, Prausnitz & Susskind irradiated 100 mice with 9270 MHz microwaves at 100 mW/cm^2 for 9.5 min daily over a period of 59 weeks and reported an increase in white blood cells accompanied by lymphocytosis. It was reported that leukaemia occurred in 35% of exposed mice, compared with 10% of the controls. However, it appears that no attempt has been made to replicate these studies.

A decrease in erythrocytes, leukocytes, and haemoglobin in mice was observed by Gorodeckij, ed. (1964) immediately after exposure to 10 GHz at 450 mW/cm^2 for 5 min, and 1 and 5 days later, while recovery was evident after 10 days. The influence of microwaves on the response of immunocompetent lymphocytes was investigated in mice by Czerski (1975). The animals were exposed to 2.95 GHz microwaves at 0.5 ± 0.2 mW/cm^2 for 2 h per day, 6 days per week for 6 and 12 weeks. During the 2-h exposure, the animals were deprived of food and water and were located in separate cages. After exposure, the animals were immunized with antigen and the immune response determined by the number of antibody-forming cells in the lymph nodes. Significant differences were found between the control group and the group exposed for 6 weeks, but not the group exposed for 12 weeks. The author attributed this result to adaptation. In nonimmunized irradiated mice there was an increased number of lymphoblasts in lymph-node cells, but no differences in the number of plasmocytes.

Blast transformation of human lymphocytes *in vitro* was observed by Stodolnik-Baranska (1967, 1974) after exposure to 2950 MHz microwaves at power densities of 7 and 20 mW/cm^2. However, Smialowicz (1977) was unable to detect any differences between the blastogenic responses of microwave-exposed (2450 MHz, 19 W/kg for 1-4 h) and control mouse splenic lymphocytes activated with various mitogens *in vitro*.

The effects on haemopoietic-stem cells in mice of exposure to 2.45 GHz microwaves at 100 mW/cm^2 for 5 min were investigated by Kotkovská & Vacek (1975). The response appeared to occur in 2 stages. In the first, the number of leukocytes in the blood increased and both bone marrow and spleen cell numbers decreased for 3-4 days following exposure. In the second stage, the number of nucleated cells in the spleen and the total number of cells in the femur, as detected by incorporation of ^{59}Fe, increased until the twentieth day after exposure. The incorporation of ^{59}Fe in the spleen decreased to 78% of the control value 24 h after exposure and increased to 50% after 14 days.

When Lin et al. (1979) studied the effects on mice of single and repeated exposures to 148 MHz radiation at 1 mW/cm^2 for 1 h per day, 5 days per week for ten weeks, they did not find any significant changes in the blood.

In studies on 3 strains of rats, a 7-h exposure to 24 GHz microwave radiation at 20 mW/cm^2 induced significant leukocytosis, lymphocytosis, and neutrophilia with recovery in 1 week; after a 10-min exposure at 20 mW/cm^2 or a 3-h exposure at 10 mW/cm^2, recovery occurred in 2 days (Deichman et al., 1964). The changes observed were strain-dependent because in 2 strains the number of leukocytes, erythrocytes, and neurophiles increased, while in one strain it decreased.

Decreases in lymphocytes, erythrocytes, and leukocytes, and increases in granulocytes and reticulocytes were observed in rats by Kitsovskaja (1964) after 3 GHz exposure at 40 mW/cm^2 (15 min per day for 20 days) and 100 mW/cm^2 (5 min per day, for 6 days). Exposure at 10 mW/cm^2 (1 h per day for 216 days) resulted in decreases in total WBC and lymphocytes and an increase in granulocytes with no changes in other blood components. However, in a study on rats exposed to 2.4 GHz microwaves at 5 mW/cm^2 (1 h per day for 90 days), Djordjevic et al. (1977) did not observe any significant differences in the haematocrit, mean cell volume, and haemoglobin between the exposed and control groups during 90 days of exposure and for 30 days afterwards. Furthermore, there were no significant differences in the number of leukocytes, erythrocytes, lymphocytes, and neutrophiles.

Smialowicz et al. (1977) completed a comprehensive study on rats chronically exposed to 425 MHz radiation at 10 mW/cm^2 (SAR, 3-7 mW/g) and to 2.45 GHz radiation at 5 mW/cm^2 (SAR, 1-5 mW/g). The rats were exposed *in utero* and for the first 40 days of life for 4 h per day. The only change in the haemopoietic or immunocompetent

systems was observed in the response of lymphocytes to mitogen.

The effects on guineapigs and rabbits of prolonged intermittent exposures to 3 GHz radiation at 3.5 mW/cm^2 for 3 h per day over 3 months were investigated by Baranski (1971). Increases in absolute lymphocyte counts in peripheral blood, and abnormalities in nuclear structure and mitosis in erythroblast cells in the bone marrow, and in lymphoid cells in lymph nodes and spleen, were found. Rabbits exposed at 3 mW/cm^2 (2950 MHz continuous and pulsed) for 2 h per day, for 27 and 79 days showed a decrease in erythropoiesis, as determined by ^{59}Fe uptake. Pulsed radiation was found to be more effective than continuous radiation at the same power level (Czerski et al., 1974a).

The effects on blood serum in rabbits exposed to 2.45 GHz continuous and pulsed radiation at 5, 10, and 25 mW/cm^2 for 2 h were investigated by Wangemann & Cleary (1976). Changes in the blood chemistry of animals irradiated at the three power densities were found to be consistent with a dose-dependent response to thermal stress. Out of the ten serum components that were analysed, statistically significant increases were observed in serum glucose, blood urea nitrogen, and uric acid. Dose-dependent transient increases returned to normal levels during the week following exposure. No differences in the animal's responses to cw and pulsed radiations (10-micro-second duration, peak power 485 mW/cm^2) were found at the same average power density.

Dogs were exposed to 1285 MHz, 2.8 GHz and 24 GHz at power densities between 20 and 165 mW/cm^2 (Michaelson et al., 1964, 1971). Following exposure to 1285 MHz radiation at 100 mW/cm^2 for 6 h, a marked increase in leukocytes and neutrophils was found. After 24 h, the neutrophil count continued to increase but the lymphocyte and eosinophil counts decreased. Neutrophil counts after exposures at 50 and 20 mW/cm^2 (1285 MHz) did not differ significantly from those of control animals. A decrease in lymphocytes was noted after the exposures at 100 mW/cm^2 and 50 mW/cm^2, but not after that at 20 mW/cm^2 (Michaelson et al., 1971). Haematological examination of the dogs for 12 months after exposure at 20 mW/cm^2 did not reveal any end points that differed from the control groups.

A number of studies are listed in Table 16 with details of exposure conditions and results of microwave-induced changes in the haemopoietic and immunocompetent cell systems.

This section on the effects of microwaves on the blood forming and immunocompetent cells can be summarized as follows:

(a) Changes in the red and white blood cell counts seem to depend on the dose of microwave energy applied. In most of the studies reporting positive findings, the effects seem to result from thermal stress.

(b) Repeated exposures to 5 mW/cm^2 or below do not appear to affect the peripheral blood picture. Effects reported from exposures to 15 mW/cm^2 or more, depending on the biological system exposed, tend to be reversible following termination of exposure.

(c) The response of the haemopoietic system to microwave radiation is significantly different from that to exposure to elevated ambient temperatures, even when both result in the same increase in rectal temperature. This can be attributed to the nonuniform deposition of microwave energy in the body, and the greater depth and rate of heating.

(d) There is evidence that lymphocyte stimulation and effects on response may occur under certain experimental conditions, especially after exposure to pulsed radiation for repeated or prolonged periods at sufficiently high power densities.

Table 16. Microwave-induced effects induced in the blood-forming and immunocompetent cell systems[a]

Radiation Frequency (GHz)	Intensity (mW/cm^2)	Exposure duration	Species	Results	Reference
3	1,5	15,30	granulocyte cells in culture	Liberation of hydrolases (1 mW/cm^2) cell death (5 mW/cm^2; 60 min) lysosomal enzyme release (5 mW/cm^2; 60 min).	Szmigielski (according to Cleary (1978))
2.95	0.5	2 h/day for 8 days/week for 6 and/ 2 weeks	mouse	Lymphoblasts in lymph nodes, lymphoblastoid transformation during first 2 months and 1 mo	Czerski (1975 b)

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				after exposure.	
2.45	100	5 min	mouse	Leukocyte (2 maxima) total cell volume in the bone marrow end spleen, ^{59}Fe Incorporation into spleen, nucleated cells in spleen immediately after exposure total cell number in femur 5-7 days after exposure. Colony forming unit numbers of stem cells, return to normal 12 h after exposure.	Rotkowska & Vacek (1975)

Table 16 (Cont'd)

Radiation Frequency (GHz)	Intensity (mW/cm^2)	Exposure duration	Species	Results	Reference
3.0	3.5	4 h/day	rat	Leukocyte, altered nuclear structure, altered mitotic activity in erythroblasts, bone marrow cells & lymphatic cells in lymph nodes & spleen.	Baranski (1971)
24	220,10	varied	rat	Leukocyte lymphocyte neutrophil, all cell counts returned to normal in 7 days.	Deichman et al. (1959)
2.95	3	2 h/day for 37 days pw & cw, 2 h/day for 79 days cw	rabbit	Erythrocyte production alterations in circadian rhythms in haemapoietic cell mitosis.[a]	Czerski et al. (1974 a)
2.45	3,10,25	2 h	rabbit	Serum glucose blood urea nitrogen, uric acid, all values return to normal 7 days after exposure.	Cleary & Wangemann (1978)
1.28, 2.8	100-165	7 h	dog	Maximum increase in ^{59}Fe incorporation 45 days after exposure.	Michaelson et al. (1951)

[a] From: Bramall (1971).

7.6 Genetic and Other Effects in Cell Systems

Investigations of biological systems such as cells in culture are conducted to gain an understanding of basic mechanisms of interaction. Although, these systems are less complex and the dosimetry can be better quantitated than in animal studies, the results have to be interpreted carefully in assessing potential health hazards to man.

Microwave exposure has been reported to produce chromosomal aberrations (Janes et al., 1969; Mykolajkzyk, 1970; Yao & Jiles, 1970; Baranski et al., 1971; Yao, 1971; Czerski et al., 1974b) and mitotic alterations (Baranski et al., 1969; Mykolajkzyk, 1970; Baranski et al., 1971; Baranski, 1972; Czerski et al., 1974) in cells.

Yao & Jiles (1970) studied the effects of microwave radiation on cell proliferation and on the induction of chromosomal aberrations in cultured rat kangaroo cells. Cells were exposed to 2.45 GHz radiation in the near field at 1 W/cm^2 and 5 W/cm^2 and in the far field at 0.2 W/cm^2. Exposure to 0.2 W/cm^2 for 1 min caused increased cell proliferation, but after 30 min, it decreased. Exposure at higher power densities significantly reduced the rate of proliferation, Exposure at 5 W/cm^2 induced chromosomal aberrations, but it is evident that high temperatures were involved in this result, since the energy absorption rate measured was 15.2 mW/g.

Chromosomal aberrations and changes in the duration of particular phases of mitosis (mitotic abnormalities) were reported by Baranski et al. (1969, 1971) in human lymphocyte cultures and cultures of monkey kidney cells following exposures at 3 and 7 mW/cm^2 to 10 cm pulsed and cw microwaves. Mitotic disorders in the lymphocytes of guineapigs and rabbits were also found following exposure to 3 GHz at 3.5 mW/cm^2 for 3 h per day over 3 months (Baranski, 1972).

Manikowska et al. (1979) studied 16 mice subjected to 9.4 GHz pulsed (width 0.5 µs, repetition rate 1000 Hz) microwaves at power

densities of 0.1, 0.5, 1.0 and 10 mW/cm^2 for 1 h/day for 2 consecutive weeks (5 days/week). Disturbances in meiosis were detected at power density levels as low as 0.1 mW/cm^2. This study needs confirmation since no other studies on effects of microwaves on meiosis could be found.

Exposure of murine splenic lymphocytes *in vitro* to 2450 MHz radiation at 10 mW/cm^2 (dose rate of 19 mW/g) did not result in any changes in capacity to synthesize DNA (Smialowicz, 1977). This technique used to assess blastic transformations of lymphocytes, was not the same as that used by Baranski (1972), which may explain the discrepancy in results. Elder & Ali (1975) found similarly negative results when they exposed mitochondria of isolated rat liver to 2.45 GHz radiation at 10 and 50 mW/cm^2 for 3.5 h. Furthermore, no effects were found in oxidation of substrate, electron transport, oxidative phosphorylation, or calcium transport.

The effects of 2450 MHz microwaves and a 43°C water bath on normal and virus-transformed fibroblasts of mice were compared by Janiak & Szmigielski (1977). Short-term heating by both methods resulted in reversible changes in the active transport of potassium through the cell membrane. Prolonged heating (over 20 min at 32°C) caused irreversible damage and the membrane became permeable to large molecules.

In another comparative study, Lin & Cleary (1977) did not find any differences in the release of potassium ions, haemoglobin levels, and the osmotic fragility of the red-cell membrane between samples exposed to microwaves at 2.45, 3.0, and 3.95 GHz and conventionally heated samples.

Chinese hamster ovarian cells exposed to 2.45 GHz microwaves or treated in a water bath at the same temperature did not show any differences in response when cell survival and sister chromatid exchanges were the end points (Livingston et al., 1979).

In studies by Blackman et at. (1975), the colony forming ability of *Escherichia coli B* was not inhibited by exposure to 1.7 GHz, 2.45 GHz, 68-74 GHz, and 136 GHz at power densities ranging from 0.3 to 20 mW/cm^2. This was in contrast to an inhibitory effect of microwave radiation at 136 GHz previously reported (Webb & Dodds, 1968). However, in a more recent study of colony-forming ability and of alterations in the molecular structure of living *E. coli B,* there were no changes in colony growth, or in molecular structure or conformation after irradiation at frequencies between 2.6 and 4 GHz with a specific absorption rate of 20 mW/g (Corelli et al., 1977).

Thus, it can be concluded that:

(a) Chromosomal aberrations and mitotic alterations can be produced by microwaves at high power densities where thermal mechanisms play a definite role. However, as there are many conflicting reports, some doubts remain as to whether these effects can occur at lower power densities.

(b) Studies at the cellular and subcellular level are important for understanding basic interaction mechanisms. Chromosomal aberrations and mitotic alterations are potential early indications of biological changes and may reflect a response of specific tissue, but not genetic injury in the organism.

(c) Recent studies on cell proliferation and capacity to synthesize DNA indicate that power densities sufficient to produce thermal damage are necessary for effects to appear. This is shown by experiments comparing the effects of both water baths and microwave exposure. Exposure of animals to resonant frequencies (e.g., 2450 MHz for mice), could be expected to induce effects at low power densities because a larger proportion of the incident radiation is absorbed and converted into heat.

7.7 Effects on Reproduction and Development

Detrimental effects of microwaves on testicular function, impregnation, developing embryos, and on offspring have been reported in the literature.

Van Ummersen (1961) exposed 48-h chick embryos to 2450 MHz cw microwave radiation through the intact shell. The power density was 20-40 mW/cm^2 and exposures were given for 280-300 min, causing the yolk temperature to rise from 37°C to 42.5°C. Abnormalities which were observed appeared to be caused by the inhibition of cell differentiation and growth. Development of hind limbs, tail, and allantois was suppressed. When control eggs were incubated at 42.5°C for the same length of time and the temperature of the eggs was the same as that of microwave-treated eggs, no abnormalities were found. It was concluded that the abnormalities from microwave exposure were caused by other than thermal factors.

Mice were subjected to 2.45 GHz microwaves at the near lethal dose rate of 38 mW/g for 10 min per day during the 11th-14th days of

gestation. There were no increases in fetal mortality or deformations in treated animals compared with untreated controls and maze performance was the same in both groups (Chernovetz et al, 1975).

When rats were irradiated between days 1 and 16 of pregnancy with 27 MHz radiation at power densities that caused the rectal temperature to rise to 42°C, a variety of teratological effects related to the developmental stage of the fetus was found. The effect on the development of the rat of repeated exposures *in utero* to 2.45 GHz radiation at 10 mW/cm^2 for 5 h per day from day 3 to day 19 of gestation was investigated by Shore et al. (1977). Two groups of animals were exposed under different conditions of configuration in the field. One group was placed in the exposure field in such a way that the long axis of each animal was parallel to the electric field; animals of the second group were placed with the long axis parallel to the magnetic field (orientation parallel to the electric field results in substantially greater absorption of microwave energy). No significant differences in litter size were observed between the control and irradiated animals. Decreases in body and brain mass were observed in animals irradiated with the long axis of the body parallel to the electric field.

Rats were exposed to 2.45 GHz radiation at 10 and 40 mW/cm^2 for 1 h per day during critical periods of gestation, and their functional development was studied during the 21-day period to weaning (Michaelson et al., 1977a). Offspring of rats exposed at 40 mW/cm^2 showed a significantly higher level of corticosterone during the first 24 h of life and an increase in levels of thyroxin at 14 and 16 days of age. Thyroxin levels tended to be lower in one-week-old rats from dams that had been exposed at 10 mW/cm^2, but increased during the second week of life. Adrenal wet mass and ratios of adrenal-to-body mass in 7-day-old rats were significantly higher in irradiated animals. The authors suggested that while microwave radiation might change the developmental process and accelerate the rate of maturation, it might also result in some deficiencies. A similar result was found by Johnson et al. (1977) who exposed rats *in utero* to 918 MHz at 5 mW/cm^2 for a total of 380 h and found an increase in body mass at birth and an acceleration in the time of eye opening. Later a deficiency in avoidance response was observed.

Repeated exposures to 9.4 GHz at power density levels below 10.0 mW/cm^2 may induce disturbances in spermatogenesis and meiosis in mice (Manikowska et al., 1979). However, Cairnie & Harding (1979) were unable to find any differences in the sperm counts of mice, after *in vivo* exposure to 2450 MHz radiation at 20-32 mW/cm^2 for 4 days (16 h/day). Testicular damage was observed in mice exposed to 2450 MHz at a power density of 6.5 mW/cm^2 for 230 h over a 2-month period (Haidt & McTighe, 1973); these positive findings could be explained on the basis of a thermal mechanism because 2450 MHz is around the resonant frequency for mice.

Changes in testicular morphology were observed by Varma & Traboulay (1975) in mice exposed to 1.7 and 3.0 GHz microwaves at 10 mW/cm^2 for 100 min, and at 50 mW/cm^2 for 30-40 min. Both Bereznitskaja (1968) and Polozitkov et al. (1961) reported that chronic exposure of mice to 3 GHz at 10 mW/cm^2 or even lower levels resulted in a prolonged estrus cycle, partial sterility, and an increased, early mortality of the offspring. However, other research workers were unable to find any changes in the reproductive performance of dogs exposed to 24 GHz microwaves at 24 mW/cm^2 for 33 and 66 weeks (Deichman et al., 1963) and to 1.28 GHz at 20 mW/cm^2 (Michaelson et al., 1971) or female rats and mice exposed to 3.1 GHz at 8 mW/cm^2 for prolonged periods of time and to 300 mW/cm^2 for a short period of time (Shore et al., 1977).

A comparative study of heating the testes of rats by microwaves and in warm water was performed by Muraca et al. (1976). Radiation of 2.45 GHz was used at 80 mW/cm^2 with the exposure time varied to maintain the desired temperature within ± 0.5°C. Repeated treatments during 5 consecutive days resulted in more damage in microwave-irradiated animals. However, it was determined that if non-thermal effects occurred, it appeared that microwave-induced heating was necessary to produce damage.

The threshold value for testicular damage in dogs exposed to 2880 MHz microwaves at more than 10 mW/cm^2 for unlimited periods was studied by Ely et al. (1964). A temperature of 37°C was produced more rapidly with exposure to higher power densities. This temperature was determined as critical for damage based on a minimal demonstrable histological change in the most sensitive animal from the test group. The authors pointed out that the changes, including sterility, were reversible.

In summary, microwave radiation can affect reproduction and development. Both are particularly sensitive to thermal stress, although specific effects that are not attributable to heating cannot be excluded. Microwave exposure at power density levels causing temperature increases results in testicular lesions, and particularly

affects spermatogenesis, in experimental animals. These lesions seem to be readily reversible unless necrosis occurs. Baranski & Czerski (1976) in their review of the subject concluded that no serious effects should be expected at power density levels below 10 mW/cm^2. Substantial differences between thermal effects induced by microwaves and by other methods of heating may be attributed to different spatial distributions of internal heating and different rates of heating. Developmental effects seem to be critically dependent on the time of exposure to microwaves making it difficult to compare some of the experimental data.

8. HEALTH EFFECTS IN MAN

The available data concerning the health effects of microwave radiation in man are insufficient, although some surveys of the health status of personnel occupationally exposed to microwaves have been carried out. The main difficulty in the evaluation of such information is the assessment of the relationship between exposure levels and observed effects. As often happens in clinical work, it is difficult to demonstrate a causal relationship between a disease and the influence of environmental factors, at least in individual cases. Large groups must be observed to obtain statistically significant epidemiological data. The problem of adequate control groups is controversial and hinges mostly on what is considered "adequate" (Silverman, 1973; Czerki et al. 1974a; NAS/NRC, 1977).

In view of the lack of good instrumentation, especially of personal dosimeters, the quantitation of exposure during work is extremely difficult. This is particularly the case where personnel move around in the course of their duties and are exposed to stationary and non-stationary fields, and both near- and far-field exposures. It is impossible to evaluate within reasonable limits the exposure over a period of several years. Consequently, investigation of the health status of personnel exposed occupationally to microwaves necessitates the examination of large groups of workers exposed for various periods, if any statistically valid results are to be obtained.

Observations on the health status of personnel exposed to microwaves in the USSR have been discussed in detail in monographs edited by Petrov, ed. (1970) and Tjagin (1971).

8.1 Effects of Occupational Exposure

Prior to the establishment of safety standards, it had been observed in some countries that occupational microwave exposure led to the appearance of autonomic and central nervous system disturbances, asthenic syndromes, and other chronic exposure effects (Gordon, 1966; Marha et al., 1971; Dumanski et al., 1975; Serdjuk, 1977). The pathogenesis of these syndromes is controversial, their existence has been reported on a number of occasions but often without the level of exposure. Another problem with earlier reports is that measurement techniques were not properly developed at that time (For a detailed discussion see Baranski & Czerski (1976) pp. 153-162). Subjective complaints consisted of headaches, irritability, sleep disturbance, weakness, decrease in sexual activity (libido), pains in the chest, and general poorly defined feelings of in health. On physical examination, tremor of fingers with extended arms, acrocyanosis, hyperhydrosis, changes in dermographism, and hypotonia were reported in the USSR (Gordon, 1966). Similar syndromes were reported in France by Deroche (1971) and in Israel by Moscovici et al. (1974).

Examination of the circulatory function included determination of the velocity of propagation of the pulse wave. Various coefficients may be calculated and used for the evaluation of vascular tonus and the state of the neurovegetative system. This method is widely used in the USSR, but seldom elsewhere. Disturbances in the functioning of the circulatory system are demonstrable using this method whereas, with the exception of signs of bradycardia, no significant findings are obtained using electro-, vecto-, and ballisto-cardiography. Mechanocardiography demonstrated normal or increased systolic and minute heart volume in individuals with hypotonia (Tjagin, 1971).

Gordon (1966) and her colleagues reported studies on occupationally exposed workers who were divided into 3 groups according to levels of exposure to microwave radiation:

(a) Periodic exposure at power densities from 0.1 to 10 mW/cm^2 (and higher) of maintenance personnel and workers, who had been employed in repair shops since 1953;

(b) Periodic exposure at power densities from 0.01 to 0.1 mW/cm^2 of technical maintenance workers, some users of microwave devices, and research workers, employed after 1960; and

(c) Systematic low-level exposure of personnel using various microwave devices, mainly radar.

Functional changes in the nervous and cardiovascular systems were reported in the first 2 groups. In the first group, a marked disturbance in cardiac rhythm, expressed by variability or pronounced

bradycardia was reported. In the third group, similar effects were observed but symptoms were less evident and easily reversed. Only about 1000 individuals were observed over a period of 10 years and some doubts exist regarding the exact exposure received by the workers.

Clinical observations on the health status of 2 groups of workers occupationally exposed to emissions from various types of radio equipment were reported by Sadcikova (1974). The first group consisted of 1000 workers exposed to RF radiation at a few mW/cm^2, the second group, of 180 workers who had been exposed at a few hundredths of a mW/cm^2 over short periods of time. A control group of 200 was matched with respect to sex, age and character of work. The health status of both exposed groups was reported to differ considerably from that of the controls, with a higher incidence of changes in the nervous and cardiovascular systems in the exposed groups.

In Poland (Siekierzynski, 1974; Czerski et al., 1974c; Siekierzynski et al., 1974a, b), a selected group of 841 males, aged 20-40 years and occupationally exposed to microwaves at power densities ranging from 0.2 to 6 mW/cm^2, was studied. No relationship was found between the level or length of occupational exposure and the incidence of disorders or functional disturbances such as organic lesions of the nervous system, changes in the translucent media of the eye, primary disorders of the blood system, neoplastic diseases or endocrine disorders, neurasthenic syndrome, disturbances of the gastrointestinal tract, and cardiocirculatory disturbances with abnormal ECG.

A 3-year epidemiological study aimed at determining health risks from microwave exposure in US naval personnel was reported by Robinette & Silverman (1977). Mortality, morbidity, reproductive performance, and health of children were investigated in 20 000 occupationally exposed subjects and 20 000 controls. No significant differences were found between the 2 groups.

Cases of whole body or partial body overexposure may occur among personnel operating high-power equipment. Exposure of the head and resultant injury to the brain have been reported (Servantie et al., 1978). The person concerned may not realize that exposure is taking place, if there is no sensation of heat. The symptoms may appear later, and a syndrome of meningitis or symptoms similar to those of heat stroke may develop.

It has been emphasized by many research workers, including Silverman (1973), that the inadequacies and uncertainties of radiation measurements and exposure data from existing, clinical studies, make it impossible to determine if, and under what conditions, microwave radiation can induce neural or behavioural changes in man. Unfortunately, the same problem exists for other studies carried out on human subjects exposed to microwaves, making it difficult to draw conclusions on health status.

8.1.1 Effects on the eyes

Epidemiological surveys of lenticular effects in microwave workers have been performed in Poland (Siekierzynski et al., 1974a, b; Zydecki, 1974), Sweden, (Tengroth & Aurall, 1974) and the USA (Cleary & Pasternack, 1966; Appleton & McCrossan, 1972; Shacklett et al., 1975). No statistically significant increases in the number of cataracts in personnel occupationally exposed to microwave radiation were observed in any of the surveys. Tengroth & Aurell (1974) indicated a statistically significant increase in lenticular defects and retinal lesions in 68 workers in a Swedish factory, where microwave equipment was tested. These authors were some of the first to point out possible retinal lesions from exposure to microwaves. However, survey data on the intensity of radiation were not provided and the control group was not age-matched. Statistically significant differences in lens opacities between exposed and control groups were not found in any of the other surveys. In cases of confirmed cataracts, there had been reported exposures at densities exceeding 100 mW/cm^2; indeed, power densities as high as 1000 mW/cm^2 were cited.

8.1.2 Effects on reproduction and genetic effects

There is little information on the effects of microwave radiation on male or female reproductive functions. Reports of sterility or infertility from exposure to microwaves are questionable. No changes in the fertility of radar workers were found by Barron & Baraff (1958).

Marha et al. (1971) attributed decreased spermatogenesis, altered sex ratio of births, menstrual pattern changes, congenital effects in newborn babies, and decreased lactation to the occupational exposure of mothers to RF radiation. According to their report, such effects occurred at power densities exceeding 10 mW/cm^2.

8.1.3 Cardiovascular effects

Functional damage to the cardiovascular system as manifested by hypotonus, bradycardia, delayed auricular and ventricular conductivity, and flattening of ECG waves, has been reported, by several USSR clinicians, to result from chronic exposure of workers to RF fields (Gordon, 1966, 1967; Tjagin, 1971; Baranski & Czerski, 1976). Decreases in blood pressure from exposure have also been reported. Some authors in the USSR have indicated that the nature and seriousness of cardiovascular reactions to prolonged exposure is related to changes in the nervous system, and depends on the characteristics of the individual. Some patients exhibited only minor asthenic symptoms while others developed marked autonomic vascular dysfunction.

8.2 Medical Exposure

Controlled follow-up studies of patients treated with microwave and RF diathermy could yield important data on effects, at least for partial body exposure. Such studies could not be found in the available literature. However, cases of congenital malformations ascribed to exposure to microwave or RF diathermy during early pregnancy have been found in the literature by Marha et al. (1971).

9. RATIONALES FOR MICROWAVE AND RF RADIATION PROTECTION STANDARDS

9.1 Principles

An important part of the rationale for standards should be the definition of the population to be protected. Occupational health standards are aimed at protecting healthy adults exposed under controlled conditions, who are aware of the occupational risk and who are likely to be subject to medical surveillance. General population standards must be based on broader considerations, including health status, special sensitivities, possible effects on the course of various diseases, as well as limitations in adaptation to environmental conditions and responses to any kind of stress in old age. As many of these considerations involve insufficiently explored interactions, standards for the general population must involve adequate safety factors, including taking into account the possibility of 24-h general population exposure compared with 8-h occupational exposure.

A distinction should be made between exposure limits for workers and equipment emission standards. The latter are based on safe operational considerations, should be derived from exposure limits, and they should not allow exposure above the adopted exposure limits. The USA performance standard for microwave ovens (US Code of Federal Regulations, 1970) may serve as an example. This standard limits the emission of unintentional radiation (microwave leakage) to 1 mW/cm^2 at a distance of 5 cm from the surface of the oven. Only a few countries have formally adopted standards. Where standards have been promulgated, the procedures of enforcement vary from regulations enforceable by law to voluntary guidelines.

Existing radiation protection guides (RPG) or exposure standards may be divided into 3 groups according to the exposure limits adopted (Czerski, 1976).

The first group comprises standards and recommendations in which microwave exposure of the order of tens of $microwatts/cm^2$ (up to 100 $\mu W/cm^2$) is allowed. The second group includes exposures of the order of hundreds of $microwatts/cm^2$ (1000 $\mu W/cm^2$), and the third group allows exposures of thousands of $microwatts/cm^2$ (10 000 $\mu W/cm^2$). This division does not correspond to any classification of RPG or exposure limits on a national or regional geographical basis. As exposure standards have been revised or introduced they have recently tended towards group 2 (Repacholi, 1978).

9.2 Group 1 Standards

The first group is represented by the exposure standards of Bulgaria (Bulgarian National Standard, 1979) and the USSR (Ministry of Health of the USSR, 1970; USSR Standard for Occupational Exposure, 1976; USSR Standard for Public Exposure, 1978).

The original USSR occupational microwave exposure limits were established in 1959 (Ministry of Health of the USSR, 1970). The current standard (USSR Standard for Occupational Exposure, 1976) reaffirmed the exposure limits for microwaves (300 MHz-300 GHz) and introduced exposure limits for RF (60 kHz-300 MHz). A special standard was introduced for public exposure in 1978 (USSR Standard for Public Exposure, 1978). Detailed data on exposure limits are given in Table 18 at the end of section 9.5. The exposure limits representative for this group of standards are those of the USSR occupational standard (USSR Standard for Occupational Exposure, 1976): microwave radiation (300 MHz-300 000 MHz) at working locations should not exceed 10 $microwatt/cm^2$ (0.1 W/m^2) for exposure during the whole working day, 100 $microwatt/cm^2$ (1 W/m^2) for exposures of not more than 2 h per working day, and 1000 $microwatt/cm^2$ (10 W/m^2) for exposures of

not more than 15-20 min per working day, providing that protective goggles are used and that the radiation (exposure) does not exceed 10 microwatt/cm^2 (0.1 W/m^2) during the rest of the working day.

The principle of establishing exposure levels in standards, according to Gordon (1966, 1970), is the avoidance of risks during long-term (many years) occupational exposure.

In the USSR standard concerning general population exposure to microwaves in the range of 300 MHz-300 GHz (Fig. 15), a value of 5 μW/cm^2 has been adopted as the exposure limit over a 24-h period, for inhabited areas. This standard covers radiation from scanning and rotating antennae, which turn with a frequency below 0.5 Hz. The irradiation time of a point in space should not exceed one tenth of the scanning duty cycle, and the relation between the maximum energy levels in comparable time intervals should not exceed 10.

The USSR occupational and public health safety standards are based on the principle of complete prevention of health risks and therefore include large safety factors.

9.3 Group 2 Standards

The second group of standards may be illustrated by those of Czechoslovakia (Principal Hygienist of CSSR, 1965, 1970), the German Democratic Republic Standard (GDR Standard TgL 32602/01, 1975), the Polish regulations on microwave exposure limits (Council of Ministers, 1972) and RF exposure limits (Ministers of Labour, Wages and Social Affairs and Health and Social Welfare, 1977), as well as the USA Bell

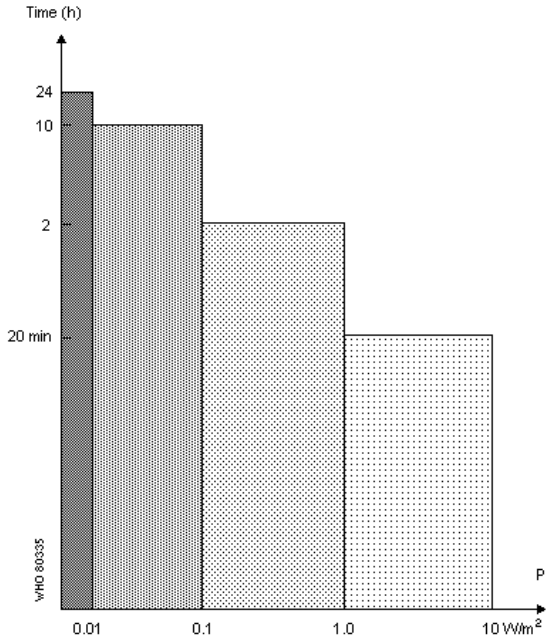


Fig. 15. Permissible limits for occupational (≤ 10 h) and general public (24-h) exposure to microwave radiation (0.3 -- 300 GHz), in the USSR.

Telephone recommendations (Weiss & Mumford, 1961). The recently introduced Canadian (National Health and Welfare, Canada, 1979) and Swedish (IVA-Committee, 1976; Worker Protection Authority, 1976) exposure standards and the Australian proposal (Cornelius & Vigilione, 1979) might also be placed in this group.

The Czechoslovak standard is discussed in detail by Marha et al. (1971), who claim that "biological knowledge" was taken into account in establishing the permissible exposure levels and a safety factor of 10 introduced. Ten microwatts/cm^2 (0.1 W/m^2) mean power density was accepted as safe for long-term exposures to pulsed waves. For the "demonstrably less risky" continuous wave exposure, 25 microwatts/cm^2 was permitted. These rules were first adopted in 1965 and were revised in 1970 (Principal Hygienist of CSSR, 1965, 1970) in order to incorporate a time-weighted averaging procedure.

RPG values based on an 8-h working day for occupational exposure and over 24-h for the general population have also been introduced. For occupational continuous wave exposure to microwaves, the exposure limit may not exceed 25 microwatts/cm^2. The permissible exposure levels are calculated according to a formula from which a continuous wave exposure to 1.6 mW/cm^2 or pulsed wave exposures to 0.64 mW/cm^2 during 1-h per working day are permissible. This is considerably higher than the values accepted in the USSR. No advice is given concerning exposure lasting for a few minutes. Details of measuring methods and equipment are also given by Marha et al. (1971)

Continuous generation is defined as operation with a ratio of on-to-off time greater than 0.1. The overall impression is that the values accepted in Czechoslovakia for short periods of exposure (2 or 10 min), may be compared with those recommended by the American National Standards Institute (ANSI, 1974, 1979).

Poland adopted the same exposure limits as those of the USSR in 1961. In 1963, additional information on interpretation was introduced. Effective irradiation time was defined by the following expression for far-field exposure to intermittent radiation from scanning beams:

$$t_{ef} = (\text{phi}/360)\ t_p$$

where t_{ef} = effective irradiation time (h)
t_p = time of emission of microwaves
phi = effective beam width in degrees.

Special formulae were given for the near-field zone. Because of the difficulties of solving all the doubts arising out of practical situations, new exposure limits were subsequently proposed. These were based on detailed discussions of findings in Czechoslovakia, the USSR

and the USA, radiation protection guides, standards, and rules, and epidemiological analysis of the health status of personnel professionally exposed to microwaves (Czerski & Piotrowski, 1972). The new proposals were accepted and introduced in laws passed in Poland by the Council of Ministers (1972) and the Minister of Health and Social Welfare (1972) (Fig. 16). For the general population, the values of 10 and 100 µW/cm^2 were adopted for continuous and intermittent exposures, respectively. These values were taken as the upper limits for a safe zone, in which occupation could be unrestricted. Three other zones were defined, based on power density. For stationary (continuous) fields, these were:

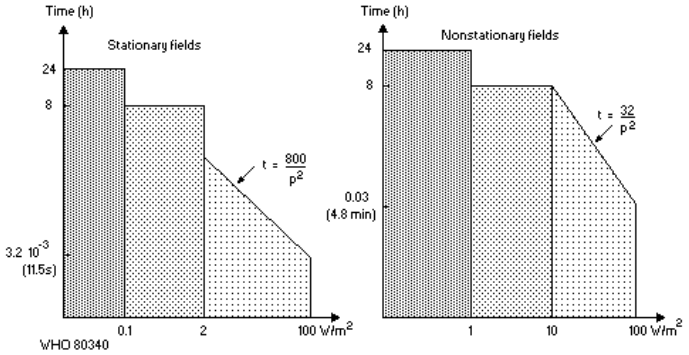


Fig. 16. Permissible limits for occupational (≤ 10-h) and general public (24-h) exposure to microwave radiation (0.3 -- 300 GHz) in Poland.

(a) safe zone -- the mean power density not to exceed 0.1 W/m^2, human exposure unrestricted;

(b) intermediate zone -- minimum value 0.1 W/m^2, upper limit 2 W/m^2, occupational exposure allowed during a whole working day (normally 8 h, but, in principle, could be extended to 10 h);

(c) hazardous zone -- minimum value 2 W/m^2, upper limit 100 W/m^2, occupational exposure time per 24 h to be determined by the formula:

$$t = 32/\ p^2$$

where t = exposure time (h) and p = mean power density (W/m2);

(d) dangerous zone -- mean power density in excess of 100 W/m^2 (10 mW/cm^2), human exposure forbidden.

For exposures to non-stationary fields, i.e., intermittent exposure, the following values were adopted:

(a) safe zone -- mean power density not to exceed 1 W/m^2 (0.1 mW/cm^2);

(b) intermediate zone - minimum value 1 W/m^2, upper limit 10 W/m^2, occupational exposure allowed during a whole working day, as defined earlier;

(c) hazardous zone -- minimum value 10 W/m^2, upper limit 100 W/m^2, the professional exposure time per 24 h to be determined by the formula:

$$t = 800/p^2$$

where t = exposure time (h) and p = mean power density (W/m^2);

(d) dangerous zone -- mean power density in excess of 100 W/m^2 (10 mW/cm^2), human exposure forbidden.

The Polish law (Council of Ministers, 1972) names the bodies to be responsible for health surveillance, supervision of working conditions, and the manner of carrying out the measurements (in principle, every 3 years, and after changes in equipment or its displacement). The main responsibility for decisions on admissibility of working conditions rests with the sanitary epidemiological stations of the Public Health Service. Newly designed equipment must be evaluated by the Ministry of Health and Social Welfare, before production and/or installation is allowed. For installation of microwave equipment, permission is required from the sanitary epidemiological station of the province.

These Polish regulations, in common with those of Czechoslovakia and the USSR, have the following characteristics:

(a) Exposure limits determined separately for occupational and general population exposures, medical examinations of microwave workers limit occupationally exposed population to healthy adults only;

(b) unified methods of measurement, measuring equipment, and evaluation of results for health purposes;

(c) unified methods of medical examinations and evaluation of the results obtained;

(d) determination of responsibility for compliance with RPG.

Sweden has introduced regulations for occupational exposure with 1 mW/cm^2 as the normal limit for microwave exposure and allows short-term excursions to a maximum of 25 mW/cm^2. In the range 10-300 MHz, the limits are 5 mW/cm^2 and 25 mW/cm^2 (IVA Committee, 1976; Workers Protection Authority, 1976).

A new Canadian standard has now been published (National Health and Welfare, Canada, 1979). This standard was developed following an in-depth scientific evaluation of the literature (National Health and Welfare, Canada, 1977, 1978) and was proposed (Repacholi, 1978) as a draft so that it could be extensively reviewed. The final standard applies to both occupational exposure and exposure of the general population. Table 17 summarizes the exposure limits for whole or partial body exposure to either continuous or modulated electromagnetic radiation in the frequency range 10 MHz-300 GHz.

Higher occupational exposure is permitted for periods of less than 1 h. However, the maximum power density, averaged over a 1-min period should not exceed 25 mW/cm^2. Fig. 17 shows the permitted occupational exposure in Canada.

Recently, the Australian Radiation Laboratory published a draft proposal (Cornelius & Viglione, 1979) for exposure limits in the range of 10 MHz-300 GHz. The values proposed are shown in Fig. 18 and, according to the authors, are the result of a "worst case analysis". Although, the rationale and some of the calculations presented in this paper may be questioned on a formal basis, it is interesting to note that the values for exposure limits agree well with those of the group 2 of standards.

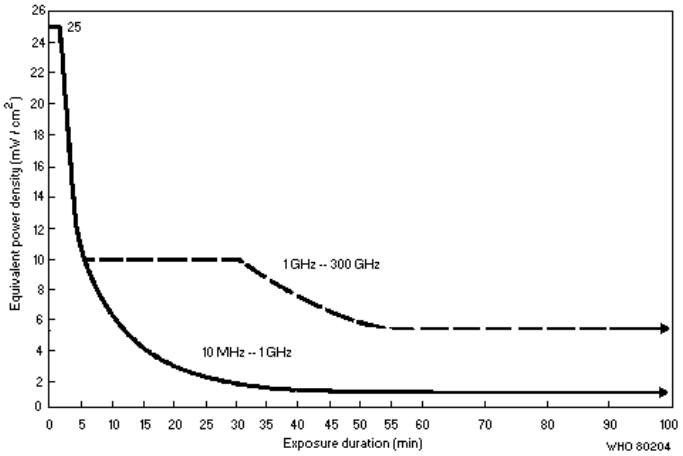


Fig. 17. Occupational exposure limits for workers exposed to microwaves in the frequency range 10 MHz -- 300 GHz (From: National Health and Welfare, Canada, 1979).

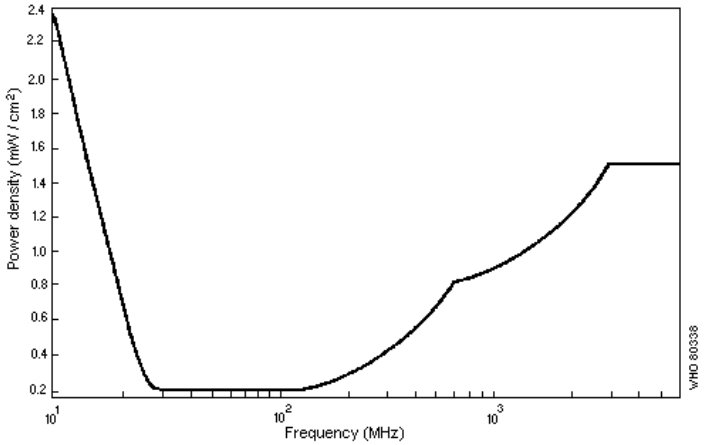


Fig. 18. Maximum permissible exposure limits according to an Australian draft proposal (From: Cornelius & Viglione, 1979).

Table 17. Canadian exposure limits for whole or partial body exposure continuous or intermittent radiation from 10 MHz-300 GHz[a]

Group	Frequency range	Exposure limits
General population	10 MHz--300 GHz	1 mW/cm^2 60 V/m 0.16 A/m Averaged over 1 min
Occupational	10 MHz--1 GHz	1 mW/cm^2 60 V/m 0.16 A/m Averaged over 1 h
	1 GHz--300 GHz	5 mW/cm^2 140 V/m 0.36 A/m Averaged over 1 h

[a] From: National Health and Welfare, Canada (1979).

9.4 Group 3 Standards

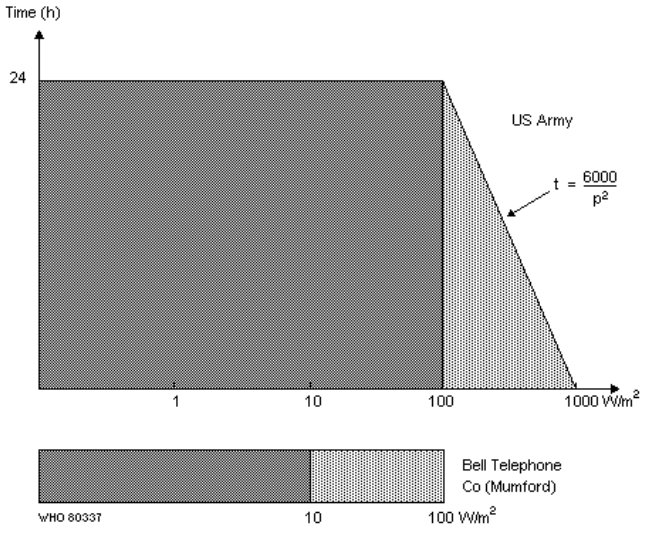
The third group of standards may be illustrated by the 1966 US Army regulations (Polmisans & Peczenik, 1966), The American National Standards Institute Standard (ANSI, 1966) and recommendations of the American Conference of Governmental Industrial Hygienists (ACGIH, 1971, 1979). Fig. 19 presents a comparison of these standards with the Bell Telephone recommendations (Weiss & Mumford, 1961).

The US Army Standard is obviously intended as an occupational safety RPG to microwaves and RF. Unlimited exposure is allowed at levels below 10 mW/cm^2 but exposure at power densities higher than 100 mW/cm^2 is considered dangerous. Within the range of 10-100 mW/cm^2, exposure is allowed for a limited time according to the formula:

$$t = 6000/ P_d^2$$

where t = exposure time (min) and

P_d = mean power density (mW/cm^2).



Practical values:	min per 1 h	P W/m²
Army	2	350
	6	320
US ANSI	1	600
	6	100
ACGIH (8 h)		100
250 W/m² ceiling value	10	100 - 250

Fig. 19. Comparison of some of the exposure limits proposed in the USA (see also Table 18).

A practical upper limit of 55 mW/cm^2 is imposed, based on the assumption that exposure of less than 2 min duration cannot be properly regulated.

It is also recommended that, wherever possible, exposure levels inside military installations should be reduced to a minimum.

The recommendations drawn up by the C-95.1 Committee of the American National Standards Institute do not set an upper limit of exposure (ANSI, 1966). However, this limit is defined indirectly by the recommendation that the power density to which people may be exposed should not exceed 10 mW/cm^2 as averaged over any period of 0.1 h. No distinction between pulsed or continuous wave exposure is made. These recommendations allow a 1-min exposure to 60 mW/cm^2, which may be repeated 10 times per hour. US Army recommendations allow only a single 2-min exposure at 55 mW/cm^2 during 1 h. On the other hand, ANSI recommendations allow a 6-min exposure at only 10 mW/cm^2, while the US Army accepts 32 mW/cm^2 for this period.

The ANSI C.95.1 Committee revised its standard in 1974 (ANSI 1974) and is considering a draft proposal to reduce the permissible exposure limits (ANSI, 1979). A comparison of the ANSI exposure limits in successive standards can be found in Table 18 at the end of this section.

The American Conference of Governmental Industrial Hygienists has also made recommendations for the frequencies of 300 MHz-300 GHz (ACGIH, 1971, 1979, 1980):

(a) For average power density levels up to, but not exceeding 10 mW/cm^2, total exposure time should be limited to the 8-h working day (continuous exposure).

(b) Exposure to higher average power density levels is permitted for short periods of time. For example, exposure to 25 mW/cm^2 is permitted for 2.4 min during each 6-min period in an 8-h working day (intermittent exposure);

(c) For average power density levels exceeding 25 mW/cm^2, no exposure is permissible (ceiling value).

(d) Under conditions of moderate to severe heat stress, the values recommended may need to be reduced.

These Group 3 recommendations are based on human thermal balance characteristics contained in the studies by Schwan & Piersol (Schwan, 1978; Schwan & Piersol, 1954, 1955) on the biophysical and physiological aspects of the absorption of electromagnetic energy in body tissues. These views (Schwan, 1976) can be presented briefly as

follows:

(a) the principal effects of microwaves consist of temperature increases in the irradiated object;

(b) because of heat balance characteristics in man, indefinite exposure to 10 mW/cm^2 is possible, higher values may be accepted for short-term exposure;

(c) the formation of cataracts or lenticular opacities cannot be expected at power densities below 100 mW/cm^2;

(d) biophysical considerations exclude the possibility of microwave interaction with nerve cells;

(e) there is no evidence of untoward effects of microwave radiation in man at power densities below 10 mW/cm^2.

The US ANSI Committee is in the process of revising its standard and it appears likely from review documents, which have been circulated, that the 10 mW/cm^2 value will be reduced to 1 mW/cm^2 in the frequency range 30-300 MHz with increased levels on either side of this frequency range (ANSI, 1979). This standard would then come in Group 2.

9.5 RF Radiation Standards (100 kHz to 300 MHz)

The USA exposure limits covering the range 10 MHz-100 GHz and some other national standards (e.g., the United Kingdom) include a part of the RF range. Standards intended specifically for RF radiation (as defined by international agreement), have been introduced only in Czechoslovakia (Principal Hygienist of CSSR, 1965, 1970), the German Democratic Republic (GDR Standard -- TGL 32602, 1973), Poland (Ministers of Labour, Wages and Social Affairs and of Health and Social Welfare, 1977), and in the USSR (USSR Standard for Occupational Exposure GOST 12.1.00.76, 1976; USSR Standard for Public Exposure SN-1823-78, 1978).

In the USSR occupational standard, values from 5 V/m to 50 V/m have been adopted in the range of 60 kHz to 300 MHz (see Table 18). The USSR values for inhabited areas (public health standards) are as follows:

	E field
in the range of 30--300 kHz	20 V/m
in the range of 0.3-- 3 MHz	10 V/m
in the range of 3-- 30 MHz	4 V/m
in the range of 30--300 MHz	2 V/m

In the Czechoslovak standard (Marha et al., 1971), the approach to RF exposure is similar to that for microwave exposure. The permissible exposure duration for the frequency range 30 kHz-30 MHz is calculated from the formula:

$$E \times t = 120$$

where E = peak electric field strength (V/m)
t = time (h)

For 24-h exposure, 5 V/m is considered safe. In the range of 30 MHz-300 MHz, the equivalent is 1 V/m.

Occupational exposure guide values are: 400 for 40 kHz-30 MHz and 80 for the range 30 MHz-300 MHz allowing 50 V/m and 10 V/m, respectively, for an 8-h working day.

The Polish proposal uses the concept of 4 zones, i.e., safe, intermediate, hazardous, and dangerous, and exposure limits presented in Fig. 20 and 21 are of the same order of magnitude as those for Czechoslovakia and the USSR.

Table 18 includes examples of microwave and RF exposure limits adopted or proposed by various countries.

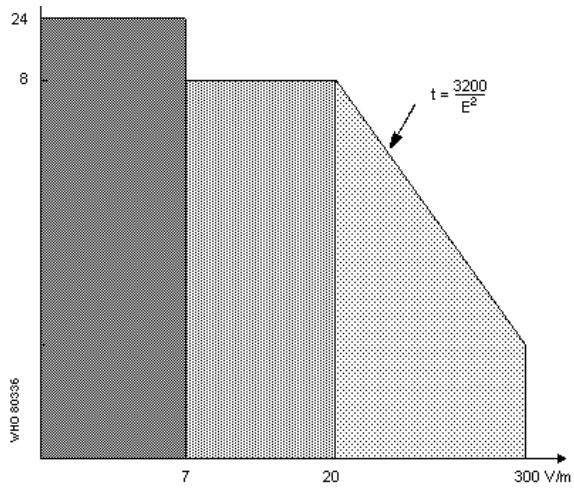


Fig. 20. Permissible limits for occupational (≤ 10-h) and general public (24-h) exposure to radiofrequency radiation (10 -- 300 MHz) in Poland.

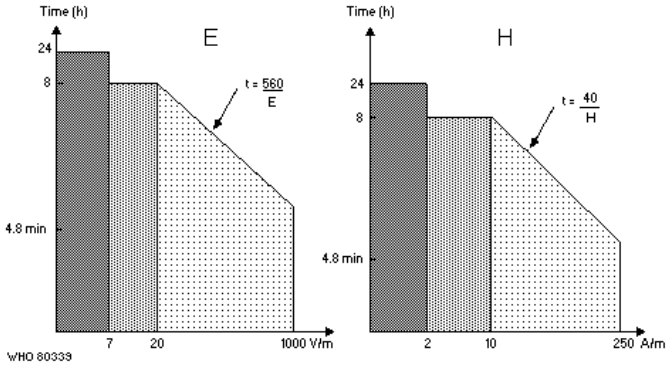


Fig. 21. Permissible limits for occupational (≤ 10-h) and general public (24-h) exposure to radiofrequency radiation (0.1-10 MHz) in Poland.

Table 18. Examples of microwave and RF exposure limits in various countries

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
Australia							
Australian Radiation Laboratory (Cornelius & Viglione, 1979)	Draft proposal for both occupational and public exposure		Frequency (f) MHz dependent limit (L) mWh/cm^2 for time integrated exposures average over any 1-h period and 4 (L) mW/cm^2 averaged over any 1-s period for periods of less than 1 h	24 h	both	both	Compare Fig. 18; a proposal for near-field exposure limits is also included, peak pules exposure is limited to 1 W/cm^2.
		10-30 MHz 30-130 MHz 130-600 MHz 0.6-3 GHz 3-300 GHz	$L = 5.4 - 0.365 f + 0.0064 f^2$ L = 0.2 L = 0.2 + 0.00128 (f + 130) L = 0.8 + 0.00029 (f + 600) L = k.5				
Bulgaria							
State (National) Committee for standardization (1979)	Legal national standards; enforceable by law; occupational	60 kHz-3 MHz 3 MHz-30 MHz 30 MHz-50 MHz 50 MHz-300 MHz	Electric field strength V/m 50 V/m 20 V/m 10 V/m 5 V/m	working day working day working day working day	-	-	

Table 18 (Cont'd)

Country,

agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
			Magnetic field strength A/m	working day			
		60 kHz-1.5 MHz	5 A/m	working day			
		30 MHz-50 MHz	0.3 A/m	working day			
			Power density W/m^2	working day			
		300 MHz-300 GHz	up to 0.1	working day	both	stationary	
		300 MHz-300 GHz	0.1-1 W/m^2	no more than 2 h	both	stationary	Up to 0.1 during the remainder of the working day.
		300 MHz-300 GHz	1.0-10.0 W/m^2	no more than 20 min	both	stationary	Up to 0.1 during the remainder of the working day-protective goggles required.
		300 MHz-300 GHz	up to 1.0 W/m^2	working day	both	rotating	
		300 MHz-300 GHz	1.0-10.0 W/m^2	no more than 2 h	both	rotating	If the ambient temperature is over 28 °C or simultaneous exposure to X-rays occurs, exposures over 1.0 W/m^2 are not allowed.

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
Canada							
Canadian Standards Association (1966)	Voluntary, occupational	10 MHz-100 GHz	10 mW/cm^2	no limit	cw	both	No longer applies, as the 1979 national standard is more conservative.
			1 mWh/cm^2	0.1 h	pulsed	both	
National Health & Welfare (1979)	National health and occupational safety regulation, enforceable by law.						
	Occupational	10 MHz-1 GHz	1 mW/cm^2 power density 60 V/m rms electric field strength 0.16 A/m rms magnetic field strength	no limit averaged over 1 h	both	both	See also Fig. 17.
		1 GHz-300 GHz	5 mW/cm^2 power density 140 V/m rms electric field strength 0.36 A/m rms magnetic field strength	averaged over 1 h	both	both	

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
		10 MHz-300 GHz	25 mW/cm^2 power density 300 V/m rms electric field strength 0.8 A/m rms magnetic field strength	1 min	both	both	These values cannot be exceeded and constitute "ceiling levels". Some provisions for "special" cases, under strictly controlled

							conditions were added. 10 mW/cm^2 cannot be exceeded when averaged over 1-h period.
	General population	10 MHz-300 GHz	1 mW/cm^2 power density 60 V/m rms electric field strength 0.16 A/m rms magnetic field strength	no limit, averaged over 1 min			
Czechoslovakia							
Principal Hygienist of the CSSR (1970)	National health and occupational safety regulation enforceable by law						

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
	Occupational	30 kHz--30 MHz	Exposure limit (L) V/m calculated according to formula: L × t (h) = 400, i.e., 50 V/m for 8 h	Exposure duration (t) in hours calculated according to the formula in the next column to the left	-	-	Occupationally exposed persons are under obligatory medical surveillance (periodical examinations as specified by law).
		30 MHz--300 MHz	L × t (h) = 80, i.e., 10 V/m for 8 h				
		300 MHz--300 GHz	Exposure limit (L) μW/cm^2 calculated according to formula L × t (h) = 200 i.e., 25 μW/cm^2 for 8 h	as above	cw	both	Unified measuring methods imposed and specified by the same regulations. The regulations dated 1965 limited peak pulse power (instantaneous exposure) to 1 kW/ omitted in the revision dated 1970.
		300 MHz--300 GHz	L × t (h) = 80, i.e., 10 μW/ cm^2 for 8 h	as above	pulsed	both	
	General population	30 kHz--30 MHz	Exposure limit (L) V/m calculated according to formula L × t (h) = 120, i.e., 5 V/m for 24 h	as above	--	--	
		30 MHz--300 MHz	Exposure limit (L) V/m calculated according to the formula L × t (h) = 24. i.e., 1 V/m for 24 h	as above	-	-	
		300 MHz--300 GHz	Exposure limit (L) μW/cm^2 calculated according to the formula L × t (h) = 60. i.e., 2.5 μW/cm^2 for 24 h	as above	cw	both	

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
		300 MHz--300 GHz	L × t (h) = 24, i.e., μW/ cm^2 for 24 h	as above	pulsed	both	
German Democratic Republic							
National Committee for Standardization, Measurements and Products Control (1975)	National occupational health standards, enforceable by law	60 kHz--3 MHz	50 V/m electric field strength	working day	_	_	Supersedes a standard dated 1972, microwave exposure limits did not change, RF exposure limits were introduced by the new version.
		3 MHz--30 MHz	20 V/m electric field strength	working day	_	_	
		30 MHz--50 MHz	10 V/m electric field strength	working day	--	--	
		50 MHz--300 MHz	5 V/m electric field strength	working day	--	--	
		300 MHz--300 GHz	10 μW/cm^2 power density	up to 8 h	both	stationary	
		300 MHz--300 GHz	100 μW/cm^2 power density	up to 2 h	both	stationary	
		300 MHz--300 GHz	1000 μW/cm^2 power density	up to 20 min	both	stationary	
		300 MHz--300 GHz	100 μW/cm^2 power density	up to 8 h	both	rotating	
		300 MHz--300 GHz	1000 μW/cm^2 power density	up to 2 h	both	rotating	1000 μW/cm^2 is a "ceiling level" that cannot be exceeded.

Poland

Council of Ministers (1972)	National regulation, enforceable by law	300 MHz--300 GHz	up to 0.1 W/m^2 (safe zone)	unlimited (implicit general public)	both	stationary	Supersedes a 1961 regulation establishing essentially the same exposure

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
		300 MHz-300 GHz	0.1 W/m^2-2 W/m^2 (intermediate zone)	working day	both	stationary	limits, as those in the USSR.
		300 MHz-300 GHz	2 W/m-100 W/m^2 (hazardous zone)	32 hours P^2	both	stationary	Although an occupational standard. It
		300 MHz-300 GHz	Exceeding 100 W/m^2 (danger zone)	human occupancy prohibited betide (ceiling level)	both	stationary	established a "safe" zone, within which human occupancy is unrestricted.
		300 MHz-300 GHz	up to 1 W/m^2 (safe zone)	unlimited (implicit general public)	both	rotating	Only workers (persons occupationally exposed) having a medical certificate of fitness and
		300 MHz-300 GHz	1 W/m^2-10 W/m^2 (intermediate zone)	working day	both	rotating	subject to periodic medical examinations may enter the "intermediate"
		300 MHz-300 GHz	10 W/m^2-100 W/m^2 (hazardous zone)	800 hours P^2	both	rotating	and "hazardous" zones. In this

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
		300 MHz-300 GHz	Exceeding 100 W/m^2 (danger zone)	human occupancy prohibited (ceiling level)	both	rotating	way an implicit general population exposure limit has been established. A regulation establishing general public and environmental protection exposure limits for microwave, RF, and ELF was drafted and will be adopted in 1980. Compare Fig. 16 and section 9.3. Occupational exposure durations and definitions of electromagnetic fields, stationary versus rotating antennae, determined by a

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks

							separate regulation (Minister of Health & Social Welfare, 1972). P = power density W/m^2.
The Ministers of Labour, Wages and Social Affairs and for Health and Social Welfare (1977)	National regulation enforceable by law	0.1 MHz-10 MHz	20 V/m rms electric field strength (safe zone)	unlimited (implicit general population)	--	--	The same concept of safe, intermediate, hazardous, & danger zones makes the standard an implicit general population one. Within the 0.1-10 MHz range, rms magnetic field strength values were given but, as they exceed corresponding rms electric field values, only these are used in
			20 V/m-70 V/m rms electric field strength (intermediate zone)	working day	both	_	
			70 V/m-1000 V/m rms electric field strength (hazardous zone)	560/E	both	rotating	
			Exceeding 1000 V/m rms electric field strength (danger zone)	human occupancy prohibited (ceiling level)	both	rotating	

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
			up to 7 V/m rms electric field strength (safe zone)	unlimited (implicit general population)	both	rotating	practice, as the limiting factor in permissible exposure values. Compare Fig. 21 and Fig. 22. E = ams electric field strength.
		10 MHz-300 MHz	7 V/m-20 V/m rms electric field strength (intermediate	working day			
			20 V/m-300 V/m rms electric field strength (hazardous zone)	3200/E^2	both	rotating	
			Exceeding 300 V/m rms electric field strength (danger zone)	human occupancy prohibited (ceiling level)	both	rotating	
Sweden							
Workers Protection Authority (1976)	National occupational safety regulation	10-300 MHz	5 mW/cm^2	8 h	both	rotating	
		0.3-300 GHz	1 mW/cm^2	8 h			
		0.3-300 GHz	1-25 mW/cm^2	60/P	both	rotating	P = power density mW/cm^2.
		10 MHz-300 GHz	25 mW/cm^2	averaged over	both	rotating	Ceiling level.

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
USA							
American National Standards Institute (ANSI) (1966)	Occupational voluntary consensus standard (recommendation)	10 MHz-300 GHz	10 mW/cm^2	no limit (for periods of 0.1 h or more)	both	both	Under "moderate environmental" conditions, people with circulatory difficulties and certain other ailments are
			1 mWh/cm^2	during any 0.1-h period	both	both	more vulnerable. Techniques end instrumentation
ANSI (1974)	Occupational voluntary consensus standard (recommendation)	10 MHz-300 GHz	10 mW/cm^2 power density 200 V/m electric field strength 0.5 A/m magnetic field strength	no limit	cw	both	for measurements are given in ANSI-C95.3-1973 publication. Prevention of

			10 mW/cm^2 power density 1 mWh/cm^2 energy density 40 000 V^2/m^2 mean squared electric field strength (E^2) 0.25 A^2/m^2 mean squared magnetic field strength (A^2)	0.1 h	pulsed	both	associated hazards -- see Institute of Makers of Explosives (1971). The US Department of Labour adopted the ANSI 1968 standard in its proposed rules (Fed. Register,

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
							Vol. 38, No. 166, para 1910, 345, p. 23046, 1973) and finally adopted 10 mW/cm^2 as maximum safe exposure limit for occupational exposure (Fed. Register, Vol. 40. No. 59, point 12, p. 13138, 1975). This standard is a recommendation and the Dept of Labour is preparing a new standard.
ANSI (1979)	Draft proposal for voluntary consensus standard (recommendation)	0.3-3 MHz	100 mW/cm^2 power density 400 000 V^2/m^2-E^2 2.5 A^2/m^2-H^2	no limit, averaged over any 0.1-h period	both	both	Mean squared electric field strength (E^2) and mean squared magnetic field strength (H^2) are applicable to near-field exposures.

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
		3-30 MHz	$\frac{900}{f^2}$ mW/cm^2 - power density $\frac{4000 \times 900}{f^2}$ V^2/m^2 - E^2 $\frac{0.025 \times 900}{f^2}$ A^2/m^2 - H^2	averaged over any 0.1-h period	both	both	f is the frequency in MHz.
		30-300 MHz	1.0 mW/cm^2 power density 4000 V^2/m^2-E^2 0.025 A^2/m^2-H^2	averaged over any 0.1-h period	both	both	
		0.3-1.5 GHz	$\frac{f}{300}$ mW/cm^2 $\frac{4000 \times f}{300}$ V^2/m^2-E^2 $\frac{0.025 \times f}{300}$ A^2/m^2-H^2	averaged over any 0.1-h period	both	both	
		1.5-300 GHz	5 mW/cm^2 power density 20000 V^2/m^2-E^2 0.125 A^2/m^2-H^2	averaged over any 0.1-h period	both	both	

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
American Conference of Governmental Industrial Hygienists (ACGIH) (1979)	Recommendation	10 MHz-100 GHz	Same as ANSI (1974)	same as ANSI (1974)	both	both	A ceiling level of 25 mW/cm^2 was added to ANSI (1974) recommendations. Note: A legally enforceable USA standard is an equipment emission standard for microwave ovens (US Code of Federal Regulations, 1970).
USSR							
National Standards Committee at the Council of Ministers of the USSR, 1976 (USSR Standard for Occupational Exposure, 1976)	Occupational national standard, enforceable by law	60 kHz-3 MHz	50 V/m electric field strength	working day	both	both	Supersedes earlier regulations and standards (section 9.2) without essential changes.
		3 MHz-30 MHz	20 V/m electric field strength				
		30 MHz-50 MHz	10 V/m electric field strength				
		50 MHz-300 MHz	5 V/m electric field strength				
		60 kHz-1.5 MHz	5 A/m magnetic field strength	working day	both	both	
		30 KHz-50 Mhz	0.3 A/m magnetic field strength	working day	both	both	
		300 MHz-300 GHz	up to 0.1 W/m^2 power density	working day	both	stationary	
			0.1 to 1.0 W/m^2 power density	up to 2 h per day	both	stationary	During the remainder of the working day up to 0.1 W/m^2.

Table 18 (Cont'd)

Country, agency, or organization, date	Type of standard	Frequency	Exposure limit	Exposure duration	cw/ pulsed	Antenna stationary/ rotating	Remarks
		300 MHz-300 GHz	1.0 to 10 W/m^2 power density	up to 20 min per day	both	stationary	During the remainder of the working day up to 0.1 W/m^2. protective goggles are required.
		300 MHz-300 GHz	up to 1.0 W/m^2 power density	during the working day	both	rotating	
			1.0 to 10 W/m^2 power density	up to 2 h per day	both	rotating	During the remainder of the working day up to 1.0 W/m^2.
Ministry of Health Protection (USSR Public Health Standard, 1978) (1978)	Public health regulation enforceable by law	see section 9.2					

10. SAFETY PROCEDURES FOR OCCUPATIONALLY EXPOSED PERSONNEL

Broadcasting, radio, radar, industrial heating, and medical equipment are essentially the same in all countries. Thus, the field strengths associated with different types of equipment will be similar and typical examples are shown in Fig. 22. In many instances, much higher field strengths may be encountered. Where personnel may be exposed to potentially high field strengths, they should receive appropriate training and be made aware of possible risks to health from the improper use of the equipment. This is especially important where the operation of equipment does not necessitate professional training or skills, e.g., plastic sealers. It is likely that service work or repairs will entail greater risk than operation since protective devices such as screens and interlocks would, in many cases, have to be rendered inoperable to carry out the servicing or repairs. Furthermore, service or repair personnel would generally be closer to the microwave/RF source.

Reviews of safety procedures can be found in Mumford (1961), ANSI (1973), Minin (1974), Krylov & Jucenkova (1979), and National Health & Welfare, Canada (1979) (Safety Code 6).

10.1 Procedures for Reducing Occupational Exposure

The basic methods of controlling and limiting microwave/RF exposure, in order of desirability are: (a) engineering -- safe design and construction; (b) siting; (c) administrative; and (d) personnel protection.

All unnecessary emissions should be minimized at the source, preferably by containment or otherwise effective screening. This approach is clearly impractical as far as the antenna system of deliberate emitters is concerned. In this case, siting can be very important in keeping both the number of people, who may be exposed, and the levels of exposure as low as possible. The same considerations apply where emission is unintentional but some leakage is unavoidable.

Where people can be exposed to potentially hazardous levels, access to such areas should be controlled and restricted to persons who are trained and are aware of any risks. The use of special warning signs described in the Health and Welfare Canada Safety Code 6 (National Health and Welfare, Canada, 1979) would be particularly useful. Time spent in the area should be kept as short as possible and, wherever practicable, microwave/RF power levels should be kept as low as readily achievable.

The use of protective clothing is not generally recommended as it may initiate other hazards to the wearer, e.g., RF burns.

For more detailed information, the reader is referred to the Health and Welfare Canada Safety Code 6 (National Health and Welfare, Canada, 1979).

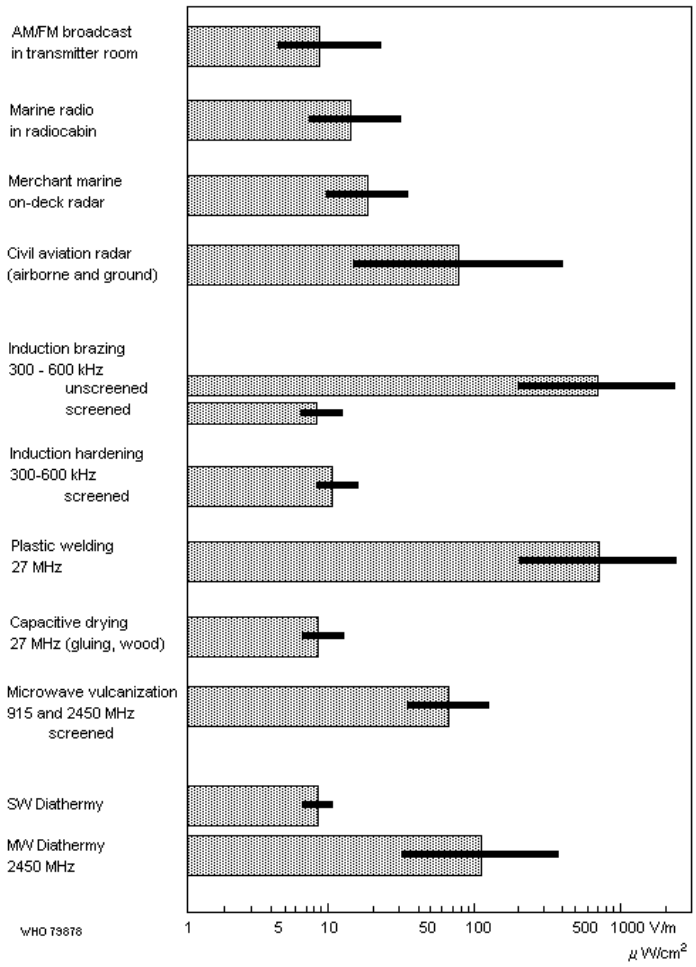


Fig. 22. Field strengths typically occurring in the vicinity of industrial equipment and work places.

11. ASSESSMENT OF DATA ON BIOLOGICAL EFFECTS AND RECOMMENDED EXPOSURE LIMITS

Major difficulties exist in assessing the potential health hazards to man of exposure to microwave and RF radiation, because of the

highly complex relationship between the exposure conditions and the energy absorbed. The absorbed dose and rate of energy absorption depend critically on such variables as frequency, power density, field polarization, the size and shape of the exposed subject, and environmental factors. Many of the experiments contain insufficient information on the dosimetry, thus, difficulties arise in the exact interpretation of results.

Experimental results indicate that most reported effects can be explained on the basis of microwave-induced, nonuniform heating. However, other investigations which have been carried out to evaluate the mechanisms involved, e.g., comparison of effects induced by microwaves with those produced by a water bath, indicate that nonthermal mechanisms may be involved. Further thorough studies of these nonthermal mechanisms are necessary, as their contribution to the understanding of microwave effects may be of great importance.

Since most biological effects have been reported as phenomena, little information exists on quantitated dose-effect relationships. Studies on dose-effect threshold levels and their frequency dependence are badly needed in most areas. Because of the lack of such data, recommendations for exposure limits can only be made on the best available interpretations of the literature. Such interpretations also require an assessment of whether effects reported as phenomena truly present a hazard to health. Many effects are transient or easily reversible while others may cause permanent damage.

From the summaries in sections 7 and 8, the following recommendations can be made:

(a) Effects have been reported at power densities too low to produce biologically significant heating.

(b) The occupationally-exposed population consists of healthy adults exposed under controlled conditions, who are aware of the occupational risk. The exposure of this population should be monitored.

It is possible to indicate exposure limits from available information on biological effects, health effects, and risk evaluation. For workers, whole or partial body exposure to continuous or pulsed microwaves or Rf radiation having average power densities within the range 0.1-1 mW/cm^2 includes a high enough safety factor to allow continuous exposure to microwaves/RF from any part of the frequency range, over the whole working day. Higher exposure may be

permissible over part of the frequency range and for intermittent or occasional exposure. Special considerations may be indicated in the case of pregnant women.

(c) The general population includes persons of different ages (infants, small children, young adults and senior citizens) and different states of health, including pregnant women. The possible greater susceptibility of the developing fetus to microwave/RF exposure may deserve special consideration. Exposure of the general population should be kept as low as possible and limits should generally be lower than those for occupational exposure.

In view of the fact that data are still required to clarify interaction mechanisms and determine threshold levels for effects, it is recommended that microwave and RF exposure of occupationally-exposed workers and the general population should be kept as low as readily achievable.

More precise exposure limits over the frequency range 100 kHz - 300 GHz for both occupational and general population exposure to microwaves/RF will be recommended in follow-up documents.

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GLOSSARY

Wherever possible, this glossary gives terms and definitions standardized by the International Electrotechnical Commission in the International Electrotechnical Vocabulary (IEV) or by the International Organization for Standardization (ISO). In such cases, the IEV number, or the number of the ISO standard in which the definition appears, is given in parentheses. The great majority of the terms and definitions are those of the IEV, and the help of Mr C. J. Stanford, General Secretary, International Electrotechnical Commission, in compiling the necessary information is gratefully acknowledged.

An annex at the end of the glossary includes a number of additional terms that have not been standardized.

absorption In radio wave propagation, attenuation of a radio wave due to its energy being dissipated, i.e., converted into another form such as heat (IEV 60-20-105).

absorption cross-section; effective area Of an [antenna], oriented for maximum power absorption unless otherwise stated, an area determined by dividing the maximum power absorbed from a plane wave by the incident power flux density, the load being matched to the [antenna] (IEV 60-32-035).

admittance The current flowing in a circuit divided by the terminal voltage; the reciprocal of the impedance (IEV 05-40-035).

antenna That part of a radio system which is designed to radiate electromagnetic waves into free space [or to receive them]. This does not include the transmission lines or waveguide to the radiator (IEV 60-30-005).

antenna directivity See *directivity*

antenna gain See *power gain of an antenna*

antenna, dipole See *dipole*

antenna, horn See *horn*

antenna, isotropic See *isotropic radiator*

antenna pattern See *radiation pattern*

antenna scanning See *scanning*

attenuation The progressive diminution in space of certain quantities characteristic of a propagation phenomenon (IEV 05-03-115).

attenuation coefficient The real part of the propagation coefficient. Synonym: *attenuation constant* (deprecated) (IEV 55-05-255).

bel; decibel Transmission units giving the ratio of two powers. The number of bels is equal to the logarithm to the base ten of the power ratio. The decibel is equal to one-tenth of a bel (IEV 55-05-120).

coaxial pair Two conductors, one being a wire or tube coaxially surrounded by the other which is in the form of a tube (IEV 55-30-45). A cable consisting principally of one or more coaxial pairs is termed a coaxial cable (IEV 55-30-50).

conductance The reciprocal of resistance (IEV 05-20-170). Symbol: *G*. Unit: siemens (S).

conductivity The scalar or matrix quantity whose product by the electric field strength is the conduction current density (IEV 121-02-1). It is the reciprocal of resistivity.

continuous wave A wave whose successive oscillations are, under steady-state conditions, identical.

cross section A measure of the probability of a specified interaction between an incident radiation and a target particle or system of particles. It is the reaction rate per target particle for a specified process divided by the flux density of the incident radiation (microscopic cross section) (IEV 26-05-605).

current density A vector of which the integral over a given surface is equal to the current flowing through the surface. The mean density in a linear conductor is equal to the current divided by the cross-sectional area of the conductor (IEV 05-20-045).

cycle The complete range of states or values through which a phenomenon or periodic function passes before repeating itself identically (IEV 05-02-050).

decibel See *bel*

dielectric constant See *permittivity*

dielectric (material) A material in which all of the energy required to establish an electric field in the material is recoverable when the field or impressed voltage is removed. A perfect dielectric has zero conductivity and all absorption phenomena are absent. A complete vacuum is the only known perfect dielectric.

dielectric saturation Response of a dielectric in the limit of high electric field strengths, leading to a decrease of the real part of the permittivity with increasing field strength.

dipole A centre-fed open [antenna] excited in such a way that the standing wave of current is symmetrical about the mid point of the [antenna] (IEV 60-34-005).

directivity That property of an [antenna] by virtue of which it radiates more strongly in some directions than in others (IEV 60-32-130).

displacement See *electric flux density*

dissipation factor The reciprocal of the *Q-factor* (IEV 55-05-285). See *Q factor*.

duty factor The ratio of (1) the sum of pulse durations to (2) a stated averaging time. For repetitive phenomena, the averaging time is the pulse repetition period (IEV 531-18-15).

duty ratio The ratio, for a given time interval, of the on-load duration to the total time (IEV 151-4-13).

effective area See *absorption cross-section*

effective radiated power in a given direction The power supplied to

the [antenna] multiplied by the gain of the [antenna] in that direction relative to a half-wave dipole (IEV 60-32-095).

electric charge; quantity of electricity Integral of electric current over time (ISO 31/V). Symbol: *Q*. Unit: coulomb (C).

electric field strength A vector the value of which equals the force exerted on a quantity of electricity divided by this quantity and the direction of which is that of the force (IEV 05-15-45).

electric flux Across a surface element, the scalar product of the surface element and the electric flux density (ISO 31/V).

electric flux density A vector quantity whose divergence equals the electric volume charge density. *Note: In vacuo,* it is at all points equal to the product of the electric field strength and the electric constant (IEV 121-01-21). Symbol: *D*. Obsolete synonym: displacement.

electric susceptibility The scalar or matrix quantity whose product by the electric field strength is the electric polarization (IEV 121-02-09).

electromagnetic energy The energy stored in an electromagnetic field (IEV 121-01-39).

electromagnetic wave A wave characterized by variations of the electric and magnetic fields (IEV 121-01-38).

electrostatic field That portion of the total electromagnetic field produced by a current-carrying conductor or charge distribution, the energy of which returns to the conductor when the current ceases or the charge distribution goes to zero.

energy density See *radiant energy density*

far zone See *radiation zone*

ferromagnetic material A material in which the predominant magnetic phenomenon is ferromagnetism. *Note:* The atoms or ions have magnetic moments which, over certain regions (domains), are aligned approximately in the same direction even in the absence of an externally applied magnetic field. When such a field is applied, the resultant moments of the domains tend to align so that the material exhibits considerable permeability. The degree of alignment within a domain decreases with increasing temperature (IEV 901-01-29).

ferromagnetism A phenomenon by which the magnetic moments of neighbouring atoms are aligned approximately in the same direction due to mutual interaction (IEV 901-01-28).

field 1. *In a qualitative sense,* a region of space in which certain phenomena occur. 2. *In a quantitative sense,* a scalar or vector quantity the knowledge of which allows the effects of the field to be evaluated (IEV 05-01-040).

field strength In radio wave propagation, the magnitude of a component of specified polarization of the electric or magnetic field. The term normally refers to the root-mean-square value of the electric field (IEV 60-20-070).

flux See *electric flux, magnetic flux*

flux density See *electric flux density, magnetic flux density*

Fraunhofer region Of a transmitting [antenna] system, the region which is sufficiently remote from the [antenna] system for the wavelets arriving from the various parts of the system to be considered to follow parallel paths (IEV 60-32-60).

free space An ideal, perfectly homogeneous medium possessing a dielectric constant of unity and in which there is nothing to reflect, refract, or absorb energy. A perfect vacuum possesses these qualities.

frequency The reciprocal of *period,* q.v.

Fresnel region Of a transmitting [antenna] system, the region near the [antenna] system where the wavelets arriving from the various parts of the system cannot be considered to follow parallel paths (IEV 60-32-065).

gain The increase in power between two points 1 and 2 at which the power is respectively P_1 and P_2, expressed by the ratio P_2/P_1 in transmission units (IEV 55-05-185).

H field See table

horn An elementary [antenna] consisting of a waveguide in which one or more transverse dimensions increase towards the open end

(IEV 60-36-055).

impedance The complex representation of potential difference divided by the complex representation of current (ISO 31/V).

impedance characteristic Of a uniform transmission line, the impedance with which one end of the line must be terminated in order that the impedance presented at the other end shall have the same value as the terminating impedance. *Note:* The term is occasionally applied to a symmetrical two-terminal-pair network to denote the common value assumed by the two image impedances and the two iterative impedances (IEV 55-20-155).

impedance, wave (at a given frequency) The ratio of the complex number (vector) representing the transverse electric field at a point, to that representing the transverse magnetic field at that point. The sign is so chosen that the real part is positive (IEV 62-05-095).

induction field That part of the field of an [antenna] which is associated with a pulsation of energy to and fro between the [antenna] and the medium. *Note:* The induction field extends theoretically over the whole of space, but is negligible compared with the radiation field except in the neighbourhood of the [antenna] (IEV 60-32-045).

induction zone; near zone The region surrounding a transmitting [antenna] in which there is a significant pulsation of energy to and fro between the [antenna] and the medium. *Note:* The magnetic field strength (multiplied by the impedance of space) and the electric field strength are inequal and, at distances less than one tenth of a wavelength from an [antenna], vary inversely as the square or cube or the distance, if the [antenna] is small compared with this distance (IEV 60-32-055).

insertion loss The loss due to the insertion of a transducer between two impedances Z_E (generator) and Z_R (load) is the expression in transmission units of the ratio P_1/P_2 where P_1 is the apparent power received by the load Z_R before the insertion of the said transducer, and P_2 is the apparent power received by the load Z_R after the insertion of the said transducer (IEV 55-05-160). Unit: decibel (dB).

irradiation, partial body Exposure of only part of the body to incident electromagnetic energy.

irradiation, whole body Exposure of the entire body to incident electromagnetic energy.

isotropic Having the same properties in all directions.

isotropic radiator An [antenna] which radiates uniformly in all directions. This is a hypothetical concept used as a standard in connection with the gain function (IEV 60-32-110).

joule The work done when the point of application of 1 ... unit of force [newton] moves a distance of 1 metre in the direction of the force (Comité international des Poids et Mesures, 1946).

magnetic field strength An axial vector quantity which, together with magnetic induction, specifies a magnetic field at any point in space. It can be detected by a small magnetised needle, freely suspended, which sets itself in the direction of the field. The free suspension of the magnetised needle assumes, however, that the medium is fluid or that a small gap is provided of such a shape and in such a direction that free movement is possible. As long as the induction is solenoidal, the magnetic field is irrotational outside the spaces in which the current density is not zero, so that it derives a potential (non-uniform) therefrom.

On the other hand, in the interior of currents, its curl, in the rationalised system, is equal to the vector current density, including the displacement current.

The direction of the field is represented at every point by the axis of a small elongated solenoid, its intensity and direction being such that it counterbalances all magnetic effects

in its interior, whilst the field intensity is equal to the linear current density of the solenoid (IEV 05-25-020). Symbol: *H*. Unit: ampere per metre (A/m).

magnetic flux The area integral of the magnetic flux density (IEV 901-01-04). Symbol: *PHI*. Unit: weber (Wb).

magnetic flux density A solenoidal axial vector quantity which at any point defines the magnetic field at that point. Its value is such that the force exerted on an electric charge at that point moving at a given velocity is equal to the charge multiplied by the vector product of the velocity and the magnetic flux density (IEV 901-01-03). Symbol: *B*. Unit: tesla (T).

microwaves Electromagnetic waves of sufficiently short wavelength that practical use can be made of waveguide and associated cavity techniques in their transmission and reception (IEV 60-02-025). (*Note:* for the purposes of the foregoing document the term is taken to signify waves having an approximate frequency range of 0.3-300 GHz).

near zone See *induction zone*

peak envelope power Of a radio transmitter, the average power supplied to the [antenna] transmission line or specified artificial load by a transmitter during one radio frequency cycle at the highest crest of the modulation envelope, taken under conditions of normal operation (IEV 60-42-260).

peak pulse amplitude See *pulse amplitude*

peak pulse output power The maximum value of output power during a stated time interval, spikes excluded (IEV 531-41-17).

period The minimum interval of the independent variable after which the same characteristics of a periodic phenomenon recur (IEV 05-02-40). Symbol: *T*. Unit: second (s).

permeability The scalar or matrix quantity whose product by the magnetic field strength is the magnetic flux density. *Note:* For isotropic media, the permeability is a scalar; for anisotropic media, a matrix (IEV 121-01-37). Synonym: absolute permeability. If the permeability of a material or medium is divided by the permeability of cacuum (magnetic constant)m the result is termed *relative permeability*. Symbol: μ. Unit: henry per metre (H/m).

permittivity; dielectric constant A constant giving the influence of an isotropic medium on the forces of attraction or repulsion between electrified bodies (IEV 05-15-120). Symbol: *E*. Unit: Farad per metre (F/m).

permittivity, relative The ratio of the permittivity of a dielectric to that of a vacuum (IEV 05-15-140). Symbol: *Er*.

phase Of a periodic phenomenon, the fraction of a period through which the time has advanced relative to an arbitrary time origin.

phase change coefficient The imaginary part of the propagation coefficient. *Note:* This coefficient determines the change of phase of the voltages or currents (IEV 55-05-260). Deprecated synonyms: phase constant, wavelength constant. Symbol: β. Unit: radian per metre (rad/m).

polarization A vector quantity representing the state of dielectric polarization of a medium, and defined at each point of the medium by the dipole moment of the volume element surrounding that point, divided by the volume of that element (IEV 05-15-115).

polarization, plane of In a linearly polarized wave, the fixed plane parallel to the direction of polarization and the direction of propagation. *Note:* In optics the plane of polarization is normal to the plane defined above (IEV 60-20-010).

potential, electric For electrostatic fields, a scalar quantity, the gradient of which, with reversed sign, is equal to the electric field strength (ISO 31/V; also IEV 05-15-050).

power 1. Mean power, work (or energy) divided by the time in which this work (or energy) was produced or absorbed. In periodic phenomena, the average power during a period is generally taken. 2. Instantaneous power, the limit of the average power when the interval of time considered becomes infinitely small (IEV 05-04-025). Symbol: *P*. Unit: watt (W).

power flux density; field intensity In radio wave propagation, the power crossing unit area normal to the direction of wave propagation (IEV 60-20-075). Symbol: *W*. Unit: watts per square metre (W/m^2).

power gain The ratio, usually expressed in decibels, of (1) the output power of an [amplifying device] operated under stated conditions to (2) the driving power (IEV 531-17-26). Symbol: *G*.

power gain of an [antenna] (in a given direction) The ratio, usually expressed in decibels, of the power that would have to be supplied to a reference [antenna] to the power supplied to the [antenna] being considered, so that they produce the same field strength at the same distance in the same direction; unless otherwise specified, the gain is for the direction of maximum radiation; in each case the reference [antenna] and its direction of radiation

must be specified, for example: half-wave loss-free dipole (the specified direction being in the equatorial plane), an isotropic radiator in space (IEV 60-32-115). Symbol: *G*. Unit: decibel

(dB).

Poynting vector A vector, the flux of which through any surface represents the instantaneous electromagnetic power transmitted through this surface (IEV 05-03-85). Synonym: power flux density.

propagation constant A complex constant characterizing the attenuation and phase change per unit of length of the current or voltages which are propagated along a uniform line supposed to be infinitely long (IEV 05-03-150). Symbol: *alpha*.

pulse amplitude The peak value of a pulse (IEVV 55-35-100).

pulse duration The interval of time between the first and last instant at which the instantaneous value of a pulse (or of its envelope if a carrier frequency pulse is concerned) reaches a specified fraction of the peak amplitude (IEV 55-35-105).

pulse output power The ratio of (1) the average output power to (2) the pulse duty factor (IEV 531-41-14).

pulse repetition rate The average number of pulses in unit time during a specified period (IEV 55-35-125).

Q A measure of the efficiency of a reactive circuit (especially an oscillating circuit) or a component thereof. Its precise definition depends on the nature of the circuit; for an oscillating system without lumped *L* or *C* it is equal to 2pi times the average energy stored in the field divided by the energy dissipated during one half cycle. Synonyms: *Q* factor, quality factor.

radar The use or radio waves, reflected or automatically retransmitted, *to gain information concerning a distant object. The measurement of range is usually included (IEV 60-72-005).*

radar scan See *scanning*

radiant flux (surface) density Quotient of the radiant flux at an element of the surface containing the point, by the area of that element (IEV 45-05-155). Symbol: *E*. When this quantity relates to radiation incident on a surface, it is termed *irradiance;* when it relates to radiation emitted from a surface, it is termed *radiant exitance* Symbol: *M* (deprecated synonym: radiant emittance) (IEV 45-05-160/170). Unit: watts per square metre (W/m^2).

radiation field That part of the field of an [antenna] which is associated with an outward flow of energy (IEV 60-32-040).

radiation zone; far zone The region sufficiently remote from a transmitting [antenna] for the energy in the wave to be considered as outward flowing. *Note:* In free space, the magnetic field strength (multiplied by the impedance of space) and the electric field strength are equal in this region and, beyond the Fresnel region, vary inversely with distance from the [antenna]. The inner boundary of the radiation zone can be taken as one wavelength from the [antenna] if the [antenna] is small compared with this distance (IEV 60-32-050).

radiant intensity For a source in a given direction, the radiant power leaving the source, or an element of the source, in an element of solid angle containing the given direction, divided by that element of solid angle (ISO 31/VI). Symbol: *I*. Unit: watt per steradian (W/sr). With reference to antennas, this quantity is also called *radiated power per unit solid angle in a given direction* (IEV 60-32-090).

radiation pattern; radiation diagram; directivity pattern A diagram relating power flux density (or field strength) to direction relative to the [antenna] at a constant large distance from the [antenna]. *Note:* Such diagrams usually refer to planes or the surface of a cone containing the [antenna] and are usually normalized to the maximum value of the power flux density or field strength (IEV 60-32-135).

radio frequency Any frequency at which electromagnetic radiation is useful for telecommunication (IEV 55-05-060). (See Annex).

reactance Imaginary part of impedance (ISO 31/V). Symbol: *X*. Unit: ohm (OMEGA).

reflected wave A wave, produced by an incident wave, which returns in the opposite direction to the incident wave after reflection at the point of transition (IEV 25-50-065).

reflection coefficient; return current coefficient The complex ratio of reflected signal current to incident signal current at the termination (IEV 55-20-180). Symbol: *G*.

refractive index The ratio of the velocity of electromagnetic

radiation *in vacuo* to the phase velocity of electromagnetic radiation of a specified frequency in a medium (ISO 31/VI). Symbol: *eta*.

scanning Of a radar [antenna], systematic variation of the beam direction for search or angle tracking (IEV 60-72-095). The term is also applied to periodic motion of a radiocommunication antenna.

scattering The process by which the propagation of electromagnetic waves is modified by one or more discontinuities in the medium which have lengths of the order of the wave length (IEV 60-20-120); a process in which a change in direction or energy of an incident particle or incident radiation is caused by a collision with a particle or a system of particles (ISO 921). The extent to which the intensity of radiation is decreased in this manner is measured in terms of the *attenuation coefficient (scattering)*.

scattering cross section The cross section for the scattering process (IEV 26-05-650). See *cross section; scattering*.

shield A mechanical barrier or enclosure provided for protection (IEV 151-01-18). The term is modified in accordance with the type of protection afforded; e.g., a magnetic shield is a shield designed to afford protection against magnetic fields.

standing wave A state of vibration in which the oscillatory phenomena at all points are governed by the same time function, with the exception of a numerical factor, varying from one point to another (IEV 05-03-065).

standing-wave ratio The ratio of the maximum to the minimum amplitude of the current, voltage or field, measured respectively at an adjacent node and antinode in a line or waveguide carrying a standing wave (IEV 60-32-235). Symbol: *(S)*.

thermograph A term applied to a variety of instruments for measuring and recording temperature, especially (1) the heat radiated by the human body and (2) atmospheric temperature. The record produced by such an instrument is termed a *thermogram* and the technique is termed *thermography*. *Note:* None of these terms should be used in the context of thermal analysis, where they are deprecated.

time constant On an exponentially varying quantity, time after which the quantity would reach its limit if it maintained its initial rate of variation. If a quantity is a function of time given by *F(t) = A + Be* -t/tau then tau is the time constant (ISO 31/II).

transmission factor Ratio of the transmitted radiant ... flux to the incident flux (IEV 45-20-085).

transmission loss Over a given transmission path and for a given frequency, the amount, expressed in decibels, by which the available power at the input to a receiver is less than that available from the output stage of a transmitter (IEV 60-20-100).

wave A modification of the physical state of a medium which is propagated as a result of a local disturbance (IEV 05-03-005).

wave, diffracted A wave caused by the scattering of an incident wave upon an obstacle (IEV 101-05-15).

waveguide A system for the transmission of electromagnetic energy by a wave not of TEM type. It may, for example, consist of a metal tube, a dielectric rod or tube, or a single wire (IEV 62-10-005).

wave incident A travelling wave before it reaches a transition point (IEV 25-50-055).

wavelength The distance between two successive points of a periodic wave in the direction of propagation, in which the oscillation has the same phase (IEV 05-03-030). Symbol: *lambda*. Unit: metre (m).

wave, plane A wave such that the corresponding physical quantities are uniform in any plane perpendicular to a fixed direction (IEV 05-03-010).

wave, transmitted A wave (or waves) produced by an incident wave which continue(s) beyond the transition point (IEV 25-50-060).

wave, transverse A wave characterised by a vector at right angles to the direction of propagation (IEV 05-03-070).

ANNEX

The terms and explanations included in this annex are for the purposes of this publication only, and are not necessarily valid for any other purpose.

athermal effect An effect in a living organism that occurs

predominantly as a result of some phenomenon other than a local or whole body rise in temperature.

depth of penetration For a plane-wave electromagnetic field incident on the boundary of a lossy medium, the depth of penetration of the wave is taken to be that depth at which the field strength of the wave has been reduced to 1/ *e* or approximately 37% of its original value.

exposure, high level At the Warsaw symposium it was agreed that, in the microwave range, "high-level exposure"covers exposure to power flux densities exceeding 10 mW/cm^2. There is no agreement as to the meaning of the term when applied to radiation in the RF range.

exposure, intermittent This term refers to alternating periods of exposure and absence of exposure varying from a few seconds to several hours. If exposure lasting a few minutes to a few hours alternates with periods of absence of exposure lasting 18-24 hours (exposure repeated on successive days), "repeated exposure" might be a more appropriate term.

exposure, long-term This term indicates exposure during a major part of the lifetime of the animal involved; it may, therefore, vary from a few weeks to many years in duration.

exposure, low-level At the Warsaw symposium it was agreed that, in the microwave range, "low-level exposure" covers exposure to power flux densities up to 1 mW/cm^2. There is no agreement on the meaning of the term when applied to radiation in the RF range.

exposure, medium-level At the Warsaw symposium it was agreed that, in the microwave range, "medium-level exposure" covers exposure to power flux densities of 1-10 mW/cm^2. There is no agreement on the meaning of the term when applied to radiation in the RF range.

exposure, repeated This term refers to exposures lasting from a few minutes to a few hours repeated on successive days.

exposure, short-term This term covers exposures lasting from a few hours to 24 hours, or exposures for a few hours per day repeated for a few days per week.

exposure, single This term usually refers to an uninterrupted short-term exposure.

non-thermal effect See *athermal effect*.

radiofrequency In the present document, this term is used to designate frequencies ranging from 100 kHz to 300 MHz.

thermal effect An effect resulting predominantly from a local or whole body temperature rise in the living organism.

See Also:
Toxicological Abbreviations

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Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective☆

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ABSTRACT

Exposure to low frequency and radiofrequency electromagnetic fields at low intensities poses a significant health hazard that has not been adequately addressed by national and international organizations such as the World Health Organization. There is strong evidence that excessive exposure to mobile phone-frequencies over long periods of time increases the risk of brain cancer both in humans and animals. The mechanism(s) responsible include induction of reactive oxygen species, gene expression alteration and DNA damage through both epigenetic and genetic processes. *In vivo* and *in vitro* studies demonstrate adverse effects on male and female reproduction, almost certainly due to generation of reactive oxygen species. There is increasing evidence the exposures can result in neurobehavioral decrements and that some individuals develop a syndrome of "electro-hypersensitivity" or "microwave illness", which is one of several syndromes commonly categorized as "idiopathic environmental intolerance". While the symptoms are non-specific, new biochemical indicators and imaging techniques allow diagnosis that excludes the symptoms as being only psychosomatic. Unfortunately standards set by most national and international bodies are not protective of human health. This is a particular concern in children, given the rapid expansion of use of wireless technologies, the greater susceptibility of the developing nervous system, the hyperconductivity of their brain tissue, the greater penetration of radiofrequency radiation relative to head size and their potential for a longer lifetime exposure.
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1. Introduction

Electromagnetic fields (EMFs) are packets of energy that have no mass. They vary in frequency and wavelength. At the high end of the electromagnetic spectrum there are cosmic and X-rays that have enough energy to cause ionization, and therefore are known as ionizing EMFs. Below in frequency and energy are ultraviolet, visible light and infrared EMFs. Excessive exposure to ultraviolet EMFs poses clear danger to human health, but life on earth would not be possible without visible light and infrared EMFs. Below these forms of EMF are those used for communications (radiofrequency or RF-EMFs, 30 kHz-300 GHz) and those generated by electricity (extremely low-frequency or ELF-EMFs, 3 Hz-3 kHz). These EMFs do not have sufficient energy to directly cause ionization, and are therefore known as non-ionizing radiation. RF-EMFs at sufficient intensity cause tissue heating, which is the basis of operation of the microwave oven. However the question to be addressed here is human health effects secondary to exposures to non-ionizing EMFs at low intensities that do not cause measureable heating.

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In spite of a large body of evidence for human health hazards from non-ionizing EMFs at intensities that do not cause measureable tissue heating, summarized in an encyclopedic fashion in the Bioinitiative Report (www.bioinitiative.org), the World Health Organization (WHO) and governmental agencies in many countries have not taken steps to warn of the health hazards resulting from exposures to EMFs at low, non-thermal intensities, nor have they set exposure standards that are adequately health protective. In 2001 the International Agency for Research on Cancer (IARC, 2002), part of the WHO, declared ELF-EMFs to be "possibly carcinogenic to humans", and in 2011 they made a similar declaration for RF-EMFs (Baan et al., 2011; IARC, 2013). The classification of RF-EMFs as a "possible" human carcinogen was based primarily on evidence that long-term users of mobile phones held to the head resulted in an elevated risk of developing brain cancer. One major reason that the rating was not at "probable" or "known" was the lack of clear evidence from animal studies for exposure leading to cancer. The US National Toxicology Program has released preliminary results of a study of long term exposure of rats to cell phone radiation which resulted in a statistically significant increase in brain gliomas, the same cancer found in people after long-term cell phone use, and schwannomas, a tumor similar to the acoustic neuroma also seen after intensive mobile phone use (Wyde et al., 2016). Similar results in rats have been reported in an independent study at the Ramazzini Institute with exposures similar to those from a mobile phone base station (Falcioni et al., 2018). This evidence, in conjunction with the human studies, demonstrates conclusively that excessive exposure to RF-EMF results in an increased risk of cancer. In light of this new evidence for cancer in rodents in response to prolonged exposure to mobile phone frequencies, the IARC rating should be raised at least to "probable" (Group 2A) if not "known" (Group 1).

Unfortunately the International EMF Project of the WHO, which is part of the Department of Public Health, Environment and Social Determinants of Health in Geneva, has consistently minimized health concerns from non-ionizing EMFs at intensities that do not cause tissue heating (WHO, 2014). In this regard WHO has failed to provide an accurate and human health-protective analysis of the dangers posed to health, especially to the health of children, resulting from exposure to non-thermal levels of electromagnetic fields. The Department of Public Health, Environment and Social Determinates of Disease takes its advice on the issues related to human health effects of non-ionizing EMFs from the International Commission on Non-ionizing Radiation Protection (ICNIRP). Almost all members of the core group preparing the new Environmental Health Criteria (EHC) document for the WHO are members of ICNIRP (Starkey, 2016; Hardell, 2017), a non-goverment organization (NGO) whose members are appointed by other members. In spite of recent efforts to control for conflicts of interest, ICNIRP has a long record of close associations with industry (Maisch, 2006). When queried as to why the WHO would take recommendations from such a group, WHO staff replied that ICNIRP is an official NGO which works closely with the WHO. Why this should exclude other scientific research groups and public health professionals is unclear, particularly since most members of ICNIRP are not active researchers in this field. We are particularly concerned that a new WHO EHC document on RF-EMFs is scheduled to be released soon, and that the members of the EHC Core Group and the individuals whose assistance has been acknowledged are known to be in denial of serious non-thermal effects of RF-EMFs in spite of overwhelming scientific evidence to the contrary (Starkey, 2016; Hardell, 2017).

Others have dismissed the strong evidence for harm from ELF- and RF-EMFs by arguing that we do not know the mechanism whereby such low energetic EMFs might cause cancer and other diseases. We have definitive evidence that use of a mobile phone results in changes in brain metabolism (Volkow et al., 2011). We know that low-intensity ELF- and RF-EMFs generate reactive oxygen species (ROS), alter calcium metabolism and change gene expression through epigenetic mechanims, any of which may result in development of cancer and/or other diseases or physiological changes (see www.bioinitiative.org for many references). We do not know the mechanisms behind many known human carcinogens, dioxins and arsenic being two examples. Given the strength of the evidence for harm to humans it is imperative to reduce human exposure to EMFs. This is the essence of the "precautionary principle".

There are a number of reasons for our concern. In the past the major exposure of the general population to RF-EMFs came from radio and television signals. Now there are almost as many mobile phones as there are people in the world, all of them being exposed to RF-EMFs. There are mobile phone towers everywhere, and in many developing countries there are no land-lines that allow communication without exposure to RF-EMFs. There is rapid movement in many developed countries to place small cell transmitting devices (5G) operating at higher frequencies (24–70 GHz) every approximately 300 m along sidewalks in residential neighborhoods. There are other significant sources of exposure, coming from WiFi, smart meters and soon from automobiles operating without a human driver. Therefore human exposure has increased dramatically in recent years, and continues to increase rapidly. While we already are seeing harm from these exposures, the degree of harm will only increase with time because of the latency that is known to occur between exposure and development of diseases such as cancer.

Standards for protection of human health from EMFs vary greatly around the world. Many countries set standards based on the false assumption that there are no adverse health effects of RF-EMFs other than those that are caused by tissue heating. This is the case in North America, Australia and some European countries. Many countries from the former Soviet Union have much more restrictive standards. However information from cellular and human studies show biological effects that constitute hazards to human health at exposure levels that are often exceeded during daily life.

This report follows a recent non-official meeting in Geneva with WHO representives, where the authors urged WHO to acknowlege low intensity effects of ELF-EMFs and non-thermal health effects of RF-EMFs. This report does not attempt to present a complete overview of the subject [see the Bioinitiative Report (www.bioinitiative.org) for that] but rather to provide a holistic picture of the processes explaining most or all of the adverse effects of EMF exposures. It summarizes the evidence for cancer resulting from exposure to EMFs, and identifies other diseases or pathological conditions such as Alzheimer's disease and hypofertility that have been shown to be associated with excesive exposure to low-intensity EMFs. We also focus on electrohypersensitivity (EHS) in both children and adults and cognitive and behavioural problems in children resulting from the increasing exposure. Finally we discuss what is known about the mechanisms whereby non-thermal EMF radiation can cause disease with special reference to EMF-related free radical production and epigenetic and genetic mechanisms.

2. Mobile phone use and the risk for glioma, meningioma and acoustic neuroma

The brain is the main target for exposure to RF-EMF radiation during use of handheld wireless phones, both mobile and cordless phones (Cardis et al., 2008; Gandhi et al., 2012). An increased risk for brain tumors has been of concern for a long time. The results of the Swedish National Inpatient Register have documented an

increasing incidence of brain tumors in recent years (Carlberg and Hardell, 2017). In May 2011 RF radiation in the frequency range 30 kHz–300 GHz was evaluated to be a Group 2B, i.e. a "possible" human carcinogen, by IARC (Baan et al., 2011; IARC, 2013). This was based on an increased risk for glioma and acoustic neuroma in human epidemiological studies. In the following an updated summary is given of case-control studies on brain and head tumors; glioma, meningioma and acoustic neuroma. The Danish cohort study on 'mobile phone users' (Johansen et al., 2001; Schüz et al., 2006) is not included due to serious methodological shortcomings in the study design, including misclassification of exposure (see Söderqvist et al., 2012a).

2.1. Glioma

Glioma is the most common malignant brain tumor and represents about 60% of all central nervous system (CNS) tumors. Most of these are astrocytic tumors that can be divided into low-grade (WHO grades I-II) and high-grade (WHO grades III-IV). The most common glioma type is glioblastoma multiforme (WHO grade IV) with peak incidence in the age group 45–75 years and median survival less than one year (Ohgaki and Kleihues, 2005). Three research groups have provided results in case-control studies on glioma (Interphone, 2010; Coureau et al., 2014; Hardell and Carlberg, 2015). Hardell and colleagues have published results from case-control studies on use of wireless phones and brain tumor risk since the end of the 1990s (Hardell et al., 1990; for more discussion see Carlberg and Hardell, 2017).

A random effects model was used for meta-analyses of published studies, based on test for heterogeneity in the overall group ("all mobile"). Note that only the Hardell group also assessed use of cordless phones. Thus their reference category included cases and controls with no use of wireless phones in contrast to the other studies investigating only mobile phone use. In Table 1 results for highest cumulative use in hours of mobile phones is given. All studies reported statistically significant increased risk for glioma and the meta-analysis yielded an odds ratio (OR) = 1.90 [95% confidence interval (CI) = 1.31–2.76]. For ipsilateral mobile phone use the risk increased further to OR = 2.54 (95% CI = 1.83–3.52) in the meta-analysis based on 247 exposed cases and 202 controls.

Carlberg and Hardell (2014) found shorter survival in patients with glioblastoma multiforme associated with use of wireless phones compared with patients with no use. Interestingly mutation of the p53 gene involved in disease progression has been reported in glioblastoma multiforme in patients with mobile phone use ≥3 h per day. The mutation was statistically significantly correlated with shorter overall survival time (Akhavan-Sigari et al., 2014). Further support for the increased risk of glioma associated with mobile phone use has been obtained in additional analyses of parts of the Interphone study (Cardis et al., 2011; Grell et al., 2016; Momoli et al., 2017).

2.2. Meningioma

Meningioma is an encapsulated, well-demarked and rarely malignant tumor. It is the most common benign tumor and accounts for about 30% of intracranial neoplasms. It develops from the pia and arachnoid membranes that cover the CNS. It is slowly growing and gives neurological symptoms by compression of adjacent structures. The most common symptoms are headaches and seizures. The incidence is about two times higher in women than in men. Meningioma develops mostly among middle aged and older persons (Cea-Soriano et al., 2012). Carlberg and Hardell (2015) included meningioma in their case-control studies. The results of the meta-analysis for cumulative exposure in the highest category are given in Table 2. In total there was an increased (but not statistically significant) risk for cumulative exposure but the increased risk was statistically significant for ipsilateral use of mobile phones (OR = 1.49, 95% CI = 1.08–2.06).

2.3. Acoustic neuroma

Acoustic neuroma, also called vestibular schwannoma, is a benign tumor located on the eighth cranial nerve from the inner ear to the brain. It is usually encapsulated and grows in relation to the auditory and vestibular portions of the nerve. It grows slowly and due to the narrow anatomical space may give compression of vital brain stem structures. First symptoms of acoustic neuroma are usually tinnitus and hearing problems. Results for use of mobile phones in Interphone (2011) and Hardell et al. (2013) are given in Table 3. Statistically significant increased risk was found for cumulative ipsilateral use ≥1640 h yielding OR = 2.71 (95% CI = 1.72–4.28).

The study by Moon et al. (2014) was not included in the meta-analysis because data on cumulative mobile phone use with numbers of cases and controls were not given. Support of an increased risk was seen in the case-case part of the study (Moon et al., 2014) and also in the report by Sato et al. (2011). Pettersson et al. (2014) made a case-control study on acoustic neuroma in Sweden not overlapping the Hardell et al. (2013) study. An increased risk for the highest category of cumulative use of both mobile phone (≥680 h OR = 1.46, 95% CI = 0.98–2.17) and cordless phone (≥900 h OR = 1.67, 95% CI = 1.13–2.49) was found.Pettersson et al. (2014) was not included in the meta-analysis due to the many scientific shortcomings in the study, e.g. laterality analysis was not made for cordless phone, the numbers in the laterality analysis for mobile phone are not consistent in text and tables and the 'unexposed' reference category included subjects using either mobile and cordless phone, which is clearly not correct (Hardell and Carlberg, 2014).

Table 1
Numbers of exposed cases (Ca) and controls (Co) and odds ratio (OR) with 95% confidence interval (CI) for glioma in case-control studies in the highest category of cumulative hours of mobile phone use.

	All			Ipsilateral		
	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Interphone 2010						
Cumulative use ≥1640 h	210/154	1.40	1.03–1.89	100/62	1.96	1.22–3.16
Coureau et al., 2014						
Cumulative use ≥896 h	24/22	2.89	1.41–5.93	9/7	2.11	0.73–6.08
Carlberg and Hardell, 2015						
Cumulative use ≥1640 h	211/301	2.13	1.61–2.82	138/133	3.11	2.18–4.44
Meta-analysis						
Longest cumulative use	445/477	1.90	1.31–2.76	247/202	2.54	1.83–3.52

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Table 2
Numbers of exposed cases (Ca) and controls (Co) and odds ratio (OR) with 95% confidence interval (CI) for meningioma in case-control studies in the highest category of cumulative hours of mobile phone use.

	All			Ipsilateral		
	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Interphone 2010						
Cumulative use ≥1640 h	130/107	1.15	0.81–1.62	46/35	1.45	0.80–2.61
Coureau et al., 2014						
Cumulative use ≥896 h	13/9	2.57	1.02–6.44	6/4	2.29	0.58–8.97
Carlberg and Hardell 2015						
Cumulative use ≥1640 h	141/301	1.24	0.93–1.66	67/133	1.46	0.98–2.17
Meta-analysis						
Longest cumulative use	284/417	1.27	0.98–1.66	119/172	1.49	1.08–2.06

Table 3
Numbers of exposed cases (Ca) and controls (Co) and odds ratio (OR) with 95% confidence interval (CI) for acoustic neuroma in case-control studies in the highest category of cumulative hours of mobile phone use.

	All			Ipsilateral		
	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Interphone 2011						
Cumulative use ≥1640 h	77/107	1.32	0.88–1.97	47/46	2.33	1.23–4.40
Hardell et al., 2013						
Cumulative use ≥1640 h	27/301	2.40	1.39–4.16	19/133	3.18	1.65–6.12
Meta-analysis						
Cumulative use ≥1640 h	104/408	1.73	0.96–3.09	66/179	2.71	1.72–4.28

2.4. In summary

Based on case-control studies there was a consistent finding of increased risk for glioma and acoustic neuroma associated with use of mobile phones. Similar results were found for cordless phones in the Hardell group studies, although such use was not reported by the other study groups. The findings are less consistent for meningioma although somewhat increased risk was seen in the meta-analysis of ipsilateral mobile phone use. A longer follow-up time is necessary for this type of slow growing tumor.

The results on glioma and acoustic neuroma are supported by results from animal studies showing co-carcinogenic and tumor promoting effects from RF-EMF (Tillmann et al., 2010; Lerchl et al., 2015). Recent results from the National Toxicology Program (NTP) study showed genotoxicity of RF radiation in rats and mice exposed to RF-EMF (Smith-Roe et al., 2017). That result supports previous findings of DNA strand breaks in rat brain cells exposed to RF-EMF (Lai and Singh, 1997).

Of importance also is that the results in the NTP and Ramazzini studies both demonstrated an increased incidence of tumors of the same type, glioma and malignant schwannoma, as has been seen in humans with mobile phone use (Wyde et al., 2016; Falcioni et al., 2018). Acoustic neuroma (vestibular schwannoma) is a similar type of tumor as malignant schwannoma, although benign. In fact, rates of brain tumors are increasing in Sweden and use of wireless phones has been suggested to be the cause (Hardell and Carlberg. 2017).

3. Other diseases and pathological conditions attributed to exposure to low-intensity EMFs

The evidence for harm from RF-EMF is strongest for cancer as a consequence of intensive mobile phone use, especially gliomas, glioblastomas and acoustic neuromas. But there is other evidence for elevation in risk of leukemia among children living near to very high intensity radio transmission towers (Michelozzi et al., 2002; Ha et al., 2007). This is particularly interesting because leukemia is the cancer most associated with elevated exposure to ELF-EMFs arising from power lines (Ahlbom et al., 2000; Greenland et al., 2000). There is some evidence for elevations in breast cancer risk among women who wear their mobile phones in their bra (West et al., 2013). Heavy use of a mobile phone was associated with significantly elevated rates of ipsilateral parotid tumors in studies from both Israel (Sadetzki et al., 2007) and China (Duan et al., 2011). No increased risk was found in a Swedish study, but the results were limited by low number of participants and lack of data on heavy and long-term use of wireless phones (Söderqvist et al., 2012b).

There are other significant human health hazards of concern. There is strong animal and human evidence that exposure to RF-EMFs as well as ELF-EMFs reduces fertility in both males (reviewed by McGill and Agarwal, 2014) and females (Roshangar et al., 2014). An association between spontaneous abortion and non-thermal EMF exposure including ELF-EMFs was reported in several case-control studies (Dodge, 1970; Juutilainen et al., 1993; Li et al., 2017). The increased use of mobile phones and increased exposure coming from WiFi, smart meters and other wireless devices has been paralled in time with male hypofertility and sperm abnormalities in semen (Rolland et al., 2013). These effects may be related to holding an active wireless laptop in a man's lap or having an active mobile phone on their belt, but more study is needed. There is evidence that isolated human sperm exposed to RF-EMFs are damaged by generation of reactive oxygen species (Agarwal et al., 2009).

There are other diseases or physiologic alterations which have been reported to be associated with exposure to non-thermal EMFs in humans and in animals (Belyaev et al., 2016). Alzheimer disease has been shown to be significantly associated with chronic ELF-EMF occupational exposure in prospective epidemiological studies (García et al., 2008; Davanipour and Sobel, 2009). Exposure to RF-EMFs has been reported to increase neuropsychiatric and behavioural disorders (Johansson et al., 2010; Divan et al., 2012), trigger cardiac rhythm alteration and peripheral arterial pressure instability (Havas, 2013; Saili et al., 2015), induce changes in immune system function (Lyle et al., 1983; Grigoriev et al., 2010; Sannino et al., 2011, 2014) and alter salivary (Augner et al., 2010) and

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thyroid (Koyu et al., 2005; Mortavazi et al., 2009; Pawlak et al., 2014) function. There is an urgent need for more study of these diseases or biological alterations in relation to exposure to both ELF- and RF-EMFs.

4. An emerging concern: cognitive and neurobehavioral problems in children

Children, and especially fetuses, are more vulnerable than adults for most environmental exposures (Sly and Carpenter, 2012). This is because their cells are rapidly dividing and their organ systems are not mature. As a result, events that perturb cellular function early in life can result is abnormalities that last. There is a building body of evidence indicating that exposure to RF-EMFs has adverse effects on cognition and neurobehavior, especially in children and adolescents. Concern about the particular sensitivity of children to RF-EMFs emitted from mobile phone was first raised in 2000 by a British independent expert group (IEG, 2000) that noted that the increased sensitivity to EMFs of children could be due not only to the natural vulnerability of the developing nervous system, but also to the smaller head size and thickness of the skull. These factors, plus the higher conductivity of the young nervous system, result in greater penetration of RF-EMFs into the brain (Gandhi et al., 1996). Of concern is the fact that any adverse effects during development may have life-long consequences and that young people, because they will have a longer life span, will receive a greater cumulative exposure than adults (Kheifets et al., 2005; Hansson Mild et al., 2006).

There are several reasons to be concerned. Animal studies have shown that *in utero* RF-EMF exposure from mobile phones affects fetal programming and leads to alteration in neurodevelopment and behavior of offsprings (Aldad et al., 2012; Zhang et al., 2015). Exposure of young rats to non-thermal intensities impairs learning and spatial memory secondary to a deleterious impact of EMFs on hippocampal, pyramidal or cortical neurons. Similar detrimental cognitive and behavioural defects were also observed in adult animals exposed to low-intensity.

EMFs (Bas et al., 2009; Deshmukh et al., 2015; Kumari et al., 2017; Shahin et al., 2017). The exposure induces markers of oxidative stress and inflammation in the brain (Dasdag et al., 2012; Megha et al., 2015).

There are human data consistent with these animal studies. Divan et al. (2008) reported that prenatal and to a lesser degree postnatal exposure to cell phones is associated with emotional and hyperactivity problems in 7-year old children. This finding was confirmed in a second replicative study involving different participants (Divan et al., 2012). Birks et al. (2017) used data from studies in five cohorts from five different countries (83,884 children) and concluded that maternal mobile phone use during pregnancy increased the risk that the child will show hyperactivity and inattention problems. A meta-analysis involving 125,198 children (mean age 14.5 years) reported statistically significant associations between access to and use of portable screen-based media devices (e.g. mobile phones and tablets) and inadequate sleep quality and quantity and excessive daytime sleepiness (Carter et al., 2016). Early life exposure to lead has long been known to cause a reduction in cognitive function and shortened attention span (Needleman et al., 1979). Two studies have shown that prenatal (Choi et al., 2017) or postnatal (Byun et al., 2017) mobile phone exposure results in greater neurobehavioral effects in children with elevated lead levels than those seen with elevated lead alone. These results raise concern that EMFs may have synergistic actions with other environmental contaminants known to cause a reduction in intelligence quotient (IQ) and attention, such as polychlorinated biphenyls, methyl mercury, environmental tobacco smoke and probably others (Carpenter, 2006).

Finally the problem should be considered at the societal, worldwide level. Many adolescents (Lenhart, 2015) and even very young children and infants (Kabali et al., 2015) use cordless devices immoderately, to such a point that the common intensive use of devices in children and adolescents has been ascribed as an addiction (Paz de la Puente and Balmori, 2007; Roberts et al., 2014).

The specific absorption rate (SAR)-based ICNIRP safety limits were established on the basis of simulation of EMF energy absorption using standardized adult male phantoms, and designed to protect people only from the thermal effects of EMFs. These assumptions are not valid for two reasons. Not only do they fail to consider the specific morphological and bioclinical vulnerabilities of children, but also they ignore the effects known to occur at non-thermal intensities. The same criticisms apply to other so called “independent” advisory groups or agencies, such as the Advisory Group of Non-Ionizing Radiation in the UK (AGNIR, 2012), the French Agency for Food, Environmental and Occupational Health & Safety in France (ANSES, 2013), and the Scientific Committee on Emerging Newly Identified Health Risk (SCENIHR, 2009), all of whom deny the detrimental health effects of low intensity, non thermal EMF exposure and make recommendations based only on thermal SAR considerations.

Although several scientific authorities, such as the US American Academy of Pediatrics (AAP, 2013), and the Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP, 2011) have made specific recommendations to not allow the use of mobile phones by children and to limit their use by adolescents, unfortunately these age categories remain a target for marketing of mobile phone devices [http://www.who.int/peh-emf/project/mapnatreps/RUSSIA%20report%202008.pdf]. The RNCNIRP has warned that if no rational, health-based safety limits are adopted for children and adolescents and no measures are taken to limit the use of cordless devices, we can expect disruption of memory, decreases in learning and cognitive capabilities, increases in irritability, sleep disturbance, and loss of stress adaptation in this population. There will also be long-term effects, including an increase in brain cancer, infertility, EHS, Alzheimer disease and other neurodegenerative diseases (RNCNIRP, 2011; Markov and Grigoriev, 2015). National and international bodies, particularly the WHO, will bear major responsiblity for failing to provide specific science-based guidance and recommendations so as to avoid such global health threats.

5. Electrohypersensitivity, microwave illness or idiopathic environmental intolerance attributed to electromagnetic fields

There is a segment of the human population that is unusually intolerant to EMFs. The term “electromagnetic hypersensitivity” or “electrohypersensitivity (EHS)” to describe the clinical conditions in these patients was first used in a report prepared by a European group of experts for the European Commission (Bergqvist et al., 1997). Santini et al. (2001, 2003) reported similar symptoms occurring in users of digital cellular phones and among people living near mobile phone base stations.

In 2004, because of the seemingly increasing worldwide prevalence, WHO organized an international scientific workshop in Prague in order to define and characterize EHS. Although not acknowledging EHS as being caused by EMF exposure, the Prague working group report clearly defined EHS as “a phenomenon where individuals experience adverse health effects while using or being in the vicinity of devices emanating electric, magnetic or electromagnetic fields” (www.who.int/pehemf/EHS_Proceedings_June2006.pdf). Following this meeting, WHO acknowledged EHS as an adverse health condition (WHO, 2005).

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According to the Prague Workshop recommendations, it was proposed to use the term “idiopathic environmental intolerance (IEI) attributed to electromagnetic fields” (IEI-EMF) because of the lack of a proven causal link with EMF exposure (Hansson Mild et al., 2006). This pathological disorder is identical to what has been previously described under the term “microwave illness” (Carpenter, 2015).

This syndrome is characterized by fatigue, chronic pain and impaired cognitive function (see the Paris appeal, http://appel-de-paris.com/?lang=en). The precise mechanism(s) whereby environmental exposure to either ELF- or RF-EMFs can cause the development of this syndrome are still uncertain. However several lines of experimental and clinical data are sufficiently strong so as to indicate that ELF-EMFs and RF-EMFs exposure is associated with adverse biological and clinical health effects in humans as well as animals (Rea et al., 1991; McCarty et al., 2011; Belpomme et al., 2015; Hedendahl et al., 2015; Irigaray et al., 2018a). The prevalence of EHS has been estimated to range 1–10% in developed countries (Hallberg and Oberfeld, 2006) but appears today to be around 3% (Huang et al., 2018).

Since WHO official reports on mobile phone exposure and public health (WHO, 2014) and more particularly on EHS (WHO, 2005), much clinical and biological progress has been made to identify and objectively characterize EHS, as was summarized during the international scientific consensus meeting of the 5th Paris Appeal Congress that took place in May 2015 in Brussels at the Royal Belgium Academy of Medicine (ISD, 2015). EHS has many characteristics in common with other IEI pathological disorders, including chronic fatigue syndrome, fibromyalgia, Gulf War Illness and especially the syndrome of multiple chemical senssitvity (MCS), which Belpomme et al. (2015) have shown to be associated with EHS in many patients who report being electrohypersensitive.

5.1. Bioclinical identification and characterisation of electrohypersensitivity

In a prospective study involving systematic face-to-face questionnaire-based interviews and clinical physical examinations of nearly two thousand patients who self-reported having EHS or EHS and MCS, Belpomme and colleagues reported that EHS is a well-defined clinico-biological entity, characterized by the progressive occurrence of neurologic symptoms, including headache, tinnitus, hyperacusis, superficial and/or deep sensibility abnormalities, fibromyalgia, vegetative nerve dysfunction and reduced cognitive capability. These symptoms are repeatedly reported by the patients to occur each time they are exposed to EMFs, even of weak intensity. They result in chronic insomnia, fatigue, emotional lability and depressive tendency (Belpomme et al., 2015; Irigaray et al., 2018b).

Table 4 presents the detailed symptomatic picture which was obtained during face-to-face interviews with subjects with EHS in comparison to those with both EHS and MCS and to a series of apparently healthy control subjects that showed no evidence of EHS and/or MCS. As shown in the Table, the symptoms reported are consistent with those in other published questionnaire-based studies of EHS patients (Dodge, 1970; Johansson et al., 2010; Nordin et al., 2014; Medeiros and Sanchez, 2016; Röösli, 2008). The clinical symptoms observed in EHS or EHS/MCS patients are statistically significantly much more frequent that those in apparently normal controls. Although many of these symptoms are non-specific, the general clinical picture resulting from their association and frequency strongly suggests that EHS can be recognized and identified as a specific neurological disorder.

Because of the multiple and relatively common symptoms and the lack of recognized objective diagnosis criteria, studies on EHS were left with only the patient's self-reported interpretation for many years. As a result, EHS has unfortunately been considered to be a psychiatric disease of unknown origin. This helps explain why most mainstream public health and societal bodies claim there is not sufficient data proving that the clinical symptoms experienced and reported by EHS patients are caused by EMF exposure. Therefore they refuse to acknowledge EHS as a true neuropathological disorder. This negative point of view was supported by some blind or double blind studies showing that most individuals who report they suffer from EHS were not able to identify when they were exposed to either EMFs or sham controls (Rubin et al., 2011; Eltiti et al., 2015). However other studies have found that EHS subjects can identify EMF exposure in a statistically significant manner when they are blinded to whether or not the exposure was on (Rea et al., 1991; McCarty et al., 2011).

To account for these seemingly negative results a nocebo effect was suggested (ANSES, 2017). However there is presently no consensus on a biological mechanism through which a nocebo effect could occur (Medeiros and Sanchez, 2016; Chrousos and Gold, 1992; Jakovljevic, 2014). Moreover, results obtained in a carefully designed psycho-clinical study in self-reporting EHS patients are not consistent with an initial nocebo response to perceived EMF exposure, even though it is plausible that after the onset of the disease such phenomena may intervene secondarily through an acquired learning and conditioning process (Dieudonné, 2016). In addition, a meta-analysis of cross sectional studies has documented a 38% greater risk of development of headaches among mobile phone users than non-users, and an increasing risk of headache with longer daily call duration (Wang et al., 2017).

Belpomme, Irigaray and colleagues recently identified several biomarkers in EHS and/or MCS patients which allow physicians to identify and objectively characterize EHS as a true somatic pathological disorder, discounting the hypothesis of a causal psychosomatic or nocebo-related process. These came in part from a prospective clinical and biological analysis of a series of several hundred consecutive cases of individuals who self-reported that they suffered from EHS or both EHS and MCS (Belpomme et al., 2015) and more recently from the prospective anlaysis of an additional series of EHS patients (Irigaray et al., 2018a). Table 5 summarizes the different biomarkers that have been measured in the peripheral blood of these patients and the results which have been obtained based on the EHS and EHS/MCS patient groups. Note that among the different markers, the 6-hydroxymelatonin sulfate/creatinine ratio in urine appears to be the best marker to be used in medical practice since it has been found to be decreased in all cases evaluated to date (Belpomme et al., 2015).

By measuring different major oxidative stress-related biomarkers, such as thiobarbituric acid reactive substances (TBARS), oxided glutathione (GSSG) and nitrotyrosine (NTT) in EHS patients, Irigaray et al. (2018b) have recently shown that near 80% of the EHS patients present with detectable oxidative stress biomarkers (Fig. 1). More than 40% of EHS patients present with at least one positive biomarker, 20% with two and 15% will all three of the biomarkers investigated. This indicates that in addition to the inflammation-related biomarkers previously associated with EHS, EHS patients are also characterized by exhibiting biomarkers of oxidative stress (Belpomme et al., 2015; Irigaray et al., 2018a,b).

The significance of the different biomarkers measured in the peripheral blood of EHS and EHS/MCS patients is that these results imply that these patients present with some degree of oxidative/nitrosative stress, inflammation and autoimmune response. Increased levels of several of these markers (notably protein S100B and NTT) may reflect hypoxia-associated oxidative stress-induced blood brain barrier (BBB) opening. It has been previously hypothesized that opening of the BBB can be caused by environmental

Table 4
Clinical symptom occurrence in EHS and EHS/MCS patients in comparaison with normal controls[a].

	EHS	EHS/MCS	p[b]	Normal controls	p[c]	p[d]
Headache	88%	96%	0.065	0%	<0.0001	<0.0001
Dysesthesia	82%	96%	0.002	0%	<0.0001	<0.0001
Myalgia	48%	76%	<0.0001	6%	<0.0001	<0.0001
Arthralgia	30%	56%	<0.001	18%	0.067	<0.0001
Ear heat/otalgia	70%	90%	<0.001	0%	<0.0001	<0.0001
Tinnitus	60%	88%	<0.0001	6%	<0.0001	<0.0001
Hyperacousis	40%	52%	0.118	6%	<0.0001	<0.0001
Dizziness	70%	68%	0.878	0%	<0.0001	<0.0001
Balance disorder	42%	52%	0.202	0%	<0.0001	<0.0001
Concentration/Attention deficiency	76%	88%	0.041	0%	<0.0001	<0.0001
Loss of immediate memory	70%	84%	0.028	6%	<0.0001	<0.0001
Confusion	8%	20%	0.023	0%	0.007	<0.0001
Fatigue	88%	94%	0.216	12%	<0.0001	<0.0001
Insomnia	74%	92%	0.001	6%	<0.0001	<0.0001
Depression tendency	60%	76%	0.022	0%	<0.0001	<0.0001
Suicidal ideation	20%	40%	0.003	0%	<0.0001	<0.0001
Transitory cardiovascular abnormalities	50%	56%	0.479	0%	<0.0001	<0.0001
Occular deficiency	48%	56%	0.322	0%	<0.0001	<0.0001
Anxiety/Panic	38%	28%	0.176	0%	<0.0001	<0.0001
Emotivity	20%	20%	1	12%	0.176	0.176
Irritability	24%	24%	1	6%	<0.001	<0.001
Skin lesions	16%	45%	<0.0001	0%	<0.0001	<0.0001
Global body dysthermia	14%	8%	0.258	0%	<0.0001	<0.007

[a] This data results from the clinical analysis of the 100 first clinically evaluated cases issued from the already published series of EHS and/or MCS patients who have been investigated for biological markers [Belpomme et al., 2015]. It has been compared symptomatically with data obtained from a series of 50 apparently normal subjects matched for age and sex, used as controls.
[b] Significance levels (p values) obtained for compararison between the EHS and EHS/MCS groups.
[c] Significance levels (p values) obtained for compararison between the EHS and normal control groups.
[d] Significance levels (p values) obtained for compararison between the EHS/MCS and normal control groups.

Table 5
Patient mean values and standard deviations of biomarker levels in comparison with normal reference values as well as the percentage of patients with abnormal values in the peripheral blood in subjects with EHS or both EHS and MCS (Belpomme et al., 2015).

Biomarker and Normal reference values	Patients groups			
	EHS Mean ± SD	% Above normal	EHS/MCS Mean ± SD	% Above Normal[a]
hs-CRP < 3 mg/l	10.3 ± 1.9	15%	6.9 +/1.7	14.3%
Vitamine D > 30 ng/ml	20.6 ± 0.5	69.3%	14.5 ± 1.3	70.1%
Histamine< 10 nmol/l	13.6 ± 0.2	37%	13.6 ± 0.4	41.5%
IgE< 100 UI/ml	329.5 ± 43.9	22%	385 ± 70	24.7%
S100B < 0.105 μg/l	0.20 ± 0.03	14.7%	0.17 ± 0.03	19.7%
Hsp 70 < 5 ng/ml	8.2 ± 0.2	18.7%	8 ± 0.3	25.4%
Hsp 27< 5 ng/ml	7.3 ± 0.2	25.8%	7.2 ± 0.3	31.8%
Anti-O-myelin auto-antibodies[b]	Positive	22.9%	Positive	23.6%
24-h urine 6-OHMS/creatinine ratio >0.8[c]	0.042 ± 0.003	100%	0.048 ± 0.006	100%

hs-CRP, high-sensitivity C-reactive protein; IgE, Immunoglobulin E; S100B, S 100 calcium binding protein B; Hsp 27, heat shock protein 27; Hsp 70, heat shock protein 70; anti-O-myelin auto-antibodies, auto-antibodies against O-myelin; 6-OHMS, 6-hydroxymelatonin sulfate.
[a] There is no statistically significant difference between the two groups of patients for the different biomarkers analyzed, suggesting that EHS and MCS share a common pathological mechanism for genesis.
[b] Qualitative test.
[c] Data restricted to those not on neuroleptic medication as the simultaneous use of several psychotherapeutic drugs may also be associated with a decrease of this 24-h urine ratio by modifying melatonine metabolism.

stressors, be they chemicals or EMFs. This may have occurred in these patients, as has been shown to occur in several (but not all) animal experiments involving EMF exposure (Oscar and Hawkins, 1977; Persson et al., 1997; Eberhardt et al., 2008; Sirav and Seyhan, 2009). Comparable data using metabolic and genetic biomarkers were also obtained in another large series of EHS patients (De Luca et al., 2014). Overall these data indicate that the clinical use of biomarkers allows the objective characterisation and identification of EHS and MCS as two etiopathologic facets of a unique pathological disorder, and also allows insight into the genesis of these two diseases.

The development of new imaging techniques has also greatly increased our ability to objectively characterize EHS and MCS. Using ultrasonic cerebral tomosphygmography (UCTS) (Parini et al., 1984), EHS- and EHS/MCS-patients were found to have a statistically significant decrease in mean pulsometric index in several middle cerebral artery-dependant portions of the temporal lobes, especially in the capsulo-thalamic area, which is part of the limbic

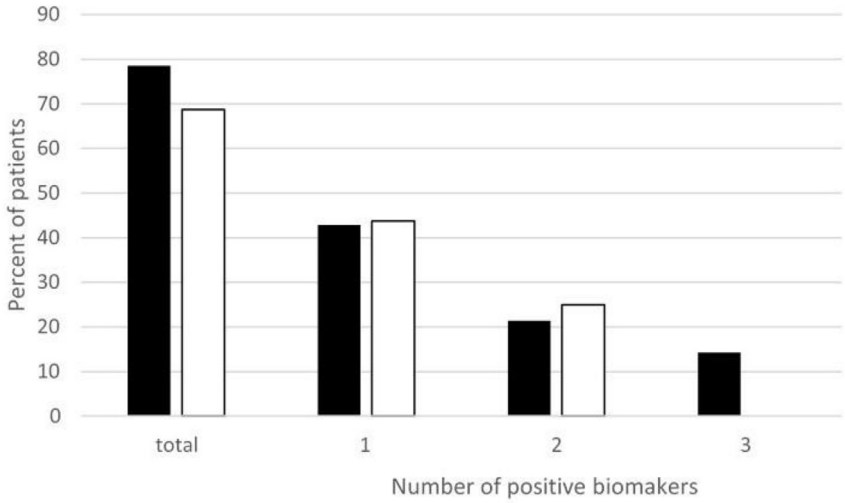


Fig. 1. Percentage of EHS self-reporting patients having positive TBARs, GSSG and/or NTT oxidative stress biomarkers measured in the peripheral blood. "Positive" biomarkers correspond to marker levels above the upper normal limit; "total" corresponds to the patients with one or more positive biomarker levels. Black bars show the percentage of patients with one, two or all three of the biomarkers for TBARS, GSSG and NTT. The white bars show the percentage of patients with either TBARs or GSSG or both oxidative stress markers.

system and the thalamus. This suggests that EHS and EHS/MCS may be associated with a brain blood flow (BBF) deficiency and/or neuronal dysfunction in these brain structures (Belpomme et al., 2015; Irigaray et al., 2018a,b). Irigaray et al. (2018c) have recently confirmed that UCTS is the best imaging technique to diagnose EHS and to follow patients treated for EHS and/or MCS.

In addition, using positron emission tomography (PET) it has been shown that short term exposure to pulse-modulated RF-EMF causally affects regional BBF in normal subjects using a mobile phone (Aalto et al., 2006; Huber et al., 2005), a finding that may account for the modifications observed in the sleep and waking EEG (Huber et al., 2002). By use of functional MRI (fMRI) in EHS patients exposed chronically to ELF-EMFs, regional BBF changes have been reported in the frontal lobes, such as abnormal default mode network and more particularly a decrease in BBF and cerebral metabolism. These observations indicate that fMRI may also be a tool for diagnosis of EHS and clinical follow up of patients (Heuser and Heuser, 2017). A decreased BBF-associated pulsometric index decrease in both hemispheres was also recently observed by the Belpomme group by using transcranial Doppler ultrasound (TDU) (Purlauastja and Sorond, 2012) applied to the middle cerebral artery in a study involving 120 EHS and/or MCS patients. This study revealed a decrease in pulsatility index and an increase in diastolic flow velocity in 70% of the 120 cases investigated to date.

In summary it is the strong opinion of the authors that there is presently sufficient clinical, biological and radiological data emanating from different independent international scientific research groups for EHS, whatever its causal origin, to be acknowledged as a well-defined, objectively characterized pathological disorder. As a result, patients who self-report that they suffer from EHS should be diagnosed and treated utilizing presently available objective biological tests, among which are the concentration of peripheral blood biomarkers and the use of imaging techniques such as PET, fMRI and TDU and, when available, UCTS. Whatever its etiological origin and mechanism of action, EHS should be acknowledge by the WHO as a real and distinct neurological and pathological disorder (McCarty et al., 2011; Hedendahl et al., 2015) and thus be included in the International Classification of Diseases.

5.2. Possible etiopathogenic processes involved in genesis of electrohypersensitivity

EMFs, both RF-EMFs at non-thermal intensities and ELF-EMFs, have been found to cause persistent adverse biological effects in microorganisms (Fojt et al., 2004), plants (Roux et al., 2008; Maffei, 2014), birds (Balmori, 2005; Balmori and Hallberg, 2007; Frey, 1993), and mammals. Therefore the effects observed in humans cannot be due to only a nocebo or psychosomatic effect. These biological effects may be due both to the pulsed and polarised characteristics of man-made EMFs emitted by electric or wireless technologies as opposed to the terrestrial non-polarised and continuously emitted natural EMFs (Blackman, 2009; Belyaev, 2015; Panagopoulos et al., 2015).

The inflammatory and oxidative/nitrosative states that have been documented in EHS patients are remarkable since they confirm the data obtained experimentally in animals exposed to non-thermal EMFs (Esmekaya et al., 2011; Burlaka et al., 2013), and especially in the brain (Megha et al., 2015; Kesari et al., 2011). The limbic system–associated capsulo-thalamic abnormalities that the Belpomme group has observed by using UCTS in EHS and/or MCS patients (Belpomme et al., 2015; Irigaray et al., 2018a,c) may likely correspond to the hippocampal neuronal alterations caused by EMF exposure in the rats (Bas et al., 2009; Furtado-Filho et al., 2015; Deshmukh et al., 2013). Fig. 2 summarizes our hypothesis regarding the inflammation and oxidative stress-related mechanisms which may account for EMF- and/or chemically-related health effects in the brain and consequently for EHS genesis.

6. Mechanisms whereby low intensity electromagnetic fields cause biological effects and harm

Arguments used in the past to attempt to discount the evidence showing deleterious health effects of ELF-EMFs and RF-EMF exposure at non-thermal SAR levels were based on the difficulties encountered in understanding the underlying biological effects and the lack of recognized basic molecular mechanisms accounting for these effects. This is no longer the case. There are a number of well-documented effects of low intensity EMFs that are the mechanistic basis behind the biological effects documented above (www.

bioinitiative.org). These include induction of oxidative stress, DNA damage, epigenetic changes, altered gene expression and induction including inhibition of DNA repair and changes in intracelluar calcium metabolism. Both low-intensity ELF-EMF and non-thermal RF-EMF effects depend on a number of physical parameters and biological variables and physical parameters, which account for the variation in health outcomes (Belyaev, 2015; Belyaev et al., 1999). Importantly, the most severe health effects are observed with prolonged chronic exposures even when intensities are very low (Belyaev, 2017). The physics of non-equilibrium and non-linear systems and quantum mechanics are at least in part the basis of the physical mechanisms responsible for the non-thermal molecular and biological effects of non-thermal EMF radiation (Belyaev, 2015), although a detailed report on these actions is beyond the scope of this review.

Lower RF-EMF intensity is not necessarily less bioactive or less harmful. Non-thermal EMF effects can be observed at intensities which are very close to ordinary background levels and quite similar to intensities emitted by mobile phone base stations. There are time windows for observation of non-thermal EMF effects which may be dependent upon the endpoint measured, the cell type and the duration and power density of exposure. Non-thermal RF-EMF effects are affected by static magnetic fields and electromagnetic stray fields, which result in the variation of non-thermal EMF effects from mobile phones because of adjacent electrical appliances, power lines and other sources of ELF and static magnetic fields, including changes in the geomagnetic field (Gapeev et al., 1999a and b).

Cell-to-cell interactions potentiate the response to non-thermal EMFs (Belyaev et al., 1996). Biological responses to EMFs have been shown to be influenced by sex and age (Zhang et al., 2015; Sirav and Seyhan, 2016). Physiological parameters such as the stage of cell growth, oxygen, divalent ions and temperature are important variables affecting cellular responses to EMFs (Liburdy and Vanek, 1987; Sannino et al., 2011).

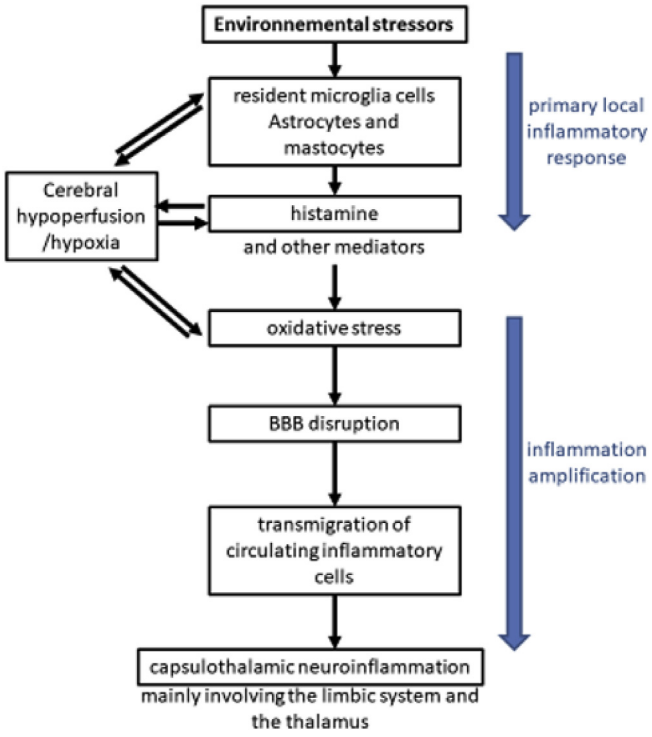


Fig. 2. Hypothetical EHS/MCS common etiopathogenic model based on neuroinflammation and oxidative/nitrosative stress-induced blood brain barrier disruption (Belpomme et al., 2015).

6.1. Combined exposures

EMFs at non-thermal intensities may interfere with other environmental stressors, showing an interplay of molecular pathways and resulting in either beneficial or detrimental health effects, depending on the nature and conditions of co-exposures (Novoselova et al., 2017; Ji et al., 2016). One example is the demonstration that RF-EMF exposure modulates the DNA damage and repair induced by ionizing radiation (Belyaev et al., 1993). Another example is the synergistic of exposure to lead and EMFs on cognitive function in children described above (Choi et al., 2017; Byun et al., 2017). These co-exposure factors should be considered when assessment of detrimental effects, including carcinogenicity, is performed.

Not all of the effects of EMFs on the nervous system and other organs are necessarily harmful. The best example of a positive effect is the well-documented and clinically useful benefit of applied magnetic fields to promote bone healing (Bassett, 1994). Both ELF-EMF (Zhang et al., 2015) and RF-EMF (Arendash et al., 2010) have been reported to slow cognitive decline in rodent models of Alzheimer's disease. Some human studies report a facilitating effects of cognitive performance (Lee et al., 2001) while Koivisto et al. (2000) reported an increase in response time and vigilance tasks but a decrease in mental arithmetic tasks. These studies clearly show that EMFs have biological effects at non-thermal intensities, but suggest that not all biological effects are necessarily harmful.

6.2. Duration of exposure and dose intensity

Such parameters as power density, dose, and duration of exposure have been analyzed for development of reliable safety standards, which would protect against the detrimental health effects of chronic exposure to RF-EMFs at non-thermal intensities. Some studies show no effect under fixed short-term exposures, but this does not imply that there are no effects from longer-term exposures (Choi et al., 2014). Exposure in studies showing RF-EMF effects was on average twice the duration as those with no significant effects (Cucurachi et al., 2013). The response to non-thermal EMFs depends on both power density and duration of exposure. Importantly, the same response is observed with lower power density but prolonged exposure as at higher power density and shorter exposure (Nordenson et al., 1994). While SAR is a good surrogate for thermal RF effects from acute exposures, many studies have shown that SAR should be either replaced by “dose-specific absorption” or power density complimented by duration of exposure for description of non-thermal RF effects (Belyaev, 2015). Recent studies have provided more evidence for the greater importance of dose and duration of exposure than SAR alone for biological and health effects from long-term exposures to non-thermal RF-EMFs (Furtado-Filho et al., 2015).

6.3. Oxidative stress

Non-ionizing radiation does not have sufficient energy to directly break chemical bonds, and therefore the DNA damage that occurs with non-ionizing EMF exposures is primarily a consequence of generation of reactive oxygen species (ROS), resulting in oxidative stress. There are numerous animal experiments which clearly demonstrate that non thermal EMFs can cause oxidative stress (Esmekaya et al., 2011; Burlaka et al., 2013), particularly in the brain (Shahin et al., 2017; Dasdag et al., 2012; Megha et al., 2015; Furtado-Filho et al., 2015). Oxidative stress is known to

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play a central role in development of cancer and aging and serves as a signaling agent in the inflammatory response (Holmstrom and Finkel, 2014).

The brain is a particularly important organ for sensitivity to EMFs. Brain cancer resulting from EMF exposures is a serious concern, and EHS is a disease of the central nervous system. Several mechanisms at the cellular and molecular levels have been reported that may be the basis of these non-thermal RF-EMF effects on brain function. ELF- and/or RF-EMF exposure at embryonic or early postnatal stages can alter *in vivo* synaptic efficacy and plasticity of neurons (Balassa et al., 2014), a finding which was further supported by *in vitro* studies showing a significant decrease in the differentiation of neural stem cells into neurons (Eghlidospour et al., 2017), the alteration of transcript levels of neuronal differentiation-related genes and impairment of neurite outgrowth of embryonic neural stem cells exposed to ELF- or RF-EMFs (Ma et al., 2014). These observations support the conclusion that low-intensity but prolonged exposure to non-thermal EMFs may have adverse effects on neurogenesis during development and indicate how important it is to protect the fetus and young child from excessive exposure to all mobile devices.

Animal studies have documented that 900 MHz or 2.45 GHz non thermal RF-EMF exposure in rats, either short term or chronic, can trigger neuronal dysfunction and even apoptosis of hippocampal pyramidal cells (Bas et al., 2009; Shahin et al., 2017) and cerebellum Purkinje cells (Sonmez et al., 2010) through induction of oxidative stress. Exposure of pregnant dams elicited EMF oxidative stress-induced neuronal pathologic changes in offspring (Odaci et al., 2016). Such pathological changes could be due to ROS-induced opening of the BBB (Nordal and Wong, 2005) and/or to ROS-associated brain hypoxia caused by a decrease in EMF-induced BBF and/or EMF-induced hemoglobin deoxygenation (Mousavy et al., 2009; Muehsam et al., 2013). The resulting hypoxia may induce metabolic neuronal dysfunction as in the case of EHS patients (Belpomme et al., 2015) but also neuronal cell death by either apoptosis or necrosis as in the case of Alzheimer's disease and other forms of dementia (Bell and Zlokovic, 2009).

While some consider the laboratory data on EMFs as being inconsistent, showing either detrimental or no effects and on occasion even beneficial effects, the vast majority still show detrimental effects. For example Henry Lai in the Bioinitiative Report Research Summaries Update of November 2017, Chapter 6 on Genotoxic Effects, reported that i) of 46 studies on ELF genotoxicity with the comet assay as the end point, 34 studies (74%) showed detrimental effects, ii). Of 189 total studies on ELF and oxidative stress, 162 (87%) showed a positive correlation, and iii) of 200 studies on RF and free radicals, 180 (90%) showed detrimental effects. One reason for variability between laboratory studies is the strong dependence on low-threshold EMF effects on a number of physical and biological variables (Belyaev, 2010).

6.4. Genetic and epigenetic mechanisms

Genetic effects are the most direct cause for carcinogenicity. This is true both for genotoxic changes caused by exposure to EMFs and existing polymorphic genetic differences within a population that increase susceptibility to cancer. DNA can no longer be considered to be unaffected by environmental EMF levels, as many studies have shown that DNA can be activated and damaged by EMFs at levels that have been considered to be safe (Blank and Goodman, 1999).

The primary mechanism through which low-intensity EMFs can alter DNA is through ROS production. Lai and Singh (2004) first reported that a 2 h exposure of rats to 60 Hz EMFs at 0.1–0.5 mT resulted in DNA strand breaks in neurons, and provided evidence that this effect was mediated by free radical formation and blocked by free radical scavengers. Vijayalaxmi and Prihoda (2009) in a meta-analysis of 87 publications found a biologically small but statistically significant difference between DNA damage in ELF-EMF-exposed somatic cells as compared to controls, and reported evidence for epigenetic changes for some outcomes. For ELF-EMFs this breakage effect was stronger when exposure was intermittent rather than continuous (Nordenson et al., 1994).

Yang et al. (2008) have reported an OR = 4.31 (95% CI = 1.54–12.08) for leukemia in children living within 100 m of a high voltage powerline if they had a certain polymorphism of a DNA repair gene.

Exposure to RF-EMFs can also induce DNA damage under specific conditions (Markova et al., 2005). Tice et al. (2002) and Vijayalaxmi et al. (2013) reported DNA damage and micronuclei formation in cultured human leukocytes and lymphocytes upon exposure to RF-EMF signals of at least 5 W/kg. Not all cell types showed similar responses. Schwartz et al. (2008) reported micronucleus changes in fibroblasts but not lymphocytes exposed to 1950 MHz EMFs. Kesari et al. (2014) also demonstrated DNA strand breaks in the brains of rats exposed for 2 h per day for 60 days to a 3G mobile phone. Changes in DNA secondary structure (Semin, 1995; Diem et al., 2005) and chromosome instability (Mashevich, 2003) have been observed upon exposure to RF-EMFs emitted by mobile phones.

Epigenetic changes, rather than genetic changes in DNA, may underlie many or even most of the biological effects of non-thermal EMFs (Sage and Burgio, 2017). Non-thermal EMFs are epigenetic stressors which can alter gene expression by acting through physical or biochemical processes and be reflected as chromatin remodeling (Belyaev et al., 1997), histone modification (Wei et al., 1990) or altered microRNA (Dasdag et al., 2015) at intensities far below those that cause measureable tissue heating.

Chromatin plays a key regulatory role in controlling gene expression and, more particularly, the access of transcription factors to DNA. It has been shown that extremely low intensity RF-EMF exposure, i.e. at intensities comparable to that of mobile phone and towers, results in changes in chromatin conformation and gene expression (Belyaev et al., 1997; Belyaev and Kravchenko, 1994; Belyaev et al., 2006; Belyaev et al., 2009). In a large number of cells and tissues, compaction of chromatin in specific loci may lead to gene silencing, loss of histone regulatory effects and DNA repair capacity (Wei et al., 1990). Belyaev and collaborators (Markova et al., 2005; Belyaev et al., 2009) have shown that exposure to RF-EMFs emitted by GSM mobile phone alters chromatin conformation in human lymphocytes and inhibits formation of p53-binding protein 1 (53BP1) and phosphorylated histone H2AX (γ-H2AX) DNA repair foci.

EMFs in both the ELF and RF ranges may epigenetically affect DNA by inducing the expression of stress response genes and consequently the synthesis of chaperone stress proteins (Blank and Goodman, 2011a and b). A specific gene sequence has been identified that acts as a sort of antenna, specifically sensitive and responsive to EMFs (Blank and Goodman, 2011b). This is a gene sequence coding for HSP70, a protein belonging to a family of conserved, ubiquitously expressed “heat shock proteins” that sense danger signals and protect cells from the most disparate stress conditions. This is an unambiguous demonstration that EMF exposure even at non-tissue heating intensities has the potential to be harmful to cells and organisms. The HSP70 promotor contains different DNA regions that are specifically sensitive to diverse stressors, thermal and non-thermal. The EMFs are specifically perceived by the sequences sensitive to non-thermal stimuli. During the process of HSP70-response induction, EMFs can activate directly the HSP70 gene promoter (Rodrequez-De la Fuente et al.,

2010) which contains a magnetic field-responsive domain (Lin et al., 1999, 2001).

EMF-related HSP70 and HSP27 stress responses have been detected in the hippocampus of rats exposed to non-thermal EMFs (Yang et al., 2012). Shahin et al. (2017) reported that mice exposed to 2G mobile phones continuously for four months showed elevated ROS, lipid peroxidation, total nitrate and nitrite concentrations and malondialdehyde levels in homogenates of different tissues, and decreased levels of several antioxidant enzymes. These observations justify the use of these markers to characterize EHS in patients who report that they are sensitive to EMFs.

The EMF effects have been suggested to be mediated by the mitogen-activated protein kinase (MAPk) cascades, which is a central signaling transduction pathway which governs all stress-related cellular processes occurring in response to extracellular stimuli (Friedman et al., 2007). It has been shown that long term exposure of cells to mobile phone frequencies or to ELF-EMFs (Goodman et al., 2009) activates the extracellular-signal regulated kinase (ERK), which is one of the four MAPk cascades so far identified.

Non-thermal RF-EMFs may also alter expression of other genes. As long ago as Byus et al., 1988 showed that 450 MHz RF increased ornithine decarboxylase activity in hepatoma cells. Markova et al. (2005) exposed human fibroblasts and mesenchymal stem cells to mobile phone RF-EMFs with analysis of tumor suppressor p53 binding protein 1. Formation of 53BP1 foci was inhibited in both cells types, but the stem cells always showed a greater response. Fragopoulou et al. (2011) exposed mice to either a typical mobile phone or a wireless DECT base station and analyzed the brain proteome. They found significant alteration in 143 specific proteins (ranging from a 0.003 fold downregulation to up to a 114-fold overexpression.) Luo et al. (2013) exposed pregnant women undergoing a first trimester abortion to a mobile phone applied to the abdomen and performed a proteomic analysist of placental villous tissue. They report 15 proteins which were significantly altered by at least 2- to 2.5-fold in exposed women as compared to control women. Twelve of these proteins were identified. Yan et al. (2008) exposed rats to mobile phones 6 h per day for 126 days, and found upregulation of specific mRNAs that regulated several proteins, including calcium ATPase, neural cell adhesion molecule, neural growth factor and vascular endothelial growth factor. EMFs at non thermal levels may not only alter the expression of many proteins but also may directly affect protein conformation (Fragopoulou et al., 2011; Bohr and Bohr, 2013; Beyer et al., 2013) and modify enzyme activity (Vojisavljevic et al., 2010), so altering the regulating capacity of the epigenome. These are epigenetic, not genetic, effects (Sage and Burgio, 2017).

Non-thermal EMF exposure can epigenetically interfere with the differentiation and proliferation programs of stem cells in fetal and adult tissues through ROS production (Wolf et al., 2007; Falone et al., 2007; Ayşe et al., 2010; Park et al., 2014). Stem cells are the most sensitive cells to EMF exposure (Eghlidospour et al., 2017; Markova et al., 2010) and this is particularly the case for neural stem cells of the hippocampus (Leone et al., 2014).

The endogenous natural ionic currents and electrical fields in the human body (Jaffe and Nuccitelli, 1977) are vulnerable to the oscillary properties of non-thermal EMFs. These consequently may cause detrimental effect on cell differentiation and proliferation in adult tissues (Levin, 2003) in addition to the effects on cell differentiation, proliferation and migration in the fetus (Wolf et al., 2007; Ayşe et al., 2010; Leone et al., 2014). Fetal programming cannot be reduced to only genetic programs. Developmental processes are essentially epigenetic (Leone et al., 2014), and exposure to epigenetic stressors such as non-thermal EMFs are much more dangerous for the fetus than for the adults.

6.5. Calcium regulation

There has long been evidence that EMFs alter several aspects of calcium function. This is important because calcium regulates many different aspects of cell function. Bawin and Adey (1976) reported that very weak ELF-EMFs trigger efflux of calcium from isolated chick brain, although the implications of this observation were not clear. Later they reported a similar action of RF-EMFs (Adey et al., 1982). Pulsed low-frequency EMFs promote bone healing and promote calcium uptake into bone (Spadaro and Bergstrom, 2002) and osteoblasts (Zhang et al., 2010). 50 Hz EMFs increase the number of voltage-gated calcium channels in neuroendocrine cells (Grasso et al., 2004) and presynaptic nerve cell terminals (Sun et al., 2016). Wei et al. (2015) found that ELF-EMFs also altered the frequency of calcium transients in cardiomyocytes and decreased calcium concentrations in sarcoplasmic reticulum. These changes in calcium in heart muscle may be the basis for the cardiovascular effects reported in humans on exposure to EMFs (Havas, 2013). In spite of numerous studies reporting altered calcium metabolism upon exposure to both ELF- and RF-EMFs, the overall implications of these effects are still not clear. However, some have suggested (Ledoigt and Belpomme, 2013) that calcium activation of proteins could be the initial event that results in altered protein configuration, leading to generation of ROS and ultimately activating the molecular pathways to cancer.

7. Public Health Implications of Human Exposure to EMFs

The incidence of brain cancer in children and adolescents has increased between 2000 and 2010 (Ostrom et al., 2015). Gliomas are increasing in the Netherlands (Ho et al., 2014), glioblastomas are increasing in Australia (Dobes et al., 2011) and England (Philips et al., 2018) and all brain cancers are increasing in Spain (Etxeberrua et al., 2015) and Sweden (Hardell and Carlberg, 2017). The latency period between initial exposure and clinical occurrence of brain cancer is not known but is estimated to be long. While not all reports of brain cancer rates show an increase, some do. The continually increasing exposure to EMFs from all sources may contribute to these increases. The prevalence of EHS is unknown, but various reports suggest that it is between 1 and 10% of the population (Hallberg and Oberfeld, 2006; Huang et al., 2018). Male fertility has been declining (Geoffroy-Siraudin et al., 2012; Levine et al., 2017). EMFs increase the risk of each of these diseases and others. Alzheimer's disease is increasing in many countries worldwide and its association with ELF-EMF occupational exposure has been clearly demonstrated through several independent epidemiological studies (Davanipour and Sobel, 2009; Sobel et al., 1996; Qiu et al., 2004) and a meta-analysis of these studies (García et al., 2008). A recent meta-analysis (Huss et al., 2018) has reported an increased risk of amyotrophic lateral sclerosis in workers occupationally exposure to ELF-EMFs.

Safety limits for RF exposure have been based (until today) on the thermal effects of EMFs. But these standards do not protect people, particularly children, from the deleterious health effects of non-thermal EMFs (Nazıroğlu et al., 2013; Mahmoudabadi et al., 2015). Each of these diseases is associated with decrements in health and quality of life. Brain cancer patients often die is spite of some improvement in treatment, while EHS patients present with increased levels of distress, inability to work, and progressive social withdrawal. The ability for humans to reproduce is fundamental for the maintenance of our species.

The scientific evidence for harm from EMFs is increasingly strong. We do not advocate going back to the age before electricity or wireless communication, but we deplore the present failure of public health international bodies to recognize the scientific data

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showing the adverse effects of EMFs on human health. It is encouraging that some governments are taking action. France has removed WiFi from pre-schools and ordered Wi-Fi to be shut off in elementary schools when not in use (http://www.telegraph.co.uk.news/2017/12/11/france-ipose-total-ban-mobile-phones-schools/). The State of California Department of Public Health has issued a warning on use of mobile phones and offered advice on how to reduce exposure (State of California, 2017). There are many steps that are neither difficult nor expensive that can be taken to use modern technology but in a manner that significally reduces threats to human health.

It is urgent that national and international bodies, particularly the WHO, take this significant public health hazard seriously and make appropriate recommendations for protective measures to reduce exposures. This is especially urgently needed for children and adolescents. It is also important that all parts of society, especially the medical community, educators, and the general public, become informed about the hazards associated with exposure to EMFs and of the steps that can be easily taken to reduce exposure and risk of associated disease.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.envpol.2018.07.019.

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World Health Organization, radiofrequency radiation and health - a hard nut to crack (Review)

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Abstract. In May 2011 the International Agency for Research on Cancer (IARC) evaluated cancer risks from radiofrequency (RF) radiation. Human epidemiological studies gave evidence of increased risk for glioma and acoustic neuroma. RF radiation was classified as Group 2B, a possible human carcinogen. Further epidemiological, animal and mechanistic studies have strengthened the association. In spite of this, in most countries little or nothing has been done to reduce exposure and educate people on health hazards from RF radiation. On the contrary ambient levels have increased. In 2014 the WHO launched a draft of a Monograph on RF fields and health for public comments. It turned out that five of the six members of the Core Group in charge of the draft are affiliated with International Commission on Non-Ionizing Radiation Protection (ICNIRP), an industry loyal NGO, and thus have a serious conflict of interest. Just as by ICNIRP, evaluation of non-thermal biological effects from RF radiation are dismissed as scientific evidence of adverse health effects in the Monograph. This has provoked many comments sent to the WHO. However, at a meeting on March 3, 2017 at the WHO Geneva office it was stated that the WHO has no intention to change the Core Group.

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1. Introduction

The use of wireless digital technology has grown rapidly during the last couple of decades (http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf). During use, mobile phones and cordless phones emit radiofrequency (RF) radiation. The brain is the main target organ for RF emissions from the handheld wireless phone (1,2). An evaluation of the scientific evidence on the brain tumour risk was made in May 2011 by the International Agency for Research on Cancer (IARC) at the World Health Organization (WHO). IARC is independently financed and has its own governing and scientific councils, which WHO staff only attend as observers (http://www.who.int/ionizing_radiation/research/iarc/en/).

Epidemiological studies provided supportive evidence of increased risk for head and brain tumours, i.e., acoustic neuroma and glioma. The working group reached the conclusion that RF radiation from devices that emit non-ionizing RF radiation in the frequency range 30 kHz-300 GHz, is a Group 2B, i.e. a 'possible', human carcinogen (3,4). Later studies have corroborated these findings and have thus strengthened the evidence (5-8).

Several laboratory studies have indicated mechanisms of action for RF radiation carcinogenesis such as on DNA repair, oxidative stress, down regulation of mRNA and DNA damage with single strand breaks (9-13). A report was released from The National Toxicology Program (NTP) under the National Institutes of Health (NIH) in USA on the largest ever animal study on cell phone RF radiation and cancer (14). An increased incidence of glioma in the brain and malignant schwannoma in the heart was found in rats. Acoustic neuroma or vestibular schwannoma is a similar type of tumour as the one found in the heart, although benign. Thus, this animal study supported human epidemiological findings on RF radiation and brain tumour risk (8).

The IARC cancer classification includes all sources of RF radiation. The exposure from mobile phone base stations, Wi-Fi ac[Return to Home Page]and tablets can be long-ter[Return to Home Page]th at home and at

school. For children this risk may be accentuated because of a cumulative effect during a long lifetime use (15). Developing and immature cells can also be more sensitive to exposure to RF radiation (9).

In spite of the IARC evaluation little has happened to reduce exposure to RF fields in most countries. On the contrary, with new technology increasing environmental exposure levels are found as in measurements of ambient RF radiation at e.g. Stockholm Central Station and Stockholm Old Town in Sweden (16,17). The exposure guideline used by many agencies was established in 1998 by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and was based only on established short-term thermal (heating) effects from RF radiation neglecting non-thermal biological effects (18). The heating effects arise when radiation is so high that it warms up the whole body by 1˚C or more after 30 min exposure at 4 W/kg specific absorption rate. The guidelines are set with a safety factor of 50 for the general public (http://www.who.int/peh-emf/about/WhatisEMF/en/index4.html).

Basis for limiting exposure according to ICNIRP: 'Only established effects were used as the basis for the proposed exposure restrictions. Induction of cancer from long-term EMF exposure was not considered to be established, and so these guidelines are based on short-term, immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF. In the case of potential long-term effects of exposure, such as an increased risk of cancer, ICNIRP concluded that available data are insufficient to provide a basis for setting exposure restrictions, although epidemiological research has provided suggestive, but unconvincing, evidence of an association between possible carcinogenic effects.' (http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf).

This is an exceptional statement by ICNIRP, and found in many statements of groups following the ICNIRP philosophy like the AGNIR and on the WHO EMF Project's homepage as well, that epidemiology found 'suggestive, but unconvincing' evidence. What is convincing or not is so decidedly subjective that no scientific body will ever make this as a basis for a decision. There might be gaps in knowledge that make it difficult to decide about the mechanisms that underlie an observation and even an observation could be considered unreliable but the conviction must not enter a rational discourse about a scientific issue.

The guidelines were updated in 2009 but still do not cover cancer and other long-term or non-thermal health effects. ICNIRP gives the guideline 2 to 10 W/m^2 for RF radiation depending on frequency, thus only based on a short-term immediate thermal effect (19). ICNIRP is a private organisation (NGO) based in Germany. New expert members can only be elected by members of ICNIRP. Many of ICNIRP members have ties to the industry that is dependent on the ICNIRP guidelines. The guidelines are of huge economic and strategic importance to the military, telecom/IT and power industry.

In contrast to ICNIRP, the BioInitiative Reports from 2007 and updated in 2012, based the evaluation also on non-thermal health effects from RF radiation (20,21). The scientific benchmark for possible health risks was defined to be 30 to 60 μW/m^2. Thus, using the significantly higher guideline by ICNIRP gives a 'green card' to roll out the wireless digital technology thereby not considering non-thermal health effects from RF radiation. Numerous health hazards are disregarded such as cancer (8), effects on neurotransmitters and neuroprotection (22,23), blood-brain-barrier (24,25), cognition (26-29), psychological addiction (30-32), sleep (33-36), behavioral problems (37-41) and sperm quality (13,42,43).

No doubt the IARC decision started a world-wide spinning machine to question the evaluation. It was similar to the one launched by the tobacco industry when IARC was studying and evaluating passive smoking as a carcinogen in the 1990s (44). Sowing confusion and manufacturing doubt about scientific facts is a well-known strategy used by the tobacco and other industries (8,45-48).

2. The WHO fact sheet

A Fact Sheet from WHO issued in June 2011 shortly after the IARC cancer classification in May 2011 stated that 'To date, no adverse health effects have been established as being caused by mobile phone use' (http://www.who.int/mediacentre/factsheets/fs193/en/). This statement was not based on scientific evidence at that time on a carcinogenic effect from RF radiation. It was certainly a remarkable conclusion by WHO since IARC is part of WHO although seemingly independent, see above.

However, it is also important to note that the statement in the Fact Sheet does not fully contradict the IARC statement. A Group 2B carcinogen is considered by IARC as an agent where an association with cancer has been detected that can be causally interpreted but for which chance, bias and confounding cannot be ruled out with sufficient scientific certainty. Hence, the statement in the Fact Sheet is in line with IARC's classification although, of course, it will rather be understood as a full dismissal of claims of harm.

In the WHO Fact Sheet it was also stated that 'WHO will conduct a formal risk assessment of all studied health outcomes from radiofrequency fields exposure by 2012.' The pertinent question is why WHO was so keen to make a new risk evaluation shortly after the IARC evaluation. It was hardly expected that new studies would be published in short time changing the classification of RF radiation as a possible, Group 2B, human carcinogen. Considering the WHO statement of 'no adverse health effects' the aim might have been to undermine the IARC decision and give the telecom industry a 'clean bill' of health (8). It might, however, be argued that as a result of the IARC classification, it was necessary for WHO to also look at other effects, and not just tumours.

3. The WHO EMF project

The biophysicist Michael Repacholi from Australia was the first chairman of ICNIRP in 1992. His own research within this field is scanty, although a study on lymphoma incidence in mice exposed to RF radiation published in 1997 has attracted interest (49). Repacholi suggested in 1995 that WHO should start the [Return to Home Page] WHO in 1996, see WHO P[illegible]ernational project

to assess health effects of electric and magnetic fields; 4 June 1996 (50). Repacholi was during 1996-2006 the leader of the WHO department of electromagnetic radiation, the WHO EMF project.

The WHO EMF project is supposed to: 1) provide information on the management of EMF protection programs for national and other authorities, including monographs on EMF risk perception, communication and management; 2) provide advice to national authorities, other institutions, the general public and workers, about any hazards resulting from EMF exposure and any needed mitigation measures. (http://www.who.int/peh-emf/project/EMF_Project/en/index1.html).

Michael Repacholi immediately set up a close collaboration between WHO and ICNIRP (being head of both organizations) inviting the electric, telecom and military industries to meetings. He also arranged for large part of the WHO EMF project to be financed by the telecommunication industry's lobbying organisations; GSM Association and Mobile Manufacturers Forum, now called Mobile & Wireless Forum (MWF) (51) in addition to WHO, see the International EMF Project, Progress Report June 2005-2006 (http://www.who.int/peh-emf/publications/reports/IAC_Progress_Report_2005-2006.pdf).

Repacholi acted like a representative for the telecom industry while responsible for the EMF health effects department at the WHO (http://microwavenews.com/news/time-stop-who-charade). Since he left WHO in 2006 he has been involved in industry propaganda video interviews with GSM Association and Hydro Quebec (https://www.youtube.com/watch?v=fDZx7MphDjQ; https://www.youtube.com/watch?v=1MI_fa5YsgY) where he clearly speaks in favor of the telecommunications and the power industries, respectively.

Michael Repacholi is still the Chairman emeritus at ICNIRP (http://www.icnirp.org/en/about-icnirp/emeritus-members/index.html) and has propagated during almost 20 years worldwide the 'only thermal effect' paradigm of health risks from RF-EMF exposure, ignoring the abundant evidence for non-thermal effects or cancer risks.

Repacholi recruited Emilie van Deventer to the WHO EMF Project in 2000. She is the current project manager at WHO for the EMF project. She has been a long time member of the industry dominated organization Institute of Electrical and Electronics Engineers (IEEE). IEEE is the world's most powerful federation of engineers. The members are or have been employed in companies or organizations that are producers or users of technologies that depend on radiation frequencies, such as power companies, the telecom and the military industry. IEEE has prioritized international lobbying efforts for decades especially aimed at the WHO, for more information see (http://www.ices-emfsafety.org/wp-content/uploads/2016/10/Approved-Minutes-TC95-Jan_16.pdf).

Van Deventer is an electrical engineer. She has no formal or earlier knowledge in medicine, epidemiology or biology, so it is surprising that she was selected for such an important position at the WHO (http://www.waves.utoronto.ca/people_vandeventer.htm) (http://www.itu.int/ITU-T/worksem/emc-emf/201107/bios.html).

The very same year she was recruited to the WHO EMF Project Toronto University Magazine wrote about Emilie van Deventer's work stating that it was 'invaluable' to industry: 'The software modelling done by teams like van Deventer's is invaluable.' 'The industrial community is very interested in our research capabilities,' says van Deventer. 'It always needs to be working on the next generation of products, so it turns to universities to get the research done.' (http://www.research.utoronto.ca/edge/fall2000/content2b.html).

The importance of this work is reflected in the research funding van Deventer and her team received from the Natural Sciences & Engineering Research Council of Canada (NSERC), Communications & Information Technology Ontario (CITO), and their major industrial partner, Nortel. 'We are fulfilling a very real need in the industry today, which will only increase as technology creates more opportunity. In the process, consumers will continue to enjoy faster computers, lighter cell phones, smaller electronic organizers and the vast array of other electronic gadgets the high-tech world has to offer.' (http://www.research.utoronto.ca/edge/edgenet/fall2000/a-clear-signal/).

4. WHO radio frequency fields: Environmental health criteria monograph

Two years after the anticipated 'formal risk assessment' by WHO in 2012 a draft was launched in 2014 (http://www.who.int/peh-emf/research/rf_ehc_page/en/). It was open for public consultation until December 31, 2014, but is now closed according to the WHO home page.

It was stated that: 'The process used in developing the chapters is described in Appendix X. Note that the chapters 1, 13 and 14 which will provide a summary, health risk assessment and protective measures are not available for this consultation. The drawing of conclusions from the literature and the drafting of these chapters is the remit of a formal Task Group that will be convened by WHO at a later stage in the process.'

It must be regarded to be unusual and scientifically inadequate not to provide for review the health risk assessment and protective measures which would be most important parts of the Monograph. Furthermore, it turned out that of the six members in the WHO Core Group four are active members of ICNIRP and one is a former member. This was published in 2016 (52) and also discussed more recently (8). Only one person seems to be independent of ICNIRP, see Table I. Several persons have also affiliation(s) to other advisory groups, authorities and/or committees. Six of the 20 additional experts are affiliated with ICNIRP.

Being a member of ICNIRP is a conflict of interest in the scientific evaluation of health hazards from RF radiation through ties to military and industry. This is particularly true since the ICNIRP guidelines are of huge importance to the influential telecommunications, military and power industries. Another conflict of interest is for members officially assessing possible health effects below their own set ICNIRP guidelines, which they have already stated as beeing safe, see also discussion in (52). Such persons would hardly have different opinions than those stated by ICNIRP. Critical views are not heard and a balanced scientific evaluation is not obtained.

It should be noted that the Ethical Board at the Karolinska Institute already in 2008 that being a conflict of interest that

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Table I. Members of WHO Monograph core group and their involvement in different other groups (8).

Name	WHO	ICNIRP	UK/AGNIR	SSM	SCENIHR
Simon Mann	X	X	X		
Maria Feychting	X	X	X	X[a]	
Gunnhild Oftedal	X	X			
Eric van Rongen	X	X		X	
Maria Rosaria Scarfi	X	X[a]		X	X
Denis Zmirou	X				

[a]Former. WHO, World Health Organization; ICNIRP, International Commission on Non-Ionizing Radiation Protection; AGNIR, Advisory Group on Non-Ionising Radiation; SSM, Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority); SCENIHR, Scientific Committee on Emerging and Newly Identified Health Risks.

should be stated officially whenever a member from ICNIRP makes opinions on health risks from EMF (Karolinska Institute diary number: 3753-2008-609). No statement of such conflict of interest can be found in the WHO draft of the Monograph on RF radiation.

Several persons and groups have sent critical comments to WHO on the many shortcomings in the draft of the Monograph on RF fields. In general WHO has not responded to these comments and it is unclear to what extent, if any, they are considered. Due to the short time for submission our (Lennart Hardell, Michael Carlberg) comments related only to section 12.1 Cancer Epidemiology. Our concluding remarks dated December 15, 2014 were: 'In conclusion the WHO draft is biased towards the null results. Findings on an association between use of wireless phones (mobile phones and cordless phones) and increased risk for brain tumours are misinterpreted, selectively reported and/or omitted in total. The draft cannot be used as science-based evaluation of increased risk. It needs to be re-written in a balanced way by scientists trained in epidemiology and oncology, not the least in medicine, and without conflicts of interest.'

Moreover, after the formal closing date for comments on the Monograph several additional submissions have been made to WHO. Professor Michael Kundi at Center for Public Health, Institute of Environmental Health, Vienna, Austria stated in his summary dated January 12, 2015: 'I was only able to check chapter 12 about cancer and only the epidemiological studies. While the EHC (Environmental Health Criteria) team did a great job in allocating the relevant literature with only few more recent papers missing, I'm not fully satisfied with the assessment of the evidence. There is a striking imbalance in the comments made on studies that were positive in contrast to those that were negative. Only the most obvious shortcomings of studies that didn't report an effect of exposure are mentioned while positive findings are often discussed at length, sometimes with very far-fetched assumptions about potential sources of bias. This is in marked contrast to other EHC monographs that are discussing the evidence in a way not to overlook a potential harmful effect. My comments, giving reference to the lines of the draft are detailed on the following pages.'

The BioInitiative Working Group issued December 19, 2016 a 'No Confidence' Letter to the WHO EMF Program Manager: 'The BioInitiative Working Group urges the World Health Organization to make changes to the WHO RF EHC Core Group membership to more fairly reflect membership and expertise of the 2011 IARC RF Working Group. At present, the WHO RF EHC Core Group is indistinguishable from ICNIRP... undermining credibility of the process and ensuring doubt about conclusions... Even if schedule delays occur as a result, an acceptable outcome depends on public confidence. There [are] now many thousands of high quality scientific papers indicating possible non-thermal RF risks to health and those experts most competent by virtue of their research contributions are absent from this process... Both human and animal results are now available to incorporate in the RF EHC risk assessment. This important effort can only be assured with a more balanced composition of core participants in the process. As well, the membership needs to be inclusive of under-represented countries such as Russia, China, India, Turkey, and Iran whose research communities have produced the majority of studies on non-thermal effects of RF in recent years.' (http://www.bioinitiative.org/report/wp-content/uploads/2016/12/BIWG-final-draft-WHO-RF-EHC-Monograph-team-composition.pdf).

This letter was followed by another from the BioInitiative Working Group on January 24, 2017 including suggestion of experts to replace present persons in the Core Group and Additional Experts: 'We have not yet received a reply acknowledging our letter... It is important that the most knowledgeable panel of experts be appointed to prepare the RF EHC Monograph. At present, the EHC Core Group members uniformly represent attitudes and scientific positions of ICNIRP, an organization whose membership has steadfastly refused to accept new scientific evidence of potential health risks from non-thermal, low-intensity radiofrequency radiation despite recent scientific advances in knowledge on the subject. We are recommending substitutions for membership as indicated on the attached page. Please note that we are suggesting a complete replacement for those persons currently holding positions.' (http://www.bioinitiative.org/report/wp-content/uploads/2017/01/BIWG-EHC-substitution-letter.pdf).

Call for Protection from Non-ionizing Electromagnetic Field Exposure was made by the International Electromagnetic Field Sc[Return to Home Page]te May 11, 2015, latest ve[Return to Home Page]h 222 signatures

from 41 nations: 'We are scientists engaged in the study of biological and health effects of non-ionizing electromagnetic fields (EMF)... Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans. Damage goes well beyond the human race, as there is growing evidence of harmful effects to both plant and animal life. These findings justify our appeal to the United Nations (UN) and, all member States in the world, to encourage the World Health Organization (WHO) to exert strong leadership in fostering the development of more protective EMF guidelines, encouraging precautionary measures, and educating the public about health risks, particularly risk to children and fetal development. By not taking action, the WHO is failing to fulfil its role as the preeminent international public health agency.' (https://www.emfscientist.org/index.php/emf-scientist-appeal).

A press release was issued on February 24, 2017 by the European coordination of organizations for an EMF exposure regulation which truly protects public health. The European citizens' organizations failed, however, to include in their letter the conflict of interest associated with ICNIRP members assessing possible effects below set ICNIRP guidelines, see discussion above. They stated that: 'The Conflict of Interest Scandal is repeating itself in the WHO: European citizens' organizations uncover conflicts of interest between the health and radiofrequency WHO expert group and telecommunications or electric companies. Almost 40 organizations and European Platforms (which in turn include many regional, national or local social organizations), supported by the International EMF Alliance (IEMFA), denounce the flagrant conflict of interest of the Core Group of experts for drafting, in the current year, of a WHO Environmental Health Criteria Monograph on Radio-Frequency Fields...

The preponderant presence of members of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) reminds us that this organization (and other institutions with the same criteria) refused to accept new scientific evidence of potential health risks from non-thermal, low-intensity radiofrequency radiation despite recent scientific advances in knowledge on the subject. The ICNIRP not only does not guarantee transparency or independence but conflicts of interest of its members are well known and reported, due to their relationships with telecommunications or electric companies, thereby undermining the impartiality that should govern the regulation of Public Exposure Standards for non-ionizing radiation... By not taking action, the WHO is failing to fulfill its role as the preeminent international public health agency...' (http://www.peccem.org/DocumentacionDescarga/Plataforma-Estatal/notasprensa/European.coordination.press.release-february-2017.pdf).

Letter dated March 1, 2017 from Russian National Committee on Non-Ionizing Radiation Protection to Maria Neira, Director, Public Health and Environment with copy to Dr. E. van Deventer, Public Health and Environment, WHO: 'It has just come to our attention that the WHO RF Working group consists mainly from present and past ICNIRP members. In general, the WG is not balanced and... the private self-elected organization ICNIRP, similar as majority of the current WHO RF WG members, does not recognize the non-thermal RF effects,... Thus, the guidelines of ICNIRP are irrelevant to present situation when majority of population over the world is chronically exposed to non-thermal RF from mobile communication.' (http://www.radiationresearch.org/articles/rusncnirp-letter-to-who/), letter available at (http://www.mast-victims.org/resources/docs/RNCNIRP-letter-WHO/2017_03_01.pdf).

5. Human Health Effects of Non-Ionizing Radiation - Informal meeting at WHO March 3, 2017

It is quite obvious that it would be of utmost value to learn what is on-going at WHO regarding the Monograph on RF radiation, especially since formal responses to submissions with comments are virtually absent. Thus, some 9 months after initial contact Dr Maria Neira accepted to organize a meeting, relating to the effects of electromagnetic fields on health, in her office at WHO in Geneva. The request for a meeting was made by independent researchers from different universities. An informal meeting was organized on March 3, 2017. (http://eceri-institute.org/fichiers/1490952497_newsletter_ECERI_5.pdf).

Dr Maria Neira is Director of the Public Health and the Environment Department at WHO. Present at the meeting was also Dr Emilie van Deventer, the Team Leader of the Radiation Programme at WHO which deals with non-ionizing and ionizing radiation topics related to human health. She has been working at WHO since 2000 where she heads the International EMF Project, the Ultraviolet INTERSUN Programme and the International Radon Project. Dr van Deventer received a Ph.D. in Electrical Engineering from the University of Michigan, USA. She was adjunct professor of Electrical and Computer Engineering, financed by the telecom industry, at the University of Toronto in Canada from 1992 to 2000. She is the WHO Observer on the Main Commission of ICNIRP, e.g. participating in ICNIRP meetings. (http://www.itu.int/en/ITU-T/Workshops-and-Seminars/emf/201307/Pages/vanDEVENTERTaheraEmilie.aspx). She is also one of 8 members of the Swedish Radiation Safety Authority (SSM).

The allocated time at the WHO office was 1.5 h. Dr Maria Neira opened the meeting stressing that it was not official but informal. She told that her department is very much interested in challenging science. In addition to myself, four additional experts were also present. The experts gave short presentations on health effects of RF radiation, biological effects from exposure to non-thermal RF radiation, overview of epidemiological studies on brain tumour risk, RF radiation and electromagnetic hypersensitivity (EHS), and finally epigenetic mechanisms by which children are especially-vulnerable to RF radiation. Obviously the five presentations were very short in order to give time for discussions, the most important part of the meeting.

The participating team of five experts with considerable knowledge and own research within this area offered to collaborate with WHO, especially to finalize the WHO Monograph on RF radiation. Maria Neira stated clearly that no collaboration with[Return to Home Page]ther that she does not inter[Return to Home Page]e group. However,

Table II. World Health Organization (Geneva, Switzerland) levels of RF-radiation March 3, 2017 (μW/m^2) treating values at detection limit as 0.[a]

	n	Mean	Median	Min	Max
FM	1,813	2.0	1.2	0.0	128.4
TV3	1,813	0.0	0.0	0.0	1.7
TETRA I	1,813	0.1	0.0	0.0	136.7
TETRA II	1,813	0.0	0.0	0.0	0.0
TETRA III	1,813	0.0	0.0	0.0	3.2
TV4&5	1,813	0.1	0.0	0.0	11.9
LTE 800 (DL)	1,813	1.3	0.4	0.0	101.9
LTE 800 (UL)	1,813	0.0	0.0	0.0	0.0
GSM + UMTS 900 (UL)	1,813	0.0	0.0	0.0	4.7
GSM + UMTS 900 (DL)	1,813	8.6	4.9	0.3	268.2
GSM 1800 (UL)	1,813	0.3	0.0	0.0	182.1
GSM 1800 (DL)	1,813	4.2	1.7	0.3	268.2
DECT	1,813	0.3	0.1	0.0	38.2
UMTS 2100 (UL)	1,813	0.0	0.0	0.0	0.4
UMTS 2100 (DL)	1,813	4.5	2.5	0.4	199.1
WIFI 2G	1,813	0.0	0.0	0.0	1.3
LTE 2600 (UL)	1,813	0.0	0.0	0.0	0.0
LTE 2600 (DL)	1,813	0.0	0.0	0.0	0.6
WIMax	1,813	0.0	0.0	0.0	0.0
WIFI 5G	1,813	0.0	0.0	0.0	4.0
Total	1,813	21.5	13.3	4.8	432.3

[a]Frequency bands and number (n) of readings are given.

she added that she is open to new data. She also said that there is no conflict of interest with ICNIRP since ICNIRP is a WHO collaborative organization. The scientific group, as above, was instead invited to send to WHO peer-reviewed publications, especially meta-analyses that would be the 'best gift'.

It was stated by the WHO officials that ICNIRP is an NGO with an official relationship with WHO that 'helps us a lot in our analyses' and their members work as WHO's experts. Thus, in spite of five of six persons in the Core Group for the Monograph being affiliated with ICNIRP, WHO seems to have no intention to change these members. On the other hand, the Task Group is not finalized. According to the meeting all experts are selected on individual basis and not as members of ICNIRP. Further, it was stated that the WHO guideline documents are in full WHO's responsibility. It is not known when the Monograph on RF radiation will be published. WHO still 'keeps looking at the evidence' and is still adding new documents to the Monograph.

The decision by the Ethical Board at the Karolinska Institute in Stockholm, Sweden from 2008 that being a member of ICNIRP may be a conflict of interest that should be stated in scientific publications was brought into attention during the meeting. WHO was unaware of that document and promised to 'look into it'. Obviously that conflict of interest applies to almost the whole Core Group of the Monograph, several members of additional experts, not to say Emilie van Deventer and thus the whole WHO EMF project and the Monograph on RF radiation.

6. Exposure to RF radiation within the WHO building in Geneva

In our on-going project on measurements of ambient RF radiation in some cities Geneva is part of the study. Results of parts of Stockholm, Sweden have been published (16,17) and will be used e.g. for comparison with levels in the future due to further development of this technology. In Geneva also measurements within the WHO building; main entrance, some corridors and the meeting room were included. These previously unpublished results have been communicated to the representatives at WHO including that they will be published. There has been no reaction from the WHO.

An EME Spy 200 exposimeter with a valid calibration was used to collect the exposure data. The exposimeter measures 20 predefined frequency bands that cover frequencies from 88-5,850 MHz. The sampling time was every 4th sec which is the fastest for the given exposimeter, for further details see our publications. For frequency modulation (FM), TV3, TETRA, TV4&5, Wi-Fi 2G and Wi-Fi 5G, the lower detection limit is 0.01 V/m (0.27 μW/m^2); for all other bands, the lower detection limit is 0.005 V/m (0.066 μW/m^2) (16,17).

The results, presented in Table II, show low mean total exposure level, 21.5 μW/m^2, thus below the scientific benchmark of 30 to [Return to Home Page] to be the 'lowest observed [illegible]on, see Chapter 24

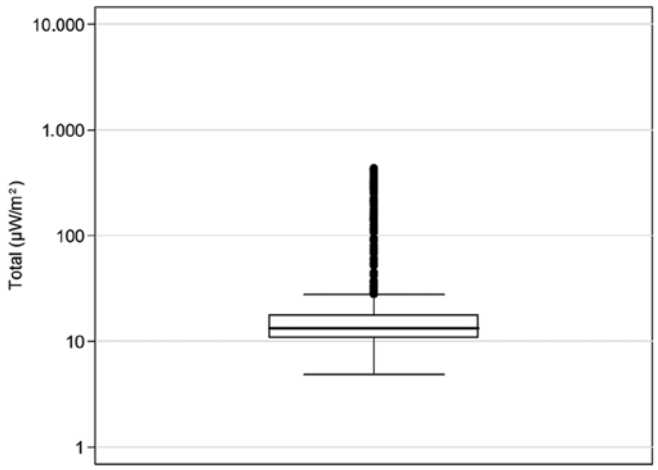


Figure 1. World Health Organization, 20 Avenue Appia, CH-1211 Geneva 27, Switzerland. Box plot for total exposure in μW/m2, logarithmic scale. The median is indicated by a black line inside the box; the bottom and top of the boxes show first and third quartiles; the end of the whisker is calculated as 1.5xIQR (interquartile range). Points represent outliers.

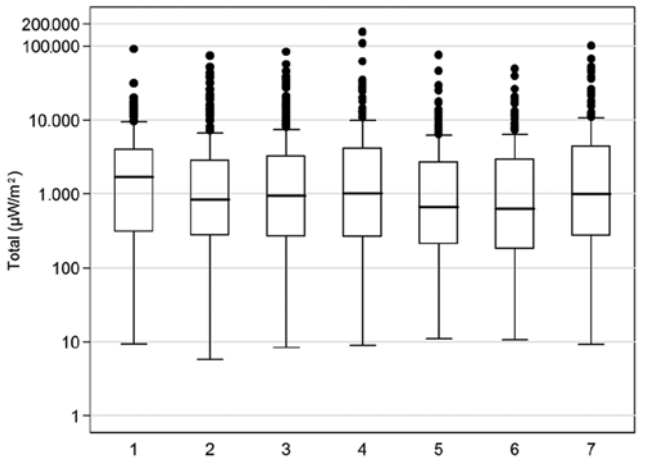


Figure 3. Box plot for total exposure in μW/m^2 for the seven measurement rounds in the Stockholm Central Railway Station (16). The median is indicated by a black line inside each box; the bottom and top of the boxes show first and third quartiles; the end of the whiskers are calculated as 1.5xIQR (interquartile range). Points represent outliers.

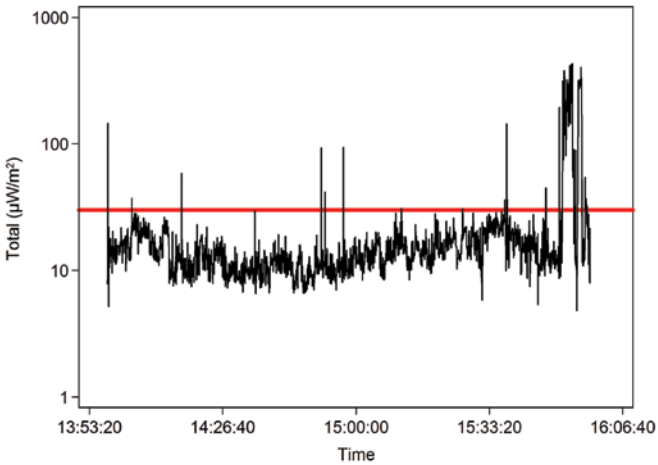


Figure 2. World Health Organization, Geneva, Switzerland. Total RF field exposure (μW/m^2, mean exposure=21.5 μW/m^2, logarithmic scale) over time of one exposure round, March 3, 2017 time 13:57:53-15:58:31. The horizontal line represents the LOEL exposure limit of 30 μW/m^2 suggested by the Bioinitiative Report (21).

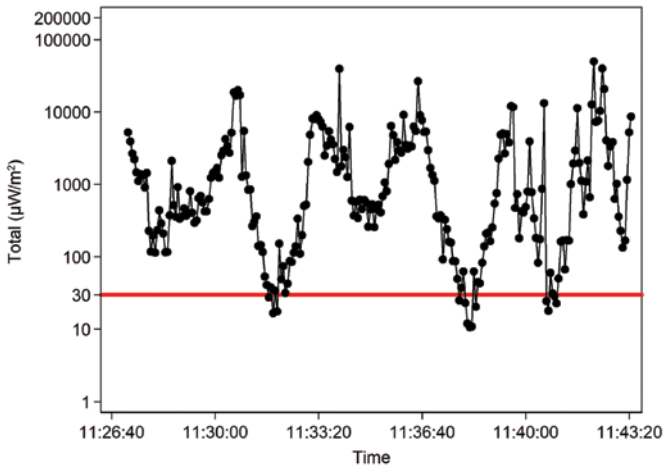


Figure 4. Total radiofrequency field exposure (μW/m^2) of the lowest exposure round (November 9, 2015; mean exposure 2,817.0 μW/m^2) by walking across the Stockholm Central Station (16). The line represents the exposure limit of 30 μW/m^2 suggested by the Bioinitiative Report (21).

of the BioInitiative Report (21). Note that only for the mean it is possible to calculate the total as the sum of means of the individual frequency bands, mathematically this is not possible for median, min and max in Table II. The major sources were GSM + UMTS 900 DL (3G), GSM 1800 DL (2G) and UMTS 2100 DL (3G), i.e. downlink (DL) of RF radiation from outside base stations. The results for total exposure are also presented as box plot in Fig. 1. In Fig. 2 total exposure over time is presented. Almost all RF radiation was below 30 μW/m^2, the LOEL of RF radiation for possible health risks as shown with the horizontal line. The highest peak level, 432.3 μW/m^2, was measured at 15:54:07. Most contribution was from GSM 1800 (DL), 268.2 μW/m^2, and UMTS 2100 (DL), 110.4 μW/m^2. This was measured just inside the building at the entrance and represent RF radiation from base stations in the vicinity.

The exposure to RF radiation within the WHO building is very low compared to other measurements, for example our measurements inside the Stockholm Central station where people both are passing through but also are there for hours each day such as security and police staff, cafe workers, shop workers, janitors, information counter people, etc., see Figs 3 and 4. Here, the mean total exposure for the lowest exposure round was 2,817 μW/m^2, mostly from down loading from GSM, 3G and 4G base stations (16). Thus, the measured mean level in the WHO building is more than 130 times lower than in the Stockholm Central Station.

7. Concluding remarks

The meeting at WHO was an obvious disappointment. During the discussion the two WHO officials showed little interest to collaborate with the scientists convened at the meeting in spite [Return to Home Page] se health effects. Their in bers of ICNIRP,

although not exclusively. This may explain why only short-term thermal effects from RF radiation are accepted as proofs of harm, and why non-thermal biological effects are ignored. In the draft of the Monograph a large bulk of peer-reviewed scientific publications on non-thermal effects are dismissed, c.f. as also by ICNIRP (19). Most remarkable is that WHO has no intention to replace the Core Group of experts affiliated with ICNIRP. Thereby ICNIRP is given full access to and exclusive possibilities to influence the Monograph. In view of the huge economic interests built into the ICNIRP guidelines, and several of its expert members' ties to industry, no doubt this is a large conflict of interest that will seriously undermine not only the credibility of the Monograph on RF radiation but also the credibility of WHO as a protector of world health. Seriously enough, the Monograph will be the hallmark for years to come on evaluation of health hazards from RF radiation and pave the way for increasing exposure to RF radiation to people and environment, e.g. the fifth generation (5G), internet of things, etc.

Children and adolescents may be more sensitive to RF radiation than adults (2). Thus as an authoritative agency, WHO has an obligation to reference all the scientific research results and call the experts from all the related fields like engineering, health and medicine to engage in the re-evaluation of all health effects including non-thermal of RF radiation. Related agencies should launch an objective and transparent project for this assessment. The EMF project was started many years ago and many new wireless digital technologies are developed and new devices are popularizing with a very fast speed.

Protests and comments by scientific experts and several organizations seem to be ignored. The Monograph might be political and industry supportive more than scientific and health promoting. For a definitive conclusion a more thorough review of the whole draft document would be needed. By now it is time for laymen, NGOs and scientists to exert pressure on politicians to change the WHO agenda on RF radiation and health hazards and decide that WHO's purpose is to support world health instead of industry interests. It is also time to evaluate the competence of the persons making the evaluations and decisions before publishing the Monograph. Of note, evidence has been published (52) which indicated that members of ICNIRP have written scientifically incorrect and misleading information. It is unknown if WHO has responded to this evidence of suggested scientific misconduct.

To evaluate cancer risks it is necessary to include scientists with competence in medicine, especially oncology. Furthermore, what are the personal advantages, at least in the short time, for those refusing to accept peer-reviewed scientific publications on adverse effects on health and environment from RF radiation? Ironically enough, whether knowingly or not, the WHO staff seems to protect themselves from high involuntary RF radiation levels at least in the measured areas within the Geneva building.

Acknowledgments

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228 BROOKLINE ST

OWNER NAME 1	OWNER NAME 2	MAILING ADDRESS	CITY	ST	ZIP	PARCEL ID	PROPERTY ADDRESS
CARDINALI, WALTER M. & SONIA	CARDINALI, CARL E.	235 BROOKLINE ST	NEEDHAM	MA	02492	1990560001000000	235 BROOKLINE ST
ALPER, NEIL O. +	ALPER, CAROL D.	245 BROOKLINE ST	NEEDHAM	MA	02492	1990560001100000	245 BROOKLINE ST
ZADEH, RODAN &	ZADEH, EMILY S.	227 BROOKLINE ST	NEEDHAM	MA	02492	1990560000900000	227 BROOKLINE ST
GUSTAFSON, DEBORAH A. &	WILLIAMSON, SHIRLEY M.	21 DELL AVE	NEEDHAM	MA	02492	1990290005600000	21 DELL AVE
MA, QIUFU &	XIONG, YANHONG	215 BROOKLINE ST	NEEDHAM	MA	02492	1990560000700000	215 BROOKLINE ST
MAXWELL, STEVEN R. &	MAXWELL, HELEN	234 BROOKLINE ST	NEEDHAM	MA	02492	1990290003100000	234 BROOKLINE ST
DESAULNIERS, JANET C. &	IRITI, DOMENCO	222 BROOKLINE ST	NEEDHAM	MA	02494	1990290005800000	222 BROOKLINE ST
BORSKIY, ALEXANDER &	BORSKIY, DARYA	12 HOLMES ST	NEEDHAM	MA	02492	1990290003200000	12 HOLMES ST
RIXNER, BRIAN PATRICK &	RIXNER, CARA JOAN	20 HOLMES ST	NEEDHAM	MA	02492	1990290003300000	20 HOLMES ST
VAJDA, SANDOR &	VAJDANE, GABRIELLA	228 BROOKLINE ST	NEEDHAM	MA	02492	1990290005700000	228 BROOKLINE ST
CHENG, YUAN & FENG, YAN	HYPERSUN PROPERTIES, LLC	191 BURROUGHS RD	BOXBOROUGH	MA	01719	1990560000800000	219 BROOKLINE ST
RIZZO, MICHAEL R.		216 BROOKLINE ST	NEEDHAM	MA	02492	1990290005900000	216 BROOKLINE ST

Certified as list of parties in interest under Mass. General Laws and Needham Zoning By-Law, to the Best of our knowledge
for the Needham Board of Assessors.....

Needham Public Health Division

July 9, 2019

Tobacco Compliance Checks

The Needham Public Health Division, in conjunction with the Needham Police Department conducts quarterly tobacco compliance checks in the Town to enforce the Needham Board of Health Tobacco Regulation (Article 1). Under Article 1, no tobacco permit holder in the Town may sell to persons less than 21 years of age. Article 1 § D.3 reads, "Each person selling or distributing tobacco products shall verify the age of the purchaser by means of government-issued photographic identification containing the bearer's date of birth that the purchaser is twenty-one (21) years or older. Verification is required for any person under the age of 27." There are currently 10 permitted tobacco vendors in the Town. During the compliance checks, the Environmental Health Agent and a Needham Police Officer work with a local student under 21 years of age. The student attempts to buy tobacco products from each tobacco permit holder without an ID. If sales are made to the student, the tobacco permit holder is subject to the following penalties under Article 1 § S.:

a) In the case of a first violation, a fine of three hundred dollars ($300.00) and the Tobacco Product Sales Permit shall be suspended for seven (7) consecutive business days.
b) In the case of a second violation within 36 months of the date of the first violation, a fine of three hundred dollars ($300.00) and the Tobacco Product Sales Permit shall be suspended for fourteen (14) consecutive business days.
c) In the case of a third violation within 36 months of the date of the first violation, a fine of three hundred dollars ($300.00) and the Tobacco Product Sales Permit shall be suspended for thirty (30) consecutive business days.
d) In the case of a fourth violation within 36 months of the date of the first violation, a fine of three hundred dollars ($300.00) and the Tobacco Product Sales Permit shall be suspended for ninety (90) consecutive business days.
e) In the case of a fifth violation or repeated, egregious violations of this regulation within a 36 month period, the Board of Health shall hold a hearing in accordance with subsection 4 of this section and shall permanently revoke a Tobacco Product Sales Permit.

For the July 9, 2019 compliance checks, one underage male student from Olin College assisted with the compliance check with the current Environmental Health Student Intern. **One sale made to the underage buyer.** Attached is a complete summary detailing each compliance check.



Participant – age 19

Establishment:	Roche Bros. Supermarket, Inc.
Type of Establishment:	Chain
Style of Establishment:	Grocery Store
Time:	6:16 pm
Purchaser asked for ID?:	Yes
Purchaser asked age?:	No
Sex of Clerk:	Female
Age of clerk:	Adult
Type of tobacco asked for:	Marlboro Reds
Outcome:	No Sale Made
Notes:	The purchaser attempted a buy of cigarettes.

Establishment:	7-Eleven #32485B, 845 Highland Ave.
Type of Establishment:	Chain
Style of Establishment:	Convenience Store
Time:	5:36 pm
Purchaser asked for ID?:	**No**
Purchaser asked for age?:	**No**
Sex of Clerk:	Female
Age of Clerk:	Adult
Type of tobacco asked for:	JUUL Pods
Outcome:	Sale Made

Notes: The participant attempted a buy of JUUL Pods. The sales clerk did not ask for ID and sold the JUUL Pods to the participant. The participant did not receive a receipt. The health agent and police officer conducting the compliance check entered the establishment and spoke with a male clerk at the counter who alerted them that the owner was in the store. As the owner approached the health agent and officer, a female clerk stated she had just sold the JUUL pack to a customer. When asked if she checked ID, she stated she did not. The owner came over and the health agent explained that a clerk had sold JUUL pods to an underage person. The agent then explained the process of a Board of Health hearing to the owner and the potential for fines and suspension. The owner began to argue with the health agent and alleged the Public Health Division was "targeting his location and could not prove the sale was made in the store without a receipt". He did not believe that an underage participant was sent in to conduct a tobacco compliance check. The clerk stated she did not understand why the Public Health Division had to come in and conduct the tobacco compliance checks. The health agent asked if there were security cameras around that could be reviewed to verify that JUUL pods had been sold to the participant. The owner refused to review the tapes with the health agent because "there was no warrant". He also stated that it may be possible "the cameras were off at the time of sale". The officer made her presence known and was allowed to watch footage as the owner searched. The time requested to check was between 5:36 and 5:38 pm. The owner stated that it would take too long to pull up the video so the officer was not able to view any video. The health agent asked to see the transaction history. The owner stated that the point-of-sale system only keeps the last three transactions in the memory to print out receipts so it would not

	be possible to print a receipt. The officer and the agent asked where the transaction record that keeps track of sales would be located. The owner again refused to let the health agent see anything but the officer was able to see a transaction for JUUL pods sold by the female employee in the time period the participant was in the establishment. The participant was brought back into the establishment with ID which was shown to the owner to prove he was under 21 years old. The owner proceeded to take a copy of the participant's ID. The clerk backtracked on her earlier comment claiming to have sold the pods to a person in a white shirt. The participant was wearing a black shirt with a white design. The health agent stated a letter will be sent from the Public Health Division explaining the next steps and all left the establishment.

Establishment:	Great Plain Ave. Gas, Inc.
Type of Establishment:	Chain
Style of Establishment:	Gas Mini-Mart
Time:	5:02 pm
Purchaser asked for ID?:	Yes
Purchaser asked for age?:	No
Sex of Clerk:	Male
Age of Clerk:	Adult
Type of tobacco asked for:	JUUL Pods
Outcome:	No Sale Made
Notes:	The purchaser attempted to buy JUUL Pods.

Establishment:	Needham Service Center, Inc.
Type of Establishment:	Independent
Style of Establishment:	Gas Mini-Mart
Time:	5:10 pm
Purchaser asked for ID?:	Yes
Purchaser asked for age?:	No
Sex of Clerk:	Male
Age of Clerk:	Older Adult
Type of tobacco asked for:	Marlboro
Outcome:	No Sale Made

Notes:	The purchaser attempted a buy of cigarettes and no sale was made. **The clerk exited the establishment to watch where the participant went.**

Establishment:	Needham Center Fine Wine
Type of Establishment:	Independent
Style of Establishment:	Liquor Store
Time:	5:07 pm
Purchaser asked for ID?:	No
Purchaser asked for age?	Yes
Sex of Clerk:	Male
Age of Clerk:	Adult
Type of Tobacco Asked:	Cigars
Outcome:	No Sale Made
Notes:	Participant attempted to buy a cigar out of the case. The clerk asked for ID and no sale was made.

Establishment:	Sudbury Farms
Type of Establishment:	Chain
Style of Establishment:	Grocery Store
Time:	5:15 pm
Purchaser asked for ID?:	Yes
Purchaser asked for age?:	No
Sex of Clerk:	Female
Age of Clerk:	Adult
Type of tobacco asked for:	Marlboro Reds
Outcome:	No Sale Made
Notes:	The purchaser attempted a buy of cigarettes. No sale was made.

Establishment:	7-Eleven #36044H, 173 Chestnut St.
Type of Establishment:	Chain
Style of Establishment:	Convenience Store
Time:	6:11 pm
Purchaser asked for ID?:	Yes
Purchaser asked for age?:	No
Sex of Clerk:	Male
Age of Clerk:	Young Adult
Type of tobacco asked for:	JUUL pods
Outcome:	No Sale Made
Notes:	The underage purchaser attempted to buy a 4 pack of JUUL pods. No sale was made.

Establishment:	Needham Heights Auto. Shell, 875 Highland Ave
Type of Establishment:	Chain
Style of Establishment:	Gas Mini-Mart
Time:	5:22 pm
Purchaser asked for ID?:	Yes
Purchaser asked for age?:	No
Sex of Clerk:	Male
Age of Clerk:	Adult
Type of tobacco asked for:	JUUL
Outcome:	No Sale Made
Notes:	The purchaser attempted to buy a JUUL pod refill. The clerk stated they did not sell JUUL and the participant did not ask for another type of tobacco and left. No sale.

Establishment:	Speedway #2472
Type of Establishment:	Chain
Style of Establishment:	Gas Mini-Mart
Time:	5:25 pm
Purchaser asked for ID?:	No
Purchaser asked for age?:	Yes
Sex of Clerk:	Male / Male
Age of Clerk:	Young Adult / Adult

Type of tobacco asked for:	JUUL
Outcome:	No Sale Made
Notes:	**The participant attempted a buy JUUL and asked for the complete package with cartridge instead of pods by mistake. The younger clerk proceeded to grab the package and did not ask for ID. The participant stated it appeared that the younger clerk was about to scan his own ID to make the sale. The participant did not have enough money (JUUL cartridge kit is ~$37) and came back to the car. The health agent gave him $10 more and the participant tried to purchase the product again. The second time an older male clerk took the participant and asked him his date of birth. The participant stated his real date of birth and the clerk refused to sell to the participant. No sale was made.**

Establishment:	Fernandes Mini-Mart
Type of Establishment:	Chain
Style of Establishment:	Gas Mini-Mart
Time:	6:03 pm
Purchaser asked for ID?:	Yes
Purchaser asked age?:	No
Sex of Clerk:	Male
Age of Clerk:	Young Adult
Type of tobacco asked for:	JUUL/Marlboro Reds
Outcome:	No Sale Made
Notes:	The purchaser attempted a buy JUUL Pods which were not available. They then asked for Marlboro Reds. The clerk removed the item off the shelf, rang up the product and then asked for ID. The transaction was cancelled and no sale was made.

Public Health Nursing

Communicable disease investigation, surveillance, and case management.

- **This requires access by Massachusetts Department of Public Health 24/7 for emergency cases/outbreaks.**
- **Investigate outbreaks and /or conduct epidemiological surveys of all cases of diseases dangerous to the public's health.**

Hepatitis A

Tuberculosis



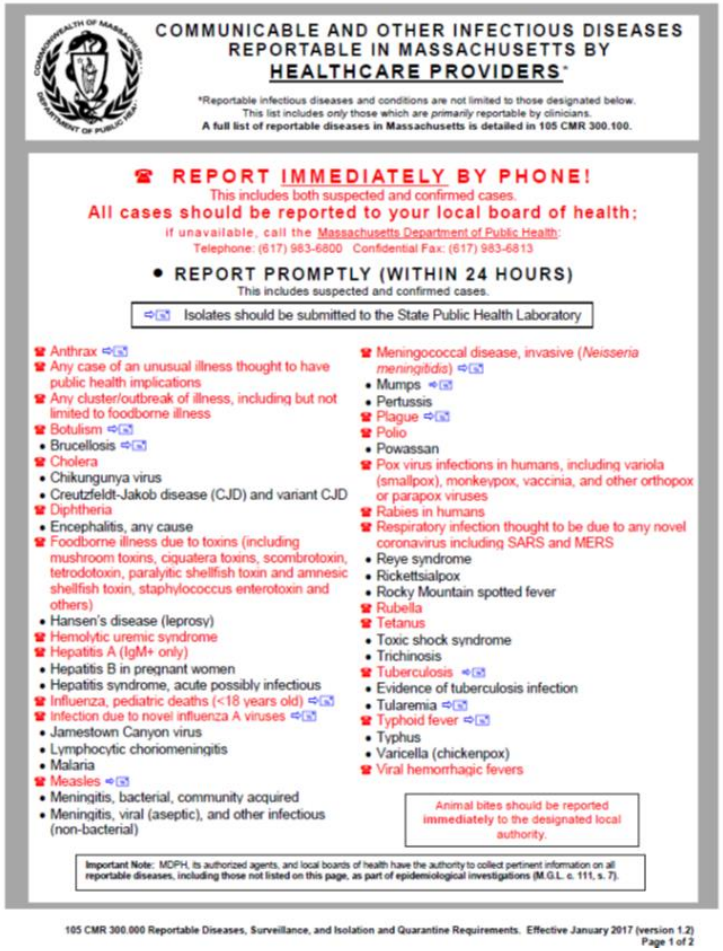
Measles

Polio

Rabies

Meningitis

Report to the State Department of Public Health all diseases on the list of diseases required to be reported by the Massachusetts General Law



COMMUNICABLE AND OTHER INFECTIOUS DISEASES REPORTABLE IN MASSACHUSETTS BY HEALTHCARE PROVIDERS*

*Reportable infectious diseases and conditions are not limited to those designated below. This list includes only those which are primarily reportable by clinicians.
A full list of reportable diseases in Massachusetts is detailed in 105 CMR 300.100.

☎ REPORT IMMEDIATELY BY PHONE!
This includes both suspected and confirmed cases.
All cases should be reported to your local board of health;
if unavailable, call the Massachusetts Department of Public Health:
Telephone: (617) 983-6800 Confidential Fax: (617) 983-6813

• REPORT PROMPTLY (WITHIN 24 HOURS)
This includes suspected and confirmed cases.
⇨ Isolates should be submitted to the State Public Health Laboratory

- ☎ Anthrax ⇨
- ☎ Any case of an unusual illness thought to have public health implications
- ☎ Any cluster/outbreak of illness, including but not limited to foodborne illness
- ☎ Botulism ⇨
- • Brucellosis ⇨
- ☎ Cholera
- • Chikungunya virus
- • Creutzfeldt-Jakob disease (CJD) and variant CJD
- ☎ Diphtheria
- • Encephalitis, any cause
- ☎ Foodborne illness due to toxins (including mushroom toxins, ciguatera toxins, scombrotoxin, tetrodotoxin, paralytic shellfish toxin and amnesic shellfish toxin, staphylococcus enterotoxin and others)
- • Hansen's disease (leprosy)
- ☎ Hemolytic uremic syndrome
- ☎ Hepatitis A (IgM+ only)
- • Hepatitis B in pregnant women
- • Hepatitis syndrome, acute possibly infectious
- ☎ Influenza, pediatric deaths (<18 years old) ⇨
- ☎ Infection due to novel influenza A viruses ⇨
- • Jamestown Canyon virus
- • Lymphocytic choriomeningitis
- • Malaria
- ☎ Measles ⇨
- • Meningitis, bacterial, community acquired
- • Meningitis, viral (aseptic), and other infectious (non-bacterial)
- ☎ Meningococcal disease, invasive (*Neisseria meningitidis*) ⇨
- • Mumps ⇨
- • Pertussis
- ☎ Plague ⇨
- ☎ Polio
- • Powassan
- ☎ Pox virus infections in humans, including variola (smallpox), monkeypox, vaccinia, and other orthopox or parapox viruses
- ☎ Rabies in humans
- ☎ Respiratory infection thought to be due to any novel coronavirus including SARS and MERS
- • Reye syndrome
- • Rickettsialpox
- • Rocky Mountain spotted fever
- ☎ Rubella
- ☎ Tetanus
- • Toxic shock syndrome
- • Trichinosis
- ☎ Tuberculosis ⇨
- • Evidence of tuberculosis infection
- • Tularemia ⇨
- ☎ Typhoid fever ⇨
- • Typhus
- • Varicella (chickenpox)
- ☎ Viral hemorrhagic fevers

Animal bites should be reported immediately to the designated local authority.

Important Note: MDPH, its authorized agents, and local boards of health have the authority to collect pertinent information on all reportable diseases, including those not listed on this page, as part of epidemiological investigations (M.G.L. c. 111, s. 7).

105 CMR 300.000 Reportable Diseases, Surveillance, and Isolation and Quarantine Requirements. Effective January 2017 (version 1.2)
Page 1 of 2

- Maintain electronic records on MAVEN (Massachusetts Virtual Epidemiologic Network)

LBOH Count - Events Per Disease and Classification in Jurisdiction

July 1, 2018 – June 25, 2019

DISEASE	STATUS	NUM_CASES
Babesiosis	DISEASE_STATUS_CONFIRMED	2
Babesiosis	DISEASE_STATUS_REVOKED	4
Babesiosis	DISEASE_STATUS_SUSPECT	1
Borrelia miyamotoi infection	DISEASE_STATUS_REVOKED	1
Calicivirus/Norovirus	DISEASE_STATUS_CONFIRMED	5
Campylobacteriosis	DISEASE_STATUS_CONFIRMED	5
Campylobacteriosis	DISEASE_STATUS_PROBABLE	1
Giardiasis	DISEASE_STATUS_CONFIRMED	1
Giardiasis	DISEASE_STATUS_PROBABLE	1
Group A streptococcus	DISEASE_STATUS_CONFIRMED	2
Group B streptococcus	DISEASE_STATUS_REVOKED	1
Hepatitis A	DISEASE_STATUS_REVOKED	3
Hepatitis B	DISEASE_STATUS_CONFIRMED	1
Hepatitis B	DISEASE_STATUS_CONTACT	2
Hepatitis B	DISEASE_STATUS_PROBABLE	4
Hepatitis B	DISEASE_STATUS_SUSPECT	1
Hepatitis C	DISEASE_STATUS_CONFIRMED	2
Hepatitis C	DISEASE_STATUS_REVOKED	4
Human Granulocytic Anaplasmosis	DISEASE_STATUS_CONFIRMED	1
Human Granulocytic Anaplasmosis	DISEASE_STATUS_SUSPECT	3
Influenza	DISEASE_STATUS_CONFIRMED	101
Influenza	DISEASE_STATUS_SUSPECT	20
Legionellosis	DISEASE_STATUS_REVOKED	1
Lyme Disease	DISEASE_STATUS_SUSPECT	40
Measles	DISEASE_STATUS_REVOKED	1
Meningitis - Unknown Type	DISEASE_STATUS_SUSPECT	1
Mumps	DISEASE_STATUS_SUSPECT	2
Pertussis (and other Bordetella species)	DISEASE_STATUS_REVOKED	1
Polio	DISEASE_STATUS_REVOKED	1
Rocky Mountain Spotted Fever	DISEASE_STATUS_REVOKED	1
Salmonellosis	DISEASE_STATUS_CONFIRMED	3
Shiga toxin producing organism	DISEASE_STATUS_PROBABLE	1
Shigellosis	DISEASE_STATUS_CONFIRMED	3
Streptococcus pneumoniae	DISEASE_STATUS_CONFIRMED	3
Streptococcus pneumoniae	DISEASE_STATUS_REVOKED	1
Tuberculosis	DISEASE_STATUS_CONFIRMED	10
Tuberculosis	DISEASE_STATUS_SUSPECT	3
Varicella	DISEASE_STATUS_CONFIRMED	1
Varicella	DISEASE_STATUS_PROBABLE	1
Varicella	DISEASE_STATUS_SUSPECT	3
Vibrio sp.	DISEASE_STATUS_CONFIRMED	1
West Nile Infection	DISEASE_STATUS_REVOKED	1

Assist residents, physicians, and facilities in control, treatment and reporting of communicable diseases

- Outbreaks
  - Assisted Living/SNFs
  - Schools (Private/Public)
  - Pre-schools
  - Tracking flu cases throughout the year to see trends: certain facilities, genders, age, locations
- Process
  - Coordination with MDPH
  - Testing stool/blood (if required)
  - Contacting all close contacts and places visited
  - Ex: parents, family, close friends
  - Evaluation of food, places visited, and activities done
  - Contact with providers

Consult and train school nurses, and community groups on communicable disease prevention and surveillance when necessary

Concerns over Vaccine Exemptions

- Newspaper articles
- Discussion with preschools
- Discussions with camps
- Multiple resident calls

Collaboration with Schools

- No hot water
- Coughing fits in a class room
- Pertussis
- Flu/Noro
- Complaints –ex: sickle cell anemia and temp control

Coordinate with environmental health agent with communicable diseases in public eating establishments



Educate the community to prevent spread of disease through articles and speaking engagements

- Flu
- Health and Wellness
- Ticks and Mosquitoes
- Dog Bites
- Any emerging public health educational need

FY 2019

- Articles:
  - Measles, collaborated with Tick/Mosquitoes, Flu
- Presentations:
  - Flu x3, Diabetes, Heart disease, Ticks/Mosquitoes

Keep updated with current trends in state/country through MDPH/CDC webinars, conference calls, and Trainings

Webinars/Conference calls:

- Rickettsia
- Measles
- Flu
- Hep A
- Acute Flaccid Myelitis

Trainings:

- Pediatric Immunization Conference
- Epidemiology Conference

Meetings with Local Hospitals to discuss trends within the Community

BID-Needham

- Frequent communication with Infection Control
- Bi-Annual meetings

Newton-Wellesley

- Quarterly community meetings
- Annual Infection Control Meeting

2. Perform diversified duties to render professional nursing services



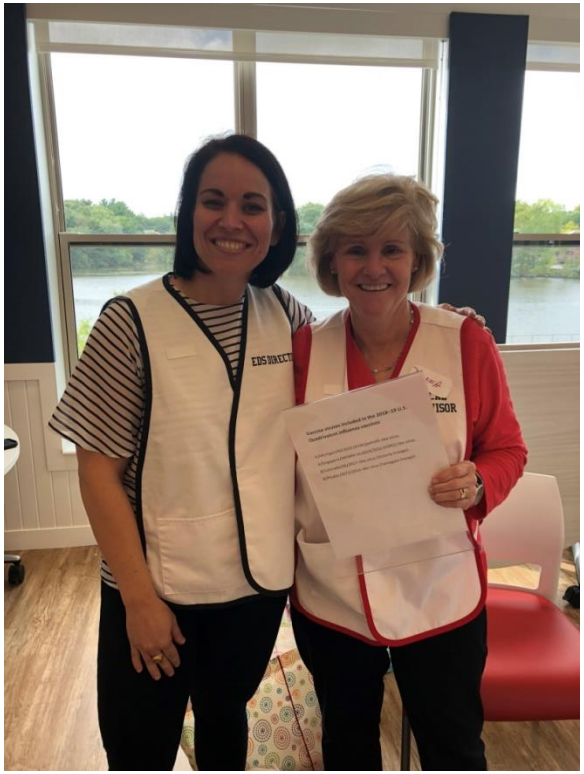
- Wellness/BP Clinics
  - RRC & COA
- TB Medication Management
- Vit B12 Shots
- Education
- HIPPA Compliance
- Referrals:
  - Riverside
  - Interface
  - Assistance Programs







Flu clinics, immunization clinics for outbreak situations in coordination with Massachusetts Department of Public Health



Flu Clinics

- 4 - Town Clinics
- North Hill
- Charles River Arc
- St Bartholomew's

Immunizations:

- Work with school nurses to coordinate immunizations as needed for new students and students in need.

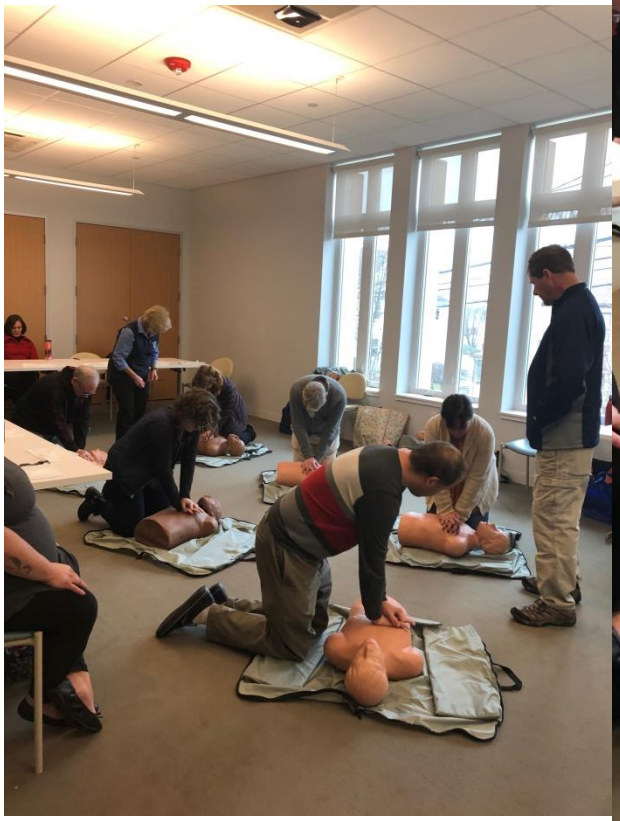
VACCINE MANAGEMENT - MIIS

- Statewide system to manage vaccines
- Electronic records for immunization registration
- Enter every immunization we give, including all flu



Total Immunization 2019: 724

Coordinate, implement and maintain Needham Public Access Defibrillation Program (PAD) including maintenance of AED's in Town Buildings as well as CPR/AED Classes for Town Employees – Teach two CPR Classes





AED

19 AEDs

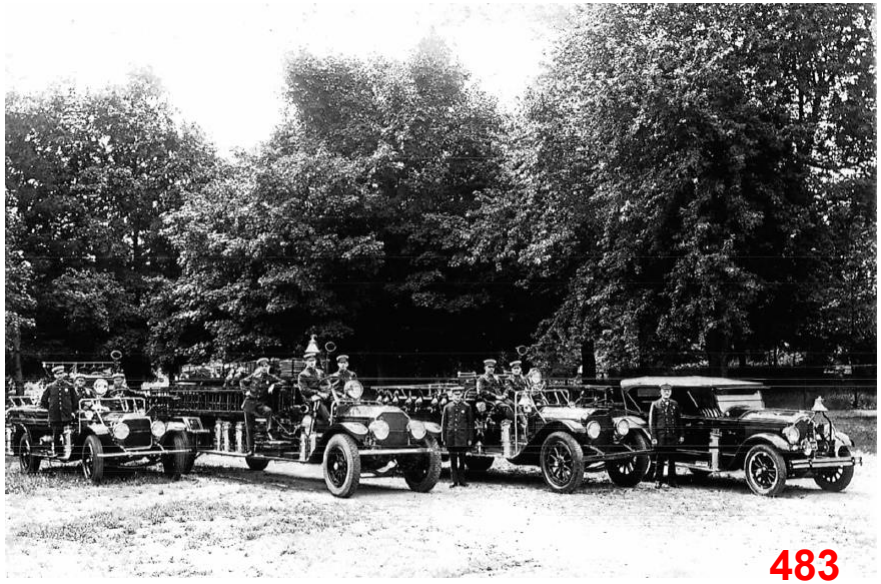
Stop the Bleed

- Trained building staff and RTS in coordination with EMS
- 19 kits to be hung with each AED
- Planning to Teach course through Needham U.



Narcan Trainings





Coordinate and collaborate with Needham Fire

Employee health- through outreach, clinics, initial assessments, screening and referrals – 4 clinics /month

- Water Department
- DPW am & pm
- RTS (as needed)

- Employee Education
  - Flu/noro
  - Tick, sun protection, mosquitos
  - General health education
- Referral and Support

Manage federal and local assistance programs for community's most vulnerable population

Self Help Inc
Programs & Resources to Help Families & Individuals Thrive (26)

Massachusetts Good Neighbor Energy Fund The Salvation Army (2)

- Local Programs:
  - Gift of Sight (2)
  - Community Council Food Pantry (10)
  - Gift of Warmth (20)
  - Park and Rec(1)

Community outreach to service groups (Rotary Club, NN Chamber of Commerce), sports groups (concussion awareness)





Collaborate with first responders and municipal departments to help prepare the community for emergencies and disasters

- Plan, Coordinate, and Lead Town Trainings
  - April 1st: Functional Exercise Emergency Operations Center
  - June 10th: Active Threat Workshop

LEPC (Local Emergency Planning Committee)



- Monthly meetings
- Presentations
- Certification Application
- Coordination of Trainings

Manage Medical Reserve Corps (MRC) Recruitment, Retention, and Training

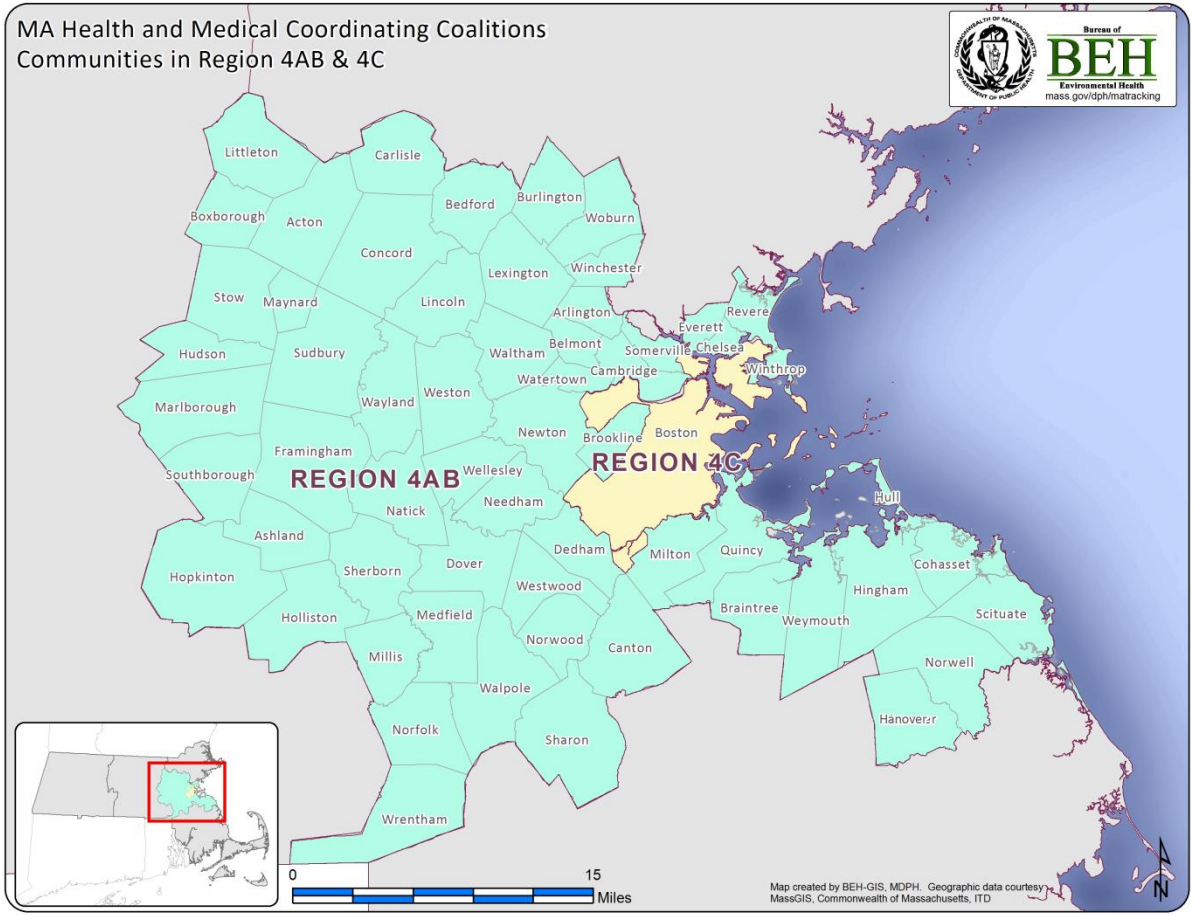




- Process paperwork for volunteers
- CORI/SORI Process
- Badging
- Uploading to RAVE System

- Sept 2019 Meet and Greet
- NC8- MRC paperwork and applications
- Region 4AB Trainings
- Quarterly Drills with MDPH for funding

MRPC Region 4AB



Collaborate with regional partners (Region 4AB) with emergency preparedness planning, developing and participating in emergency planning including drills

- Quarterly Meetings
- Trainings:
  - Emerging Infectious Diseases
  - Stop the Bleed
  - Hot Topics in Preparedness
- Stakeholder Meetings
  - Hospitals, Community Centers

Meeting CDC Requirements

- Development of Emergency Dispensing Plans
- Sheltering Plans
- CEMP
- Coordination with MEMA and FEMA on Grant opportunities and Funding for emergencies

Educate the community in preparedness planning and readiness through outreach, speaking engagements, resources and articles

- 2 Emergency Preparedness Discussions at CATH
- Presentation at St Bart's
- Collaboration with local colleges for Emergency Plans
- Work with Nursing Facilities to develop plans
- Emergency Preparedness and Climate Change series (MAPC Grant)
- Grant Writing
  - MVP
  - HMEP
  - EMPG

Maintain list of emergency supplies/ Health Department Trailer for emergency response including EDS/Sheltering

Location	Item - EDS Trailer	Number	Date Bought	Expiration Date	Last Checked	Rotate with EMS
EDS Trailer	Tissue packs	162		n/a	3/1/18	
EDS Trailer	Anti-seetipc wipes	4			3/1/18	
EDS Trailer	Industrial gloves	43			3/1/18	
EDS Trailer	PPE packets : booties, gloves, gown, googles	56			3/1/18	
EDS Trailer	Scale - no batteries required	1		n/a	3/1/18	
EDS Trailer	Vest : clinic flow and ICS	LOTS		n/a	3/1/18	
EDS Trailer	Megaphone : Need 8 C batteries per megaphone - NOT included	2		n/a	3/1/18	
EDS Trailer	Lable maker : Need 6 AA batteries - NOT included	1		n/a	3/1/18	
EDS Trailer	Shoe Covers	1			3/1/18	
EDS Trailer	Surge protector	2		n/a	3/1/18	
EDS Trailer	Caution tape rolls	4		n/a	3/1/18	
EDS Trailer	Duct tape rolls	3		n/a	3/1/18	
EDS Trailer	Needham identification tags	250		n/a	3/1/18	
EDS Trailer	Extension Cords - 50 ft	4		n/a	3/1/18	
EDS Trailer	Flashlights : Need 2 D batteries a piece	6		n/a	3/1/18	
EDS Trailer	Gauze Pad : 4x4 (1200 per box)	4200			3/1/18	
EDS Trailer	Gauze Pad : 2x2	2400			3/1/18	
EDS Trailer	Surgical Tape	120			3/1/18	
EDS Trailer	Cold Press	23			3/1/18	
EDS Trailer	BandAid	2700			3/1/18	
EDS Trailer	Stretch Gauze	96			3/1/18	
EDS Trailer	First Aid Kits (MRC) : Bandaids, Gauze, Anti-septic wipes, roll of tape	81			3/1/18	
EDS Trailer	First Aid Kit (red): CPR mirco sheild	11			3/1/18	
EDS Trailer	Infection control kits : mask, goves,cap, coverall, wipes, waste bag, bio hazard label	450			3/1/18	
EDS Trailer	CHUCKS	300			3/1/18	
EDS Trailer	Tyvek Coverall Suits L	50			3/1/18	
EDS Trailer	Tyvek Coverall Suits XL	25			3/1/18	
EDS Trailer	Gowns	640			3/1/18	
EDS Trailer	Syringe 3mL, 25 Gx1 inch	600		Mar-22	3/1/18	
EDS Trailer	Alcohol wipes	4000			3/1/18	
EDS Trailer	Goggles	330		n/a	3/1/18	
EDS Trailer	Bio Hazard Bags	250			3/1/18	
EDS Trailer	Trauma Dressings	100			3/1/18	
EDS Trailer	Backpacks	100?		n/a	3/1/18	
EDS Trailer	MRC bags	40?		n/a	3/1/18	
EDS Trailer	Theremeter	10		n/a	3/1/18	
EDS Trailer	CPR mouth barriers	62			3/1/18	
EDS Trailer	CPR pocket masks	4			3/1/18	
EDS Trailer	Gloves S	1900			3/1/18	
EDS Trailer	Gloves M	1700			3/1/18	
EDS Trailer	Gloves L	1800			3/1/18	
EDS Trailer	Gloves XL	1600			3/1/18	
EDS Trailer	Surgical Masks	1350			3/1/18	
EDS Trailer	Clock : Needs 1 AA battery , NOT included	1		n/a	3/1/18	
EDS Trailer	Wall light : Needs 4 AA batteries, NOT included	2		n/a	3/1/18	
EDS Trailer	Caps	500			3/1/18	
EDS Trailer	Shoe Covers	50			3/1/18	
EDS Trailer	Sharps Containers	24			3/1/18	
EDS Trailer	N 95 Mask	720	3/26/18	3/26/23	3/26/18	3/1/21
EDS Trailer	Ponchos	200		n/a	3/1/18	
EDS Trailer	Warming Blankets	100		n/a	3/1/18	

Trailer Supplies

High School Supplies

CATH Supplies

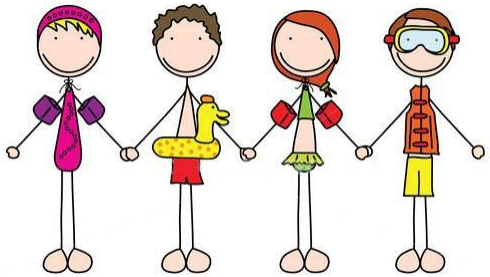
EDS Supplies

Review/ Inspect Summer Camps



















Collaborating on housing inspections through implementing and supervising plans of action with municipal & community departments with housing/hoarding situations

Collaborate with animal Control for the management of Human exposure to suspect Rabid Animals.

CCIT(Community Crisis intervention Team) – case management/resident resources

Participate on Health Department Committees and coalitions
Domestic Violence Action Committee, Substance Use Prevention

Needham DVAC

Break the Cycle

....that breaks the family





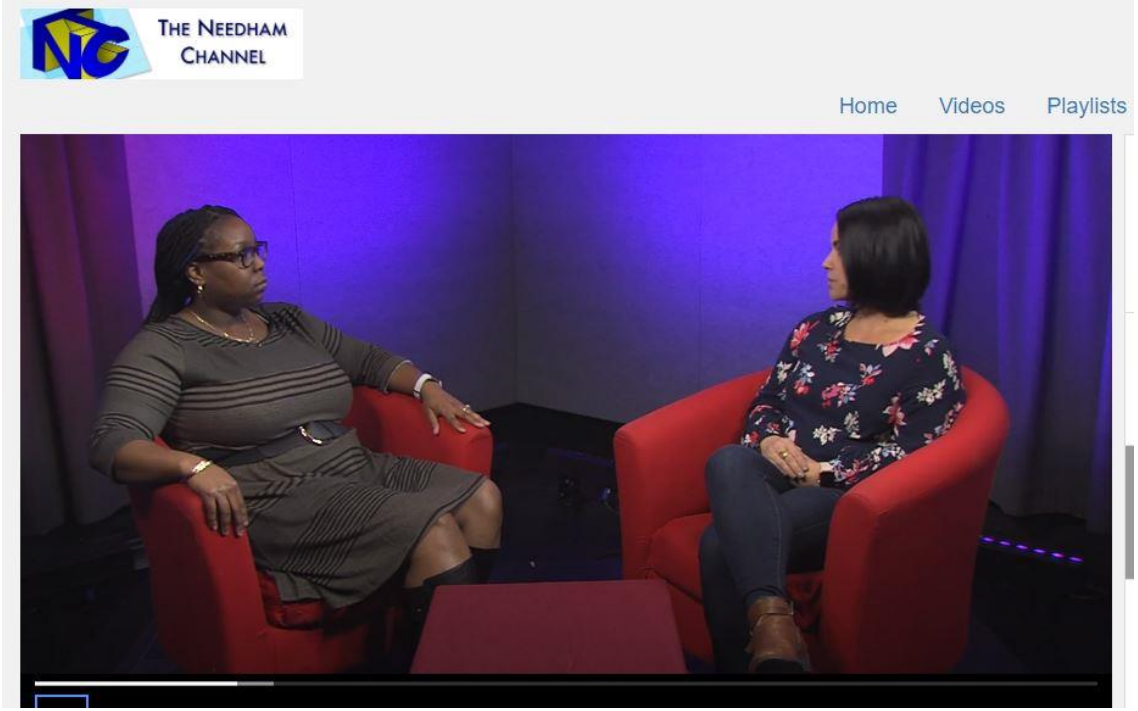
- Harvest & Street Fair
- RAD Training
- Mother's Day Donation Drive
- Cable Network Series & 3 articles
- Monthly Meetings

SAPC SUBSTANCE ABUSE PREVENTION COLLABORATIVE
Dedham | Needham | Norwood | Westwood

- Monthly Meetings
- TIPs Training
- Photo Voice Project



Preventing Domestic Violence Cable Series



https://videoplayer.telvue.com/player/O7e6JrKKSJ3H_TX3VgEvpbSSL7Dbnrk2/playlists/6287/media/424599?autostart=false&showtabssearch=true&fullscreen=false&jwsource=cl

- 5 episodes plus Senior Safety Seminar, RAD, And Violence in the Workplace

COA Collaborations

- MAPC
  - Grant to educate vulnerable populations about emergent effects of climate change
- Matter of Balance
  - 8 Week Course
  - Teaches balance and helps understand and fight the fear of falling
- Lunch and Learns
  - Flu, diabetes, women's health, summer safety
- Safety at Home Program
  - Help Seniors with aging at home

Town Participation, Policies, Procedures, Regulations

- Volunteer Deployment Policy
- Concussion regulations
  - Website
  - Policy and Procedures
  - SOP
- Solutions Group
  - Onboarding
  - Communications
- Leadership Training
  - 7 class course series

Increasing Housing Options in Needham

September 2019

If you could create more accessible and affordable housing options in Needham, what would it look like? Our community lacks affordable, accessible, age-friendly housing. Over 50% of Needham seniors state that they would consider moving out of the town due to the high cost of housing, while over 90% state it is important for them to remain in Needham as they age. [i]

Among the creative approaches embraced by many communities is the allowance of accessory dwelling units – also known as ADUs or in-law apartments. This past May, the Planning Board proposed a bylaw at the May 2019 Town Meeting (ultimately deferred to the fall) which would allow these housing units in Needham. Needham's Board of Health and Council on Aging recognize the need for increased accessible and affordable housing options and strongly support the passage of a town bylaw allowing accessory dwelling units.

Affordable, high-quality housing is linked to improved health. When living in an affordable home, individuals can put more money towards nutritious food and health care, rather than housing. Stable, affordable housing also reduces stress and improves mental health. [ii]

Needham's older adults, residents with disabilities, nannies and caregivers, and younger adults would benefit from accessory dwelling units. Many of our older neighbors are unable to stay in Needham as they age due to high housing costs and limited options for downsizing. If Needham residents were permitted to have an additional unit on their property, they could share costs with a family member while having someone available to help as they need regular assistance. And, if a family wishes to invite an elderly parent to live with them, an accessible apartment within the home might be perfect, allowing all parties privacy and independence.

Accessory units could offer nannies of young families private on-site living options. And, finally, this housing alternative could offer an affordable re-entry for those young adults who grew up in Needham and who want to return.

The Board of Health and Council on Aging Board have taken of the following steps to learn about ADUs and how they may impact Needham.

- In August 2016, the Public Health and Aging Services divisions published the *Assessment of Housing and Transit Options for Needham Seniors*, which recommends ADUs as an effective way to allow older adults to continue living in Needham.

- In August 2017, the Public Health Division studied nearby, comparable municipalities that have allowed ADUs and found that these additional housing units do not significantly alter the character of suburban neighborhoods.
- In July 2018, the Public Health Division received an AARP Community Challenge grant and produced a pamphlet and a storyboard about ADUs.
- In November 2018, both the Board of Health and the Council on Aging developed policy statements supporting zoning changes to allow ADUs.

Based on the Boards' extensive research, passing the bylaw as the Planning Board proposed is a step in the right direction. The bylaw could be made even stronger by: 1) removing the limitation allowing only family members or caregivers; 2) allowing the units to be rented, which could serve as a supplement to those on fixed incomes; and 3) removing the requirement for an interior doorway between each unit to ensure privacy and independence.

The Board of Health and the Council on Aging Board are committed to continuing this important conversation and will hold a joint public meeting in September. If you have questions about expanding housing options with accessory dwelling units, please join us. All are welcome.

For all members of our community, especially seniors and younger adults, let's advance accessory dwelling units in Needham.

DRAFT

[i] Needham Council on Aging and Needham Public Health Department. Assessment of Housing and Transit Options for Needham Seniors. 2016. http://www.needhamma.gov/DocumentCenter/View/13894/Assessment-of-Housing-and-Transit-Options-for-Needham-Seniors?bidId=

[ii] Maqbool N, Viveiros J, Ault M. The Impacts of Affordable Housing on Health: A Research Summary. Center for Housing Policy. 2015. Available: https://www.rupco.org/wp-content/uploads/pdfs/The-Impacts-of-Affordable-Housing-on-Health-CenterforHousingPolicy-Maqbool.etal.pdf

Town of Arlington
Department of Health and Human Services
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Wastehauler and Dumpster Regulations and for the Removal and Transportation of Solid Waste or Recyclables

Section 1: Statement of Purpose

Whereas the Arlington Board of Health has seen an 80% increase in rodent complaints throughout the Town since 2015;

Whereas there are 197 Food Establishments permitted in Town during 2018;

Whereas in 2014, 258.5 million tons of Municipal Solid Waste (MSW) was generated nationally[1];

Whereas in 2014, 14.9% of America's MSW was food waste[2];

Whereas on average in 2013 each American produced 4.4 pounds of waste per day[3];

Whereas Massachusetts Waste Ban regulations, as specified in 310 CMR 19.017, are in place to reduce adverse environmental impacts that may result from the human-generated solid waste;

Now, therefore it is the intention of the Arlington Board of Health to regulate dumpsters and wastehaulers that transport solid waste or recyclables to ensure that they are in compliance with the Massachusetts Waste Ban regulations and uniformly comply with permit requirements established by the Town of Arlington.

Section 2: Scope of Authority

This regulation is promulgated pursuant to the authority granted to the Arlington Board of Health by Massachusetts General Laws, Chapter 111, Section 31 that "Boards of Health may make reasonable health regulations".

Section 3: Applicability

These regulations shall apply to all commercial and residential dumpsters within the Town of Arlington, Massachusetts. Temporary dumpsters utilized in conjunction with building permits issued by Inspectional Services shall not fall under the jurisdiction of these regulations. All dumpsters utilized by a permitted food establishment in the Town of Arlington shall comply with both the regulations outlined herein and all applicable

[1] United States Environmental Protection Agency, (EPA) (2016), *Advancing Sustainable Materials Management: 2014 Tables and Figures*. Retrieved from: https://www.epa.gov/sites/production/files/2016-11/documents/2014_smm_tablesfigures_508.pdf

[2] United States Environmental Protection Agency, (EPA) (2016*), Advancing Sustainable Materials Management: 2014 Tables and Figures*. Retrieved from: https://www.epa.gov/sites/production/files/2016-11/documents/2014_smm_tablesfigures_508.pdf

[3] United States Environmental Protection Agency, (EPA) (2016), *Municipal Solid Waste*. Retrieved from: https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/

requirements as outlined by the current Food and Drug Administration (FDA) Food Code edition enforced in the Town of Arlington.

Section 4: Definitions

Board: The Board of Health or its agent or designee.

Composting: A process of accelerated biodegradation and stabilization of organic material under controlled conditions yielding a product which can be safely used, as those terms are or may be defined by *310 CMR 19.00: Solid Waste Management.*

Dumpster: Any container (other than a conventional trash can with lid) used for the outside storage of solid waste, recyclables, garbage, rubbish, organic matter, or refuse of any sort. This includes 96 gallon rolling toters supplied in lieu of a dumpster, as well as rolling toters used to collect and haul food waste and composting materials. This excludes temporary construction dumpsters permitted by Inspectional Services.

Garbage: The animal, vegetable or other organic waste resulting from the handling, preparing, cooking, consumption or cultivation of food, and containers and cans which have contained food unless such containers have been cleaned and prepared for recycling.

Owner: Any person, including a lessee or mortgagee in possession, who alone or severally with others, has lawful title to or lawful possession, care or control of any property on which a dumpster is located or proposed to be located. Owner also includes any authorized agent of such person.

Private Wastehauler: Any person, who, for compensation, supplies, maintains or services one or more dumpsters, or removes, transports or disposes of the contents thereof who is not apart of the Town's wastehauler contract.

Recycleables: A material that is banned from disposal in the Commonwealth of Massachusetts pursuant to *310 CMR 19.017: Waste Bans*. Mixed paper, cardboard, glass, metal, plastic containers are priority materials of this regulation.

Rubbish: Combustible and noncombustible waste materials, except garbage, and includes but is not limited to such material as paper, rags, cartons, boxes, wood, excelsior, rubber, leather, tree branches, yard trimmings, grass clippings, tin cans, metals, mineral matter, glass, crockery, dust, and the residue from the burning of wood, coal, coke and other combustible materials.

Solid Waste: Useless, unwanted or discarded non-recyclable solid or liquid wastes, excluding items restricted from disposal in Massachusetts, as defined by Table *310 CMR 19.017 (3)* of the Massachusetts Solid Waste regulations (*310 CMR 19.017).*

Waste Ban Materials: All materials designated as banned from disposal in the Commonweath of Massachusetts pursuant to *310 CMR 19.017*: *Waste Bans*, including: asphalt pavement, brick and concrete, cathode ray tubes, clean gypsum wallboard, ferrous and non-ferrous metals, glass and metal containers, lead acid batteries, leaves and yard waste, recyclable paper, cardboard and paperboard, single resin narrow-neckwed plastics, treated and

untreated wood and wood waste (banned from landfills only), white goods (large appliances), and whole tires (banned from landfills only).

Wastehauler: Any person, who, for compensation, supplies, maintains or services one or more dumpsters, or removes, transports or disposes of the contents thereof in accordance with the Town's wastehauler contract. This excludes landscaping companies that haul yard waste.

Section 5: Dumpster Permit Application

5.1 No dumpster shall be used or kept in the Town of Arlington after January, 2019 unless an application is submitted to the Board of Health and a permit is issued by the Board allowing the use of such dumpster. All permits shall expire at the end of the calendar year in which they are issued, and may be renewed annually with the application provided by the Board. There shall be a fee of $100.00 payable for said permit.

Section 6: Wastehauler Permit Application

6.1 No contractor, firm, or person shall supply a dumpster service in the Town of Arlington for the purpose of storage, removal, or transporting of solid waste or recyclables without first obtaining a wastehauler permit from the Board. All permits shall expire at the end of the calendar year in which they are issued, but may be renewed annually with the application provided by the Board. There shall be a fee of $11 0.00 payable for said permit.

Section 7: Dumpster Regulations

7.1 Each dumpster must be located at a distance from the lot line so as to not interfere with the safety, convenience, or health of abutters or residents. Dumpster location must be approved by the Board.

7.2 Each dumpster must be situated so as not to obstruct the view of flowing traffic.

7.3 When deemed necessary by the Board, it may be required that a dumpster site be enclosed or screened by the property owner or authorized agent.

7.4 Each dumpster must be of sufficient size and capacity to eliminate overflowing, and the property owner or authorized agent of the premises utilizing the service must take appropriate action immediately to empty contents when full.

7.5 All dumpsters must have a tight-fitting lid or cover, which shall be kept closed at all times except when being filled, cleaned or emptied. Each dumpster shall be constructed in such a way as to be leak-proof. If drain plugs are provided, they must be tight-fitting so as to prevent the leakage of liquid. All dumpsters must be maintained in good condition, without defect, as to prevent pest activity.

7.6 Any dumpster used for the disposal of liquids or organic matter shall be emptied as necessary to prevent insect or pest attraction.

7.7 The Board may order dumpster capacity size changes and/or additional pickups if in their opinion they find it necessary.

Section 8: Dumpster Permittee Responsibilities

8.1 The owner or agent of the dumpster shall have his/her business name and telephone number conspicuously displayed on the dumpster.

8.2 It shall be the responsibility of the owner and/or agent whose property is being serviced to maintain the dumpster area free of odors, scattered debris, overflowing debris, and all other nuisances. It shall also be the responsibility of the property owner and/or agent being serviced to maintain the dumpster area free from any condition that may be considered an attraction for rodents or other pests.

8.3 Dumpsters must be maintained in good condition. Rust holes, uncovered drain caps, and other physical evidence of neglect that allows rodents and other animals access to the dumpster contents are not permitted. Owners who have a history of poor maintenance shall be required to work with their contractor and swap out the dumpster for one that meets these regulations.

8.4 Dumpsters must be placed on pavement or concrete, not soil. The location must be approved by the Arlington Board of Health.

8.5 Food service establishments must also comply with *105 CMR 590.000*, the State Sanitary Code.

Section 9: Wastehauler Permittee Responsibilities

9.1 The dumpster wastehauler shall have the dumpster deodorized, washed or sanitized as directed by order of the Board as necessary to preclude pest attraction and activity.

9.2 The dumpster wastehauler shall have his/her business name and telephone number conspicuously displayed on the dumpster.

9.3 All permitted wastehaulers must be in compliance with applicable federal, state, and local laws. Each wastehauler vehicle must meet all Department of Transportation safety requirements at all times.

9.4 All materials must be securely contained in the vehicle. Littering or leaking shall be considered a violation of this regulation.

Section 10: Madatory Recycling

10.1 This regulation is intended to support and align with the Townof Arlington's Mandatory Recycling Bylaw as outlined in Massachusetts Waste Ban regulations *310 CMR 19.017*. All recycling must be in compliance with the requirements outlined in the Town's contracted wastehauler services.

Section 11: Violations; Enforcement

11.1 These regulations apply to all dumpsters and wastehaulers in the Town of Arlington whether for residential, commercial, or industrial use.

11.2 The Board is authorized to inspect a permitted dumpster or a permitted wastehauler's truck and load at any time. The Board also has the right to require weight slips or confirmation of disposal of solid waste or recyclables.

11.3 Wastehauler permits may be suspended or revoked by the Board for failure of the wastehauler to comply with the requirements of these regulations.

11.4 The Board may attach any conditions to the dumpster service permit that it deems would serve the interest of the safety, health, welfare, or quality of life of the citizens of the Town of Arlington.

11.5 The Board may, by written decision, vary the application of any provision of these regulations with respect to any particular case, when the enforcement thereof would do manifest injustice; provided that any such decision of the Board shall not conflict with the express purpose of these regulations. Any variance shall, while it is in effect, be available to the public during normal business hours in the Health Department Office.

11.6 Any person who violates the terms of these regulations shall be subject to a fine of $50.00 for the first offense and $100 for each subsequent offense under the non-criminal disposition authorized by M.G.L. Chapter 40 Section 21D and Town bylaw Title VIII, Article 3 Section 7. Each day shall constitute a separate offense.

11.7 If any provision of these regulations is declared invalid or unenforceable by any court of competent jurisdiction, the other provisions of the regulations shall not be affected thereby, but shall continue in full force and effect.

11. Effective Date

These regulations shall take effect on May 23, 2018.

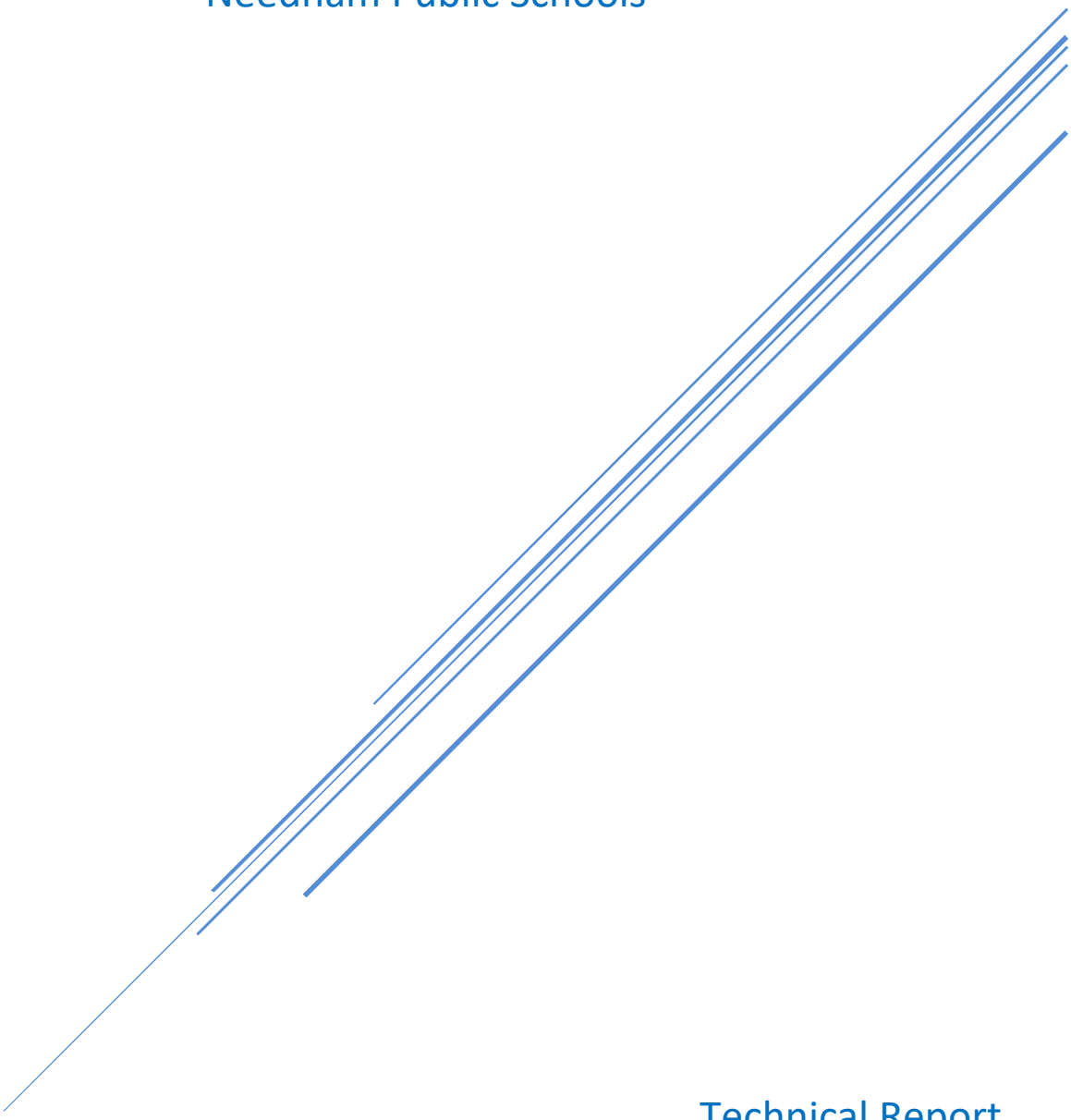
1. _____
Marie Walsh Condon, MD

2. _____
Kenneth Kohlberg, JD, MPH

3. _____
Kevin Fallon, DVM

NEEDHAM SURVEY ABOUT ELECTRONIC VAPOR PRODUCTS

Students Advocating Life without Substance Abuse (SALSA)
Substance Abuse Prevention Alliance of Needham (SPAN)
Needham Public Schools



Technical Report
June 2019

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BACKGROUND

The Needham Survey About Electronic Vapor Products was designed by the Students Advocating Life without Substance Abuse (SALSA) group at Needham High School with guidance and assistance from the Substance Abuse Prevention Alliance of Needham (SPAN) and an external research and evaluation consultant.

The purpose of this survey was to collect data to support the development of prevention messages in the 2019-2020 academic year to prevent the use of electronic vapor products among Needham Public School students.

The survey was administered as an anonymous online instrument during homeroom period on June 6, 2019. Students accessed the survey through school computers or through their own laptops or mobile devices. The survey was administered to 8th, 9th, 10th, and 11th graders so that it would be reflective of the high school population in the coming school year.

Approximately two-thirds of students enrolled in 8th, 9th, 10th, and 11th grade took part in the survey. This ranged from a high of 74% of 9th graders to a low of 49% of 11th graders. A larger number of female students (55%) than male students (43%) participated.

	8th	9th	10th	11th	Total
Completed Surveys	250	332	256	194	1,032
% of Completed Surveys	24%	32%	25%	19%	
Enrolled Students	392	450	423	400	1,665
Response Rate	64%	74%	61%	49%	62%

	Male	Female	Other[1]
Gender Identity	43% (448)	55% (569)	1.5% (15)

[1] Includes gender non-conforming (0.5%, n=5), non-binary (0.7%, n=7), not listed (0.1%, n=1), and not sure (0.2%, n=2).

The findings from this survey are only generalizable to the students who were present on the day of the survey and who opted to take part.

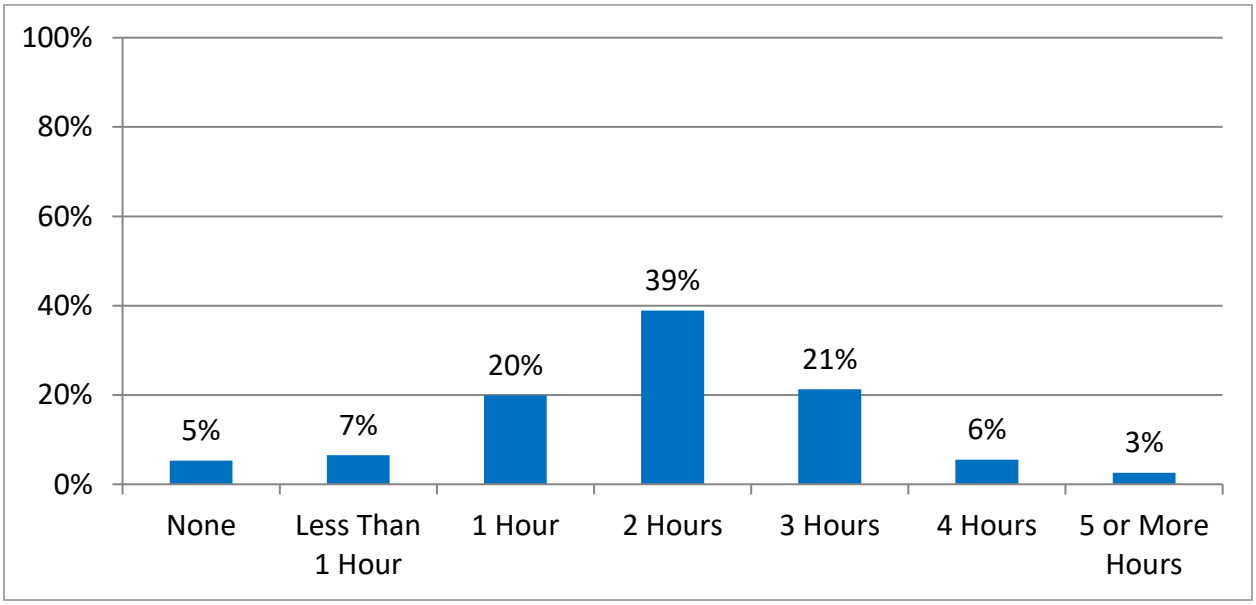
These results are **not** directly comparable to the more comprehensive MetroWest Adolescent Health Survey (MWAHS) due to differences in timing, response rate, method of administration and other factors. The findings from the MWAHS related to electronic vapor products should take prominence over these data. This survey was designed to assist the SALSA students obtain more in-depth information on vaping behaviors to design their prevention messages; this project is **not** intended to generate population-level estimates for the District.

Findings are color coded in a manner such that protective factors are presented in blue and risk factors are presented in red. The header on each page identifies the population on which the percentages were calculated.

FINDINGS – EXTRACURRICULAR ACTIVITIES

All respondents (n=1,032) were asked, "On an average school day, how many hours do you spend on extracurricular activities outside of school, like sports, clubs, and music lessons, or other nonacademic activities?" The majority of respondents (80%) reported 1-3 hours.

Figure 1: Hours Spent on Extracurricular Activities on an Average School Day



There were no significant differences in the number of hours respondents reported spending on extracurricular activities on an average school day based on whether they have ever used an electronic vapor product (e.g., Juul), their gender identity, or their age/grade.

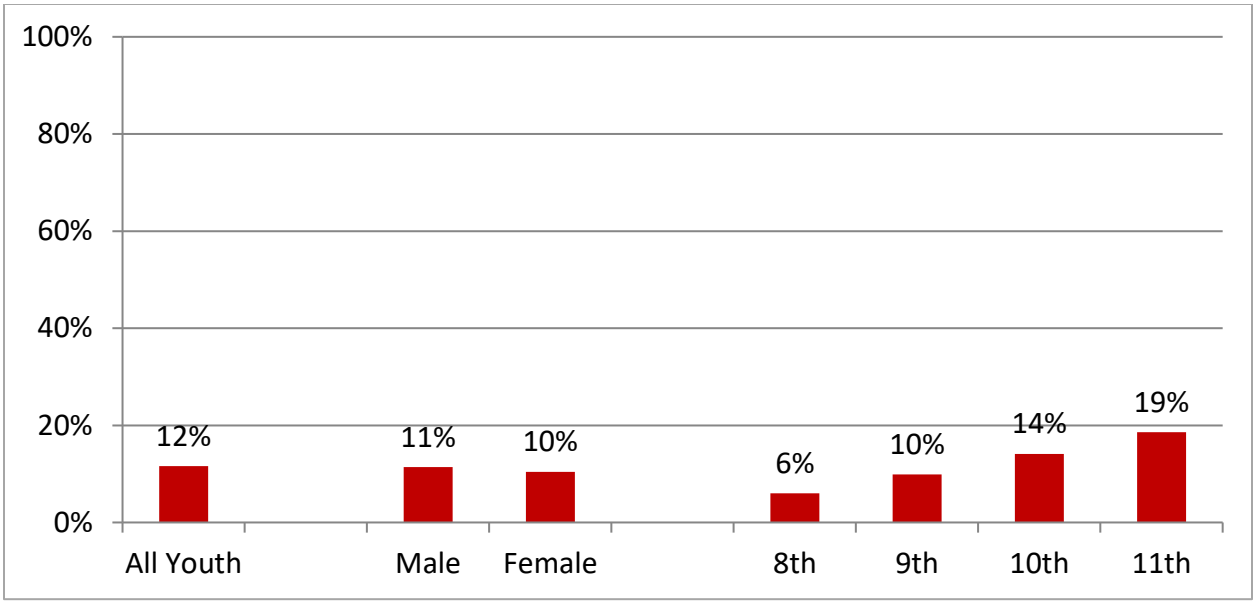
	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
None	5.3%	4.5%	8.4%	7.1%	3.7%	6.8%	3.9%	7.0%	3.6%
Under 1 hour	6.5%	6.2%	7.6%	5.6%	7.4%	7.2%	6.0%	5.9%	7.2%
1 Hour	19.9%	19.8%	20.0%	19.9%	20.4%	19.6%	22.9%	18.0%	17.5%
2 Hours	38.9%	40.5%	32.9%	41.3%	36.9%	35.6%	39.2%	39.1%	42.3%
3 Hours	21.3%	20.9%	22.7%	17.4%	24.3%	22.4%	21.4%	21.5%	19.6%
4 Hours	5.5%	5.7%	4.9%	6.5%	4.9%	5.6%	4.5%	7.0%	5.2%
5+ Hours	2.6%	2.4%	3.6%	2.2%	2.5%	2.8%	2.1%	1.6%	4.6%

FINDINGS – CIGARETTE USE

Lifetime Use of Cigarettes

All respondents (n=1,032) were asked, "Have you ever tried cigarette smoking, even one or two puffs?" Overall, 12% of respondents reported that they had ever tried cigarette smoking (lifetime use).

Figure 2: Lifetime Use of Cigarettes



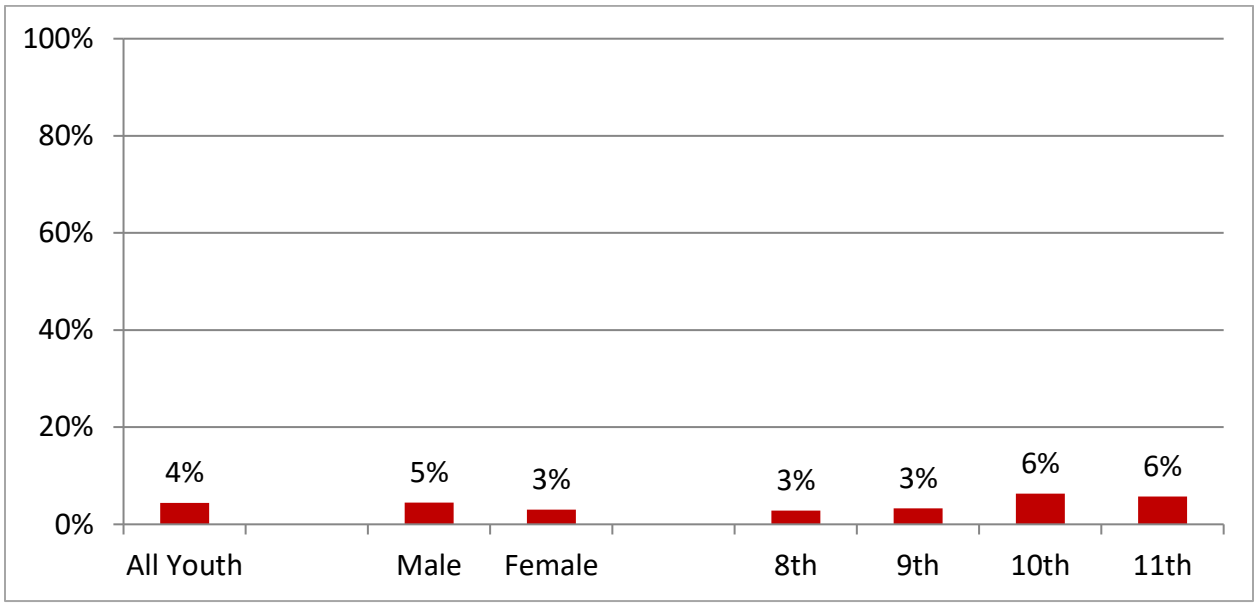
Respondents who reported that they had ever used an electronic vapor product (e.g., Juul) were significantly more likely than their peers to report that they had also used cigarettes in their lifetime – 33% of those who ever used an electronic vapor product had also used cigarettes in their lifetime. There were no significant differences in lifetime use of cigarettes by gender identity. Lifetime use of cigarettes increased significantly by the age/grade of the respondent.

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
No	88.4%	94.4%	66.7%	88.6%	89.6%	94.0%	90.1%	85.9%	91.4%
Yes	11.6%	5.6%	33.3%	11.4%	10.4%	6.0%	9.9%	14.1%	18.6%

Current Use of Cigarettes

All respondents (n=1,032) were asked, "During the past 30 days, on how many days did you smoke cigarettes?" Overall, 4% of respondents reported that they had used cigarette in the 30 days prior to the survey (current use).

Figure 3: Current Use of Cigarettes



Respondents who reported that they had ever used an electronic vapor product (e.g., Juul) were significantly more likely than their peers to report that they had also used cigarettes in the past 30 days – 17% of those who ever used an electronic vapor product had also used cigarettes in the past 30 days. There were no significant differences in current use of cigarettes by gender identity or by the age/grade of the respondent.

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
No	95.6%	99.3%	82.7%	95.5%	97.0%	97.2%	96.7%	93.8%	94.3%
Yes	4.4%	0.7%	17.3%	4.5%	3.0%	2.8%	3.3%	6.3%	5.7%

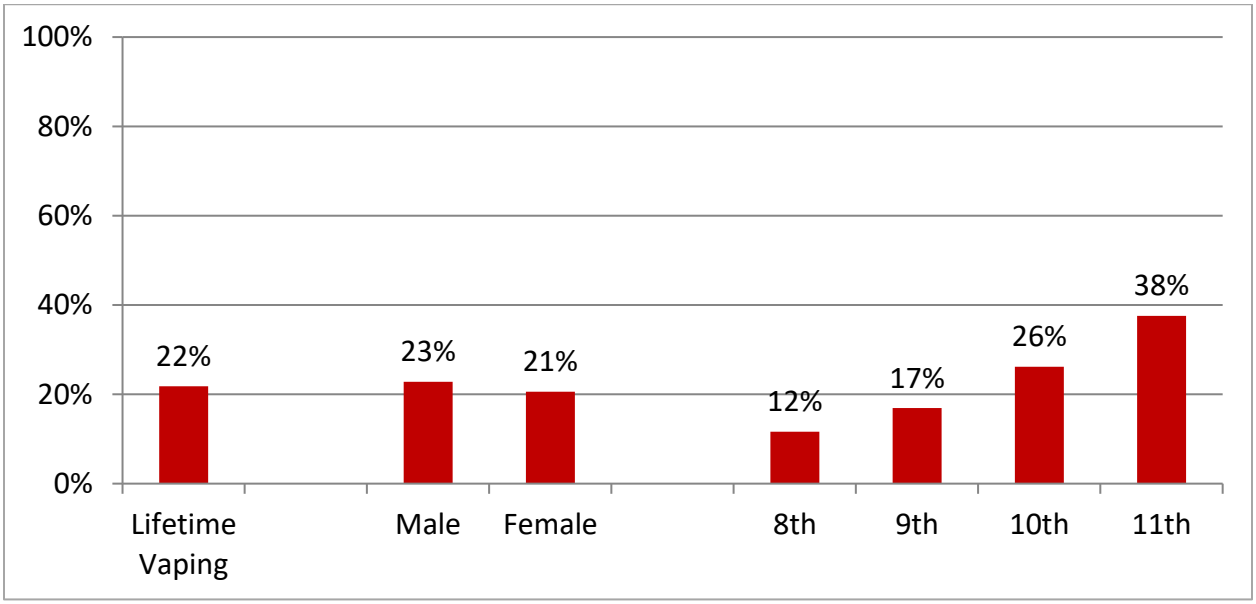
FINDINGS – ELECTRONIC VAPOR PRODUCT USE

Lifetime Use of Electronic Vapor Products

Respondents were asked about the use of electronic vapor products, such as Juul, Phix, Vuse, MarkTen, and blu. Electronic vapor products include e-cigarettes, vapes, vape pens, e-cigars, e-hookahs, Hookah pens, and mods.

All respondents (n=1,032) were asked, "Have you ever used an electronic vapor product?" Overall, 22% of respondents reported that they had ever used an electronic vapor product (lifetime use).

Figure 4: Lifetime Use of Electronic Vapor Products



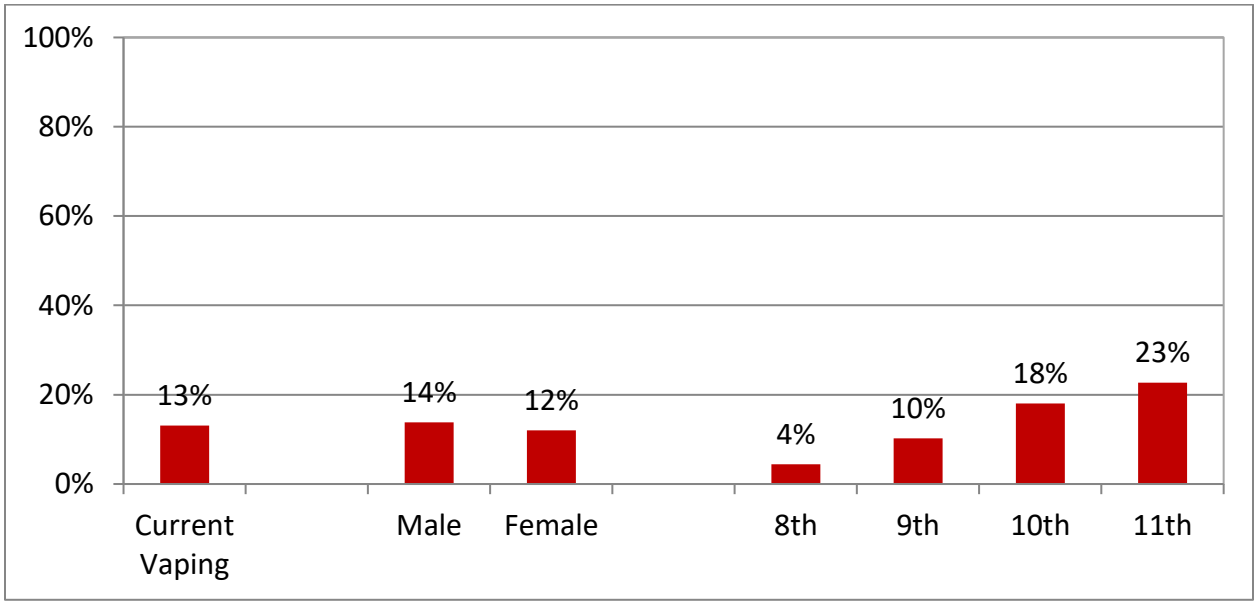
There were no significant differences in reports of lifetime use of electronic vapor products by gender identity. Lifetime use of electronic vapor products increased significantly with the age/grade of the respondent. Specifically, lifetime use of electronic vapor products increased from 12% among 8th grade respondents to 38% among 12th grade respondents.

	All Youth	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
No	78.2%	77.2%	79.4%	88.4%	83.1%	73.8%	62.4%
Yes	21.8%	22.8%	20.6%	11.6%	16.9%	26.2%	37.6%

Current Use of Electronic Vapor Products

All respondents (n=1,032) were asked, "During the past 30 days, on how many days did you use an electronic vapor product?" Overall, 13% of respondents reported that they had used an electronic vapor product in the 30 days prior to the survey (current use).

Figure 5: Current Use of Electronic Vapor Products



There were no significant differences in reports of current use of electronic vapor products by gender identity. Current use of electronic vapor products increased significantly with the age/grade of the respondent. Specifically, current use of electronic vapor products increased from 4% among 8th grade respondents to 23% among 12th grade respondents.

	All Youth	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
No	86.9%	86.2%	88.0%	95.6%	89.8%	82.0%	77.3%
Yes	13.1%	13.8%	12.0%	4.4%	10.2%	18.0%	22.7%

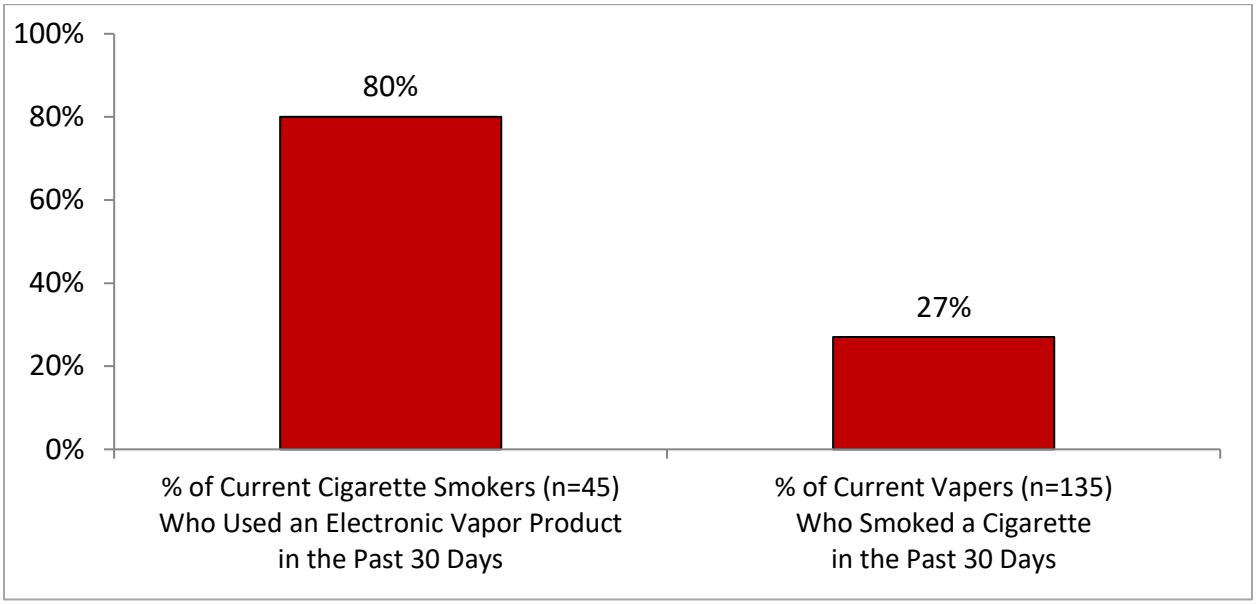
Co-Occurrence of Use of Electronic Vapor Products and Cigarettes

Of the 1,032 respondents to the survey, 45 individuals reported that they had smoked a cigarette in the 30 days prior to they survey (4.4%) and 135 individuals reported that they had used an electronic vapor product in the past 30 days (13.1%)

Most individuals who smoked a cigarette in the past 30 days *also* used an electronic vapor product in the 30 days prior to the survey (80%, n=36 of 45).

Approximately one of every three individuals who used an electronic vapor product in the past 30 days *also* smoked a cigarette in the 30 days prior to the survey (27%, n=36 of 135).

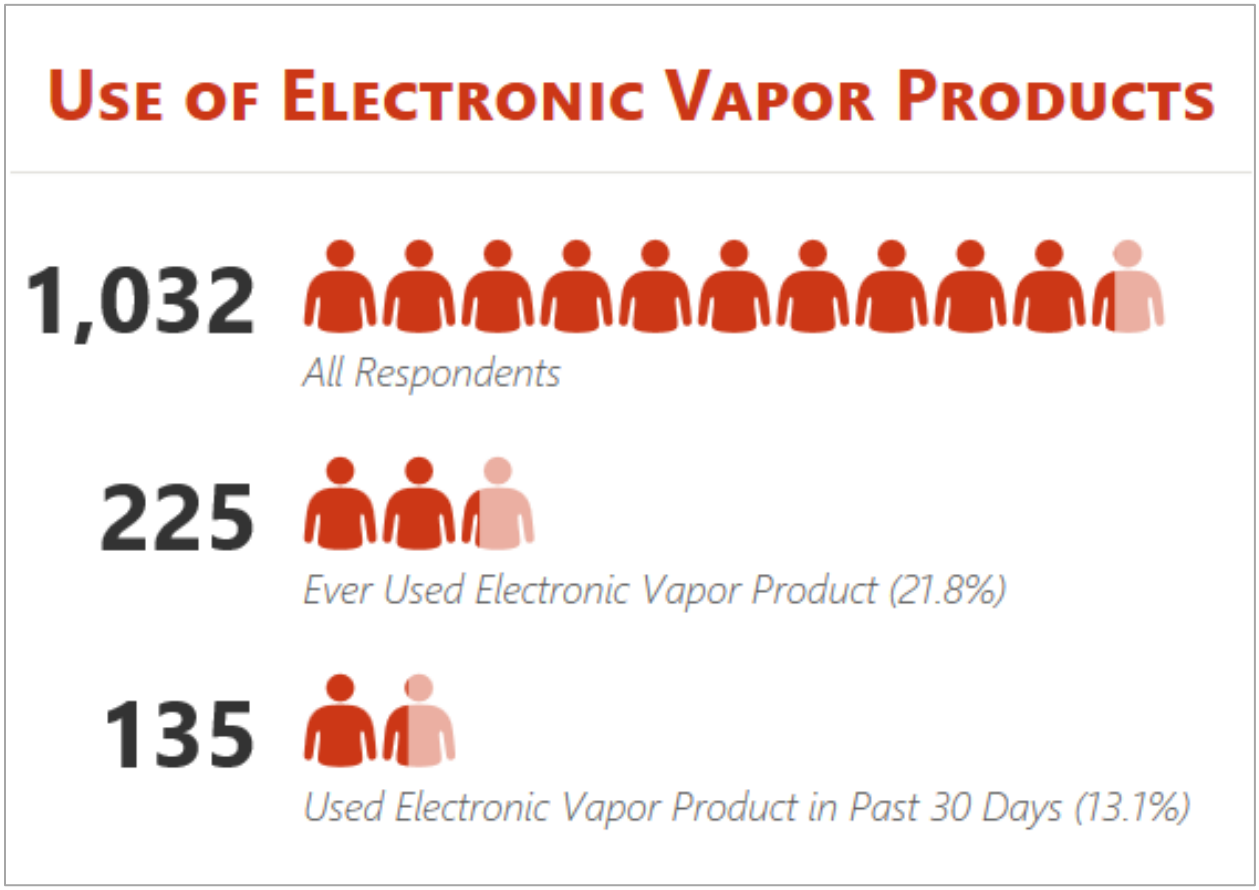
Figure 6: Co-Occurrence of Cigarette Use and Use of Electronic Vapor Products



Summary of Findings on Electronic Vapor Products

Among all respondents to the survey (n=1,032), 225 individuals reported that they had ever used an electronic vapor product in their lifetime (21.8%) and 135 individuals reported that they had used an electronic vapor product in the 30 days prior to the survey (13.1%).

Figure 7: Summary of Findings on Electronic Vapor Products

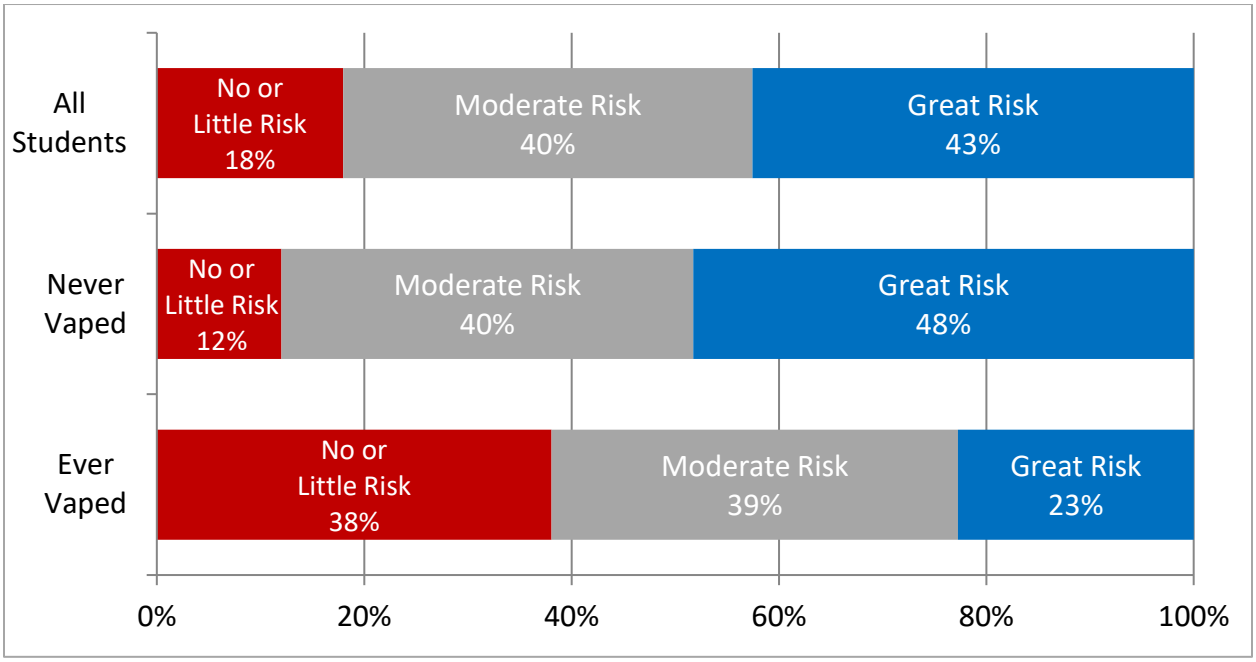


FINDINGS – ATTITUDES, OPINIONS, AND PERCEPTIONS

Perceived Risk of Harm of Using Electronic Vapor Products

All respondents (n=1,032) were asked, "How much do you think people risk harming themselves (physically or in other ways) if they use electronic vapor products?" Among all respondents, 4% reported *no risk* associated with use of electronic vapor products, 14% reported *slight risk*, 40% reported *moderate risk*, and 43% reported *great risk*.

Figure 8: Perceived Risk of Harm of Using Electronic Vapor Products



Respondents who reported that they had ever used an electronic vapor product perceived significantly *less* risk of using electronic vapor products than their peers. Female respondents perceived significantly *more* risk of using electronic vapor products than males. Perceived risk of using electronic vapor products *decreased* with the age/grade of the respondent. Specifically, the proportion of respondents who reported *great risk* associated with use of electronic vapor products declined from 51% in 8th grade to 26% in 12th grade.

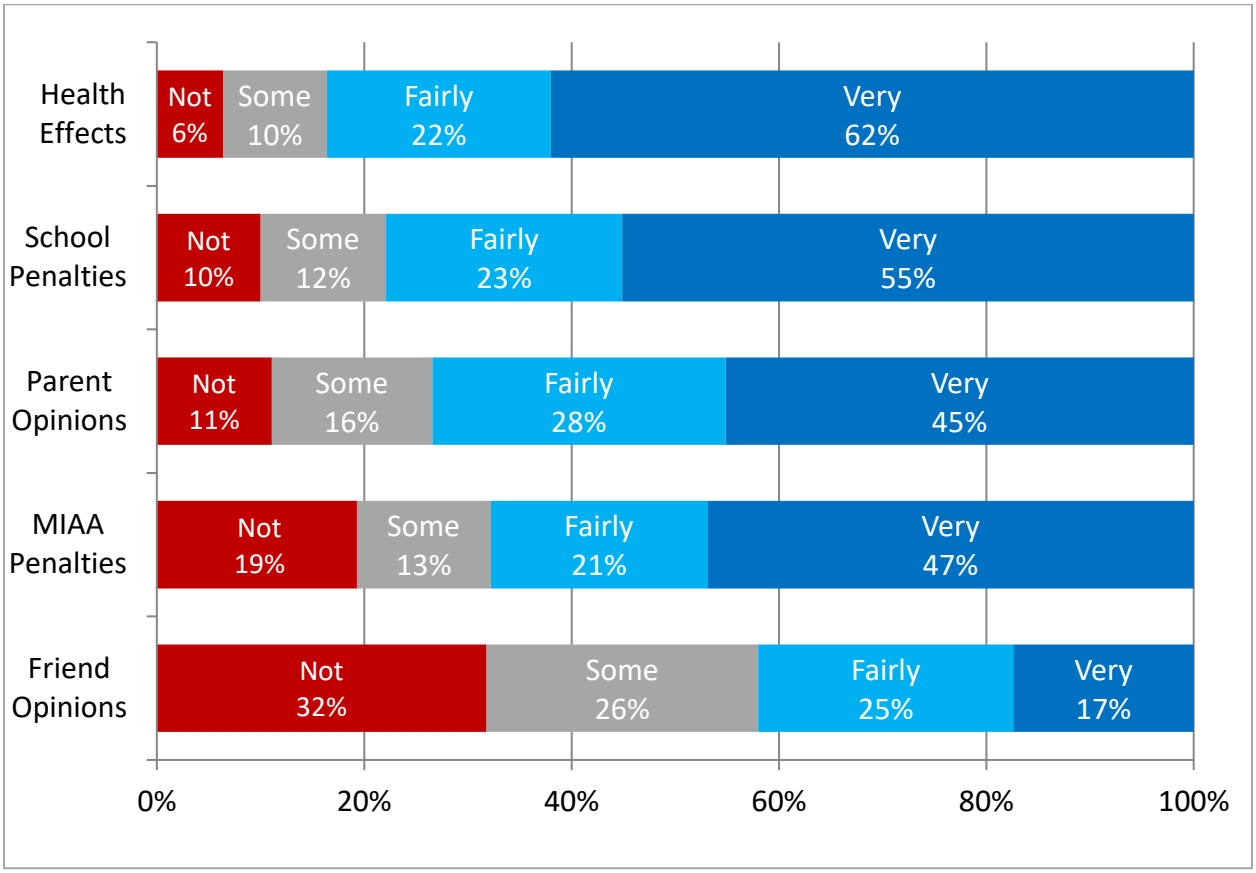
	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
No Risk	3.9%	1.7%	11.6%	4.9%	3.0%	4.4%	1.5%	4.7%	6.2%
Slight Risk	14.0%	10.4%	26.7%	18.3%	10.2%	8.0%	14.2%	14.5%	20.6%
Moderate Risk	39.5%	39.7%	39.1%	37.9%	41.1%	36.8%	36.7%	40.2%	46.9%
Great Risk	42.6%	48.2%	22.7%	38.8%	45.7%	50.8%	47.6%	40.6%	26.3%

Influences on Decisions About Using Electronic Vapor Products

All respondents (n=1,032) were asked, "How important are each of the following factors in your decision about whether to use an electronic vapor product?" The list of factors provided was: (1) what your parents would think, (2) what your friends would think, (3) potential school penalties, (4) school sports zero tolerance rules, and (5) how it might affect your health.

Among all respondents, 84% reported that potential health effects were *fairly* or *very important* to their decision, followed by potential school penalties (78% *fairly/very important*), what their parents would think (73% *fairly/very important*), school sports zero tolerance rules (68% *fairly/very important*), and what their friends would think (42% *fairly/very important*).

Figure 9: Importance of Different Factors on Decisions About Vaping



Respondents who had ever used an electronic vapor product provided significantly *lower* importance ratings than their peers to all five factors. Male respondents provided significantly *lower* importance ratings than females to all five factors. The importance of all five factors decreased significantly with age/grade. For example, 72% of 8th graders indicated that potential health effects were *very* important in their decision compared to 51% of 11th graders.

Importance of health effects in decisions about vaping

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
Not at All	3.5%	1.2%	11.6%	4.7%	2.3%	3.2%	2.7%	4.3%	4.1%
Not Very	2.9%	1.1%	9.3%	4.2%	1.9%	2.8%	1.8%	4.7%	2.6%
Somewhat	10.0%	6.9%	20.9%	11.6%	8.6%	8.8%	9.3%	9.8%	12.9%
Fairly	21.6%	20.4%	25.8%	21.7%	21.3%	13.6%	20.5%	25.0%	29.4%
Very	62.0%	70.3%	32.4%	57.8%	65.9%	71.6%	65.7%	56.3%	51.0%

Importance of potential school penalties in decisions about vaping

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
Not at All	4.1%	2.2%	10.7%	5.8%	2.6%	3.2%	2.7%	5.9%	5.2%
Not Very	5.9%	5.1%	8.9%	7.6%	4.2%	3.2%	6.3%	6.3%	8.2%
Somewhat	12.1%	11.8%	13.3%	13.8%	10.7%	9.2%	9.9%	10.5%	21.6%
Fairly	22.8%	22.6%	23.6%	23.9%	22.1%	22.8%	22.6%	21.5%	24.7%
Very	55.1%	58.4%	43.6%	48.9%	60.3%	61.5%	58.4%	55.9%	40.2%

Importance of parent opinions in decisions about vaping

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
Not at All	4.6%	2.0%	13.8%	6.3%	3.0%	4.4%	3.3%	3.9%	7.7%
Not Very	6.5%	4.7%	12.9%	6.7%	6.3%	2.8%	6.0%	8.2%	9.8%
Somewhat	15.5%	12.6%	25.8%	18.3%	13.2%	11.6%	11.1%	17.6%	25.3%
Fairly	28.3%	29.1%	25.3%	27.5%	29.0%	24.4%	28.3%	30.5%	30.4%
Very	45.2%	51.5%	22.2%	41.3%	48.5%	56.8%	51.2%	39.8%	26.8%

Importance of school sports zero tolerance rules in decisions about vaping

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
Not at All	11.8%	9.0%	21.8%	13.4%	10.2%	5.2%	9.9%	14.8%	19.6%
Not Very	7.5%	7.2%	8.4%	8.3%	6.9%	4.4%	6.9%	8.6%	10.8%
Somewhat	12.9%	12.6%	13.8%	15.0%	11.4%	8.8%	12.7%	13.3%	18.0%
Fairly	20.9%	20.3%	23.1%	21.2%	20.9%	18.4%	20.8%	21.1%	24.2%
Very	46.9%	50.8%	32.9%	42.2%	50.6%	63.2%	49.7%	42.2%	27.3%

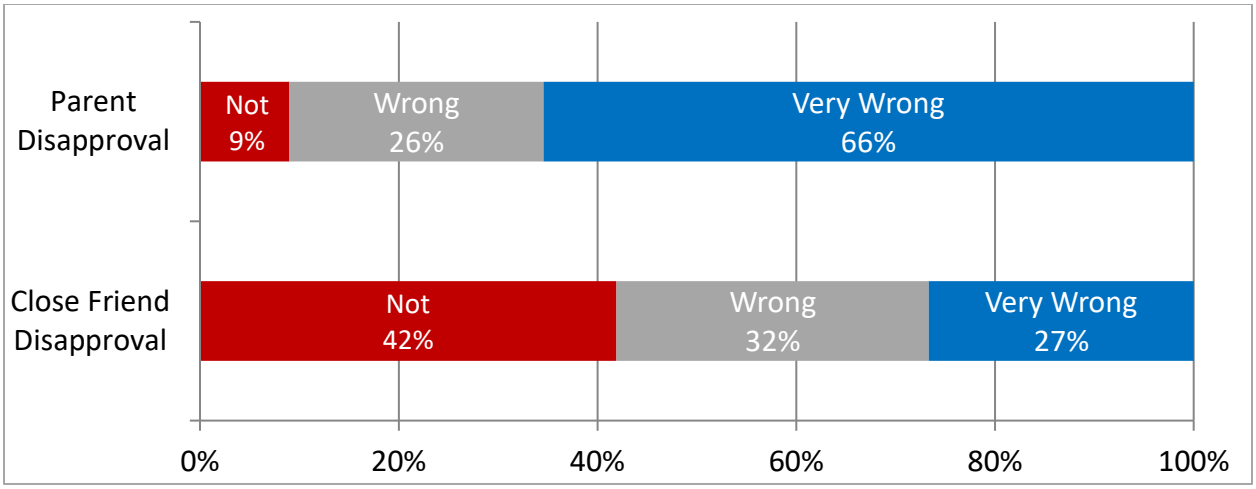
Importance of friend opinions in decisions about vaping

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
Not at All	11.7%	9.2%	20.9%	16.3%	7.9%	8.8%	7.5%	16.4%	16.5%
Not Very	20.1%	17.6%	28.9%	22.3%	18.3%	14.8%	19.9%	19.9%	27.3%
Somewhat	26.2%	26.1%	26.2%	28.1%	24.8%	25.2%	24.7%	27.3%	28.4%
Fairly	24.6%	27.5%	14.2%	19.4%	28.8%	28.4%	29.2%	20.3%	17.5%
Very	17.4%	19.6%	9.8%	13.8%	20.2%	22.8%	18.7%	16.0%	10.3%

Perception of Parental and Peer Disapproval of Using Electronic Vapor Products

All respondents (n=1,032) were asked, "How wrong do other people in your life feel it would be for you to use an electronic vapor product?" Respondents were asked how their PARENTS/ GUARDIANS would feel and how their CLOSE FRIENDS would feel. Among all respondents, 92% think their parents would feel it was *wrong* or *very wrong* for them to use an electronic vapor product compared to 59% who thought their close friends would feel similarly.

Figure 10: Perceived Parental and Peer Disapproval of Vaping



Respondents who had ever vaped perceived significantly *less* parental and peer disapproval than their peers. Male respondents perceived significantly *less* disapproval from both groups than females. Perceived parental and peer disapproval *decreased* significantly with age/grade.

Perceived PARENTAL disapproval of using an electronic vapor product

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
Not at All	2.4%	1.6%	5.3%	2.7%	1.9%	2.4%	2.1%	2.3%	3.1%
A Little	6.5%	3.6%	16.9%	7.6%	5.4%	2.4%	7.2%	7.8%	8.8%
Wrong	25.6%	24.9%	28.0%	29.0%	22.8%	21.6%	27.7%	23.8%	29.4%
Very Wrong	65.5%	69.9%	49.8%	60.7%	69.8%	73.6%	63.0%	66.0%	58.8%

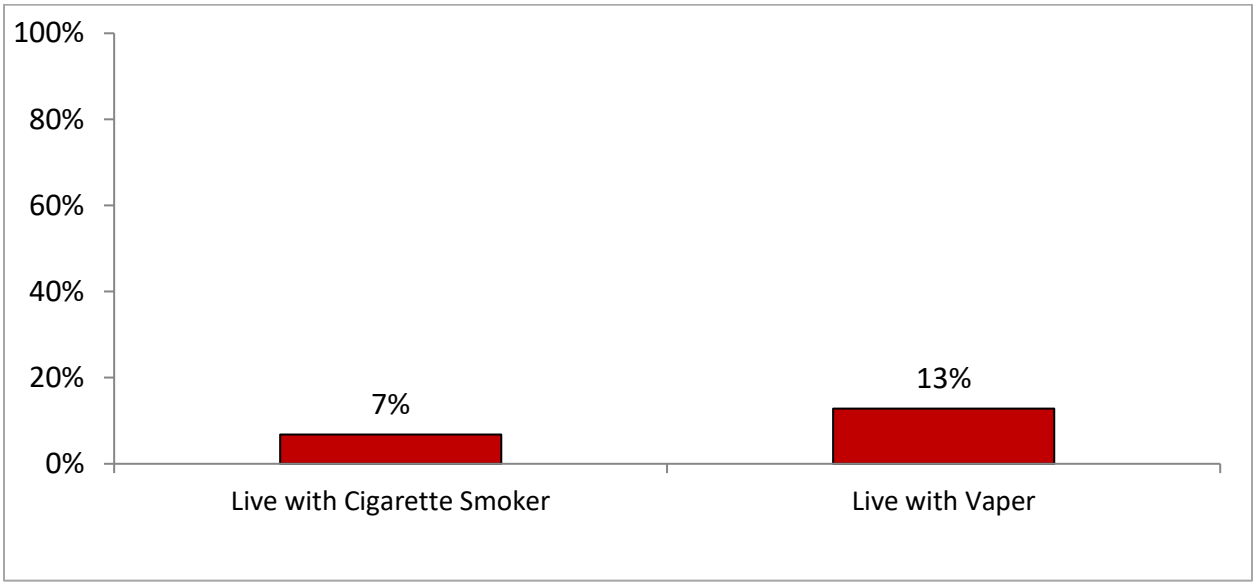
Perceived CLOSE FRIEND disapproval of using an electronic vapor product

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
Not at All	15.4%	7.3%	44.4%	17.0%	13.9%	6.4%	12.7%	17.2%	29.4%
A Little	26.4%	23.7%	36.0%	28.3%	24.8%	20.0%	24.1%	28.9%	35.1%
Wrong	31.5%	37.3%	10.7%	31.0%	32.2%	35.2%	33.1%	34.0%	20.6%
Very Wrong	26.7%	31.7%	8.9%	23.7%	29.2%	38.4%	30.1%	19.9%	14.9%

FINDINGS – ENVIRONMENTAL EXPOSURE TO VAPING AND CIGARETTES

All respondents (n=1,032) were asked whether there is anyone (other than them) living in their household who (a) smokes cigarettes and (b) uses an electronic vapor product. Among all respondents, 7% indicated that they live with someone who smokes cigarettes and 13% live with someone who uses an electronic vapor product.

Figure 11: Environmental Exposure to Cigarettes and Electronic Vapor Products



Respondents who reported that they had ever used an electronic vapor product (e.g., Juul) were significantly more likely than their peers to report that they live with someone who smokes cigarettes and to report that they live with someone who vapes. Overall, 14% of those who had ever vaped reported that they live with someone who smokes cigarettes (compared to 5% of their peers) and 32% of those who ever vaped reported that they live with someone who vapes (compared to 7% of their peers).

Live with someone who smokes cigarettes

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
No	93.2%	95.3%	85.8%	91.5%	94.7%	93.2%	94.9%	93.0%	90.7%
Yes	6.8%	4.7%	14.2%	8.5%	5.3%	6.8%	5.1%	7.0%	9.3%

Live with someone who uses an electronic vapor product

	All Youth	Never Vaped	Ever Vaped	Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
No	87.2%	92.7%	67.6%	86.8%	88.4%	90.8%	86.1%	84.4%	88.1%
Yes	12.8%	7.3%	32.4%	13.2%	11.6%	9.2%	13.9%	15.6%	11.9%

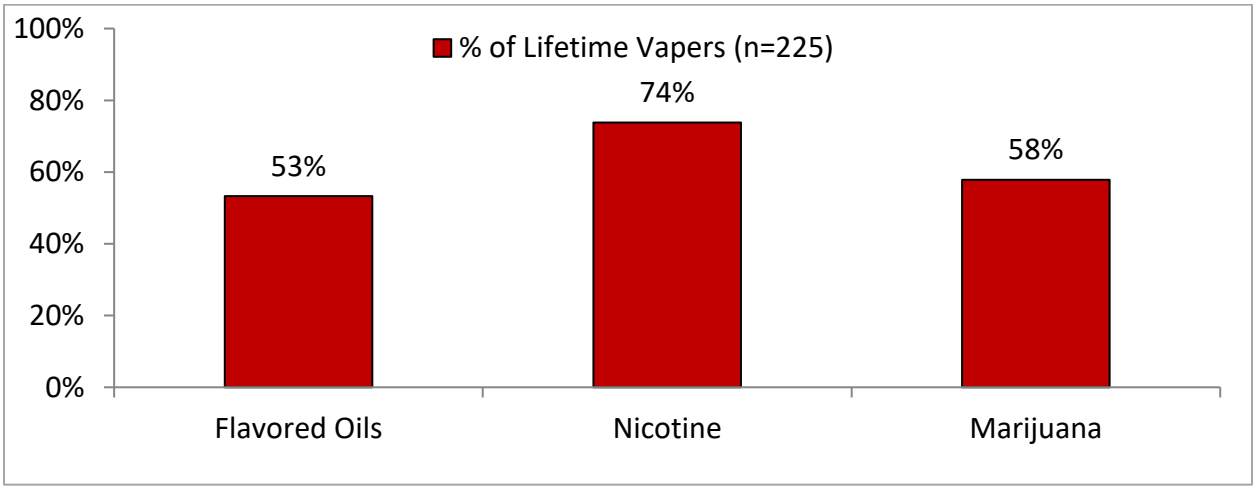
Note: The findings in this section of the report focus on the 225 respondents who report that they had ever used an electronic vapor product in their lifetime. The percentages are based on this subset of 225 respondents, **not** all 1,032 respondents who took part in the survey.

FINDINGS – VAPING BEHAVIORS AND ATTITUDES AMONG THOSE WHO EVER VAPED

Substances Vaped by Those Who Ever Vaped

Respondents who had vaped in their lifetime (n=225) were asked whether they had ever vaped: (a) nicotine-free substances such as flavored oils, (b) oils containing nicotine, and (c) marijuana. Among individuals who ever vaped in their lifetime, 53% had vaped nicotine-free flavored oils, 74% had vaped nicotine, and 58% had vaped marijuana.

Figure 12: Substances Vaped by Those Who Ever Vaped



Among respondents who ever vaped in their lifetime, those who vaped within the past 30 days were significantly *more* likely than their peers to report that they ever vaped nicotine (82% vs. 61%) and marijuana (74% vs. 33%). Ninth graders who ever vaped in their lifetime were significantly *less* likely than their peers who ever vaped in their lifetime to report that they had ever vaped nicotine-free flavored oils.

	Ever Vaped	Vaped in the Last 30 Days		Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
		No	Yes						
Ever Vaped Flavored Oils	53.3%	46.7%	57.8%	54.9%	53.0%	65.5%	35.7%	55.2%	60.3%
Ever Vaped Nicotine	73.8%	61.1%	82.2%	74.5%	74.4%	69.0%	69.6%	73.1%	79.5%
Ever Vaped Marijuana	57.8%	33.3%	74.1%	58.8%	55.6%	37.9%	64.3%	53.7%	64.4%

Reasons for Vaping Among Those Who Ever Vaped

Respondents who had vaped in their lifetime (n=225) were asked to identify what have been the most important reason(s) for their using an electronic vapor product[1].

Among individuals who ever vaped in their lifetime, the top 5 reason(s) for vaping were: to experiment – see what it's like (60%), to have a good time with friends (45%), to feel good or get high (41%), to relax or relieve tension (35%), and because it looks cool (23%).

Figure 13: Reason(s) for Vaping Among Those Who Ever Vaped



[1] Patrick, M.E., Miech, R.A., Carlier, C., O'Malley, P.M., Johnston, L.D., & Schulenberg, J.E. (2016). Self-reported reasons for vaping among 8th, 10th, and 12th graders in the US: Nationally representative results. *Drug and Alcohol Dependence*, 165: 275-278.

Among individuals who ever vaped in their lifetime, those who did not vape within the last 30 days were significantly more likely than their peers to indicate that they vaped to experiment and see what it was like (71% vs. 52%). Respondents who did vape within the last 30 days were significantly more likely than their peers to provide all of the other reasons. Male respondents were significantly more likely than females to indicate that they vaped because they are hooked and have to have it (21% vs. 7%). There were no other differences in the reasons provided by gender identity or age/grade.

	Ever Vaped	Vaped in the Last 30 Days		Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
		No	Yes						
To experiment / see what it is like	59.6%	71.1%	51.9%	57.8%	61.5%	72.4%	51.8%	58.2%	61.6%
To have a good time with friends	44.9%	27.8%	56.3%	44.1%	47.9%	31.0%	48.2%	41.8%	50.7%
To feel good or to get high	41.3%	21.1%	54.8%	40.2%	42.7%	17.2%	41.1%	44.8%	47.9%
To relax or relieve tension	34.7%	13.3%	48.9%	40.2%	29.9%	17.2%	37.5%	34.3%	39.7%
Because it looks cool	23.1%	12.2%	30.4%	27.5%	17.9%	17.2%	25.0%	23.9%	23.3%
Boredom / nothing else to do	17.3%	5.6%	25.2%	15.7%	18.8%	6.9%	14.3%	20.9%	20.5%
Because it tastes good	16.9%	7.8%	23.0%	18.6%	14.5%	13.8%	17.9%	19.4%	15.1%
Hooked / have to have it	13.3%	3.3%	20.0%	20.6%	6.8%	6.9%	17.9%	11.9%	13.7%
To help quit regular cigarettes	6.2%	2.2%	8.9%	8.8%	4.3%	3.4%	7.1%	1.5%	11.0%

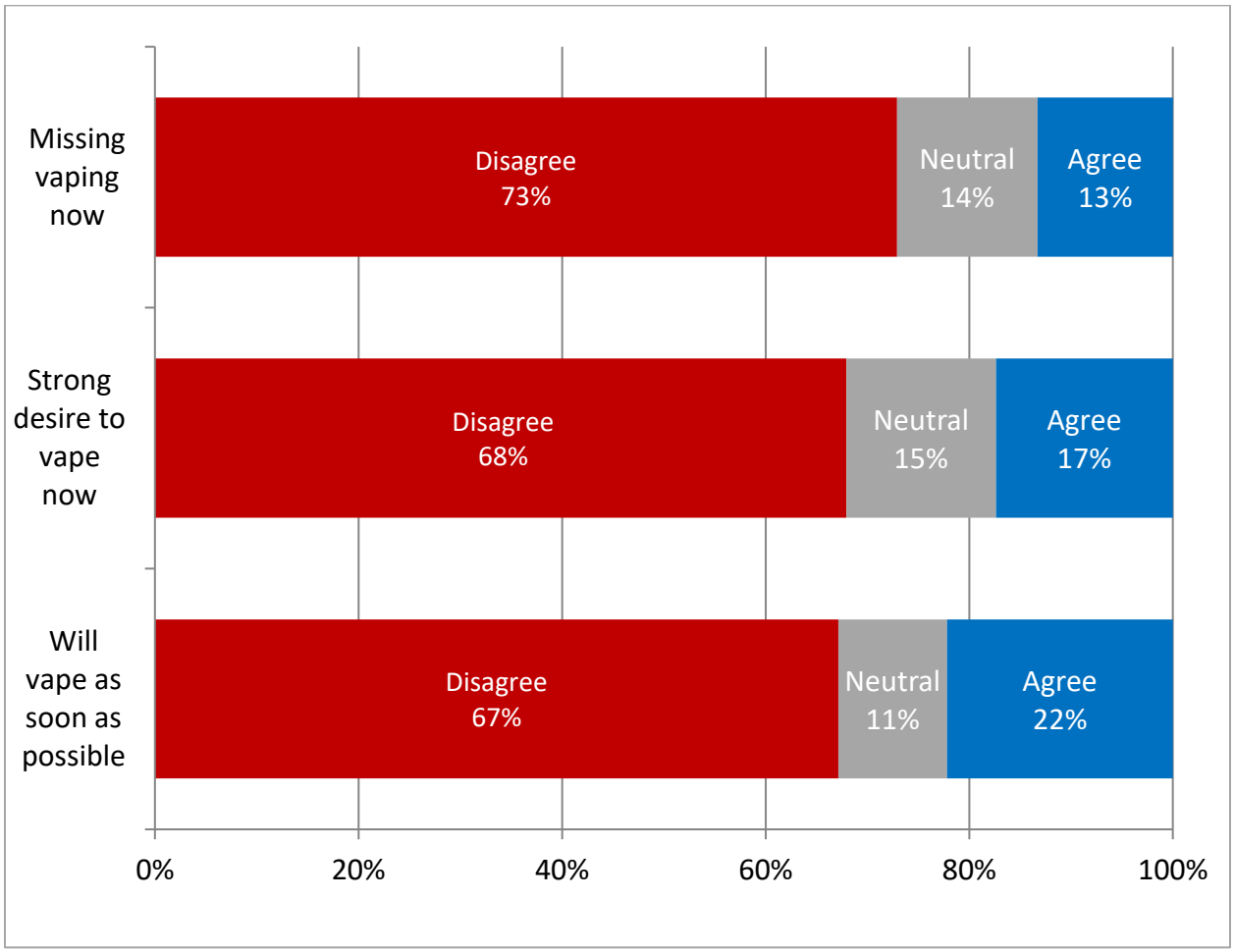
FINDINGS – CRAVINGS AND DESIRE TO VAPE AMONG THOSE WHO EVER VAPED

Cravings and Desire to Vape Among Those Who Ever Vaped

Respondents who had vaped in their lifetime (n=225) were asked three questions about vaping craving: (a) I have a strong desire to vape right now, (b) I am missing vaping right now, and (c) I will vape as soon as I get the chance. Endorsement of these questions has been associated in the peer reviewed literature with dependence, level of use, and lower confidence in ability to quit vaping[2].

Among individuals who ever vaped in their lifetime, 13% reported that they were missing vaping right now, 17% indicated a strong desire to vape right now, and 22% agreed that they will vape as soon as they get the chance.

Figure 14: Cravings and Desire to Vape Among Those Who Ever Vaped



[2] Dowd, A.N., Motschman, C.A., & Tiffany, S.T. (2019). Development and Validation of the Questionnaire of Vaping Craving. *Nicotine & Tobacco Research*, 21(1): 63-70.

Among respondents who ever vaped in their lifetime, those who vaped within the past 30 days were significantly *more* likely than their peers to positively endorse (agree) with the three questions about craving. There were no differences by gender identity or age/grade of the respondent.

I am missing vaping right now

	Ever Vaped	Vaped in the Last 30 Days		Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
		No	Yes						
Strongly Disagree	55.6%	85.6%	35.6%	56.9%	55.6%	62.1%	50.0%	58.2%	54.8%
Disagree	17.3%	10.0%	22.2%	15.7%	19.7%	10.3%	17.9%	20.9%	16.4%
Neutral	13.8%	2.2%	21.5%	11.8%	15.4%	3.4%	16.1%	13.4%	16.4%
Agree	4.4%	1.1%	6.7%	5.9%	1.7%	3.4%	8.9%	0.0%	5.5%
Strongly Agree	8.9%	1.1%	14.1%	9.8%	7.7%	20.7%	7.1%	7.5%	6.8%

I have a strong desire to vape right now

	Ever Vaped	Vaped in the Last 30 Days		Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
		No	Yes						
Strongly Disagree	49.8%	82.2%	28.1%	51.0%	51.3%	55.2%	46.4%	50.7%	49.8%
Disagree	18.2%	12.2%	22.2%	14.7%	21.4%	13.8%	16.1%	19.2%	18.2%
Neutral	14.7%	2.2%	23.0%	16.7%	12.8%	6.9%	14.3%	16.4%	14.7%
Agree	6.7%	2.2%	9.6%	6.9%	5.1%	3.4%	14.3%	5.5%	6.7%
Strongly Agree	10.7%	1.1%	17.0%	10.8%	9.4%	20.7%	8.9%	8.2%	10.7%

I will vape as soon as I get the chance

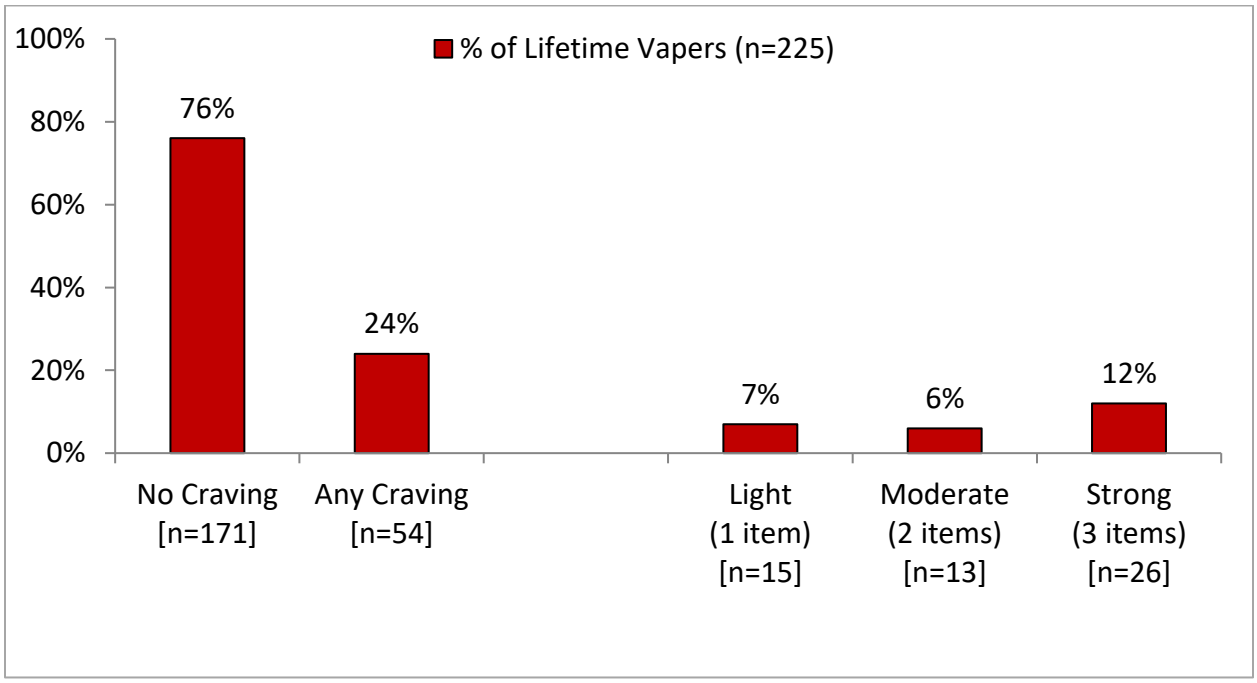
	Ever Vaped	Vaped in the Last 30 Days		Male	Female	8th Grade	9th Grade	10th Grade	11th Grade
		No	Yes						
Strongly Disagree	43.6%	74.4%	23.0%	45.1%	44.4%	41.4%	41.1%	41.8%	47.9%
Disagree	23.6%	17.8%	27.4%	20.6%	25.6%	20.7%	28.6%	23.9%	20.5%
Neutral	10.7%	5.6%	14.1%	8.8%	12.0%	3.4%	8.9%	10.4%	15.1%
Agree	9.8%	1.1%	15.6%	11.8%	8.5%	13.8%	5.4%	11.9%	9.6%
Strongly Agree	12.4%	1.1%	20.0%	13.7%	9.4%	20.7%	16.1%	11.9%	6.8%

Degree of Craving Among Those Who Ever Vaped

The degree of craving was calculated by adding together the number of craving questions where the respondent indicated that they either *agreed* or *strongly agreed* with the question. For example, if the respondent *agreed* that they have a strong desire to vape right now, they would receive a value of '1' on the scale. If they *agreed* that they have a strong desire to vape right now and *agreed* that they are missing vaping right now, they would receive a value of '2' on the scale, and so forth. Individuals that *agreed* or *strongly agreed* with one question were categorized as *Light Craving*, those who agreed with two questions were categorized as *Moderate Craving*, and those who agreed with all three questions on the craving scale were categorized as *Strong Craving*.

Among individuals who ever vaped in their lifetime, 24% (n=54) reported some level of craving: 7% (n=15) experienced light craving, 6% (n=13) experienced moderate craving, and 12% (n=26) experienced strong craving.

Figure 15: Degree of Craving Among Those Who Ever Vaped



Note: The findings in this section of the report focus on the 135 respondents who report that they used an electronic vapor product in the 30 days prior to the survey. The percentages are based on this subset of 135 respondents, **not** all 1,032 respondents who took part in the survey.

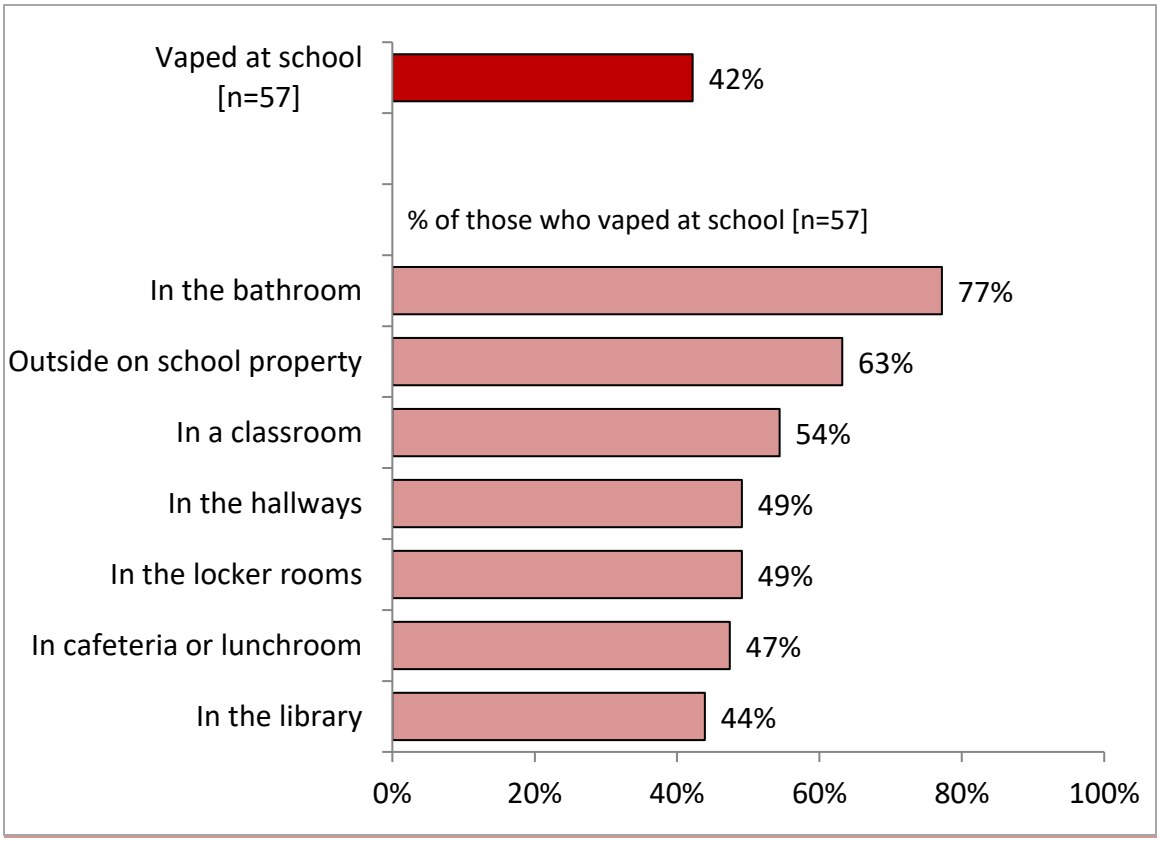
FINDINGS – VAPING BEHAVIORS AT SCHOOL IN THE PAST 30 DAYS

Vaping at School in the Past 30 Days and Location of Vaping

Respondents who used an electronic vapor product in the past 30 days (n=135) were asked whether they had vaped on school property in that time period. Among individuals who vaped in the past 30 days, 42% (n=57) reported that they vaped on school property at least one time during that time period.

Among respondents who vaped on school property (n=57), the largest proportion reported that they vaped in the bathroom (77.2%, n=44), followed by outside the building on school property (63.2%, n=36), in a classroom (54.4%, n=31), in the hallways (49.1%, n=28), in the locker rooms (49.1%, n=28), in the cafeteria or lunchroom (47.4%, n=27), and in the library (43.9%, n=25).

Figure 16: Vaping on School Property in the Past 30 Days



Overall, respondents reported vaping an average of four different places on school property – suggesting that this behavior is not isolated to a specific location for any given individual.

FINDINGS – DESIRE TO QUIT VAPING AMONG THOSE WHO VAPED IN THE PAST 30 DAYS

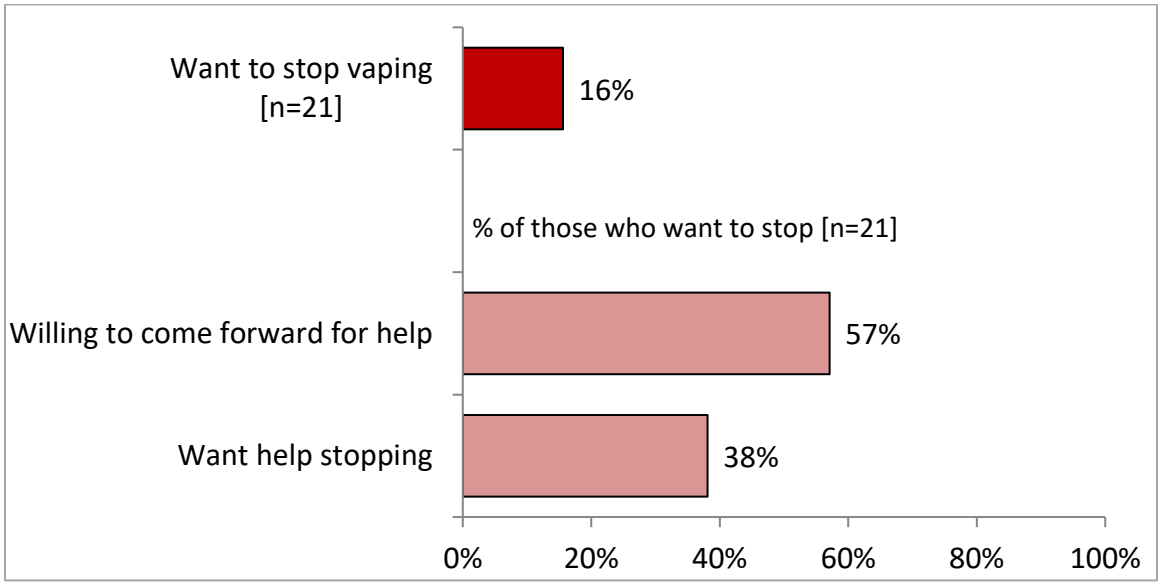
Desire to Quit Vaping Among Those Who Vaped in the Past 30 Days

Respondents who used an electronic vapor product in the past 30 days (n=135) were asked whether they ever felt like they wanted to stop using an electronic vapor product but couldn't stop on their own. Among individuals who vaped in the past 30 days, 16% (n=21) reported that they wanted to stop vaping but couldn't stop on their own.

Among the respondents who wanted to stop vaping (n=21), over half (57%, n=12) indicated that they would be willing to come forward or ask for help to stop vaping if there were no risk of consequences (school, sports, etc.).

Among the respondents who wanted to stop vaping (n=21), one-third (38%, n=8) reported that they want help to stop using an electronic vapor product.

Figure 17: Desire to Quit Vaping Among Those Who Vaped in the Past 30 Days



FINDINGS – PREVENTION MESSAGES

Respondents were asked what they would say to someone to convince them to not start vaping. Overall, 498 respondents provided one or more comments.

The open-ended comments fell into seven broad categories:

(1) Health effects and consequences (340 comments)
(2) Don't start vaping (117 comments)
(3) Consider the future (52 comments)
(4) Potential penalties from using (49 comments)
(5) Costs of using (49 comments)
(6) Friends, family, and relationships (41 comments)
(7) Seek Help (27 comments)

Representative comments from each of these areas are provided below.

Health Effects and Consequences

There were 340 comments about health effects and consequences of vaping (e.g., it's bad for you; not safer than cigarettes; you could get addicted).



"Vaping is hardly better than smoking a cigarette. You still get nicotine and get addicted."

"One e-cigarette has the same amount of nicotine as 20 packs of cigarettes."

"Vaping is exactly like smoking a normal cigarette. It has the same amount of nicotine even though it might not seem like it."

"Vaping is a very bad habit. You should never even start vaping because you will not want to stop."

"Why would you try something if you know it's bad for you and you may not be able to stop?"

"It's easy to get hooked. Also, there is not enough long-term research to say that it isn't dangerous."

"E-cigarettes have dangerous levels of nicotine and are highly addictive. All types of cigarettes/vapes are unhealthy and the consequences of using these substances/devices are grave."

"It's addictive. There is nicotine in many of the solutions they put in the pens. You can never be sure what it is you're smoking."

"Smoking might be something you'd never engage in now, but after you start vaping, there's no telling what you will do when addicted and offered a cigarette; the chances of getting addicted to real smoking is too high a danger to your health to risk now."

"Vaping is not a healthy alternative, it is just as dangerous as any cigarette, and can cause damage to your body."



"Vaping is still hurting your health, even if it's not considered as bad as cigarettes. Your health should be your priority, and there are so many other ways to stay happy without the use of drugs or vaping."

Don’t Start Vaping

There were 117 comments about not starting to vape and quitting if you are already using electronic vapor products.



“Don't smoke it's a joke.”

“I wouldn't try to talk about how bad vaping is (that will make them mad and more likely not to listen) but rather talk about how much better life would be when not using it.”

“I'd say to them that if you're going to use a vaping product, you're making all of your worst nightmares come true. I hugely recommend that you don't do it.”

“Don't be a Juul fool.”

“Don't smoke Juul in my school!”

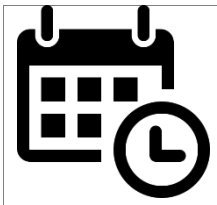
“Don't start vaping.”

“Please refrain from vaping “Stop vaping.”



Consider the Future

There were 52 comments about considering the future (e.g., you will regret it; don’t ruin your life; it could affect your goals).



“Just don't do it unless you want to sacrifice your future.”

“It can ruin your whole life and once you regret doing it you can't change the past.”

“I would tell them that they are basically ruining the rest of their lives and it will affect them forever.”

“You're throwing away all the work you put into life.”

“If your future kids were vaping what would you say to them?”

“It's a problem and if you care about yourself and your future you should stop.”

“Think about all the opportunities you could lose by vaping.”

“What would your future self say?”

“You will regret it in the future.”



Potential Penalties from Using

There were 49 comments about potential penalties from vaping (e.g., trouble at school; trouble with parents; kicked off sports team).



"I would tell them about how they can be a bad influence on others, that they can violate school and school sports rules as well."

"Think about the big picture and your high school/ athletic career."

"Think of all of the punishment with school activities and sports and how all of that could go wrong."

"It's stupid and can ruin your life because it's not going to get you anywhere. Especially in sports."

"You could be kicked out of any extracurricular activities."

"You really shouldn't do that because you could get kicked off of your sports team."

"It's very bad for your health, you can get in a lot of trouble with your parents and school, and you can lose your spot on the team you're on."

"I would say this isn't good for you. You could get in trouble. Think about what your parents would say if they found out you were smoking; they wouldn't be happy."



Costs of Using

There were 49 comments about the costs of vaping (e.g., it's expensive; there is no benefit; not worth it; waste of time).



"It's really bad for you, it costs money, and you could get in a lot of trouble."

"You will be committed and addicted to this product and will waste lots of money while doing so, and when you try to quit, it will be hard."

"You will start to do it every day and you will lose your money."

"It's overhyped and not very fun. The consequences far outweigh the little enjoyment you may get from it."

"Vaping is not a good investment and a waste of money."

"I would them that it is simply unnecessary to waste time smoking when they could use that time to do literally anything else."

"There are better things to spend your time on."

"It's not worth doing just to fit in with others."

"It's not worth it, it tastes bad anyways and there are better ways to have fun."



Family, Friends, and Relationships

There were 41 comments about family, friends, and relationships (e.g., it could affect your relationships; it's not cool; it's disgusting; bad influence on others).



"It will be very dangerous to your health and affect the relationships that you have with other people very badly."

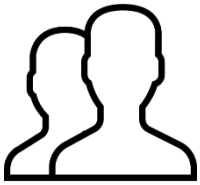
"Don't give yourself an addiction to look cool."

"It literally doesn't make you cool. Have fun being addicted to a flash drive I guess."

"I would explain to them that you don't have to vape to be cool. It is extremely detrimental to your health and addictive."

"It is not impressive or cool to ruin your health."

"Valuing can cause lots of health problems that you don't need at a young age. There's no point in harming yourself just to 'fit in' and be cool."



"Don't be a fool. Juuls aren't cool."

"Put down the Juul because that's not cuul."

Seek Help

There were 27 comments about seeking help to stop vaping (e.g., I care about you; talk to someone).



"I really don't think this is very good for your health. It can really be harmful to your body. I really don't want you getting hurt, and I really don't think anyone else would either. If you need help, I can help you."

"It isn't healthy even though they advertise it that way. I am concerned for your health."

"I care about you and your health and this will severely harm both."

"I'm worried about you, and I want to try to help you. Can you please seek help or allow me to help you."

"Get help from a medical professional if you need nicotine patches or something else to help."



"Get help from a trusted adult."

"Talk to someone you trust "It is not impressive or cool to ruin your health."

APPENDIX A:
Needham Survey About Electronic Vapor Products

2019

NEEDHAM SURVEY ABOUT ELECTRONIC VAPOR PRODUCTS

Students Advocating Life without Substance Abuse (SALSA)
Substance Abuse Prevention Alliance of Needham (SPAN)
Needham Public Schools

Directions

The Students Advocating Life without Substance Abuse (SALSA) group at Needham High School (NHS) is working with the Substance Abuse Prevention Alliance of Needham (SPAN) and NHS administrators to conduct a short survey to learn more about the use of electronic vapor products ("vaping") by students at NHS.

Please answer the following questions honestly. Your answers are private. Do not provide your name anywhere on the survey.

The findings will be used by SALSA students to develop prevention messaging next school year.

After filling out this survey, if you have any questions or concerns, please talk about them with your school nurse, school counselor, teacher, parent/guardian, or other trusted adult.

Thank you very much for answering this survey.

This section is about your personal background. Remember, no one will know your name.

1. What is your current gender identity? Please check the box that *most closely* matches your identity. (Check *one*) [All students]

- 1 ☐ Male
- 2 ☐ Female
- ☐ Gender non-conforming
- 4 ☐ Non-binary
- 5 ☐ Not listed
- 6 ☐ Not sure

2. What grade are you in now? (Check *one*) [All students]

1 ☐ 8th grade 2 ☐ 9th grade 3 ☐ 10th grade 4 ☐ 11th grade

3. On an average school day, how many hours do you spend on extracurricular activities outside of school, like sports, clubs, music lessons, or other nonacademic activities? (Check *one*) [All students]

- 1 ☐ None
- 2 ☐ Less than 1 hour per day
- 3 ☐ 1 hour per day
- 4 ☐ 2 hours per day
- 5 ☐ 3 hours per day
- 6 ☐ 4 hours per day
- 7 ☐ 5 hours per day

The next questions ask about tobacco use.

4. Have you ever tried cigarette smoking, even one or two puffs? (Check one) [All students]

1 ☐ No 2 ☐ Yes

5. During the past 30 days, on how many days did you smoke cigarettes? (Check one) [All students]

1 ☐ 0 days 2 ☐ 1-2 3 ☐ 3-5 4 ☐ 6-9 5 ☐ 10-19 6 ☐ 20-29 7 ☐ All 30 days

The next questions ask about electronic vapor products, such as Juul, Phix, Vuse, MarkTen, and blu. Electronic vapor products include e-cigarettes, vapes, vape pens, e-cigars, e-hookahs, Hookah pens, and mods.

6. How much do you think people risk harming themselves (physically or in other ways) if they use electronic vapor products? (Check *one*) [All students]

- 1 ☐ No Risk
- 1 ☐ Slight Risk
- 1 ☐ Moderate Risk
- 1 ☐ Great Risk

7. Have you ever used an electronic vapor product? (Check *one*) [All students]

1 ☐ No 2 ☐ Yes

8. Have you ever vaped any of the following? (Check *one* box on *each* line) [only appears if 7 is yes]

Have you ever…	*Yes*	*No*
a) Vaped nicotine-free substances such as flavored oils	1 ☐	2 ☐
b) Vaped oils containing nicotine	1 ☐	2 ☐
c) Vaped marijuana in any form, including THC/hash oil, etc.	1 ☐	2 ☐

9. During the PAST 30 DAYS, on how many days did you use an electronic vapor product? (Check *one*) [only appears if 7 is yes]

1 ☐ 0 days 2 ☐ 1-2 3 ☐ 3-5 4 ☐ 6-9 5 ☐ 10-19 6 ☐ 20-29 7 ☐ All 30 days

10. During the PAST 30 DAYS, on how many days did you use an electronic vapor product ON SCHOOL PROPERTY? (Check *one*) [only appears if 9 is one or more days]

1 ☐ 0 days 2 ☐ 1-2 3 ☐ 3-5 4 ☐ 6-9 5 ☐ 10-19 6 ☐ 20-29 7 ☐ All 30 days

11. During the PAST 30 DAYS, have you used an electronic vapor product ON SCHOOL PROPERTY in any of the following places? (Check *one* box on *each* line) [only appears if 10 is one or more days]

	No	*Yes*
a) In a classroom	1 ☐	2 ☐
b) In the cafeteria or lunchroom	1 ☐	2 ☐
c) In the locker rooms	1 ☐	2 ☐
d) In the hallways	1 ☐	2 ☐
e) In the bathroom	1 ☐	2 ☐
f) In the library	1 ☐	2 ☐
g) Outside on school property	1 ☐	2 ☐

12. What have been the most important reasons for your using an electronic vapor product? (Check *all* that apply) [only appears if 7 is yes]

- 1 ☐ To help me quit regular cigarettes
- 1 ☐ To experiment – see what it's like
- 1 ☐ To relax or relieve tension
- 1 ☐ To feel good or get high
- 1 ☐ Because it looks cool
- 1 ☐ To have a good time with my friends
- 1 ☐ Because of boredom, nothing else to do
- 1 ☐ Because it tastes good
- 1 ☐ Because I am hooked – I have to have it
- 1 ☐ Some other reason

13. How important are each of the following factors in your decision about whether to use an electronic vapor product? [All students]

	Not At All Important	*Not Very Important*	*Somewhat Important*	*Fairly Important*	*Very Important*
a) What your parents would think	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
b) What your friends would think	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
c) Potential school penalties	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
d) School sports zero tolerance rules	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
e) How it might affect your health	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

14. How much do you agree or disagree with each of the following statements? [only appears if 7 is yes]

	Strongly Disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*
a) I have a strong desire to vape right now	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
b) I am missing vaping right now	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
c) I will vape as soon as I get the chance	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

15. Is there anyone (other than you) living in your household who…? (Check *one* box on *each* line) [all students]

		No	*Yes*
a)	smokes cigarettes?	1☐	2☐
b)	uses an electronic vapor product?	1☐	2☐

16. How wrong do other people in your life feel it would be for you to use an electronic vapor product? [all students]

	Not at All Wrong	*A Little Bit Wrong*	*Wrong*	*Very Wrong*
a) How wrong do your PARENTS/ GUARDIANS think it would be for you to use an electronic vapor product?	1☐	2☐	3☐	4☐
b) How wrong do your CLOSE FRIENDS think it would be for you to use an electronic vapor product?	1☐	2☐	3☐	4☐

17. Do you know where a person could go to get help if they wanted to stop using an electronic vapor product and couldn't do it on their own?
(Check *one*) [All students]
1☐No 2☐Yes

18. Have you ever felt like you wanted to stop using an electronic vapor product but weren't able to stop on your own? (Check *one*) [only appears if 7 is yes]
1☐No 2☐Yes

19. Do you want help to stop using an electronic vapor product? (Check *one*) [only appears if 18 is yes]
1☐No 2☐Yes

20. Would you be willing to come forward/ask for help to stop vaping if there were no risk of consequences (school, sports, etc.)? Check *one*) [only appears if 18 is yes]
1☐No 2☐Yes

21. If you wanted to convince someone not to start vaping, what would you say to them? (type-in)
[All students]

If you want help stopping tell a trusted adult at school, home, athletic coach, faith-based leader, or The Truth Initiative – Text QUIT to 202-804-9884

Thinking about quitting...

For your family?

For children, secondhand smoke causes respiratory problems, ear infections and increases the risk of sudden infant death syndrome.



For your health?

Quitting smoking helps prevent heart disease and stroke, among other health issues.

You are at an increased risk for these diseases even if you smoke fewer than five cigarettes a day.



For your wallet?

It costs almost $3,500 a year in Massachusetts to purchase a daily pack of cigarettes.



What happens when you quit?

Immediately	In 20 min	In 2 weeks	In 1 - 9 months	In 1 year	In 2 - 5 years
You save money Your sense of smell returns to normal You stop the yellowing of teeth/fingernails			You will cough less and breathe easier		Over time, you'll be less likely to die from lung cancer or have coronary heart disease.
Your heart rate and blood pressure drop		Your heart attack risk begins to drop		Your risk of coronary heart disease is decreased by 50%	Your stroke risk is reduced to that of a nonsmoker

Tips to QUIT

- Identify your motivation for quitting and remind yourself of it often
- Participate in a group smoking cessation program
- Choose a quit date and make a plan
- Call the Helpline at 1-800-QUIT-NOW
- Visit smokefree.gov for more resources



Tues 6/13/19

Share your story!

#NeedhamQuitsSmoking

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weekly 6/13/14

Share your story!
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You save money Your sense of smell returns to normal You stop the yellowing of teeth/fingernails	Your heart rate and blood pressure drop	Your heart attack risk begins to drop	You will cough less and breathe easier	Your risk of coronary heart disease is decreased by 50%	Over time, you'll be less likely to die from lung cancer or have coronary heart disease. Your stroke risk is reduced to that of a nonsmoker

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National Association of County & City Health Officials

NWCN13801849

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Community Calendar

Thursday, June 6

The South Norfolk Mental Illness Family and Friends Support Group will hold its monthly meeting in Cafeteria B of the Lorusso Building at Norwood Hospital (800 Washington St., Norwood) this evening at 7 p.m. Mental illness is a label for a variety of diseases of the brain. Often it strikes in late adolescence, devastating the afflicted person and the family. The South Norfolk Alliance is composed of such families who find mutual support and join together to advocate for their loved ones. All families in the South Norfolk Area who are dealing with mental illness and their loved ones are welcomed. In case of inclement weather, the meeting will align with the Norwood schools. If they close, the meeting will be cancelled. For further information call Ray at (508-668-2941).

Saturday, June 8

This year's New England checkers championship will be held today at the home of Richard and Catherine White, located on 9 Bridlefield Lane in Medfield. The tournament will be round-robin, played under the rules of American checkers (English Draughts. Rules can be found at https://en.wikipedia.org/wiki/English_draughts). The highest finisher from New England will be the American Checker Federation champion for District 1; the highest finisher from any state in New England will be that state champion for 2019. There is no entry fee or prize money. Registration begins at 8:30 a.m. and the first round starts at 9. Play will continue until all rounds are complete. All are welcome.

Sunday, June 9

The Wellesley Conservation Council is hosting Spring Open Gardens at Cronk's Rocky Woodland, located at 20 Crown Ridge Road today at 4:30 p.m., at 20 Crown Ridge Road. Enjoy the spring flowers among music, explore the charming moss-covered Hansel and Gretel cottage, and learn how to help "Cronk's" continue as the wildflower garden that Gertrude Cronk established in the 1930s for all Wellesley's neighborhoods to enjoy in perpetuity.

Monday, June 10

Breaking Bread is a free community dinner held tonight - and every Monday night, including holidays. The dinner is served from 5:30 to 6:00 p.m. at United Church, 30 Common Street, Walpole; enter at right side door. All are welcome. Take-out meals can be pre-ordered by calling (508-298-4654) on Thursday. Sponsored by Walpole Families of Faith.

Tuesday, June 11

NAMI Family Mental Health Support Group is a free, structured, confidential peer-led support group for the families of individuals living with mental illness. A support group will be held this evening from 7:30 – 9 p.m. at the Newton Wellesley Hospital, located at 2014 Washington Street in Newton, on the second floor of the main building in the Bowles Conference Center. Parking will be validated. This is organized by the National Alliance for Mental Illness (NAMI).

Wednesday, June 12

'High Hopes,' featuring memorable movie songs of the 1930s to 1960s, is a multimedia presentation which film music historian Roger Lee Hall will bring to the Community Room of the Walpole Public Library, located on 143 School Street, at 7:30 tonight. A tribute to Doris Day is included in the program, and there will be door prizes of free CDs. Sponsored by the Friends of the Walpole Public Library, admission is free and all are welcome. More details at www.walpolelibraryfriends.org.

This evening at 7 p.m. at The First Church and Parish, Dedham, The Charles River Green Coalition will host a Green New Deal Town Hall. The town hall will focus on the existential threat posed by climate change and explain the Green New Deal, a stimulus package designed to combat both climate change and the burgeoning economic inequality in the United States. The evening's panel of speakers will describe the ways climate change is affecting them and how they and the community can effect change at the local, state, and federal level. The event will include an overview of the Green New Deal, opportunities for discussion, a question and answer period, and suggested action steps. Attendance at the town hall is free and open to all. The event signup page can be found at CharlesRiverGreen.org.

Monday, June 17

Breaking Bread is a free community dinner held tonight - and every Monday night, including holidays. The dinner is served from 5:30 to 6:00 p.m. at United Church, 30 Common Street, Walpole; enter at right side door. All are welcome. Take-out meals can be pre-ordered by calling (508-298-4654) on Thursday. Sponsored by Walpole Families of Faith.

'Fifty Years of Boston Red Sox Photography' is a book co-authored by sports journalist Mike Shalin, with photographer Steve Babineau. Mike – and possibly Steve also – will discuss many Red Sox memories at 7:00 this evening in the Community Room of the Walpole Public Library, located on 143 School Street. Sponsored by the Friends of the Walpole Public Library, admission is free and all are welcome. More details at www.walpolelibraryfriends.org.

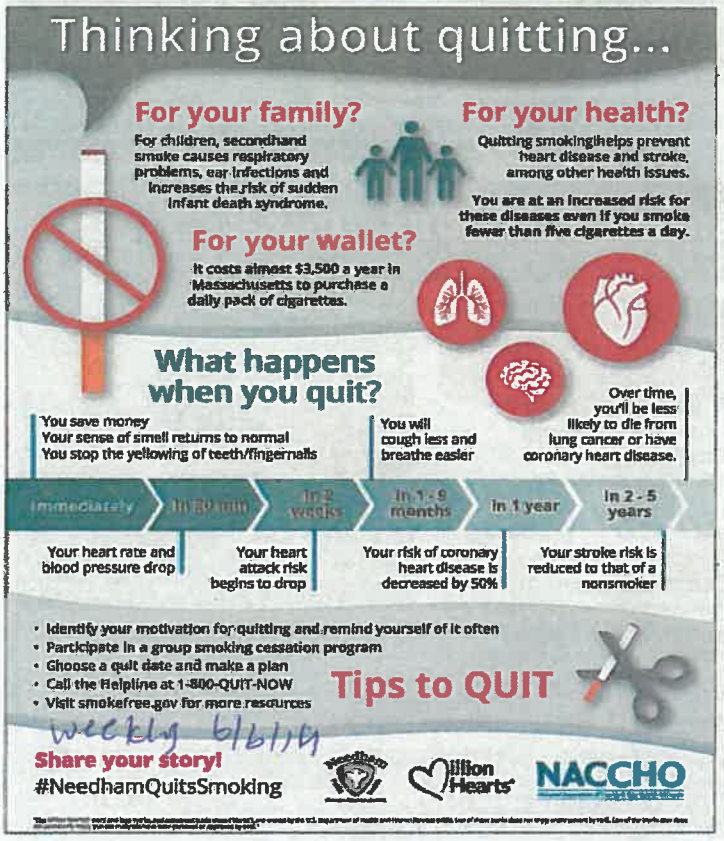
Tuesday, June 18

Bread of Life, a community dinner held at the Carter Methodist Church in Needham, will take place this evening. A spiritual reflection begins at 5:30, and the meal will be served at 6:00. All are welcome. Bread of Life is hosted on the first and third Tuesday of every month.

Wednesday, June 19

The Divorce Center will present 'Show Me the Money - How to Determine the Marital Estate' this evening from 7-8:30 p.m. at the Wellesley Library's Arnold Room. Topics addressed will include: What is an asset and property division?; What is discovery?; How to cut costs of discovery?; When is it necessary to depose?; What is Rule 410 Mandatory Discovery?; and when do you need a business evaluation? The event is free and open to the public, but an RSVP is requested via (508-446-4134) or www.thedivorcecenter.org, as space is limited.







Hometown Weekly

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NW-CN13610681

Stay Sun Safe

Time's
6/24/15

SEEK SHADE DURING MIDDAY (10 AM - 4PM)

WEAR SUNGLASSES, A HAT, AND PROTECTIVE CLOTHING

USE BROAD SPECTRUM

The Substance Prevention Alliance of Needham (SPAN) is conducting a survey of parents/guardians of 6th - 12th graders.

Please share your input today.
The survey should take 10 minutes or less to complete.

Tim'd 6/28/17

To access the survey please visit:
http://bit.ly.NeedhamParentSurvey
OR visit: www.spanneedham.org

For more information please contact: Catherine Delano at the Needham Public Health Division | cdelano@needhamma.gov

NW-CN13810677

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It's Tick Talk Time!



Train your eyes to be tick wise and learn how to fight the mosquito bite.

Tips on How to Protect Yourself



Wear a hat and light-colored clothing, specifically long-sleeved shirts and long pants tucked into boots or socks (especially if going on a hike in the woods, etc.).



Use insect repellents containing 20-50% DEET on exposed skin and clothing. Use insecticides, such as permethrin, for more protection. Permethrin can be used on clothing, but not on skin. One application to pants, socks, and shoes may be effective through several washings.



Seek medical attention if you or a family member develops symptoms of vector-borne diseases.



Weekly 6/27/19

Immediately remove ticks using fine-tipped tweezers.

Check skin, hair, underarms, and groin daily for ticks.





Wash and dry clothes using "hot" settings to kill any ticks present.



FOR ADDITIONAL INFORMATION OR QUESTIONS CONTACT
THE NEEDHAM PUBLIC HEALTH DIVISION @ 781-455-7940

Needham Public Health
Prevent. Promote. Protect.

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Public Health advises community on ticks

Ticks are tiny bugs most likely found in shady, damp, brushy, wooded, or grassy areas, especially in tall grass, including your own backyard. They attach to animals or people that come into direct contact with them. It is important to note that ticks do not fly or jump. Deer ticks and dog ticks are found throughout Massachusetts. They are tiny and you can't always tell easily when they are on you.

Tick-borne diseases like Lyme disease, babesiosis, anaplasmosis (formerly human granulocytic ehrlichiosis or HGE), tularemia, Powassan, and Rocky Mountain spotted fever are transmitted to both people and animals when bitten by an infected tick. The longer a tick is attached, the more likely the tick will be able to transmit bacteria or viruses that cause a tick-borne disease. According to the Center of Disease Control (CDC), ticks are more active from April to September, though can still be active in the winter. With the warmer months approaching, it is important to be prepared and be aware to prevent tick bites.

Be aware of areas that may contain ticks. If venturing out near grassy, brushy, or wooded areas, be sure to walk in the center of trails. Wearing light colored, long-sleeved shirts and long pants tucked into socks can help keep ticks away from your clothing and make it easier to spot any ticks that you may have come in contact with.

Additionally, use bug repellents. The CDC recommends treating clothing, boots, and gear with products containing 0.5 percent permethrin. Treated items can remain protective through several washings. Products containing DEET can be used on exposed skin. Always follow the product instructions and use repellents with no more than 30-35 percent DEET on adults and 10-15 percent DEET on children. Never use insect repellents on infants.

When returning indoors, be sure to shower as soon as possible. It is highly recommended to shower within two hours in order to wash off or find ticks that may be crawling on you. Also be sure to carefully inspect all clothing, gear, or pets that may have picked up ticks along the way. Ticks can ride into the home and attach to a person later.

Taking a shower is a perfect opportunity to conduct a full body tick check using either a handheld or full length mirror to view all parts of your body. Ticks often bite warm, dark, secluded areas of the body. Check for ticks under the arms, in and around the ears, in the belly button, behind the knees, between the legs, around the waist, and in hair.

Talk to your doctor if you develop a rash where you were bitten or experience symptoms such as fever, headache, fatigue, or sore and aching muscles.

Visit the Center for Disease Control and Prevention for further information at www.cdc.gov/ticks or call the Needham Public Health Division at (781-455-7940, x504).

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