OXFORD

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Correspondence

RE: Cellular Telephone Use and the Risk of Brain Tumors: Update of the UK Million Women Study

Linda S. Birnbaum, PhD [1], Hugh S. Taylor, MD,[2] Hillel Baldwin, MD,[3] Paul Ben-Ishai, PhD [4,5] Devra Davis, PhD, MPH [6,*]

[1]National Institute of Environmental Health Sciences and National Toxicology Program and Nicholas School of the Environment, Duke University, Durham, NC, USA; [2]Department of Obstetrics, Gynecology, and Reproductive Sciences, Yale School of Medicine, New Haven, CT, USA; [3]Neuroscience Solutions, LLC, Tucson, AZ, USA; [4]Department of Physics, Ariel University, Ariel, Israel; [5]Department of Applied Physics, Hebrew University, Jerusalem, Israel; and [6]Ondokus Mayis University, Samsun, Turkey

*Correspondence to: Devra Davis, PhD, MPH, Environmental Health Trust, Jackson, PO Box 58, Teton Village, WY 83025, USA; Ondokus Mayis University, Samsun, Turkey (e-mail: ddavis@ehtrust.org).

The Million Women Study has yielded a number of life-saving findings linking menopausal hormone therapy with breast cancer. However, a recent analysis of self-reported cell phone use of this original cohort by Shuz et al. (1) contains a number of serious errors and flaws of exposure measurement that undermine the validity of their widely publicized finding purporting that there is no risk of brain cancer from cell phone radiofrequency radiation (RFR).

Unsurprisingly for women now in their 70s and 80s, only 18% of cell phone users reported 30 minutes or more weekly use when asked in median years 2001 and 2011. Systematic reviews find increased tumor risk tied to cumulative call time of no less than 1000 hours (2). Yet, this study combined slight and regular mobile phone users.

Most are unaware that cell phones and cordless phones continuously emit RFR, which is absorbed into the brain and body. As more than 80% of UK households had landlines during the study period, it is likely many of the older women in this cohort used cordless phones, a significant source of RF unevaluated by this study.

Further, the National Toxicology Program (NTP) and Ramazzini Institute (RI) experimental animal studies are inaccurately criticized as based on small numbers, inconsistency across species, and excessively high exposures (3,4). The several thousand animals studied by the NTP and RI approximated in rodents a lifetime of human RFR exposures, and both found an increase in the same types of tumors, corroborating accumulated evidence of adverse effects at low levels.

Current outdated regulatory limits for phone RFR rest on the incorrect long-held assumption that nonthermal levels are safe. The NTP's highest RFR exposures were below thermal thresholds and below US FCC occupational guidelines of 8 W/kg specific absorption rate. In addition to "clear evidence" of carcinogenicity in male rats, the NTP found DNA damage in organs of rats and mice as well as induction of right ventricle cardiomyopathy in both male and female rats. The findings of these studies indicate that the long-held assumption that heating is the only harm from wireless RFR is no longer valid.

Shuz et al. (1) mischaracterized the RI study as using excessively high exposures. However, the RI study was designed to mimic low-level cell tower RFR exposures. In 2011, the International Agency for Research on Cancer classified RFR as a "possible human carcinogen" (5) based largely on increased tumors among long-term cell phone users. Concordance of tumor cell types with these experimental animal studies strengthens the association.

The majority of animal and cell studies have found nonionizing RFR can induce oxidative stress—a key characteristic of human carcinogens and a way that RFR can initiate or promote tumor development as well as play a role in the development of other diseases (6).

Recent experimental and epidemiological studies indicate that RFR also induces cancers of the thyroid and breast (7,8). DNA damage and cancer in these state-of-the-art studies signal the need for the public to reduce exposures to RFR now.

Funding

No funding was used for this correspondence.

Notes

Role of the funder: Not applicable.

Disclosures: No author disclosures exist or are applicable.

Author contributions: Writing, original draft—LSB, HST, HB, DD, PBI; writing, editing and revisions—LSB, HST, HB, DD, PBI.

Received: April 19, 2022; **Accepted:** May 13, 2022

CORRESPONDENCE

My public information requests show that *Montgomery County Councilman Hans Riemer got 5G "safety" data from industry tied scientist Dr. Jerrold Bushberg.*

Riemer has been very vocal that 5G cell towers near homes are safe, stating that Montgomery County residents opposed to cell towers are wrong to be concerned and he bases this opinion on his conversations with Dr. Bushberg.

Councilmember Hans Riemer has used his social media and Council meeting platforms to paint residents who oppose small cell ZTAs on the basis of RF emission health effects as "kooky" science "deniers" "anti-vaxxers" and "fear mongering" "tin foil hat"wearing "conspiracy theorists" and flat-earthers who believe COVID is cause by 5G and are pushing "junk science".

Oddly, when a Montgomery County resident wrote to Dr. Bushberg about what safety information he had shared with the Council, she was told he had not sent any information. See attachments for this information.

When I did a public information request I found numerous emails indicating Councilman Hans Riemer communicated with Dr. Bushberg on the issue of 5G safety. In fact, he wrote to a Takoma Park neighbor that

> Last week I spoke with Dr. Jerrold Bushberg, who confirmed that the science does not support concerns about 1G, 2G, 5G, or any of these nonionizing radiation forms. Dr. Bushberg is probably the top scientist in the country on this topic. https://ncrponline.org/?albdesign_popup_cpt=jerrold-t-bushberg

How do we know that Dr. Bushberg is industry connected?

Bushberg is not only featured in Industry Propaganda (See Crown Castle's Media Bundle and Understanding the Safety of 5G) but he is also is paid by wireless companies to testify as their health and safety expert.

Bushberg has been hired by companies to testify on the safety of cell towers and 5G for decades. He has a 29-year history of being paid by industry to opine on the safety cell tower deployments. Many of his engagements have been for Crown Castle, a $75 billion company that is the country's largest operator of shared cell towers and operates 155,000 cell towers.

Riemer has repeatedly omitted Bushburg's conflicts of interest and instead promoted Bushburg o the Council and to the public as an independent expert.

See a List of the Industry Consulting of Dr. Jerrold Bushberg.

1993: West Hollywood Rooftop antennas

2006: Bidwell Park CA playground for Crown Castle

2006: Fountain Valley, T-Mobile Antennas
2007: Palos Verdas Crown Castle
2008: Oceanside CA for PlanCom Inc- AT&T antennas
2009: Tonto Hills for NewPath Networks LLC
2010: Paradise Valley AZ for NewPath Networks
2011: City of Davis CA for Crown Castle
2013 Santa Barbara Crown Castle
2013 Santa Fe AT & T
2014: Los Angeles CA RICS Project
2014: City of Tracy CA for AT&T
2014 Town of Ross CA Crown Castle Sprint
2015: Oakland CA Crown Castle
2015: letter to Morgan Hunt of Crown Castle
2015: San Francisco CA for Crown Castle
2016: San Hose CA Crown Castle
2016: Oakland CA for Crown Castle
2018: Millbrae, CA for Verizon
2018: Hillsborough for Crown Castle
2019: Los Altos CA
2019: Palo Alto CA for Crown Castle, Verizon
2021: Hillsborough for Crown Castle

Emails to and From NCRp and Bushberg regarding the communications that Dr. Bushberg had with the Montgomery Council members

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---------- Forwarded message ---------
From: Laura Atwell <laura.atwell@ncrponline.org>
Date: Fri, May 27, 2022 at 10:34 AM
Subject: RE: Health risks from 5G and cell towers
To: XXX REDACTED NAME

Dear XXX REDACTED NAME

I spoke with Dr. Bushberg and to his knowledge, he has never sent anything to the Montgomery County Council on 5G, cell towers, and health issues.

Laura Atwell

Laura Atwell
Director of Operations
7910 Woodmont Avenue, Suite 400
Bethesda, MD 20814-3095
Email: laura.atwell@ncrponline.org
voice: 301.657.2652
fax: 301.560.8005
http://NCRPonline.org

From: XXX REDACTED NAME

Sent: Monday, May 23, 2022 7:32 PM
To: Jerrold Bushberg <jerrold.bushberg@ncrponline.org>
Cc: Boice <john.boice@gmail.com>; John Boice <John.Boice@ncrponline.org>; Laura Atwell <laura.atwell@ncrponline.org>; Kathy Held <Kathy.Held@ncrponline.org>
Subject: Re: Health risks from 5G and cell towers

Hi Mr. Bushberg, any luck finding the information you gave the Montgomery County Council on 5G, cell towers, and health issues?

Thanks so much for you help with this,

XXX REDACTED NAME

On Fri, Apr 29, 2022 at 8:48 PM Jerrold Bushberg <jerrold.bushberg@ncrponline.org> wrote:

I think it was me that responded. Let me look back through my emails and I'll send you what I find

Sent from my iPhone

> **On Apr 29, 2022, at 4:45 PM, John Boice <john.boice@gmail.com> wrote:**
>
> **Dear XXX REDACTED NAME**
>
> **,**
>
> **Apologies. I don't recall sending information to the Montgomery County Council with regard to 5G and cell towers. Could you provide a timeframe and "who" the correspondence was sent to, since it may have been a number of years ago? I have searched my records again but could find no indication of a correspondence. I may very well be mistaken given the many disruptions we've all experienced because of COVID-19 these past few years.**
>
> **I've also cc'd the National Council on Radiation Protection and Measurements. Our nonionizing radiation committee has just begun to look more closely at 5G issues -- in case they may have responded to any inquiries.**
>
> **Sorry I can't be more helpful.**
>
> **John Boice**
>
> **On Thu, Apr 28, 2022 at 10:09 PM XXX REDACTED NAME wrote:**
>
> **Hello Dr. Boice,**
>
> **I am interested in information on health risks from 5G and cell towers. I understand you helped the Montgomery County Council with this issue. Can you please send me what you sent the Council about health issues.**
>
> **Thanks so much, XXX REDACTED NAME**

--
John D. Boice, Jr., Sc.D.
Director of Science
National Council on Radiation Protection and Measurements
boice@ncrponline.org 301.657.2652
Professor of Medicine, Vanderbilt University School of Medicine
john.boice@vumc.org Also: john.boice@gmail.com

Wellons, Christine

From: Riemer, Hans
Sent: Thursday, April 1, 2021 3:07 PM
To: Riemer, Hans; elliottplevine@gmail.com
Subject: Fw: Thank you and following up

Sharing this older email as background info.

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Thursday, December 19, 2019 4:17 PM
To: 'walter.copan@nist.gov' <walter.copan@nist.gov>; 'jims@nist.gov' <jims@nist.gov>; 'kari.reidy@nist.gov' <kari.reidy@nist.gov>; 'paul.zielinski@nist.gov' <paul.zielinski@nist.gov>
Cc: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>; Silverman, Ken <Ken.Silverman@montgomerycountymd.gov>
Subject: Thank you and following up

Dear Dr. Copan and team:

I am very grateful for your time this week and I am writing to follow up. I would guess that meeting with Paul is my next step? I will call Paul. Following are some of the key take-aways for me:

NIST Incubator/navigator: I am very enthusiastic about your initiative to "move the fence back" and have a facility on NIST land where the private sector and NIST can integrate. I would like to move forward on this promptly and understand how Montgomery County can provide support. Do we need to take the initiative to start planning a PPP?

Lab/tech transfer working group: I intend to pull together a working group/mini-conference to delve deeper here into how the County can move ahead on these issues, involving experts from the major labs as well as select private sector leaders. I would welcome NIST's participation. Perhaps we could host it at NIST.

NIH nonprofit: You mentioned a potential need for a nonprofit attached to NIH to do transfer. I would like to discuss that further if you think that the County can provide any support.

Conflict of Interest rules: Is NIST able to provide any perspective on NIH's approach to COI and whether there are opportunities for change? This is a topic I would like to discuss further.

Post-docs: We referenced the conference that Montgomery County previously supported for post-docs; I would like to revive that initiative. I would also like to discuss a fellowship program or other entrepreneurship support for post-docs that could be provided and what NIST might advise there.

5G: I am reaching out to Dr. Jerrold Bushberg to relay our conversation. NCRP is the national academy that is designated to conduct research on radiation safety. When FDA or FCC or NIH or NIST seeks that information, apparently they turn to NCRP to provide it. Dr. Bushberg said that they would be quite willing to conduct a "literature review" of the latest information on health impacts and 5G. His sense is that other countries have done a lot of more basic research on the topic and that a literature review would be helpful and informative. I will connect you directly.
https://ncrponline.org/?albdesign_popup_cpt=jerrold-t-bushberg

Thank you again!

Hans Riemer
301-938-6899
--
Hans Riemer, Councilmember At-large
Montgomery County Council
Councilmember.riemer@montgomerycountymd.gov
www.montgomerycountymd.gov/riemer
240-777-7964

Wellons, Christine

From: elliott levine <elliottplevine@gmail.com>
Sent: Thursday, April 1, 2021 4:29 PM
To: Riemer, Hans
Subject: Re: Fw: Thank you and following up

[EXTERNAL EMAIL]

Hans,
Good range of issues discussed--especially the "pushing the walls back."
Is there anything in particular that you want me to follow up on here?
Thanks for sending.
Elliott

On Thu, Apr 1, 2021 at 3:07 PM Riemer, Hans <Hans.Riemer@montgomerycountymd.gov> wrote:
Sharing this older email as background info.

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Thursday, December 19, 2019 4:17 PM
To: 'walter.copan@nist.gov' <walter.copan@nist.gov>; 'jims@nist.gov' <jims@nist.gov>; 'kari.reidy@nist.gov' <kari.reidy@nist.gov>; 'paul.zielinski@nist.gov' <paul.zielinski@nist.gov>
Cc: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>; Silverman, Ken <Ken.Silverman@montgomerycountymd.gov>
Subject: Thank you and following up
Dear Dr. Copan and team:
I am very grateful for your time this week and I am writing to follow up. I would guess that meeting with Paul is my next step? I will call Paul. Following are some of the key take-aways for me:
NIST Incubator/navigator: I am very enthusiastic about your initiative to "move the fence back" and have a facility on NIST land where the private sector and NIST can integrate. I would like to move forward on this promptly and understand how Montgomery County can provide support. Do we need to take the initiative to start planning a PPP?
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https://ncrponline.org/?albdesign_popup_cpt=jerrold-t-bushberg

Thank you again!
Hans Riemer
301-938-6899
--
Hans Riemer, Councilmember At-large
Montgomery County Council
Councilmember.riemer@montgomerycountymd.gov
www.montgomerycountymd.gov/riemer
240-777-7964

Wellons, Christine

From: Jerrold Bushberg <jerrold.bushberg@ncrponline.org>
Sent: Sunday, January 19, 2020 6:44 PM
To: 'Copan, Walter G. (Fed)'; Riemer, Hans
Cc: Golmie, Nada T. (Fed); Dowell, Marla L. (Fed); Schufreider, James R. (Fed); Reidy, Kari M. (Fed); Zielinski, Paul R. (Fed); Singerman, Phillip A. (Fed); Kathy Held; John Boice; Laura Atwell
Subject: RE: Introduction

[EXTERNAL EMAIL]

Dear Dr. Copan:

Thank you for your email. As I am not sure how familiar you are with the National Council on Radiation Protection and Measurements (NCRP), I have provided a brief introduction and a link to our website where more detailed information can be found. One interesting fact is that the predecessor to what became the NCRP (The Advisory Committee on X-Ray and Radium Protection, established in 1929) was led by Dr. Lauriston S. Taylor who, at the time, was working for your predecessor organization, The National Bureau of Standards. In 1964, the U.S. Congress reorganized and chartered our current organization as the National Council on Radiation Protection and Measurements. Dr. Taylor served as its first President until 1977. Our close relationship continues to this day with several NIST scientists serving as either Distinguished Emeritus or current Council members. For example, Dr. Steve Seltzer was elected to Council in 1998 and is currently a Distinguished Emeritus Member and Dr. Leticia Pibida is a newly elected member of Council and Chair of our Scientific Committee (SC 3-2): Recommendations for Instrument Response Verification and Calibration for Use in Radiation Emergencies.

The NCRP operates in accordance with its mission, detailed in its Congressional Charter, as a scientific institution with the charge to provide expert analysis (principally at the request of federal agencies and Departments) on a variety of issues related to the health and safety aspects of both ionizing and non-ionizing radiation. NCRP does not receive any annual core government funding. The activities of NCRP are supported by grants, contracts, contributions, and receipts from sales of publications. The vast majority of the funds supporting NCRP activities comes from grants and contracts with federal agencies and departments.

While the majority of NCRP's work deals with ionizing radiation, we do have a number of members who are highly skilled specialists in the area of non-ionizing radiation health, safety, human exposure standards and measurements. I chair the NCRP standing Advisory Panel on Non-ionizing Radiation, which among other things has responded to many specific questions (mostly on an informal basis by email or telephone) about the health and safety of wireless communication systems especially those concerning the rollout of 5G technology.

As is often the case with so many technologies that are perceived as controversial by some segments of society, more scientific information, by itself, is often not enough to bring about the fuller and more contextual understanding that is desired. To that end, the NCRP established a Program Area Committee (PAC) comprised of communication specialist. This PAC's (PAC 7) focus is on "Radiation Education, Risk Communication and Outreach". Their contribution to our work has been of enormous value. This has been especially true when trying to convey complex technical issues to the general public.

While NCRP has not been asked recently to review the science in this area, we have responded to several requests in the past resulting in the following publications and proceedings.

1. Report 67: *Radiofrequency Electromagnetic Fields-Properties, Quantities and Units, Biophysical Interaction, and Measurements* (1981)
2. Report 82: *SI Units in Radiation Protection and Measurements* (1985)
3. Report 86: *Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields* (1986)
4. *Nonionizing Electromagnetic Radiations and Ultrasound,* Proceedings of the Twenty-Second Annual Meeting held on April 2-3, 1986 (including Taylor Lecture No. 10) (1988)
5. Report 119: *A Practical Guide to the Determination of Human Exposure to Radiofrequency Fields* (1993)
6. President Report: Letter Report on *Wireless Telecommunications Radiofrequency Safety Issues for Building Owners and Managers* (2002)
7. Commentary 18: *Biological Effects of Modulated Radiofrequency Fields* (2003)
8. Report 174: *Preconception and Prenatal Radiation Exposure: Health Effects and Protective Guidance: Chapter 8:* Nonionizing Modalities and Sources (2013)

Our Past-President and Current Director of Science, Dr. John Boice, an internationally recognized and highly respected radiation epidemiologist, has published several papers on this topic:

1. BOICE JD Jr, Morrissey J. *Epidemiologic studies related to cellular telephone communication.* In: Electricity and Magnetism in Biology and Medicine. Proceedings of the Second World Congress held in Bologna, Italy, June 8-13, 1997 (Bersani F, ed). New York: Kluwer Academic, 1999, 129-132. https://www.tib.eu/en/search/id/BLCP%3ACN042470673/Epidemiologic-Studies-Related-to-Cellular-Telephone/

2. Inskip PD, Hatch EE, Stewart PA, Heineman EF, Ziegler RG, Dosemici M, Parry D, Rothman N, BOICE JD Jr, Wilcosky TC, Watson DJ, Shapiro WR, Selker RG, Fine HA, Black PM, Loeffler JS, Linet MS. *Study design for a case-control investigation of cellular telephones and other risk factors for brain tumours in adults.* Radiat Prot Dosimetry 86:45-52, 1999.

3. Johansen C, BOICE JD Jr, McLaughlin JK, Olsen JH. *Cellular telephones and cancer - a nationwide cohort study in Denmark.* J Natl Cancer Inst 93:203-207, 2001. [PMID 11158188]

4. BOICE JD Jr, McLaughlin JK. *Epidemiologic studies of cellular telephones and cancer risk -- a review.* SSI rapport: 2002:16. Stockholm: Swedish Radiation Protection Authority, 2002, 1-38. https://pdfs.semanticscholar.org/4122/e9cc3b08a2ebead92692aa20410fe1b15f8f.pdf

5. Johansen C, BOICE JD Jr, McLaughlin JK, Christensen HC, Olsen JH. *Mobile phones and malignant melanoma of the eye.* Br J Cancer 86:348-349, 2002. [PMID 11875697, PMC2375230]

6. Christensen HC, Schüz J, Kosteljanetz M, Poulsen HS, BOICE JD Jr, McLaughlin JK, Johansen C. *Cellular telephone use and risk for brain tumours: a population-based, incident case-control study. Neurology* 64:1189-1195, 2005. [PMID 15824345]

7. Schüz J, Jacobsen R, Olsen JH, BOICE JD Jr, McLaughlin JK, Johansen C. *Cellular telephone use and cancer risk: update of a nationwide Danish cohort.* J Natl Cancer Inst 98:1707-1713, 2006. [PMID 17148772]

8. BOICE JD Jr, Tarone RE. *Cell phones, children and cancer* (Editorial). J Natl Cancer Inst 103:1211-1213, 2011. [PMID 21795667]

9. BOICE J. *It's premature to conclude that cell phones cause cancer in humans.* Invited Guest Blog. Sci Am May 31, 2016. Available at https://blogs.scientificamerican.com/guest-blog/it-s-premature-to-conclude-that-cell-phones-cause-cancer-in-humans/

10. BOICE JD. *Cell Phones and Rats — Should You Worry?* Boice Report 49. Health Physics News July 2016. https://ncrponline.org/wp-content/themes/ncrp/PDFs/BOICE-HPnews/49_July2016.pdf

The FCC is required by the National Environmental Policy Act of 1969, among other things, to evaluate the effect of emissions from FCC-regulated transmitters on the quality of the human environment. To that end the FCC relies on the

recommendations of the Federal health agencies such as the EPA, FDA, and NIOSH as well voluntary organizations that have issued recommendations for human exposure to RF electromagnetic fields. After receiving the recommendations from experts within the federal government, the Commission adopted the NCRP's recommended Maximum Permissible Exposure limits for field strength and power density for the transmitters operating at frequencies of 300 kHz to 100 GHz on August 1, 1996. Additional recommendations related to specific absorption rate (SAR) limits for devices operating within close proximity to the body (e.g. police & fire portable radios and mobile phones) published in ANSI/IEEE C95.1-1992 standards were also incorporated.

NCRP Council members are elected to Council based on their widely recognized academic reputation for excellence and their specific expertise related to some aspect of radiation effects, protection and measurements. The Council members voluntarily contribute their services in support of the Council's objectives. Their ability and experience represent the cornerstone of the Council's program and are a major force for progress in radiation protection and measurement.

Please let me know whether we might set up a teleconference and/or perhaps come to Gaithersburg to meet with you and staff at NIST to discuss how NCRP might help with concerns being raised by expansion of 5G networks or any other matters of mutual interest. A meeting or teleconference could be arranged with Laura Atwell, Operations Manager, Laura.Atwell@ncrponline.org, 301-657-2652.

With Best Regards

Jerrold T. Bushberg Ph.D.
Chair, Board of Directors
Senior-Vice President
7910 Woodmont Avenue, Suite 400,
Bethesda, MD 20814
(301) 657-2652
(301) 907-8768
jerrold.bushberg@ncrponline.org

From: Copan, Walter G. (Fed) <walter.copan@nist.gov>
Sent: Wednesday, January 15, 2020 2:47 PM
To: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>; Jerrold Bushberg <jerrold.bushberg@ncrponline.org>
Cc: Golmie, Nada T. (Fed) <nada.golmie@nist.gov>; Dowell, Marla L. (Fed) <marla.dowell@nist.gov>; Schufreider, James R. (Fed) <jim.schufreider@nist.gov>; Reidy, Kari M. (Fed) <kari.reidy@nist.gov>; Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>; Singerman, Phillip A. (Fed) <phillip.singerman@nist.gov>
Subject: RE: Introduction

Dear Hans

Many thanks for your follow-up from our meeting in December! It was a real pleasure to meet. I look forward to catching up on developments since. I'm copying Paul Zielinski and colleagues who participated in the discussion when we met on technology transfer, innovation and economic development topics.

Dr. Bushberg – we at NIST would look forward to conversation. We understand that your organization, among other things, carries out work including reviews of available literature relevant to some of the current public concerns regarding the "unknown" health effects or risks that could be created by expansion of 5G networks. This was also a topic raised when we had met with Council Member Riemer – that public perceptions concerning health risks are contributors to slowing the progress in regional 5G deploymenta.

To that end, I'm also copying Nada Golmie, lead for the NIST Communications Technology Lab in Gaithersburg, as well as Marla Dowell, the director of the NIST Communications Technology Lab, based in Boulder. https://www.nist.gov/ctl

Kind regards,
Walter Copan

Walter G. Copan, Ph.D.
Under Secretary of Commerce for Standards and Technology
Director, National Institute of Standards and Technology
100 Bureau Drive, MS 1000
Gaithersburg, MD 20899 USA
+1 301-975-2300
walter.copan@nist.gov
http://www.nist.gov

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Tuesday, January 7, 2020 10:28 AM
To: Copan, Walter G. (Fed) <walter.copan@nist.gov>; 'jerrold.bushberg@ncrponline.org' <jerrold.bushberg@ncrponline.org>
Subject: Introduction

Dr. Copan,

Copied is Dr. Jerrold Bushberg, vice chair of the National Council on Radiation Protection and Measurements, NCRP. NCRP is the Congressionally chartered academy that conducts studies on radiation health safety at the request of federal agencies.

Thank you!

Hans

https://www.nist.gov/people/walter-g-copan

https://ncrponline.org/?albdesign_popup_cpt=jerrold-t-bushberg

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Hans Riemer, Councilmember At-large
Montgomery County Council
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240-777-7964

Wellons, Christine

From: Jerrold Bushberg <jerrold.bushberg@ncrponline.org>
Sent: Wednesday, February 19, 2020 2:47 PM
To: Copan, Walter G. (Fed); Riemer, Hans
Subject: RE: Introduction

[EXTERNAL EMAIL]

Dear Dr. Copan:

Just a follow up email to be sure you had received my January 19 reply (below) to your email to me on Jan 15. Please confirm receipt of this message.

Thank you

Jerrold T. Bushberg Ph.D.
Chair, Board of Directors
Senior-Vice President
7910 Woodmont Avenue, Suite 400,
Bethesda, MD 20814
(301) 657-2652
(301) 907-8768
jerrold.bushberg@ncrponline.org

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Cc: Golmie, Nada T. (Fed) <nada.golmie@nist.gov>; Dowell, Marla L. (Fed) <marla.dowell@nist.gov>; Schufreider, James R. (Fed) <jim.schufreider@nist.gov>; Reidy, Kari M. (Fed) <kari.reidy@nist.gov>; Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>; Singerman, Phillip A. (Fed) <phillip.singerman@nist.gov>; Kathy Held <Kathy.Held@ncrponline.org>; John Boice <John.Boice@ncrponline.org>; Laura Atwell (Laura.Atwell@ncrponline.org) <Laura.Atwell@ncrponline.org>
Subject: RE: Introduction

Dear Dr. Copan:

Thank you for your email. As I am not sure how familiar you are with the National Council on Radiation Protection and Measurements (NCRP), I have provided a brief introduction and a link to our website where more detailed information can be found. One interesting fact is that the predecessor to what became the NCRP (The Advisory Committee on X-Ray and Radium Protection, established in 1929) was led by Dr. Lauriston S. Taylor who, at the time, was working for your predecessor organization, The National Bureau of Standards. In 1964, the U.S. Congress reorganized and chartered our current organization as the National Council on Radiation Protection and Measurements. Dr. Taylor served as its first President until 1977. Our close relationship continues to this day with several NIST scientists serving as either

Distinguished Emeritus or current Council members. For example, Dr. Steve Seltzer was elected to Council in 1998 and is currently a Distinguished Emeritus Member and Dr. Leticia Pibida is a newly elected member of Council and Chair of our Scientific Committee (SC 3-2): Recommendations for Instrument Response Verification and Calibration for Use in Radiation Emergencies.

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https://www.tib.eu/en/search/id/BLCP%3ACN042470673/Epidemiologic-Studies-Related-to-Cellular-Telephone/

2. Inskip PD, Hatch EE, Stewart PA, Heineman EF, Ziegler RG, Dosemici M, Parry D, Rothman N, BOICE JD Jr, Wilcosky TC, Watson DJ, Shapiro WR, Selker RG, Fine HA, Black PM, Loeffler JS, Linet MS. *Study design for a case-control investigation of cellular telephones and other risk factors for brain tumours in adults.* Radiat Prot Dosimetry 86:45-52, 1999.

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Please let me know whether we might set up a teleconference and/or perhaps come to Gaithersburg to meet with you and staff at NIST to discuss how NCRP might help with concerns being raised by expansion of 5G networks or any other matters of mutual interest. A meeting or teleconference could be arranged with Laura Atwell, Operations Manager, Laura.Atwell@ncrponline.org, 301-657-2652.

With Best Regards

Jerrold T. Bushberg Ph.D.
Chair, Board of Directors
Senior-Vice President
7910 Woodmont Avenue, Suite 400,
Bethesda, MD 20814
(301) 657-2652
(301) 907-8768
jerrold.bushberg@ncrponline.org

From: Copan, Walter G. (Fed) <walter.copan@nist.gov>
Sent: Wednesday, January 15, 2020 2:47 PM
To: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>; Jerrold Bushberg <jerrold.bushberg@ncrponline.org>
Cc: Golmie, Nada T. (Fed) <nada.golmie@nist.gov>; Dowell, Marla L. (Fed) <marla.dowell@nist.gov>; Schufreider, James R. (Fed) <jim.schufreider@nist.gov>; Reidy, Kari M. (Fed) <kari.reidy@nist.gov>; Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>; Singerman, Phillip A. (Fed) <phillip.singerman@nist.gov>
Subject: RE: Introduction

Dear Hans

Many thanks for your follow-up from our meeting in December! It was a real pleasure to meet. I look forward to catching up on developments since. I'm copying Paul Zielinski and colleagues who participated in the discussion when we met on technology transfer, innovation and economic development topics.

Dr. Bushberg – we at NIST would look forward to conversation. We understand that your organization, among other things, carries out work including reviews of available literature relevant to some of the current public concerns regarding the "unknown" health effects or risks that could be created by expansion of 5G networks. This was also a topic raised when we had met with Council Member Riemer – that public perceptions concerning health risks are contributors to slowing the progress in regional 5G deploymenta.

To that end, I'm also copying Nada Golmie, lead for the NIST Communications Technology Lab in Gaithersburg, as well as Marla Dowell, the director of the NIST Communications Technology Lab, based in Boulder. https://www.nist.gov/ctl

Kind regards,
Walter Copan

Walter G. Copan, Ph.D.
Under Secretary of Commerce for Standards and Technology
Director, National Institute of Standards and Technology
100 Bureau Drive, MS 1000
Gaithersburg, MD 20899 USA
+1 301-975-2300
walter.copan@nist.gov
http://www.nist.gov

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Tuesday, January 7, 2020 10:28 AM
To: Copan, Walter G. (Fed) <walter.copan@nist.gov>; 'jerrold.bushberg@ncrponline.org' <jerrold.bushberg@ncrponline.org>
Subject: Introduction

Dr. Copan,

Copied is Dr. Jerrold Bushberg, vice chair of the National Council on Radiation Protection and Measurements, NCRP. NCRP is the Congressionally chartered academy that conducts studies on radiation health safety at the request of federal agencies.

Thank you!

Hans

https://www.nist.gov/people/walter-g-copan

https://ncrponline.org/?albdesign_popup_cpt=jerrold-t-bushberg

--
Hans Riemer, Councilmember At-large
Montgomery County Council
Councilmember.riemer@montgomerycountymd.gov
www.montgomerycountymd.gov/riemer
240-777-7964

Wellons, Christine

From: Thomas Lonergan <Tom.Lonergan@gaithersburgmd.gov>
Sent: Wednesday, January 22, 2020 11:32 AM
To: Reidy, Kari M. (Fed)
Cc: Riemer, Hans
Subject: Re: Thank you and following up

[EXTERNAL EMAIL]

Rob and I somehow missed this. Sorry, both. Kari, when's a good time for you?

Tom

Sent from my iPhone

On Jan 22, 2020, at 11:20 AM, Reidy, Kari M. (Fed) <kari.reidy@nist.gov> wrote:

This email is from an EXTERNAL source. Please use caution when opening attachments, clicking links, or responding.

Hi Tom – we met yesterday afternoon but happy to fill you in if you'd like.
Kari

From: Thomas Lonergan <Tom.Lonergan@gaithersburgmd.gov>
Sent: Wednesday, January 22, 2020 11:18 AM
To: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Cc: Reidy, Kari M. (Fed) <kari.reidy@nist.gov>
Subject: RE: Thank you and following up
Too late for me to join this meeting?
Tom
<image001.jpg>

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Wednesday, January 15, 2020 7:55 PM
To: Robert Wu <robert.wu@gaithersburgmd.gov>; Thomas Lonergan <Tom.Lonergan@gaithersburgmd.gov>
Subject: Fwd: Thank you and following up

This email is from an EXTERNAL source. Please use caution when opening attachments, clicking links, or responding.

Hope you can join! Thanks again for your help.
--
Hans Riemer, At-Large County Councilmember

From: Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>
Sent: Wednesday, January 15, 2020 7:35 PM
To: Riemer, Hans; Schufreider, James R. (Fed); Reidy, Kari M. (Fed); Smith, Gene; benwumail@gmail.com; Bill Tompkins; Christy Blake
Cc: Silverman, Ken; Hans Riemer
Subject: Re: Thank you and following up

[EXTERNAL EMAIL]

I see Walt replied, so that seems to have worked. Perhaps 2PM on 1/21 would be good?
Paul

On: 15 January 2020 17:09,
"Riemer, Hans" <Hans.Riemer@montgomerycountymd.gov> wrote:

Thank you! I could do 1/21 in the afternoon. I am free from 1-5pm. Let me know what time please. I am copying Ben Wu as well. I hope he can join.
Do you know whether the routing issue may have affected Dr. Copan? I sent him a follow up email introducing him to Dr. Jarrold Bushberg. Just wanted to be sure he got it (as well as the original follow up email).
Thanks!

From: Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>
Sent: Wednesday, January 15, 2020 4:39 PM
To: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>; Schufreider, James R. (Fed) <jim.schufreider@nist.gov>; Reidy, Kari M. (Fed) <kari.reidy@nist.gov>
Cc: Silverman, Ken <Ken.Silverman@montgomerycountymd.gov>
Subject: RE: Thank you and following up

[EXTERNAL EMAIL]

Hans
My apologies for taking so long. This was routed incorrectly in my email. Is there any possibility of meeting on 1/20 or 1/21? I missed the first possibility and am on travel out of state the other days.
Best,
Paul
Paul R. Zielinski
Director, Technology Partnerships Office
National Institute of Standards and Technology

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Tuesday, January 7, 2020 11:39 AM
To: Schufreider, James R. (Fed) <jim.schufreider@nist.gov>; Reidy, Kari M. (Fed) <kari.reidy@nist.gov>; Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>
Cc: Silverman, Ken <Ken.Silverman@montgomerycountymd.gov>
Subject: RE: Thank you and following up
Paul, is the next step for us to meet and consider where/how we execute on these plans? If so, I could meet at various times on 1/10, 1/17, or 1/22.

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Thursday, December 19, 2019 4:18 PM
To: 'walter.copan@nist.gov' <walter.copan@nist.gov>; 'jims@nist.gov' <jims@nist.gov>; 'kari.reidy@nist.gov' <kari.reidy@nist.gov>; 'paul.zielinski@nist.gov' <paul.zielinski@nist.gov>
Cc: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>; Silverman, Ken <Ken.Silverman@montgomerycountymd.gov>
Subject: Thank you and following up
Dear Dr. Copan and team:
I am very grateful for your time this week and I am writing to follow up. I would guess that meeting with Paul is my next step? I will call Paul. Following are some of the key take-aways for me:

NIST Incubator/navigator: I am very enthusiastic about your initiative to "move the fence back" and have a facility on NIST land where the private sector and NIST can integrate. I would like to move forward on this promptly and understand how Montgomery County can provide support. Do we need to take the initiative to start planning a PPP?
Lab/tech transfer working group: I intend to pull together a working group/mini-conference to delve deeper here into how the County can move ahead on these issues, involving experts from the major labs as well as select private sector leaders. I would welcome NIST's participation. Perhaps we could host it at NIST.
NIH nonprofit: You mentioned a potential need for a nonprofit attached to NIH to do transfer. I would like to discuss that further if you think that the County can provide any support.
Conflict of Interest rules: Is NIST able to provide any perspective on NIH's approach to COI and whether there are opportunities for change? This is a topic I would like to discuss further.
Post-docs: We referenced the conference that Montgomery County previously supported for post-docs; I would like to revive that initiative. I would also like to discuss a fellowship program or other entrepreneurship support for post-docs that could be provided and what NIST might advise there.
5G: I am reaching out to Dr. Jerrold Bushberg to relay our conversation. NCRP is the national academy that is designated to conduct research on radiation safety. When FDA or FCC or NIH or NIST seeks that information, apparently they turn to NCRP to provide it. Dr. Bushberg said that they would be quite willing to conduct a "literature review" of the latest information on health impacts and 5G. His sense is that other countries have done a lot of more basic research on the topic and that a literature review would be helpful and informative. I will connect you directly.
https://ncrponline.org/?albdesign_popup_cpt=jerrold-t-bushberg
Thank you again!
Hans Riemer
301-938-6899

--
Hans Riemer, Councilmember At-large
Montgomery County Council
Councilmember.riemer@montgomerycountymd.gov
www.montgomerycountymd.gov/riemer
240-777-7964

Wellons, Christine

From: Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>
Sent: Friday, February 21, 2020 1:51 PM
To: Riemer, Hans
Cc: Reidy, Kari M. (Fed)
Subject: Re: Introduction

[EXTERNAL EMAIL]

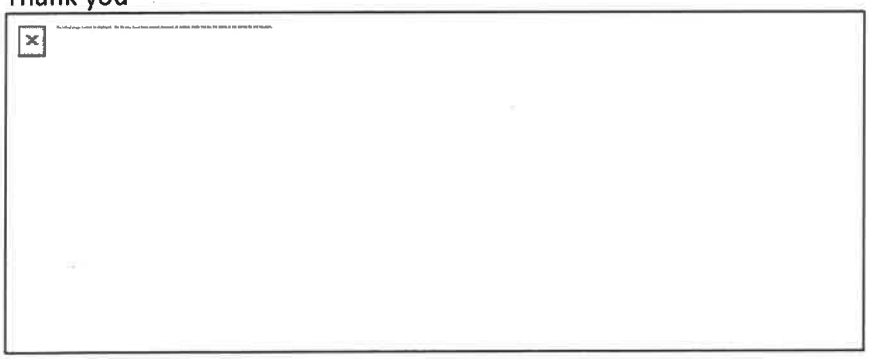
Hans

I am not sure on the status of this but will look into it. I am sure there will be a response.

Regards,

Paul

On: 21 February 2020 12:21, "Riemer, Hans" <Hans.Riemer@montgomerycountymd.gov> wrote:

> Paul, fyi – hope someone can reply
>
> **From:** Jerrold Bushberg <jerrold.bushberg@ncrponline.org>
> **Sent:** Wednesday, February 19, 2020 2:47 PM
> **To:** Copan, Walter G. (Fed) <walter.copan@nist.gov>; Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
> **Subject:** RE: Introduction
>
> [EXTERNAL EMAIL]
>
> Dear Dr. Copan:
> Just a follow up email to be sure you had received my January 19 reply (below) to your email to me on Jan 15. Please confirm receipt of this message.
> Thank you
>
> 
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> **From:** Jerrold Bushberg
> **Sent:** Sunday, January 19, 2020 3:44 PM
> **To:** 'Copan, Walter G. (Fed)' <walter.copan@nist.gov>; Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
> **Cc:** Golmie, Nada T. (Fed) <nada.golmie@nist.gov>; Dowell, Marla L. (Fed) <marla.dowell@nist.gov>; Schufreider, James R. (Fed) <jim.schufreider@nist.gov>; Reidy, Kari M. (Fed) <kari.reidy@nist.gov>;

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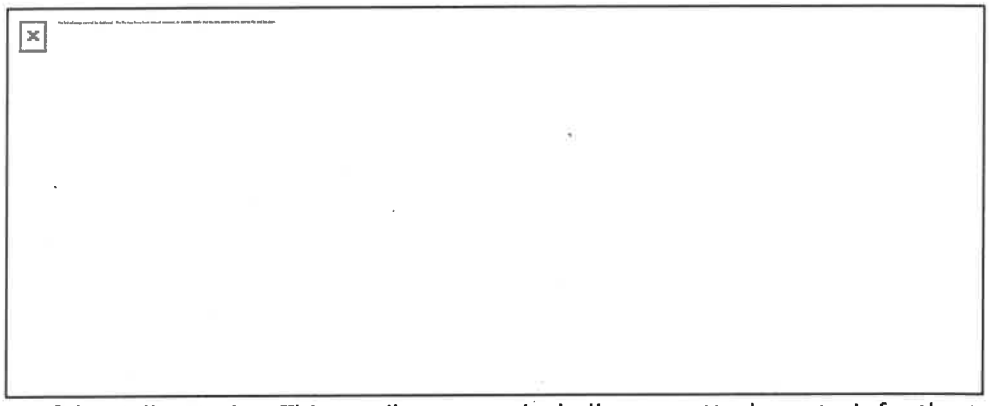

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Dear Hans
Many thanks for your follow-up from our meeting in December! It was a real pleasure to meet. I look forward to catching up on developments since. I'm copying Paul Zielinski and colleagues who participated in the discussion when we met on technology transfer, innovation and economic development topics.
Dr. Bushberg – we at NIST would look forward to conversation. We understand that your organization, among other things, carries out work including reviews of available literature relevant to some of the current public concerns regarding the "unknown" health effects or risks that could be created by expansion of 5G networks. This was also a topic raised when we had met with Council Member Riemer – that public perceptions concerning health risks are contributors to slowing the progress in regional 5G deploymenta.
To that end, I'm also copying Nada Golmie, lead for the NIST Communications Technology Lab in Gaithersburg, as well as Marla Dowell, the director of the NIST Communications Technology Lab, based in Boulder. https://www.nist.gov/ctl
Kind regards,
Walter Copan
Walter G. Copan, Ph.D.
Under Secretary of Commerce for Standards and Technology
Director, National Institute of Standards and Technology
100 Bureau Drive, MS 1000
Gaithersburg, MD 20899 USA
+1 301-975-2300
walter.copan@nist.gov

http://www.nist.gov

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Tuesday, January 7, 2020 10:28 AM
To: Copan, Walter G. (Fed) <walter.copan@nist.gov>; 'jerrold.bushberg@ncrponline.org' <jerrold.bushberg@ncrponline.org>
Subject: Introduction

Dr. Copan,

Copied is Dr. Jerrold Bushberg, vice chair of the National Council on Radiation Protection and Measurements, NCRP. NCRP is the Congressionally chartered academy that conducts studies on radiation health safety at the request of federal agencies.

Thank you!

Hans

https://www.nist.gov/people/walter-g-copan
https://ncrponline.org/?albdesign_popup_cpt=jerrold-t-bushberg

--

Hans Riemer, Councilmember At-large
Montgomery County Council
Councilmember.riemer@montgomerycountymd.gov
www.montgomerycountymd.gov/riemer
240-777-7964

Wellons, Christine

From: Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>
Sent: Wednesday, January 15, 2020 7:36 PM
To: Riemer, Hans; Schufreider, James R. (Fed); Reidy, Kari M. (Fed); Smith, Gene; benwumail@gmail.com; Bill Tompkins; Christy Blake
Cc: Silverman, Ken; Hans Riemer
Subject: Re: Thank you and following up

[EXTERNAL EMAIL]

I see Walt replied, so that seems to have worked. Perhaps 2PM on 1/21 would be good?

Paul

On: 15 January 2020 17:09,
"Riemer, Hans" <Hans.Riemer@montgomerycountymd.gov> wrote:

Thank you! I could do 1/21 in the afternoon. I am free from 1-5pm. Let me know what time please. I am copying Ben Wu as well. I hope he can join.
Do you know whether the routing issue may have affected Dr. Copan? I sent him a follow up email introducing him to Dr. Jarrold Bushberg. Just wanted to be sure he got it (as well as the original follow up email).
Thanks!

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Sent: Wednesday, January 15, 2020 4:39 PM
To: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>; Schufreider, James R. (Fed) <jim.schufreider@nist.gov>; Reidy, Kari M. (Fed) <kari.reidy@nist.gov>
Cc: Silverman, Ken <Ken.Silverman@montgomerycountymd.gov>
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My apologies for taking so long. This was routed incorrectly in my email. Is there any possibility of meeting on 1/20 or 1/21? I missed the first possibility and am on travel out of state the other days.
Best,
Paul
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Director, Technology Partnerships Office
National Institute of Standards and Technology

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Sent: Tuesday, January 7, 2020 11:39 AM
To: Schufreider, James R. (Fed) <jim.schufreider@nist.gov>; Reidy, Kari M. (Fed) <kari.reidy@nist.gov>; Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>
Cc: Silverman, Ken <Ken.Silverman@montgomerycountymd.gov>
Subject: RE: Thank you and following up
Paul, is the next step for us to meet and consider where/how we execute on these plans? If so, I could meet at various times on 1/10, 1/17, or 1/22.

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Thursday, December 19, 2019 4:18 PM
To: 'walter.copan@nist.gov' <walter.copan@nist.gov>; 'jims@nist.gov' <jims@nist.gov>; 'kari.reidy@nist.gov' <kari.reidy@nist.gov>; 'paul.zielinski@nist.gov' <paul.zielinski@nist.gov>
Cc: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>; Silverman, Ken <Ken.Silverman@montgomerycountymd.gov>
Subject: Thank you and following up

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NIST Incubator/navigator: I am very enthusiastic about your initiative to "move the fence back" and have a facility on NIST land where the private sector and NIST can integrate. I would like to move forward on this promptly and understand how Montgomery County can provide support. Do we need to take the initiative to start planning a PPP?

Lab/tech transfer working group: I intend to pull together a working group/mini-conference to delve deeper here into how the County can move ahead on these issues, involving experts from the major labs as well as select private sector leaders. I would welcome NIST's participation. Perhaps we could host it at NIST.

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5G: I am reaching out to Dr. Jerrold Bushberg to relay our conversation. NCRP is the national academy that is designated to conduct research on radiation safety. When FDA or FCC or NIH or NIST seeks that information, apparently they turn to NCRP to provide it. Dr. Bushberg said that they would be quite willing to conduct a "literature review" of the latest information on health impacts and 5G. His sense is that other countries have done a lot of more basic research on the topic and that a literature review would be helpful and informative. I will connect you directly.
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Thank you again!

Hans Riemer
301-938-6899

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Wellons, Christine

From: Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>
Sent: Thursday, January 16, 2020 1:07 PM
To: Riemer, Hans; Schufreider, James R. (Fed); Reidy, Kari M. (Fed); Smith, Gene; benwumail@gmail.com; Bill Tompkins; Christy Blake
Cc: Silverman, Ken; Hans Riemer
Subject: RE: Thank you and following up

[EXTERNAL EMAIL]

We would be happy to have you here! We can also meet at your office if that is better.

Paul

From: Riemer, Hans <Hans.Riemer@montgomerycountymd.gov>
Sent: Thursday, January 16, 2020 12:19 PM
To: Zielinski, Paul R. (Fed) <paul.zielinski@nist.gov>; Schufreider, James R. (Fed) <jim.schufreider@nist.gov>; Reidy, Kari M. (Fed) <kari.reidy@nist.gov>; Smith, Gene <Gene.Smith@montgomerycountymd.gov>; benwumail@gmail.com; Bill Tompkins <bill@thinkmoco.com>; Christy Blake <Christy@thinkmoco.com>
Cc: Silverman, Ken <Ken.Silverman@montgomerycountymd.gov>; Hans Riemer <hans.riemer@gmail.com>
Subject: RE: Thank you and following up

Let's do that. Thank you. 1/21 at 2pm.

Shall we meet at NIST?

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Thank you again!
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301-938-6899

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Hans Riemer, Councilmember At-large
Montgomery County Council
Councilmember.riemer@montgomerycountymd.gov
www.montgomerycountymd.gov/riemer
240-777-7964

Wellons, Christine

From: Riemer's Office, Councilmember
Sent: Wednesday, December 11, 2019 7:54
To: REDACTED
Subject: Re: Your position on affordable housing

Hi REDADCTED its great to hear from you and thank you for your note to me (as well as the one you sent and copied me on to the County Executive).

There's a lot of misunderstanding about the next generation of wireless service. It is is much better/faster/more reliable technology but it uses a system that is more like wifi routers than cell towers. The routers need to be placed on telephone poles and light poles. I don't really see the problem here. We all have wifi routers in our homes. If the changing technology requires routers on poles, then what are we supposed to do? I don't love having a router in my houser, either, but I certainly value what it brings me.

In fact the health research is not at all alarming. Non-ionizing radiation is nearly ubiquitous in our society and has been since at least the power lines went up. From a health perspective, it is pretty much all the same. Your home wifi router, your cell phone service, your microwave, the power lines coming to your house --- as well as the cosmic radiation that is constantly inundating us from space, and light. Nonionizing radiation has been studied extensively for decades and as a result of that research, scientists are not concerned.

Last week I spoke with Dr. Jerrold Bushberg, who confirmed that the science does not support concerns about 1G, 2G, 5G, or any of these nonionizing radiation forms. Dr. Bushberg is probably the top scientist in the country on this topic. https://ncrponline.org/?albdesign_popup_cpt=jerrold-t-bushberg

As for the issue about climate and weather --- now that is a different story. I think that's a problem. But it is not one that we can solve. We'll need the federal agencies to work that out. Any new technology is going to have some wrinkles, I am sure they can solve it.

From a local perspective, I think if we are going to fight against 5G we might as well outlaw wifi routers in homes, 4G, and microwaves. It's all the same. And why would we do that.

In any event, our current law is a 300 foot setback requirement. So that pretty much rules out all poles in the County except in very unusual circumstances. That's just not viable, desirable, or legal.

My proposal is not closer than 30 feet distance. What exactly is so bad about that? If you have a wifi router in your home, what's so bad about having one on a telephone pole in front of your house?

I don't mean to be argumentative, but since you are a person I trust, I'd be interested to know your response.

Your friend -
Hans

—
Hans Riemer

On November 24, 2019, 5:06 PM EST REDACTED wrote:

Hi Hans,
Will do. Hey, my partner, reacted attended the hearing y'all held last week on 5G. We are very much opposed to the placement of 5G towers in residential neighborhoods, and it sounds like other residents are also overwhelmingly opposed. While the research may not be definitive on adverse health effects, the research is alarming enough, and scant enough, that we should not err on the side of irreparably risking people's health. I read your open letter, but the health concerns re: cell towers long precede 5G -- Russia can't be blamed for this one. Moreover, the science IS definitive that 5G will interfere with weather forecasting. This is unacceptable, especially at a time when the ravages of climate change are only increasing.

I realize that local & state officials' hands are tied to some extent by the FCC, but I believe our reps ought to be doing all they can to limit and control placement of these towers, and am glad that we are part of the legal challenge. I support the current setback requirements for residential areas and oppose the zoning change to allow them to installed all right near our homes. I urge you to change your position on this issue.
All the best, and have a happy Thanksgiving!
-Redacted

On Sunday, November 24, 2019, 3:38:00 PM EST, Riemer's Office, Councilmember <councilmember.riemer@montgomerycountymd.gov> wrote:

Thank you Redacted Please let me know what reply you receive. Hans

—
Hans Riemer

On November 21, 2019, 10:59 PM EST Redacted wrote:

Dear County Executive Elrich,
I am writing to convey my disappointment to read in this morning's *Washington Post* that you have taken a position against building more affordable housing units in the County. I am no expert on the COG targets and whether they are bold enough, but I do know that denying that we will need these units because you hope the County will grow high- vs. low-paid jobs is not a sound reason to oppose a commitment to higher affordable housing targets.

We *already* need tens of thousands more affordable housing units. Low and middle-income people are already struggling with sky-high housing costs, especially in close-in neighborhoods. In my own family, I have several family members who are couch surfing and sleeping on people's floors because they cannot

afford even a one-bedroom apartment. In fact, there are many trends related to the future of work that indicate many of the jobs of the future will be low-paid -- e.g., home care workers, gig workers, etc. -- and our county needs to provide a home for everyone.

Please reconsider your position and do all you can to substantially increase affordable housing stock in Montgomery County for low and moderate income families.

Sincerely,
Redacted
Takoma Park, MD. 20912

ATTACHMENT B

to the Public Comment by Resident Groups of Montgomery County, Maryland

Date	Source / Statement
November 6, 2019	**Zoning for Our Wireless Future — written by Councilmember Hans Riemer, lead sponsor of the ZTA*** http://councilmemberriemer.com/2019/11/zoning-for-our-wireless-future.html "But our current zoning code was designed with big cell towers in mind, and requires that any cellular antenna be set back 300 feet from the nearest home...That is why I have joined with my colleagues Gabe Albornoz and Craig Rice to introduce a zoning change to allow small wireless antennas to be added to utility or light poles, provided they are not closer than 30 feet to a home. ***Why 30 feet? Well, the typical home is set 25 feet back from the street. With 30 feet minimum distance required, homeowners whose residences are closer to a pole than average will not bear a disproportionate visual impact***. You likely rely upon wireless. ***Will you have advanced networks at your home if your wireless company can only use utility poles that are farther than 300 feet from your house? The answer is no, because most likely none of the utility poles in your neighborhood are farther than 300 feet from the nearest house. No poles, no network. ... Without this zoning change, however, our wireless providers will not be able to install the new networks. The companies will eventually take us to court, because Congress and the FCC have already established that local governments can't block networks."*** [emphasis added] "P.S., ***You might see some people claim that Radio Frequency emissions cause cancer. Safety always comes first, I agree. But, the American Cancer Society says "Cell phone towers are not known to cause any health effects***." Read for yourself what the ACS has to say about cell phones and cell towers, based on input from many scientific studies and expert agencies. Then read this New York Times piece about 5G and health, and this piece about how Russian disinformation agents have targeted Americans with 5G scaremongering." *** Note:** This opinion piece above argues in favor of setbacks as low as 30 feet. In November 2019, the proposed version of the ZTA included a minimum setback of 60 feet, which could only be lowered to30 feet under certain conditions. However, in March 2021, the ZTA was amended to allow towers only 30 feet from homes with no notice, and zero setback after giving notice. See https://www.montgomerycountymd.gov/COUNCIL/Resources/Files/zta/2019/ZTA_19-07.pdf
January 4, 2020	**Twitter:**  **Hans Riemer** @hansriemer Jan 4, 2020 Sorry but FM radio, wifi, 3g, 4g, 5g is all the same and not dangerous. You are peddling junk science like the anti vaxxers.

March 11, 2020	**Opinion in the Washington Post titled "Montgomery County should not let junk science stop 5G"** https://www.washingtonpost.com/opinions/local-opinions/the-deployment-of-5g-sparks-a-turf-war-in-montgomery-county/2020/03/05/706510b2-5279-11ea-b119-4faabac6674f_story.html Mr. Riemer was featured in this Opinion piece **written by Art Brodsky*** as a long-time promotor of small cell deployment. It was noted that a pro small cell 5G speaker was "harassed and harangued by the true believers in junk science with such vehemence.....". **** Note that MG5Gpartnership.com prominently features a link to a "guest column" that contains this article. Mr. Brodsky is a freelance telecommunications writer who regularly appears in various publications. Similar to Mr. Riemer, Mr. Brodsky also classifies opponents of 5G as peddlers of "junk science."***
June 29, 2021	**Council meeting** video — ZTA 19–07 starts @ approx. 2:04:28 https://youtu.be/Fy98kb_omS4?t=7468 **Councilmember Hans Riemer, lead sponsor of the ZTA:** "I think it's really about whether we all and I believe we do have a better understanding of public health, and how the public health system works, and who we would listen to on matters of public health. And we I'm going to want to talk about this very briefly once at the outset, I don't think we really need to spend much time on it. ***But we're hearing a lot of false claims about health concerns for the waves that come out of our devices, you know, that connect from our device to an antenna that connect from a Wi-Fi router in our house to our laptop, you know, connect, frankly, AM FM radio or all of this is all part of a spectrum. It's called non ionizing radiation. And science has not yet found a health concern with any of it. << >> It is one of the most extensively studied issues out there. And if we were hearing from people like Dr. Fauci, Dr. Walensky, the head of the FDA that they had a concern like we would all know, if our leading scientific agencies were concerned about this. We do not hear from them."*** [emphasis added]
June 29, 2021	**Council meeting** Memorandum prepared by Council staff attorney as advice to Council, page 12. The dismissal referred to below was in the case of *Montgomery County v FCC*, which was dismissed on procedural grounds in August 2020 and later followed by a successful petition by *Environmental Health Trust et al. v FCC*, which was decided August 13, 2021. *Environmental Health Trust* advanced many of the same arguments that Montgomery County put forward when the County had previously chosen to be a co-petitioner. https://www.montgomerycountymd.gov/council/Resources/Files/agenda/col/2021/20210629/20210629_4.pdf "Under federal law, local jurisdictions are preempted from regulating telecommunications antennas because of health effects as long as those facilities are operating within **FCC**-determined power and RF ranges. In its appeal of the FCC order, the County challenged the **FCC**'s failure to address RF emissions. In addition, the County and other jurisdictions asked the **FCC** to update and complete a 2013 evaluation of the existing RF safety standards. The **FCC** has refused to review its standards and has disagreed with concerns raised about RF emissions from 5G small cell antennas. The [Ninth Circuit] dismissed the County's challenge as moot, finding that the **FCC**'s additional order considered RF exposure risks of 5G services."

July 13, 2021	**Council meeting** Memorandum prepared by Council staff attorney as advice to Council, page 5. The dismissal referred to below was later appealed successfully in *Environmental Health Trust v FCC.* https://www.montgomerycountymd.gov/council/Resources/Files/agenda/col/2021/20210713/20210713_10A.pdf “In City of Portland v. United States, the United States Court of Appeals for the 9th Circuit ruled on petitions filed by a coalition of local governments, including Montgomery County, challenging multiple **FCC** orders governing small cell telecommunications facilities. The 9th Circuit also ruled on the County’s separate petition, which argued that the FCC erred by not updating its regulations governing Radio Frequency (RF) emissions before issuing the small cell order. The 9th Circuit dismissed as moot the County’s petition”.
July 13, 2021	**Council meeting** video -– ZTA 19–07 starts @ approx. 10:36 https://www.youtube.com/watch?v=TzIFJo358Ow&t=636s **Council Vice President Gabe Albornoz, co-sponsor of the ZTA:** "I do put a tremendous amount of faith in our federal agencies ... and the systems that we currently have in place, have conducted their own extensive research on a variety of issues that impact us." **Councilmember Hans Riemer, lead sponsor of the ZTA:** "The National Institutes of Health, the National Cancer Institute, located in Montgomery County, not the only federal agency with oversight here for health, ..., you can see similar information on the **FDA** website, and is actually an agency called the National Council for Radiation Safety. And it's actually the true scientific agency charged with monitoring the research, it's based in Bethesda, they all say the same thing. The National Cancer Institute's page makes very clear that the waves coming out of our devices are not of health concern, presuming the installations follow federal policy. And that, you know, basically the way you could be injured by these waves is if you were burned by them, they were so concentrated that actually would burn your skin, that the heat would cause some kind of damage to your DNA. I think it's clear to all of us that we are nowhere, nowhere near anything like that. And that's that basic theoretical framework for this entire you know, body of research has been in place for decades. And in fact, it's one of the best understood concerns…. ***With all existing research. The weight of it all together, clearly establishes it, safety. Research is always ongoing; World Health Organization comes to the same conclusion. So if you don't believe that, you know, there is a health concern, what is the basis of trying to severely restrict these installations? I just ask everyone to think, think about that question, what is the basis of trying to severely restrict these if you actually follow the science and believe the science.***" [emphasis added]
July 20, 2021	**Council meeting** video — ZTA 19–07 starts @ approx. @ 28:31 https://youtu.be/QSta29AgP8Y?t=1711 **Councilmember Hans Riemer, lead sponsor of the ZTA:** "I have posted several times in the past few days what I think is critically important guidance from the **FDA**, the National Cancer Institute, the American Cancer Society, the World Health Organization, and many, many of all of the leading scientific institutions that have purview to this issue have weighed thousands of studies conducted over decades. And they are very clear. And their conclusion that they're not seeing evidence of health impacts from our phones."

July 27, 2021	**Council meeting** video — ZTA 19–07 starts @ approx. 3:07:57 https://youtu.be/H4VEoPHEdxc?t=11277 **Councilmember Hans Riemer, lead sponsor of the ZTA:** "What the scientific agencies do, the National Cancer Institute, the **FDA**, CDC, the World Health Organization, what they do is they look at all the studies, and they add them all up into a ledger. And they say, what is most compelling? What studies bring the strongest evidence? That is the scientific process here. And there's no real argument among those agencies, they all arrive at the same conclusion. There is an Institute based in Bethesda. It's called the National Center for Radiation Safety. It's headquartered in Montgomery County, the scientists there have been working on these issues for decades, I've spoken with them, they are very clear that the radiofrequency emissions on one side of the spectrum are very, very limited risk. And those on the other side have very high risk. That's your x rays and all those other things. ***But the spectrum kind of breaks in half. And everything on the non-ionizing side has been found for more than 100 years now not to be dangerous. It's the same thing as AM / FM radio. And when radio was started, people said that birds were dropping out of the sky from radio waves. You know, it's our home Wi-Fi. It's non-ionizing radiation. If you believe it's dangerous, you should turn off your Wi-Fi. And honestly, if we really believed it was dangerous, we should ban Wi-Fi. I mean, do we really believe it's dangerous? Now? If we did, we would act you know. So the scientific method you have to be comfortable with a little bit of more research is needed as a concept. At the same time, trusting and I'm willing to trust in the authorities that are charged with this work. ... colleagues know at times I have taken controversial views, controversial positions on issues like polystyrene, we banned polystyrene, because I was convinced that there was an issue there, we banned lawn pesticides, you know, but chemicals and radio, radio frequency waves are extremely different. And that's something that the chief scientist explained to me. You know, a chemical could have unknown impacts. radio frequency waves generally have very known impacts whatever part of the spectrum they're from, on the non-ionizing side."*** [emphasis added] "So, in any event, I think with the NIH, the **FDA**, the National Center for Radiation Safety, all headquartered Montgomery County, we would be well advised to follow their guidance. There are 1000s of employees who are our constituents. ***And last thing I'll say there is a correlation between the extreme views on this issue and other issues like vaccine criticism, anti facts and anti 5g. There's common ground there. There are 5g conspiracies, about microchips being implanted in vaccines, you've heard about that. This is what our communities are being inundated with, day in and day out is disinformation. And our job is to sift through it all."*** **Councilmember Craig Rice, Co-Sponsor of the ZTA:** "So let's not be the alarmist who tries to make it seem as though you know, we're doing something that's going to jeopardize this the health and safety of our community. Many of us have thought about that. And although we can't think about it, in terms of how we vote on this particular ZTA, it doesn't mean that we don't think about it, we're still human beings. These are our families; we have children who will be near these things. So we of course, care about it. ***So let's just be real about the fact that yes, we consider this we're the same council who, you know, ban, or who made it mandatory to be radon testing, why? Because radon is proven, right, proven to cause cancer or cause lung cancer.*** And so we took steps, I led that effort. So we do care about health, we do care about causing cancer, we are concerned about those kinds of things. So yes, while we can't, in consideration of moving the ZTA forward, say that this is a reason why we shouldn't do it. It doesn't mean that we don't think about it, then we don't care about it. And we wouldn't move forward if we thought we were doing something dangerous, period." [emphasis added] "Just lastly, when it comes to you know, Councilmember Jawando's comment about the *Environmental Health Trust v. FCC]* court case, but there are always going be court cases . . . Now, as more information comes about, obviously, ***if a court case comes down and changes where things are not just us here in little Montgomery County, but across the United States of America will have to make adjustments based on what that ruling is***. So this affects more than just Montgomery County. " [emphasis added]

July 28, 2021	**Excerpt from an email from Councilmember Hans Riemer, lead sponsor of the ZTA, to constituents following the Council's passage of ZTA 19-07 allowing cell towers in close proximity to residences** https://councilmemberriemer.com/2021/07/we-need-better-wireless-service-now-we-will-get-it.html **What do leading public health authorities say about cell phones and 5G?** Safety comes first. Fortunately, the science on wireless waves is compelling. The leading national and international scientific institutes continue to find that cell phones are not linked to health problems. The **FDA**, which we are proud to have located here, reviews the existing studies and puts them all into a balance. The **FDA** clearly says, the "weight of scientific evidence has not linked cell phones with any health problems." ***This has been a tough one. If you've seen some alarmist messages on your local listserve, I hope this email has been helpful. You might also enjoy this article about how the KGB is funding disinformation about 5G*** [emphasis added] https://www.nytimes.com/2019/05/12/science/5g-phone-safety-health-russia.html
Various **MD5GPartnership.com** articles *** Note: MD5gpartnership.com members include such wireless and infrastructure providers as T-Mobile, Crown Castle and Verizon.**	**An Overview –– Montgomery County's Small Cell Legislation** https://md5gpartnership.com/wp-content/uploads/2021/05/ZTA-one-pager.5.2.21.2.pdf * **Excerpts** Since 2017, the Council has also considered legislation that would permit and streamline small cell antennas in residential zones, with the latest effort beginning in October 2019 when residential ZTA 19-07 was introduced. Following a public hearing in November 2019, Council discussions on ZTA 19-07 were put on hold. ARE SMALL CELLS SAFE? The consensus among the scientific and health communities is that there is no evidence of any adverse effects from exposure to radiofrequency (RF) emissions below **FCC** exposure limits. RF emissions safety has been studied for more than 60 years and the research is subject to constant review by government health agencies, and standard-setting organizations, like the **FCC** and **FDA**. In December 2019, the **FCC** reaffirmed safety standards on a unanimous and bipartisan basis. RF energy from antennas used in cellular transmissions, including small cells, result in exposure levels well below **FCC** safety limits. MD5g Partnership Launches in Support of 5G Deployment Throughout Maryland https://md5gpartnership.com/md5g-partnership-launches-in-support-of-5g-deployment-throughout-maryland/ Montgomery County Should Not Let Junk Science Stop 5G https://md5gpartnership.com/montgomery-county-should-not-let-junk-science-stop-5g-2/ Will Montgomery County Fall Behind? https://md5gpartnership.com/will-montgomery-county-fall-behind/ County Council Amends Bill that Could Allow 5G Cell Antennas, Rejects Further Delay https://md5gpartnership.com/county-council-amends-bill-that-could-allow-5g-cell-antennas-rejects-further-delay/ Montgomery County: Support for ZTA 19-07 https://md5gpartnership.com/montgomery-county-support-for-zta-19-07/

ENVIRONMENTAL HEALTH TRUST

2022

5G, 4G CELL TOWER RADIATION

A REGULATORY GAP

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THE NEED FOR ACCOUNTABILITY ON WIRELESS SAFETY

EXPERT VOICES

"The National Toxicology Program studies clearly showed that non-ionizing cell phone radiofrequency radiation radiation can cause cancers and other adverse health effects. An important lesson that should be learned is that we cannot assume any current or future wireless technology such as 5G is safe without adequate testing."
-Ronald Melnick PhD 28 year scientist at National Institutes of Health

"I recommend public health organizations raise awareness and educate the public on why and how to reduce our daily exposure to wireless radio frequency radiation. Protective public health policy is needed now. It is time for regulatory bodies to fully evaluate the research and develop science based exposure limits that truly protect the public and the environment."
-Linda S. Birnbaum, PhD, Former Director, National Institute of Environmental Health Sciences and National Toxicology Program of the National Institutes of Health.

"Now we have 5G rolling out in massive quantities, without due diligence to determine are these sources of radiation safe not only for humans but for wildlife. And the answer is, no, they are not."
-Albert M. Manville II, Ph.D. Adjunct Professor, Johns Hopkins University, Wildlife Biologist (17 years), retired from Division of Migratory Bird Management, U.S. Fish & Wildlife Service

"Given the human, animal and experimental evidence, I assert that, to a reasonable degree of scientific certainty, the probability that RF exposure causes gliomas and neuromas is high."
-Christopher Portier PhD former Director of the United States National Center for Environmental Health at the CDC, former Director of the U.S. Agency for Toxic Substances and Disease Registry.

"We should not wait to protect children's brains. The science is now clear and compelling indicating that wireless technology is harmful to health, especially to for children. Wireless radiation is repeating the history of lead, tobacco and DDT."
-Devra Davis PhD, MPH, President of Environmental Health Trust, founding director of the Board on Environmental Studies and Toxicology of the U.S. National Research Council, National Academy of Sciences, and a member of the team of the Intergovernmental Panel on Climate Change scientists who were awarded the Nobel Peace Prize in 2007

ENVIRONMENTAL HEALTH TRUST

A REGULATORY GAP
No Federal Agency Ensuring Cell Tower Wireless Safety

There is no U.S. government agency with oversight for cell tower radiation health effects: no research reviews, no reports, no environmental monitoring, no risk mitigation and no post market health surveillance for the daily, full body radio-frequency (RF) radiation exposure from cell towers.

"The FDA does not regulate cell towers or cell tower radiation. Therefore, the FDA has no studies or information on cell towers to provide in response to your questions."
-Ellen Flannery, Director, FDA Policy Center for Devices and Radiological Health to a California mother with a cell tower on her street who asked the FDA about safety, July 11, 2022

"As a Federal research agency, the NCI is not involved in the regulation of radio frequency telecommunications infrastructure and devices, nor do we make recommendations for policies related to this technology"
-National Cancer Institute letter to Denise Ricciardi, member of the New Hampshire State Commission on 5G, July 30, 2020

The ACS does "not have any official position or statement on whether or not radiofrequency radiation from cell phones, cell phones towers, or other sources is a cause of cancer."
-American Cancer Society Website

"EPA's last review was in the 1984 document Biological Effects of Radiofrequency Radiation. The EPA does not currently have a funded mandate for radiofrequency matters."
-Lee Ann B. Veal Director, EPA Radiation Protection Division Office of Radiation and Indoor Air, July 8, 2020 Letter to Theodora Scarato

Fact: There are no scientific reports by the CDC on cell tower radiation safety, nor does the agency have staff with expertise monitoring the science and evaluating risk. Public information requests found that **several CDC website pages on radio frequency were found to be drafted with a wireless industry consultant.**

"The electromagnetic radiation standards used by the Federal Communications Commission (FCC) continue to be based on thermal heating, a criterion now nearly 30 years out of date and inapplicable today." **- U.S. Department of Interior Letter to FCC, 2014**

Fact: The World Health Organization (WHO) EMF Project has not reviewed the science since 1993. The WHO webpages on cell phones and cell towers are not based on a published scientific review. The WHO EMF Project webpages were written by a scientist who **used wireless industry money** to start the WHO EMF Project and who is now a consultant to industry. **In contrast, the WHO International Agency for Research on Cancer (a separate WHO entity vetted for conflicts of interest) determined RF radiation to be a Class 2 B "possible" carcinogen in 2011.** Many scientists now state **the evidence showing cancer has increased.**

Blue text *is hyperlinked to source.*

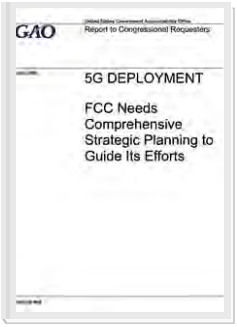
Government Accountability Office Reports

These GAO reports confirm zero review of the totality of the science and bust the industry myth that 5G will bridge the digital divide.

2020: 5G Wireless: Capabilities and Challenges for an Evolving Network

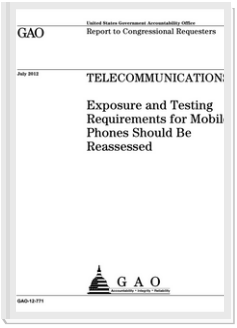
"Because there is a large and evolving body of relevant research, it is important that the results be regularly synthesized for Congress and the public."

"The FCC relies on the FDA as well as other organizations—principally IEEE and the National Council on Radiation Protection and Measurements (NCRP)—to review scientific research and provide recommendations for setting RF safety standards. **However, each of these organizations has only reviewed a subset of the relevant research…"**



2020 5G DEPLOYMENT: FCC Needs Comprehensive Strategic Planning to Guide Its Efforts

"The experts GAO convened also stated that 5G deployment would likely exacerbate disparities in access to telecommunications services, known as the "digital divide."



2012 TELECOMMUNICATIONS: Exposure and Testing Requirements for Mobile Phones Should Be Reassessed

"By not formally reassessing its current limit, FCC cannot ensure it is using a limit that reflects the latest research on RF energy exposure…"

"Some consumers may use mobile phones against the body, which FCC does not currently test, and could result in RF energy exposure higher than the FCC limit."

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LEGAL & LIABILITY ISSUES

"Electromagnetic field exclusions" are clear and common in most insurance companies. It is applied as a market standard. This exclusion serves to exclude cover for illnesses caused by long-term EMF (non-ionizing radiation) exposure."
-**Complete Markets "Electromagnetic Fields Liability Insurance**"

"Electro-magnetic signals emitted by mobile devices and base stations may be found to pose health risks, with potential impacts including: changes to national legislation, a reduction in mobile phone usage or litigation."
-Vodaphone 2017 Report ranks EMF as a "Principal Risk with "High" impact.

Swiss Re Institute (2019)

5G mobile networks are classified as a "high," "off-the-leash" risk. "Existing concerns regarding potential negative health effects from electromagnetic fields (EMF) are only likely to increase. An uptick in liability claims could be a potential long-term consequence" and "[a]s the biological effects of EMF in general and 5G in particular are still being debated, potential claims for health impairments may come with a long latency."

Crown Castle

"We cannot guarantee that claims relating to radio frequency emissions will not arise in the future or that the results of such studies will not be adverse to us...If a connection between radio frequency emissions and possible negative health effects were established, our operations, costs, or revenues may be materially and adversely affected. We currently do not maintain any significant insurance with respect to these matters."

Portland Oregon Public School Insurance

"Exclusions: This insurance does not apply to: Bodily injury, personal injury, advertising injury, or property damage arising directly or indirectly out of, resulting from, caused or contributed to by electromagnetic radiation, provided that such loss, cost or expense results from or is contributed to by the hazardous properties of electromagnetic radiation."

Verizon 10-K

"our wireless business also faces personal injury and wrongful death lawsuits relating to alleged health effects of wireless phones or radio frequency transmitters. We may incur significant expenses in defending these lawsuits. In addition, we may be required to pay significant awards or settlements."

Verizon Total Mobile Protection Plan (pg 10)

"Pollution" is defined as "any solid, liquid, gaseous, or thermal irritant or contaminant including smoke, vapor, soot, fumes, acid, alkalis, chemicals, artificially produced electric fields, magnetic field, electromagnetic field, sound waves, microwaves, and all artificially produced ionizing or nonionizing radiation and/or waste."

This PDF is hyperlinked. For more on legal liability issues go to ehtrust.org

ENVIRONMENTAL HEALTH TRUST

Cell Tower Companies Warn Shareholders of Risk From Cell Tower Radiation

Why Don't They Warn Families Living Near Cell Towers?

Verizon 10-K Report

"our wireless business also faces personal injury and wrongful death lawsuits relating to alleged health effects of wireless phones or radio frequency transmitters. We may incur significant expenses in defending these lawsuits. In addition, we may be required to pay significant awards or settlements."

Crown Castle 10-K Report

"We cannot guarantee that claims relating to radio frequency emissions will not arise in the future or that the results of such studies will not be adverse to us...If a connection between radio frequency emissions and possible negative health effects were established, our operations, costs, or revenues may be materially and adversely affected. We currently do not maintain any significant insurance with respect to these matters."

AT&T 10-K Report

"In the wireless area, we also face current and potential litigation relating to alleged adverse health effects on customers or employees who use such technologies including, for example, wireless devices. We may incur significant expenses defending such suits or government charges and may be required to pay amounts or otherwise change our operations in ways that could materially adversely affect our operations or financial results."

T- MOBILE 10-K Report

"Our business could be adversely affected by findings of product liability for health or safety risks from wireless devices and transmission equipment, as well as by changes to regulations or radio frequency emission standards."

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Cell Tower Companies Warn Shareholders of Risk From Cell Tower Radiation

Why Don't They Warn Families Living Near Cell Towers?

American Tower 10-K

"If a scientific study or court decision resulted in a finding that radio frequency emissions pose health risks to consumers, it could negatively impact our tenants and the market for wireless services, which could materially and adversely affect our business, results of operations or financial condition. We do not maintain any significant insurance with respect to these matters."

Nokia 10-K

"Although our products are designed to meet all relevant safety standards and other recommendations and regulatory requirements globally, we cannot guarantee we will not become subject to product liability claims or be held liable for such claims, which could have a material adverse effect on us."

Qualcomm 10-K

"If wireless handsets pose health and safety risks, we may be subject to new regulations, and demand for our products and those of our licensees and customers may decrease."

Ericsson Annual Report

"Any perceived risk or new scientific findings of adverse health effects from mobile communication devices and equipment could adversely affect us through a reduction in sales or through liability claims."

This PDF is hyperlinked. For more on legal liability issues go to ehtrust.org

EXPERT VOICES

"I am calling on my industry to bring safer technology to market. The current implementation of technology is not safe. Take a good look at the science. This is about our children's future. Do not be lulled into believing that 25-year-old standards can protect the youngest and most vulnerable. They simply cannot."
- Frank Clegg, Former President of Microsoft Canada, CEO of Canadians for Safe Technology

"A moratorium is urgently needed on the implementation of 5G for wireless communication."
-Lennart Hardell, MD, PhD , advisory to World Health Organization international Agency for Research on Cancer, Department of Oncology, University Hospital, Örebro, Sweden (retired) , leads the Environment and Cancer Research Foundation

"The evidence indicating wireless is carcinogenic has increased and can no longer be ignored. If the World Health Organization International Agency for Research on Cancer were to meet to review all of the evidence, we believe the weight of evidence supports a new determination- that wireless radiofrequency radiation is a human carcinogen."
-Anthony B. Miller MD, Professor Emeritus, Dalla Lana School of Public Health of the University of Toronto. Former Senior Epidemiologist for the International Agency for Research on Cancer and former Director of the Epidemiology Unit of the National Cancer Institute of Canada

"Most parents believe that cellphones were safety-tested before they came on the market. We assume that our federal health and environmental agencies regularly review the latest research and ensure that these incredible devices are safe. They do not. Children are not little adults. As we sadly learned with early childhood lead exposures leaving long-lasting impairments, the developing brain is particularly susceptible."
-Jerome Paulson, MD , Professor Emeritus, George Washington University, Milliken School of Public Health, former Chair of American Academy of Pediatrics Committee on Environmental Health

"The exposure levels of the Federal Communications Commission are totally outdated and do not protect the health of the public, especially of children. I urge you to take strong and active steps to reduce exposure of children and staff to excessive levels of radiofrequency EMFS within your schools."
-David O. Carpenter, M.D. Director, Institute for Health and the Environment University at Albany

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5G, CELL TOWERS AND WIRELESS

LEGAL & LIABILITY ISSUES

When a new cell tower or wireless network is proposed the first question to ask is "Do you have insurance for damages from long-term exposure to the radiofrequency radiation (RFR)?" Usually the answer is "No."

An Uninsurable Risk?

- Insurers rank wireless, cell tower, and 5G RFR non-ionizing electromagnetic radiation as a "high" risk, comparing the issue to lead and asbestos.
- Most insurance plans have "electromagnetic field exclusions" and do not insure for long-term RFR damages.
- Wireless RFR and non-ionizing electromagnetic radiation are defined as a type of "pollution" by wireless companies themselves.
- US mobile operators have been unable to get insurance to cover liabilities related to damages from long-term RFR exposure.
- Wireless companies warn their shareholders of RFR risk but do not warn users of their products, nor do the companies warn the people exposed to emissions from their infrastructure.

This PDF is hyperlinked. For more on legal liability issues go to ehtrust.org

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CITIES AND TOWNS WITH STRONG ORDINANCES

SETBACKS FOR CELL ANTENNAS

Many communities have setbacks for cell towers and small cells.

Shelburne, MA: 3,000 feet for schools and 1,500 feet of homes; no new wireless antennas in residential zones
Copake, NY: 1,500 feet from homes, schools, churches, or other buildings containing dwelling units
Sallisaw, OK: No commercial wireless telecommunications towers within 1,500 of homes.
Calabasas, CA: No "Tier 2" wireless telecommunications facilities within 1,000 feet of homes and schools
Bedford, NH: 750 feet from residentially-zoned property
Scarsdale, NY: No wireless facilities within 500 feet from homes, schools, parks, and houses of worship
Walnut City, California: 1,500 feet
Stockbridge, Massachusetts: 1,000 feet
San Diego County California: 1,000 feet (small cells)
Bar Harbor Maine: 1500 setback for schools

School Boards
Palo Alto, California: School Board supports the City of Palo Alto immediately establishing local municipal zoning setback rules of 1500 feet or more from an operating wireless transmitter and a school site.
West Linn-Wilsonville Oregon School Board prohibits cell towers on school property.
Los Angeles California School District: Resolutions opposing cell towers on school property and a cautionary level" for radiofrequency radiation 10,000 times lower than FCC limits.

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American Academy of Pediatrics Webpage Excerpts

Electromagnetic Fields: A Hazard to Your Health?

In recent years, concern has increased about exposure to radio frequency electromagnetic radiation emitted from cell phones and phone station antennae. An Egyptian study confirmed concerns that living nearby mobile phone base stations increased the risk for developing:

- Headaches
- Memory problems
- Dizziness
- Depression
- Sleep problems

Short-term exposure to these fields in experimental studies have not always shown negative effects, but this does not rule out cumulative damage from these fields, so larger studies over longer periods are needed to help understand who is at risk. In large studies, an association has been observed between symptoms and exposure to these fields in the everyday environment.

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Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

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.

The 2022 study "**Measurements of radiofrequency electromagnetic fields, including 5G, in the city of Columbia, South Carolina, USA**" published in World Academy of Sciences Journal authored by Tarmo Koppel and Lennart Hardell MD of the Environment and Cancer Research Foundation found the highest RF exposure readings were registered close to cell phone base station antennas mounted on top of utility poles, street lamps or traffic lights.

WORLD ACADEMY OF SCIENCES JOURNAL 4: 23, 2022

Measurements of radiofrequency electromagnetic fields, including 5G, in the city of Columbia, SC, USA

TARMO KOPPEL[1,3] and LENNART HARDELL[2]

Figure 7. Gervais Street: Cell phone base station antenna placed close to street level and causing high exposure to pedestrians and nearby café visitors (exposure scenario illustration). The antenna appears camouflaged and seemingly part of a utility pole. The measurer only discovered the antenna due to the high radiofrequency levels in the vicinity.

WORLD ACADEMY OF SCIENCES JOURNAL 4: 23, 2022

Measurements of radiofrequency electromagnetic fields, including 5G, in the city of Columbia, SC, USA

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Figure 8. Gervais Street: Another cell phone base station antenna close to street level and causing high exposure to pedestrians (exposure scenario illustration). Note the antenna appears undistinguishable from the utility pole an unnoticeable between the trees.

European Parliament

Health impact of 5G

STUDY

Panel for the Future of Science and Technology

EPRS | European Parliamentary Research Service

Scientific Foresight Unit (STOA)

PE 690.012 – July 2021

Health impact of 5G

Current state of knowledge of 5G-related carcinogenic and reproductive/developmental hazards as they emerge from epidemiological studies and in vivo experimental studies

The upcoming deployment of 5G mobile networks will allow for significantly faster mobile broadband speeds and increasingly extensive mobile data usage. Technical innovations include a different transmission system (MIMO: use of multiple-input and multiple-output antennas), directional signal transmission or reception (beamforming), and the use of other frequency ranges. At the same time, a change is expected in the exposure to electromagnetic fields (EMF) of humans and the environment. In addition to those used to date, the 5G pioneer bands identified at EU level have frequencies of 700 MHz, 3.6 GHz (3.4 to 3.8 GHz) and 26 GHz (24.25 to 27.5 GHz). The first two frequencies (FR1) are similar to those used for 2G to 4G technologies and have been investigated in both epidemiological and experimental studies for different end points (including carcinogenicity and reproductive/developmental effects), while 26 GHz (FR2) and higher frequencies have not been adequately studied for the same end points.

The International Agency for Research on Cancer (IARC) classified radiofrequency (RF) EMF as 'possibly carcinogenic to humans' (Group 2B) and recently recommended RF exposure for re-evaluation 'with high priority' (IARC, 2019). Since 2011 a great number of studies have been performed, both epidemiological and experimental. The present review addresses the current knowledge regarding both carcinogenic and reproductive/developmental hazards of RF as exploited by 5G. There are various *in vivo* experimental and epidemiological studies on RF at a lower frequency range (450 to 6000 MHz), which also includes the frequencies used in previous generations' broadband cellular networks, but very few (and inadequate) on the higher frequency range (24 to 100 GHz, centimetre/MMW).

The review shows: 1) 5G lower frequencies (700 and 3 600 MHz): a) limited evidence of carcinogenicity in epidemiological studies; b) sufficient evidence of carcinogenicity in experimental bioassays; c) sufficient evidence of reproductive/developmental adverse effects in humans; d) sufficient evidence of reproductive/developmental adverse effects in experimental animals; 2) 5G higher frequencies (24.25-27.5 GHz): the systematic review found no adequate studies either in humans or in experimental animals.

Conclusions: 1) cancer: FR1 (450 to 6 000 MHz): EMF are probably carcinogenic for humans, in particular related to gliomas and acoustic neuromas; FR2 (24 to 100 GHz): no adequate studies were performed on the higher frequencies; 2) reproductive developmental effects: FR1 (450 to 6 000 MHz): these frequencies clearly affect male fertility and possibly female fertility too. They may have possible adverse effects on the development of embryos, foetuses and newborns; FR2 (24 to 100 GHz): no adequate studies were performed on non-thermal effects of the higher frequencies.

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Very high radiofrequency radiation at Skeppsbron in Stockholm, Sweden from mobile phone base station antennas positioned close to pedestrians' heads

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Fig. 3. Street view on the Skeppsbron street with some of the mobile phone base station antennas pointed out with a circle; note the low placement of the antennas, where microwaves irradiate the pedestrian at close range.

A B S T R A C T

In urban environment there is a constant increase of public exposure to radiofrequency electromagnetic fields from mobile phone base stations. With the placement of mobile phone base station antennas radiofrequency hotspots emerge. This study investigates an area at Skeppsbron street in Stockholm, Sweden with an aggregation of base station antennas placed at low level close to pedestrians' heads. Detailed spatial distribution measurements were performed with 1) a radiofrequency broadband analyzer and 2) a portable exposimeter. The results display a greatly uneven distribution of the radiofrequency field with hotspots. The highest spatial average across all quadrat cells was 12.1 V m^{-1} (388 mW m^{-2}), whereas the maximum recorded reading from the entire area was 31.6 V m^{-1} (2648 mW m^{-2}). Exposimeter measurements show that the majority of exposure is due to mobile phone downlink bands. Most dominant are 2600 and 2100 MHz bands used by 4G and 3G mobile phone services, respectively. The average radiofrequency radiation values from the earlier studies show that the level of ambient RF radiation exposure in Stockholm is increasing. This study concluded that mobile phone base station antennas at Skeppsbron, Stockholm are examples of poor radiofrequency infrastructure design which brings upon highly elevated exposure levels to popular seaside promenade and a busy traffic street.

Studies from recent decades have shown elevated health risk under long term exposure to such highly elevated radiofrequency fields.

A review by Khurana et al. (2010) found in 80% of the available studies neurobehavioral symptoms or cancer in populations living at distances <500 m from base stations (Khurana et al., 2010). In another review exposure from base stations and other antenna arrays showed changes in immunological and reproductive systems as well as DNA double strand breaks, influence on calcium movement in the heart and increased proliferation rates in human astrocytoma cancer cells (Levitt and Lai, 2010).

When a GSM 900 MHz base station was installed in the village Rimbach in Germany it had an influence on the neurotransmitters adrenaline, noradrenaline, dopamine and phenyletylamine (Buchner and Eger, 2011). Influence on cortisol and thyroid hormones in people living near base stations was shown in other studies (Augner et al., 2010; Eskander et al., 2012).

Dode et al. (2011 compared base station (BS) clusters and cases of deaths by neoplasia in the Belo Horizonte municipality, Minas Gerais state, Brazil, from 1996 to 2006. In their study largest electric field was 12.4 V m^{-1} and the smallest was 0.4 V m^{-1}. They found cancer-related death rates be higher close to base stations. This finding confirmed earlier findings by Eger (Eger et al., 2004).

In a study from India, genetic damage using the single cell gel electrophoresis (comet) assay was assessed in peripheral blood leukocytes of individuals residing in the vicinity of a mobile phone base station and comparing it to that in healthy controls. Genetic damage parameters of DNA migration length, damage frequency, and damage index were significantly ($p < 0.001$) elevated in the sample group compared to respective values in healthy controls (Gandhi et al., 2014).

The effect of RF radiation among 20 subjects living close to mobile phone base station compared with 20 subjects living with a distance of about 1 km was studied (Singh et al., 2016). The authors concluded that: "*It was unveiled that a majority of the subjects who were residing near the mobile base station complained of sleep disturbances, headache, dizziness, irritability, concentration difficulties, and hypertension. A majority of the study subjects had significantly lesser stimulated salivary secretion ($p < 0.01$) as compared to the control subjects.*"

Zothansiama et al. (2017) in India inspected DNA damage a antioxidant status in cultured human peripheral blood lymphocy (HPBLs) of individuals residing in the vicinity of mobile phone b stations and compared it with healthy controls living further away. analyses of data from the exposed group (n = 40), residing withi perimeter of 80 m of mobile base stations, showed statistically sign cantly ($p < 0.0001$) higher frequency of micronuclei when compare the control group, residing 300 m away from the mobile base statio

The Ramazzini Institute findings (Falcioni et al., 2018) are suppor by the results in the USNTP study on rats and mice exposed to RF diation (National Toxicology Program, 2018a, 2018b). A clear evide of increased incidence of heart Schwannoma and some evidence glioma and tumours in the adreanal medulla in male rats was fo according to the expert panel, for further discussion see Hardell Carlberg (2019).

The study concluded that Skeppsbron street mobile phone base station antennas are examples of a poor radiofrequency infrastructure design with mobile phone base station antennas positioned into close range to the general public which brings upon high exposure levels. Given the low placement of the antennas (height from the street floor), the highest exposure was often registered at pedestrian head level. Given that head is one of most vulnerable parts of the body, these placements by mobile telephony service providers put pedestrians into unnecessary risk. Position of these antennas, can pose a health risk to people at close range. This is especially critical for people at particular risk, including persons with medical implants, pregnant women or chronically ill persons.

Based on the latest scientific literature regarding RF exposure and adverse health effects, this study recommends repositioning such base station antennas to areas away from the nearby inhabitants, workers and the general public. Alternatively, very low power antennas may also be considered to reduce the exposure. Occupational exposure of people

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Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays

B. Blake Levitt and Henry Lai

Abstract: The siting of cellular phone base stations and other cellular infrastructure such as roof-mounted antenna arrays, especially in residential neighborhoods, is a contentious subject in land-use regulation. Local resistance from nearby residents and landowners is often based on fears of adverse health effects despite reassurances from telecommunications service providers that international exposure standards will be followed. Both anecdotal reports and some epidemiology studies have found headaches, skin rashes, sleep disturbances, depression, decreased libido, increased rates of suicide, concentration problems, dizziness, memory changes, increased risk of cancer, tremors, and other neurophysiological effects in populations near base stations. The objective of this paper is to review the existing studies of people living or working near cellular infrastructure and other pertinent studies that could apply to long-term, low-level radiofrequency radiation (RFR) exposures. While specific epidemiological research in this area is sparse and contradictory, and such exposures are difficult to quantify given the increasing background levels of RFR from myriad personal consumer products, some research does exist to warrant caution in infrastructure siting. Further epidemiology research that takes total ambient RFR exposures into consideration is warranted. Symptoms reported today may be classic microwave sickness, first described in 1978. Non-ionizing electromagnetic fields are among the fastest growing forms of environmental pollution. Some extrapolations can be made from research other than epidemiology regarding biological effects from exposures at levels far below current exposure guidelines.

Clinical Biochemistry
Volume 45, Issues 1–2, January 2012, Pages 157-161

Case Report

How does long term exposure to base stations and mobile phones affect human hormone profiles?

Emad F. Eskander ✉, Selim F. Estefan, Ahmed A. Abd-Rabou

Objectives

This study is concerned with assessing the role of exposure to radio frequency radiation (RFR) emitted either from mobiles or base stations and its relations v human's hormone profiles.

Results

This study showed significant decrease in volunteers' ACTH, cortisol, thyroid hormones, prolactin for young females, and testosterone levels.

Current Alzheimer Research, 2022, *19*, 119-132

MINI-REVIEW ARTICLE

Low Intensity Electromagnetic Fields Act *via* Voltage-Gated Calcium Channel (VGCC) Activation to Cause Very Early Onset Alzheimer's Disease: 18 Distinct Types of Evidence

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Abstract: Electronically generated electromagnetic fields (EMFs), including those used in wireless communication such as cell phones, Wi-Fi and smart meters, are coherent, producing very high electric and magnetic forces, which act on the voltage sensor of voltage-gated calcium channels to produce increases in intracellular calcium $[Ca^{2+}]i$. The calcium hypothesis of Alzheimer's disease (AD) has shown that each of the important AD-specific and nonspecific causal elements is produced by excessive $[Ca^{2+}]i$. $[Ca^{2+}]i$ acts in AD *via* excessive calcium signaling and the peroxynitrite/oxidative stress/inflammation pathway, which are each elevated by EMFs.An apparent vicious cycle in AD involves amyloid-beta protein (Aβ) and $[Ca^{2+}]i$. Three types of epidemiology suggest EMF causation of AD, including early onset AD. Extensive animal model studies show that low intensity EMFs cause neurodegeneration, including AD, with AD animals having elevated levels of Aβ, amyloid precursor protein and BACE1. Rats exposed to pulsed EMFs every day are reported to develop universal or near universal very early onset neurodegeneration, including AD; these findings are superficially similar to humans with digital dementia. EMFs producing modest increases in $[Ca^{2+}]i$ can also produce protective, therapeutic effects. The therapeutic pathway and peroxynitrite pathway inhibit each other. A summary of 18 different findings is provided, which collectively provide powerful evidence for EMF causation of AD. The author is concerned that smarter, more highly pulsed "smart" wireless communication may cause widespread very, very early onset AD in human populations.

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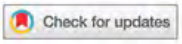

The roles of intensity, exposure duration, and modulation on the biological effects of radiofrequency radiation and exposure guidelines

Henry Lai[a] and B. Blake Levitt[b]

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ABSTRACT

In this paper, we review the literature on three important exposure metrics that are inadequately represented in most major radiofrequency radiation (RFR) exposure guidelines today: intensity, exposure duration, and signal modulation. Exposure intensity produces unpredictable effects as demonstrated by nonlinear effects. This is most likely caused by the biological system's ability to adjust and compensate but could lead to eventual biomic breakdown after prolonged exposure. A review of 112 low-intensity studies reveals that biological effects of RFR could occur at a median specific absorption rate of 0.0165 W/kg. Intensity and exposure duration interact since the dose of energy absorbed is the product of intensity and time. The result is that RFR behaves like a biological "stressor" capable of affecting numerous living systems. In addition to intensity and duration, man-made RFR is generally modulated to allow information to be encrypted. The effects of modulation on biological functions are not well understood. Four types of modulation outcomes are discussed. In addition, it is invalid to make direct comparisons between thermal energy and radiofrequency electromagnetic energy. Research data indicate that electromagnetic energy is more biologically potent in causing effects than thermal changes. The two likely functionthrough different mechanisms. As such, any current RFR exposure guidelines based on acute continuous-wave exposure are inadequate for health protection.

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KEYWORDS
Radiofrequency radiation (RFR); intensity; duration of exposure; modulation; specific absorption rate (SAR); biological effects

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MINI-REVIEW ARTICLE

Low Intensity Electromagnetic Fields Act *via* Voltage-Gated Calcium Channel (VGCC) Activation to Cause Very Early Onset Alzheimer's Disease: 18 Distinct Types of Evidence

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ELECTROMAGNETIC BIOLOGY AND MEDICINE
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REVIEW

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Genetic effects of non-ionizing electromagnetic fields

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ABSTRACT

This is a review of the research on the genetic effects of non-ionizing electromagnetic field (EMF), mainly on radiofrequency radiation (RFR) and static and extremely low frequency EMF (ELF-EMF). The majority of the studies are on genotoxicity (e.g., DNA damage, chromatin conformation changes, etc.) and gene expression. Genetic effects of EMF depend on various factors, including field parameters and characteristics (frequency, intensity, wave-shape), cell type, and exposure duration. The types of gene expression affected (e.g., genes involved in cell cycle arrest, apoptosis and stress responses, heat-shock proteins) are consistent with the findings that EMF causes genetic damages. Many studies reported effects in cells and animals after exposure to EMF at intensities similar to those in the public and occupational environments. The mechanisms by which effects are induced by EMF are basically unknown. Involvement of free radicals is a likely possibility. EMF also interacts synergistically with different entities on genetic functions. Interactions, particularly with chemotherapeutic compounds, raise the possibility of using EMF as an adjuvant for cancer treatment to increase the efficacy and decrease side effects of traditional chemotherapeutic drugs. Other data, such as adaptive effects and mitotic spindle aberrations after EMF exposure, further support the notion that EMF causes genetic effects in living organisms.

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KEYWORDS
Radiofrequency radiation; static/extremely low frequency EMF; genetic effects; genotoxicity; gene expression

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Article

The Effect of Continuous Low-Intensity Exposure to Electromagnetic Fields from Radio Base Stations to Cancer Mortality in Brazil

Nádia Cristina Pinheiro Rodrigues [1,2,*], Adilza Condessa Dode [3], Mônica Kramer de Noronha Andrade [1], Gisele O'Dwyer [1], Denise Leite Maia Monteiro [4], Inês Nascimento Carvalho Reis [1], Roberto Pinheiro Rodrigues [5,6], Vera Cecília Frossard [1] and Valéria Teresa Saraiva Lino [1]

Abstract: Background: this study aims to estimate the rate of death by cancer as a result of Radio Base Station (RBS) radiofrequency exposure, especially for breast, cervix, lung, and esophagus cancers. Methods: we collected information on the number of deaths by cancer, gender, age group, gross domestic product per capita, death year, and the amount of exposure over a lifetime. We investigated all cancer types and some specific types (breast, cervix, lung, and esophagus cancers). Results: in capitals where RBS radiofrequency exposure was higher than 2000/antennas-year, the average mortality rate was 112/100,000 for all cancers. The adjusted analysis showed that, the higher the exposure to RBS radiofrequency, the higher cancer mortality was. The highest adjusted risk was observed for cervix cancer (rate ratio = 2.18). The spatial analysis showed that the highest RBS radiofrequency exposure was observed in a city in southern Brazil that also showed the highest mortality rate for all types of cancer and specifically for lung and breast cancer. Conclusion: the balance of our results indicates that exposure to radiofrequency electromagnetic fields from RBS increases the rate of death for all types of cancer.

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Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission

A B S T R A C T

Background: In 2011, IARC classified radiofrequency radiation (RFR) as possible human carcinogen (Group 2B). According to IARC, animals studies, as well as epidemiological ones, showed limited evidence of carcinogenicity. In 2016, the NTP published the first results of its long-term bioassays on near field RFR, reporting increased incidence of malignant glial tumors of the brain and heart Schwannoma in rats exposed to GSM – and CDMA – modulated cell phone RFR. The tumors observed in the NTP study are of the type similar to the ones observed in some epidemiological studies of cell phone users.

Objectives: The Ramazzini Institute (RI) performed a life-span carcinogenic study on Sprague-Dawley rats to evaluate the carcinogenic effects of RFR in the situation of far field, reproducing the environmental exposure to RFR generated by 1.8 GHz GSM antenna of the radio base stations of mobile phone. This is the largest long-term study ever performed in rats on the health effects of RFR, including 2448 animals. In this article, we reported the final results regarding brain and heart tumors.

Methods: Male and female Sprague-Dawley rats were exposed from prenatal life until natural death to a 1.8 GHz GSM far field of 0, 5, 25, 50 V/m with a whole-body exposure for 19 h/day.

Results: A statistically significant increase in the incidence of heart Schwannomas was observed in treated male rats at the highest dose (50 V/m). Furthermore, an increase in the incidence of heart Schwann cells hyperplasia was observed in treated male and female rats at the highest dose (50 V/m), although this was not statistically significant. An increase in the incidence of malignant glial tumors was observed in treated female rats at the highest dose (50 V/m), although not statistically significant.

Conclusions: The RI findings on far field exposure to RFR are consistent with and reinforce the results of the NTP study on near field exposure, as both reported an increase in the incidence of tumors of the brain and heart in RFR-exposed Sprague-Dawley rats. These tumors are of the same histotype of those observed in some epidemiological studies on cell phone users. These experimental studies provide sufficient evidence to call for the re-evaluation of IARC conclusions regarding the carcinogenic potential of RFR in humans.

Trees in Bamberg and Hallstadt in the radiation field of 65 mobile phone base stations

Examples from a documentation about 700 trees (2006-2016)

A Tree Damages beginning on one side

The trees of the Bamberg-Documentation are numbered from 1 to 700.
Those trees which are part of the study „Radiofrequency radiation injures trees around mobile phone base stations“ (Science of the Total Environment 572 (2016) 554-569) have a second, red number.

Tree names	Tree species	No	No.	Addresses	Years of document.	felled	page
Maple	Acer platanoides	1	71	Railway station	2009-2013		3
Maple	Acer platanoides	2	56	Hauptsmoorstr. 26a	2008-2012		4
Maple	Acer platanoides	3	234	Berliner Ring	2013-2015		5
Maple	Acer platanoides	4	150	Katzenberg	2010-2011		6
Maple	Acer platanoides	5	304	P&R Heinrichsdamm	2008-2016		7
Maple	Acer platanoides	12	658	Hallstadt, LichtenfelserStr.	2008-2015		9
Maple	Acer platanoides	14	642	Hallstadt, Cemetery	2008-2016		11
Hornbeam	Carpinus betulus	17	181	Hauptsmoorstr. 85	2011-2012		12
Lime tree	Tilia sp.	28	673	Hotel Residenzschloss	2010-2015		13
Lime tree	Tilia sp.	38	668	Hallstadt, Marktplatz	2009-2015		14
Chestnut	Aesculus hippocast.	35	240	Franz-Ludwig-Straße	2008-2012		15
Locust tree	Robinia pseudoacacia	36	290	Gutenbergstraße	2008-2015		16
Mountain ash	Sorbus occuparia	38	158	Hezilostraße	2010-2016	X	17
Box elder maple	Acer negundo	39	193	Kindergarten St. Heinrich	2012-2014		18
Walnut tree	Juglans regia	41	675	Garden of St. Michael	2012-2015		19
Tree of life	Thuja occidentalis	47	118	Cemetery Gaustadt	2009-2012		20
Tree of life	Thuja occidentalis	48	309	Ottostraße	2011-2013	X	21
Douglas fir	Pseudotsuga menziesii	56	24	B22/Strullendorfer Straße	2007-2014		22
Lime tree	Tilia sp.		13	Am Kranen	2006-2011		23
Lime tree	Tilia sp.		534	Klosterhof St. Michael	2007-2012		24
Chestnuts	Aesculus hippocast.		533	Altenburg Castle	2007-2009		26
Lime tree	Tilia sp.		203	Am Hahnenweg	2007-2013		27
Birch	Betula pendula		204	Am Hahnenweg 16	2007-2016		28
Chestnut	Aesculus hippocast.		51	Schützenstraße	2008	X	29

Montain ashes	Sorbus occuparia		14	Breitäckerstraße	2008-2014	X	30
Spruce trees	Picea		538	Zollnerstraße	2008-2016	X	32
Maple	Acer platanoides		59	Robert-Bosch-Straße	2008-2013	X	34
Maple	Acer platanoides		60	Hauptsmoorstr. 67	2008-2011	X	35
Conifer	Conifer		165	Dr.-Rattel-Straße	2008-2016		37
Lime tree	Tilia sp.		226	Residenzstraße/Ottoplatz	2008-2013		38
Poplar	Populus nigra		95	Am Regnitzufer	2008-2016	X	40
Oak	Quercus		94	Bridge in Bug	2008-2014		41
Birch	Betula pendula		252	Grounds of horticult. show	2009-2015	X	42
Birches	Betula pendula		203	Am Hahnenweg	2009-2016	X	43
Walnut	Juglans regia		186	Schoolyard Gangolfschool	2009-2014	X	44
Lime tree	Tilia sp.		355	Garden Heidelsteigschool	2009-2013		45
Birches	Betula pendula		231	Bank of the river Regnitz	2009-2013	X	46
Hornbeam	Carpinus betulus		535	Hainstraße/Sodenstraße	2009-2014		47
Alders	Alnus		143	Campsite in Bamberg-Bug	2009-2013	X	48
Maple	Acer platanoides		145	Playground at the hospital	2010-2014		49
Silver maples	Acer saccharinum		146	Meadow at the hospital	2010-2014		50
Locust tree	Robinia pseudoacacia		164	Don-Bosco-Straße	2010-2013	X	51
Lime tree	Tilia sp.		275	Campsite in Bamberg-Bug	2010-2014	X	52
Pine	Pinus		170	Babenbergerring	2011-2012	X	53
Chestnut	Aesculus hippocast.		410	Beer garden Mahr's-Bräu	2011-2014	X	54
Beech	Fagus sylvatica		254	Grounds of horticult. show	2012-2016		55
Lime tree	Tilia sp.		217	Schönleinspl./Promenade	2013-2014		56
Maple	Acer platanoides		427	Babenbergerring	2014-2016		58

Maple, parking-lot at the railway station (2009-2013)

View from the east

On 27 July 2009 the difference between the two sides was striking. The leaves on the left side had brown margins, the leaves on the right side were green.

In 2010 the side difference was visible already on 3 July. Southwards (left) visual contact to phone masts Ludwigstr. 2 (275 m) und Ludwigstr. 25 (190 m). Phone mast Heiliggrabstr. 15 (280 m) westwards was hidden behind trees at that time.

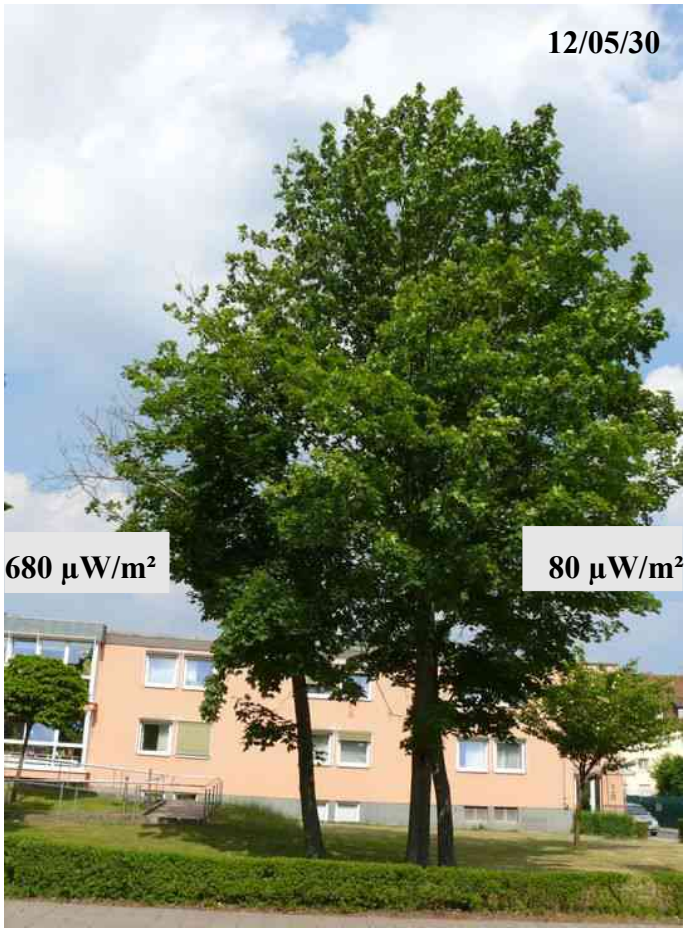
970 µW/m²
Measurement on the left side in a height of 3 m

130 µW/m²
Measurement on the right side in a height of 3 m

Measurements on 30 May 2012 standing at the top of a ladder: south side 970 µW/m² (0.60 V/m), north side130 µW/m² (0.22 V/m). On 5 Aug. 2013 the maple had already lost leaves on the left side.

Maple, Hauptsmoorstr. 26a (2008-2012)

On 8 June 2008 it was noticed, that the northern side of a group of maples (on the right) was damaged. It was the side facing the mobile phone antennas situated on the building. Side beams of the sector antennas reach the maples.



View from the west
In May 2012 the damage had increased on the left side. The right side showed no damage.

680 µW/m²

80 µW/m²

On 30 May 2012 measurements were carried out with the EMF-broadband analyzer HF 59B (27 MHz – 3300 MHz), UBB27_G3, from Gigahertz Solutions (measurement of the sum, peak values of power flux density in µW/m²). Value left side: 680 µW/m², value right side: 80µW/m². This difference can be explained by attenuation within the tree. A part of the RF-EMF is absorbed from the leaves, a part is reflected, scattered and diffracted.

Maple, Berliner Ring (2013-2015)

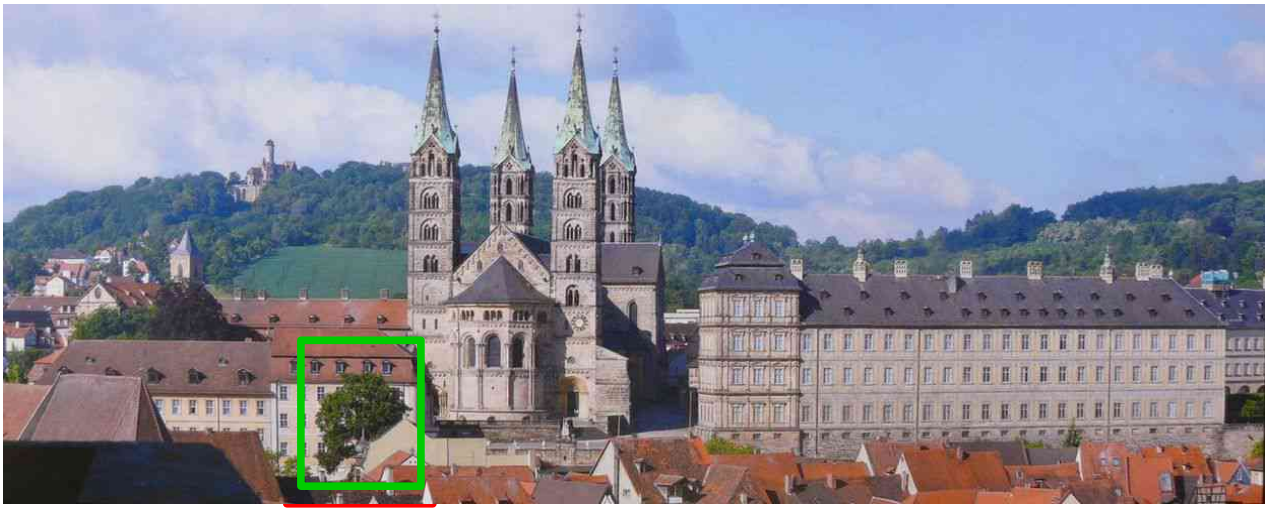
View from the east

On 13 May 2013 crown transparency was observed in the upper left section.
Phone mast Pödeldorfer Straße 144 (height 23 m, 18 sector antennas) in a distance of 77 m.

On 7 June 14 dead branches were seen in the upper left section. Leaves on the left side were brown.

On 4 June 15 the damage had increased. Measurements were carried out on 14 June 2015.

Maple at the Cathedral square (2010-2011)



Postcard: View from St. Martin to the Cathedral, the New Residence, Altenburg and the maple

Since 2008 early browning on the eastside.

Since 2011 severe crown damage.

Visual contact to phonemast Grüner Markt 23 (440 m).

Broken branches besides passing tourists.

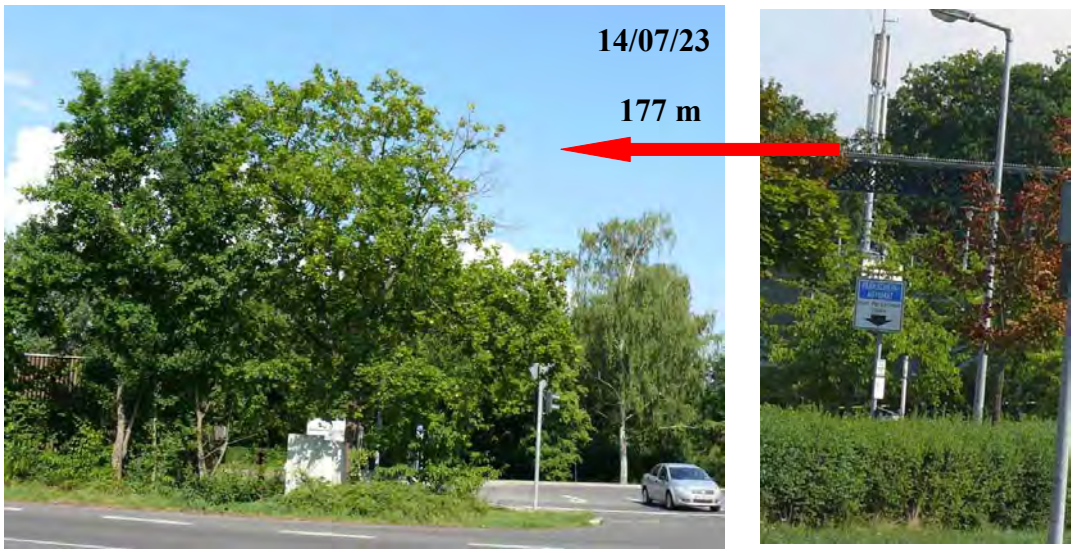
Maple, P&R-Heinrichsdamm (2008-2016)

View from the west

On 29 August 2008 crown transparency in the upper right section was remarked. Visual contact to phone mast Heinrichsdamm 33 a (height 17 m, 6 sector antennas) in a distance of 177 m was given.

On 25 September 2009 the maple had lost its leaves in the upper right section too early in the year.

On 25 August 2010 some little branches were dead.



On 23 July 2014 more branches died off. Birch with crown tranparency in the background.

On 30 July 2015 dead branches on the south side had been cut. The birch had already lost leaves. The phone mast had been enlarged (12 antennas). Measurements with the help of a telescopic rod.

On 1 July 2016 the dead birch had been felled. The injury to the maple will go on.

Maple, Hallstadt, Lichtenfelser Straße (2008-2015)

View from the west

View from the east

The lime tree on the left is shielded, the maple on the right is exposed. Damage on the exposed side.

View from the west

In May 2011 the situation was similar.

View from the northwest

Dead twigs and branches on the top.

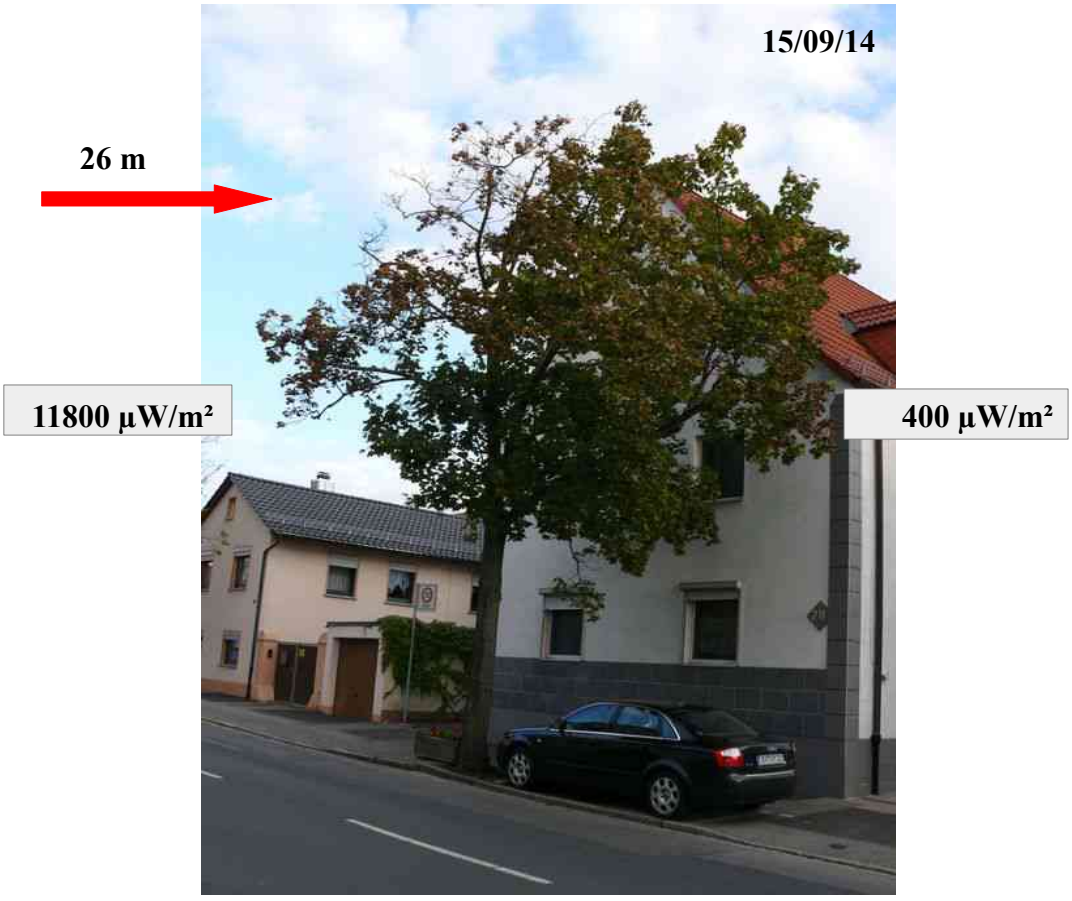
View from the west

In September 2015 the lime tree has dense, green foliage but the maple is brown and has lost leaves.

View from the northwest

View from the north

In May 2011 dead twigs and branches on treetop and on the northeast side, facing the antenna.



View from the northwest

On 14 September 2015 the difference between the northeast side and the southwest side is considerable. The measurements were done with the help of a telescopic rod.

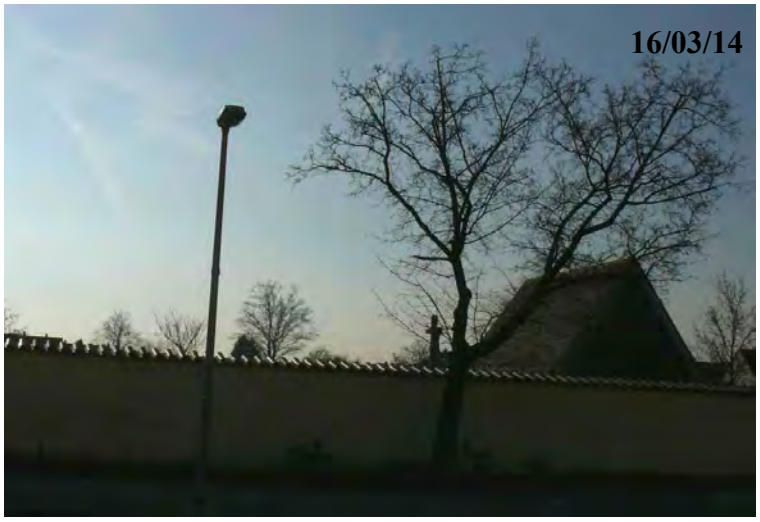
Maple, Hallstadt, cemetery (2008-2016)

View from the southeast

On 27 June 2008 dead branches were observed on the left side of the maple. Visual contact was given to phone mast Landsknechtstr. 23 (height 14-17 m, 6 sector antennas) in a distance of 142 m.

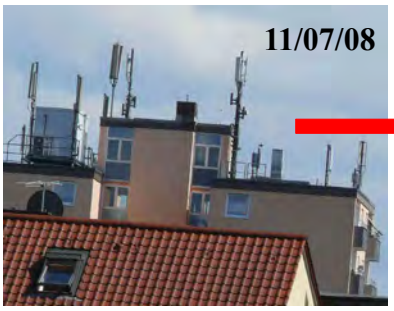
View from the west

On 5 october 2015 parts of the left side had been cut off. In the middle the tree was transparent and brown. The right side had dense, green foliage. Measurements with the help of a telescopic rod.



Numerous trees in and around the cemetery have been felled in the last years - again in winter 2015.

Hornbeam, Hauptsmoorstr. 85 (2011-2012)

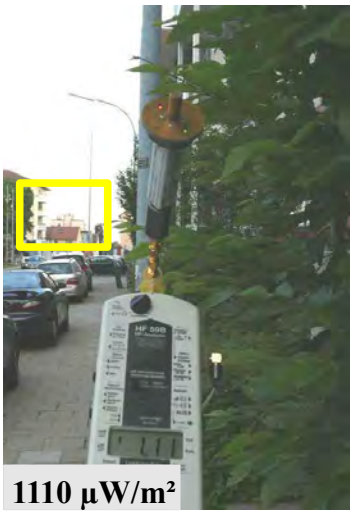


Mobile phone site
Hauptsmoorstr. 26 a
with 18 sector antennas

View from the northeast

Detail from the upper crown

On 8 July 2011 leaves on the left (southeast) side of the hornbeam had brown margins.
Visual contact was given to phonemast Hauptsmoorstr. 26a in a distance of 450 m.



View from the northwest
Scale mW/m²
Measurement on the southeast side,
visual contact to the phonemast.

Scale mW/m²
Measurement on the northwest side,
no visual contact to the phonemast.

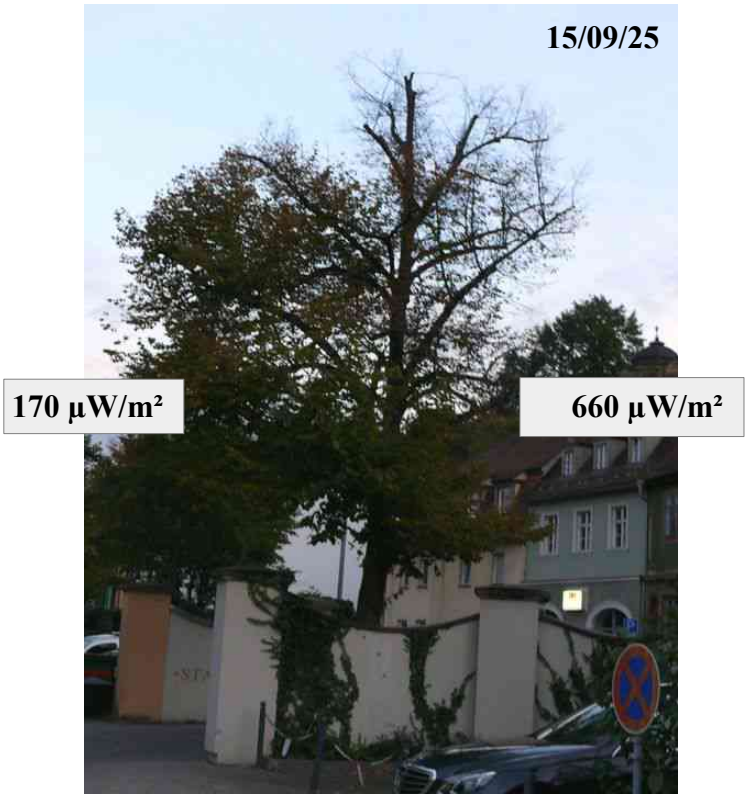
On 23 May 2012 measurements were carried out
Measured value southeast side: 1100 µW/m², northwest side: 0 µW/m².

Lime tree, Hotel Residenzschloss (2010-2015)

View from northeast over lime to the former Monastery St. Michael with phonemast

Looking from northwest the difference between the left and the right side was sharp.

On 20 August 2014 the left side was green. The right side and the top were brown or leafless

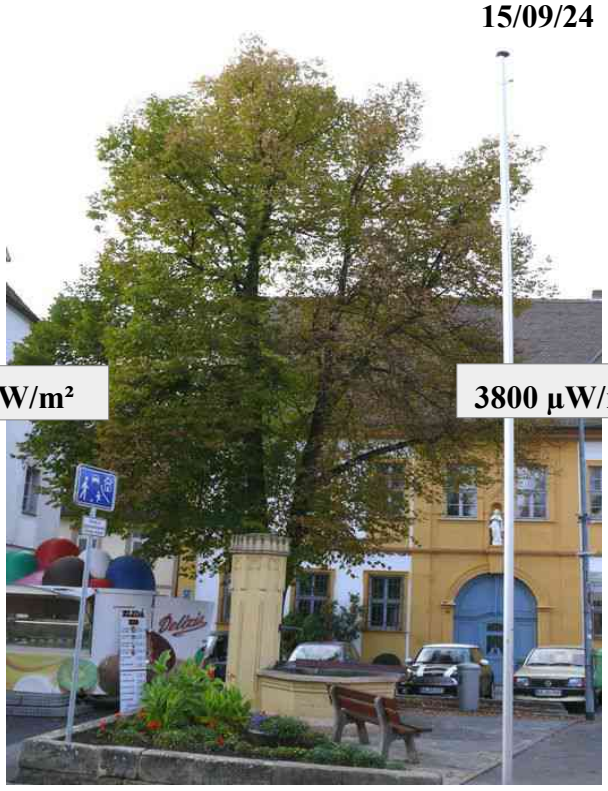


In 2015 the situation was similar. Measurements were done on 25.09.15.

Lime tree, Hallstadt, Marktplatz (2009-2015)

View from the south
On 26 September 2009 the lime tree was brown on its right (east) side.

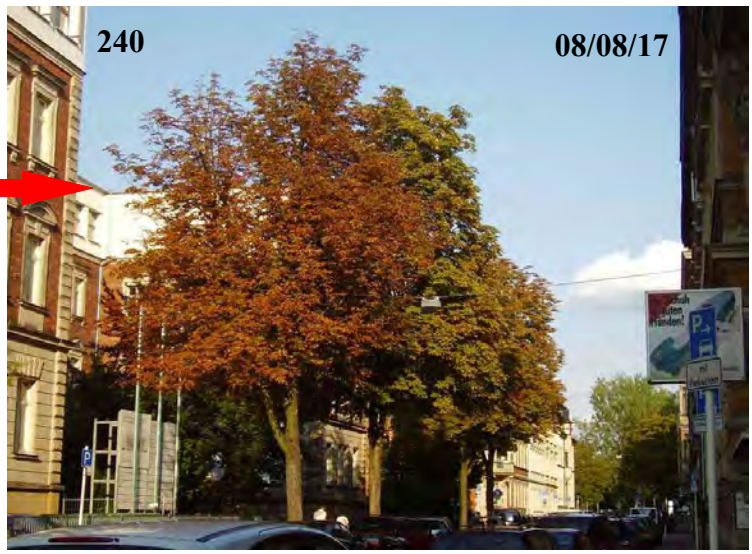
View from the southwest
From the east side visual contact to phone mast Lichtenfelser Str. (height 16 m, 6 antennas) in a distance of 354 m



On 24 September 2015 the right side was brown and had already lost leaves. .

On 9 October 2015 the right side was leafless. The phone mast had now 18 sector antennas.

Chestnuts, Franz- Ludwig- High school (2008-2012)



470 m

View from the west

In August 2008 the first chestnut was brown and on treetop leafless; the second chestnut was green.

In 2010 the first chestnut had lost already many leaves. The browning began at the leaf margins.

Measurements on 30 July 2015 in front (west) of chestnut 1: 400 µW/m², behind (east): 20 µW/m².
Visual contact from the first chestnut to phone mast Grüner Markt 23 (height 35 m, 23 antennas).

Locust tree, Gutenbergstraße (2008-2015)

View from northeast

On 29 August 2008 the beginning difference between the left (southeast) and the right side (north-west) was observed. Visual contact to phone mast Gutenbergstraße (height 39-46 m, 22 antennas).

On 1 August 2012 branches in the upper part of the right side were dead

On 14 July 2015 measurements in a height of 3 m had been carried out with the help of a ladder.

Mountain ash, Hezilostraße (2010-2016)

555 m

View from the east

In August 2010 the remarkable side difference was noticed. Altenburg Castle with Visual contact to the Altenburg Castle in the north was given (distance 555 m). 17 sector antennas

Measurement on the left side: 8.2 µW/m² (scale µW/m²)

Measurement on the right side: 83.9 µW/m² (scale µW/m²)

In 2012 the side difference was seen already in May. The left (southern) half had dense foliage. The right (northern) half showed defoliation. Measurements were carried out on 29 May 2012.

In 2014 the whole mountain ash was tranparent and partly leafless already in July. Damages at other trees in this southwestern part of Bamberg had increased also.

In May 2016 the tree had been cut down.

Box elder maple, Kindergarten St. Heinrich, Pödeldorfer Straße (2012-2014)

193 **12/05/31**

Measurement on the side of the tree, which is facing the phone mast.

View from the northwest
This Box elder maple in the garden of Kindergarten St. Heinrich had severe damage on the left side.

Measurement on the opposite side.

In summer and in autumn 2013 the gardener had cut off several branches.

Visual contact was given to phonemast Pödeldorfer Str. 144 in a distance of 125 m.

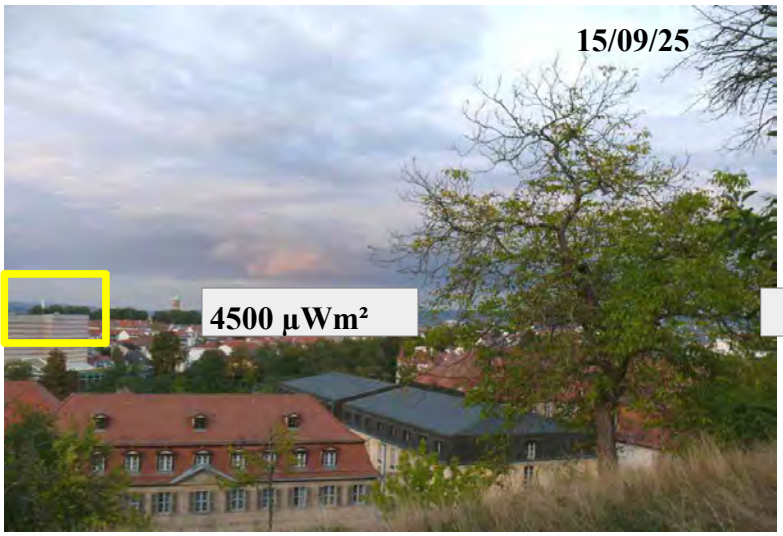
Walnut tree, Garden of the former Benedictine monastery of Michelsberg (2012-2015)

190 m

Concert and Congress Hall of the „Bamberg Symphony Orchestra“ with phone mast

View from the southwest
On 12 July 2012 the walnut tree showed severe crown tranparency.

On 6 June 2014 many branches on the north and on the east side were dead.



On 25 September 2015 the walnut tree had leaves only on its southwest side.
On the Concert and Congress Hall the number of sector antennas had increased from 6 up to 21.

Tree of life, Cemetery Gaustadt (2009-2012)

118 **09/08/25**

108 m

10/08/13

View from the southwest
On 25 August 2009 the unilateral damage of the tree of life was observed. From the right side visual contact is given to phone mast Breitäckerstr. 9 (height 27 m, 12 antennas).

On 13 August 2010 the damage was similar. On the cemetery and in the surrounding gardens numerous trees and shrubs with severe crown damage were found.

12/04/25

30 µW/m²

12/04/25

12/04/25

910 µW/m²

On 25 April 2012 the power flux density on the left side was in the range between 30 and 130 µW/m², on the right side between 360 und 1600 µW/m². The tree attenuates the radiation.

Pine tree, tree of life and maple, Ottostraße (2011-2013)

Leaves of the maple

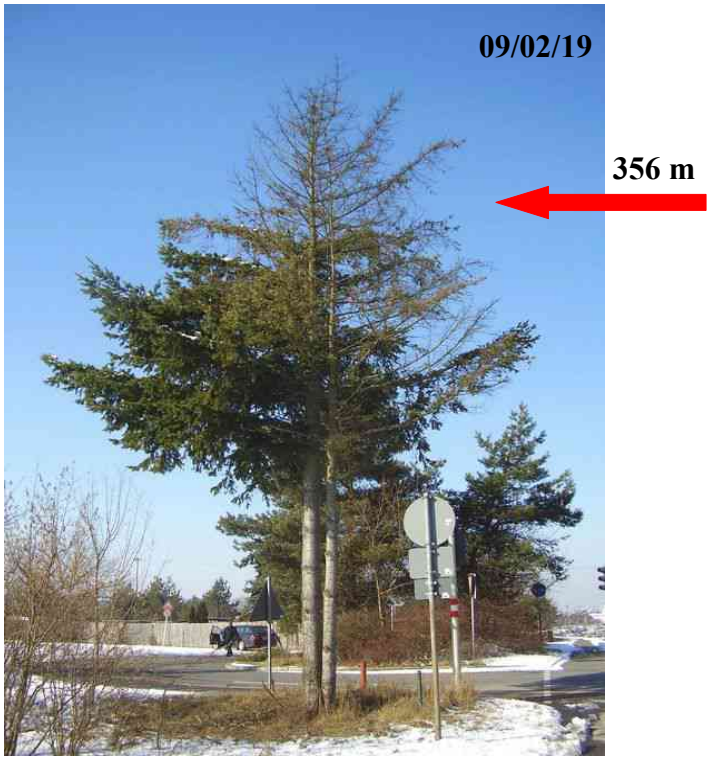
View from the southwest to pine tree, tree of life and maple. On 16 June 2011 the leaves on the south side of the maple had brown margins, the south side of the tree of life was leafless and the south side of the pine tree had lost many needles.
Visual contact was given to phone mast Hainstr. 39 (height 18 m, 6 antennas) in a distance of 395m.

View from the trees to the phone mast in the south

On 11 September 2013 the damages of the tree of life and of the maple had increased. The phone mast had been enlarged up to 21 sector antennas. Measurements were carried out at the tree of life in 2015. South side: 120 µW/m², north side 10 µW/m².

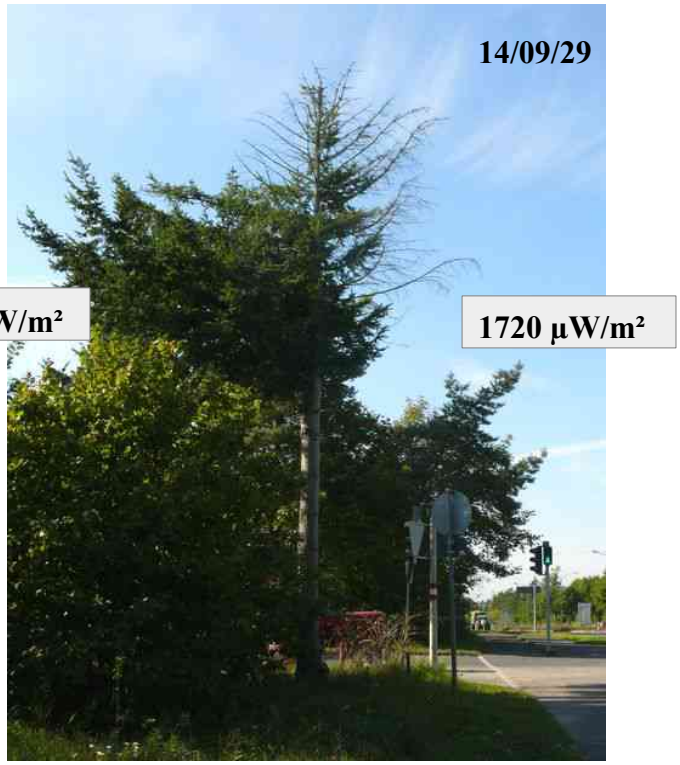
Douglas fir, B22/Strullendorfer Straße (2007-2014)

View from the south to the Douglas fir and phone mast Gutenbergstr. 20. On 24 July 2007 an unusual distribution of damage was seen.



View from the southeast to the Douglas fir. The tree had lost its needles in the upper part and on the right side.

Increase of needle loss.

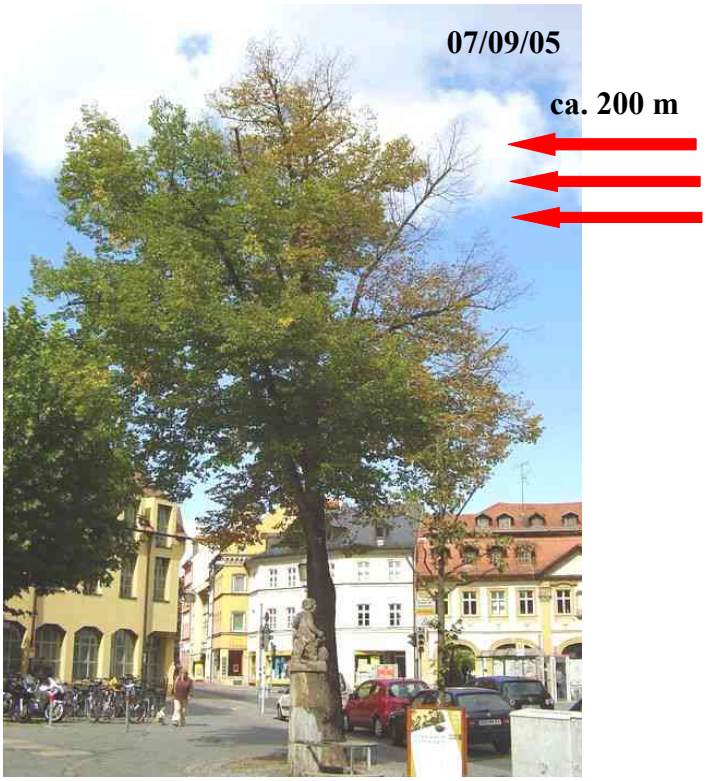


Needles only in the lower quarter on the left.

Heat, frost, drought, compaction and sealing of the soil, road salts, air and soil pollutants, diseases or pests cannot explain this “three-quarter-illness”. RF-EMF from phone mast Gutenberstr. 20 (height 39- 46 m, 22 sector antennas) reach the Douglas fir. Measurements on 27 September 2015.

Lime tree, Am Kranen (2006-2011)

View from the south
In Sept. 2006 a difference between left and right side was noticed. The right side was brown and partly leafless; the left side green with dense foliage



On 5 September 2007 the difference between left and right had increased.

On 26 Sept. 2009 branches on the right were dead.

On 17 Sept. 2011 dead parts had been cut off.

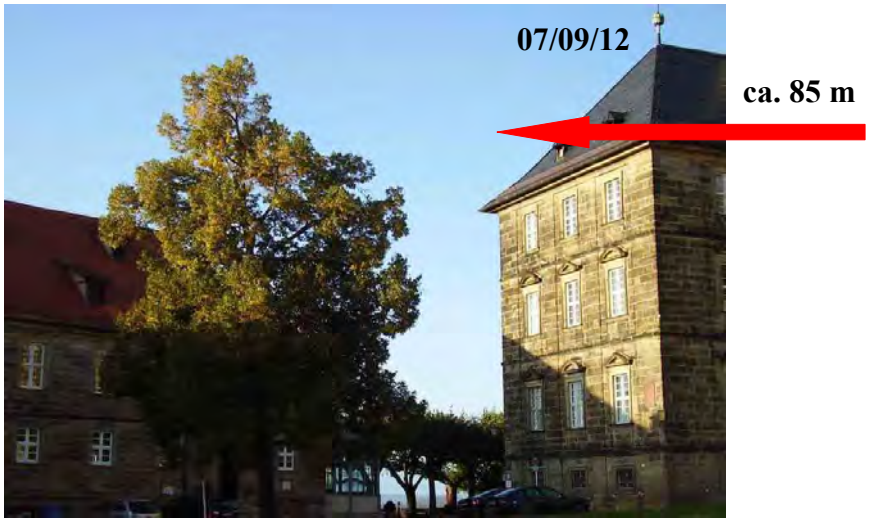
RF-EMF from phone mast Grüner Markt 23 (height 28- 35 m, 23 sector antennas) reach the tree.

Lime tree, Michelsberg Monastery (2007-2012)

View from the west

On 12 Sept. 2007 beginning crown tranparency was seen. Some leaves turned yellow too early. A phone mast is situated in the roof of the former monastery. The RF-EMF hit the lime tree. The chestnut in the background, which is located in a radio shadow, is still green

On19 August 2012 holes were noticed in the upper crown. The chestnut was healthy.



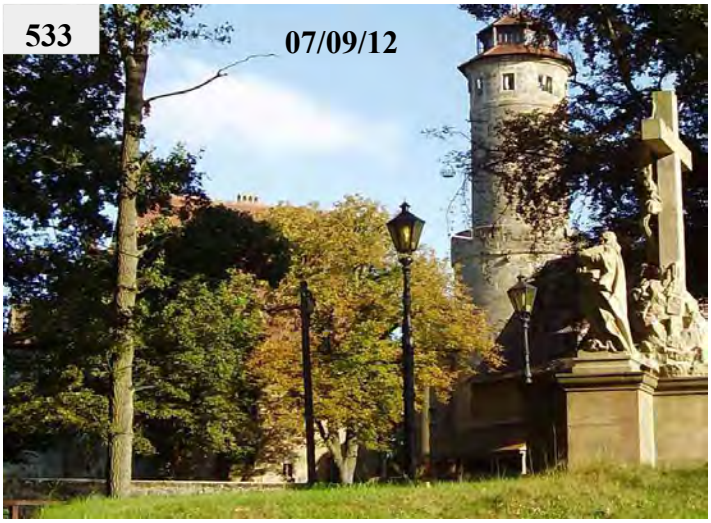
View from the south

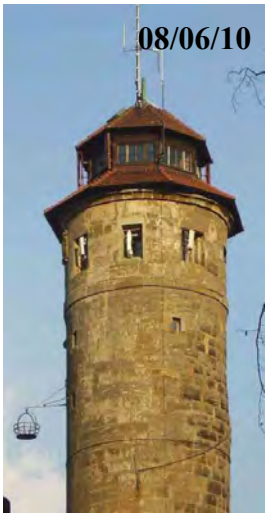
On 12 September 2007 the view from the south showed a difference between the left and the right side in the upper part The leaves on the right side on top were already brown.

On 2 October 2009 the differences between left and right and top and down were more pronounced.

On 19 October 2011 it was visible that branches had been cut. There were no construction works which could have injured the roots. In the year 2005 three sector antennas were added to the existing Nondirectional antenna. The Lime tree stands in the radiation field of the 230°- sector antenna.

Chestnuts, Altenburg (2007-2009)





Altenburg tower with 17 sector antennas and directional antennas

On 12 Sept. 2007 the difference between the two chestnuts was noticed.

On 30 August 2008 chestnut left was green, chestnut right yellowish brown (leaf margins brown).

On 20 Oct. 2009 chestnut left still had leafs. Chestnut right was leafless. The chestnut on the right is probably hit by side beams. She attenuated radiation and protected the chestnut left from RF-EMF.

Lime tree, Am Hahnenweg/Würzburger Straße (2007-2013)

View from the north
The early loss of leaves on the west side was noticed. From the west (Altenburg) RF-EMF reach the tree. Additionally directional radio link crosses here.

View from the south
In the year 2010 the brown colouring and the loss of leaves on the west side were observed already on August 22.
On the west side branches hat been cut

On 14 August 2011 it was noticed, that dead twigs and branches had again been cut off.

On 30 Sept.2013 left side leafless, right side leafy. Nearby a further phonemast was installed in 2014.

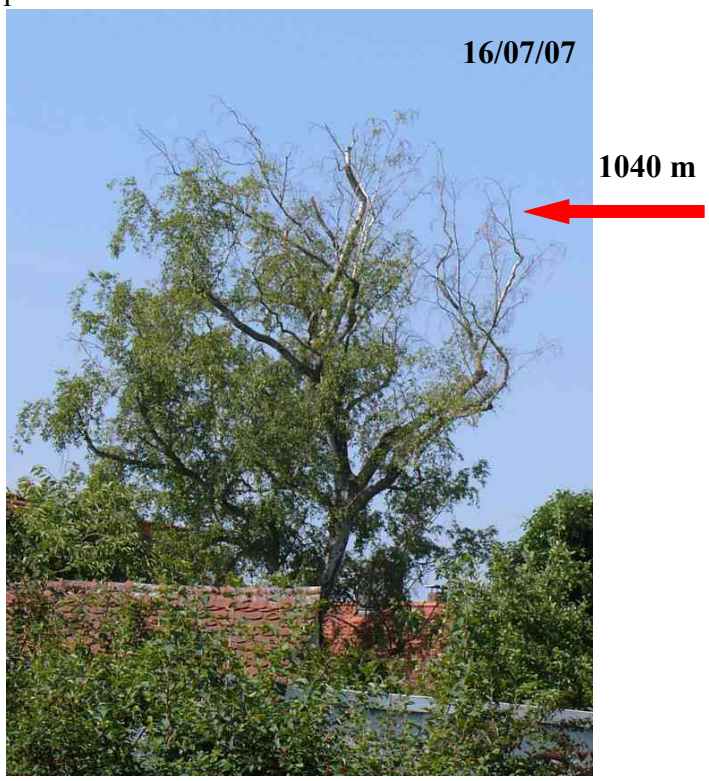
14/11/05

Birch and Conifer, Am Hahnenweg (2007-2016)

View from the south
On 18 September 2007 the birch had already lost many leaves.

View from the south
In the following years damage in the upper part of the birch was observed.

View from the southeast
In February 2011 dead parts on the top had been removed. The tree on the northwest side had been cut down. The tower of the Altenburg is visible.
The conifer had lost needles on the exposed side.



View from the northeast
This perspective shows that the damage has begun on the side which is oriented towards the Altenburg (distance 1040 m) with 17 sector antennas.

Chestnut, Schützenstraße/Busstop Sodenstraße (May- October 2008)

51 **08/05/15**

08/07/08

In May 2008 the chestnut had grown no leaves on its left side.

In July some leaves were already brown. One dead branch had been cut off.

Visual contact was given to phone mast Hainstr. 39, which started operating in 2007.

08/08/19

08/10/22

In August 2008 the whole chestnut was brown.

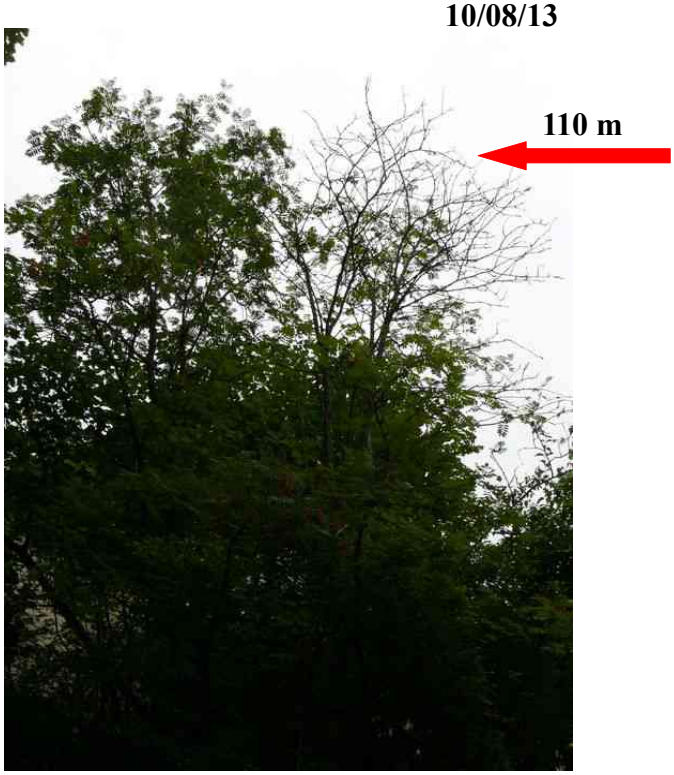
In October 2008 the chestnut had been felled.

Mountain ashes, Breitäckerstraße (2008-2014)

14 **08/06/07**

View from the northwest
On 7 June 2008 the difference between the two mountain ashes in a garden was noticed.

10/08/13



On13 August 2010 the difference had increased. Many branches of the ash on the right were dead. The ash was felled.

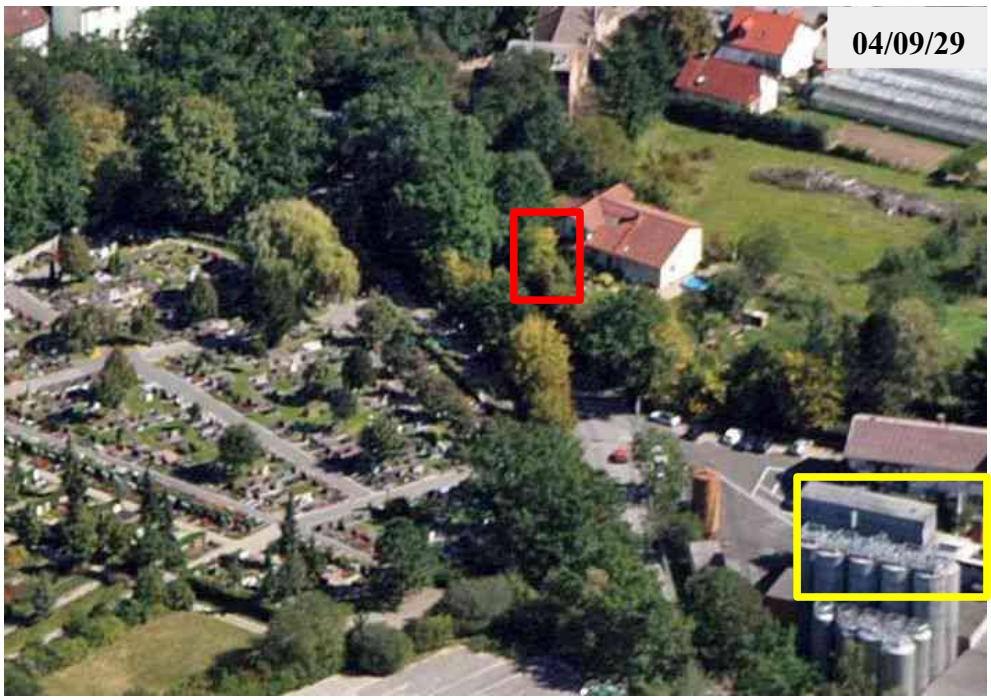
As a result the ash on the left was not shielded anymore. On 31 August 2013 the left ash had died back also.

In the summer 2014 the second mountain ash had been felled too..

This difference between the two mountain ashes in 2008 can be explained by the attenuation of radiation through leaves. In the year 2008 a great amount of the RF-EMF was absorbed from the ash on the right and reflected, scattered or diffracted. Therefore the exposure of the ash on the left was initially much lower than the exposure of the ash on the right. However, after the ash on the right hat been felled, the radiation increased considerably.
In the garden numerous other decidous trees and conifers showing damage were found. In the southern property line which is close to phonemast Breitäckerstr. 9, a gap in the tree population had occured already in 2007. Measurement in the garden on 22 November 2004: 1400 µW/m².
The phonemast is situated in a distance of 110 m from house and garden of a family with four children. The whole family suffered since 2000 from unexpainable symptoms.

29.09.04

Phone mast Breitäckerstraße 9 (07.07.10): height 25,7 m – 26,8 m, 12 sector antennas (2 x 30°, 60°, 95°, 2 x 150°, 180°, 215°, 2 x 270°, 300°, 335°) und directional radio.



Aerial picture, H. Dietz, NürnbergLuftbild

View from southwest to the cemetery of Gaustadt and the phone mast Breitäckerstr. 9 (yellow). The effects on trees could already be recognized through the early yellowing in the year 2004. The mountain ashes, which have been cut down meanwhile, are marked red.

Spruce trees and birch, Zollnerstraße (2008-2016)

View from the southwest

In June 2008, the spruce, which was closer to the phone mast (distance of 55 m), lost many needles in the upper part. The birch did not grow upwards.

In July 2011 the loss of needles had increased. The birch did not prosper.

In August 2013 most needles had gone. The phone mast was enlarged. Measurement: 3280 µW/m².

In April 2014 the situation was similar.

In April 2015 the spruce on the right had been felled.

In May 2016 the birch had died off. The spruce on the left began to loose needles.

Maple, Robert-Bosch-Straße (2008-2013)

View from the south
In June 2009 the damage on the right (east) side and on the top was noticed.

Phone mast
Robert-Bosch-Str. 40
Height 30 m,
9 antennas

In 2009 the damage had increased.
The distance to the phone mast was 320 m.

In 2011 further decline. In July 2012 the dead branch broke during a storm.
Measurement on 21.07.12: 1680µW/m².

13/05/01

Later in 2012 the maple was felled.
Large parts of the Virginia Creeper on the east side of the house died off.

Maple, Hauptsmoorstraße (2008-2011)

60 **08/07/08** **10/08/07**

280 m

View from the northeast
In July 2008 the unilateral damage of the maple tree was seen. Visual contact was given to the mobile phone site Hauptsmoorstr. 26a.

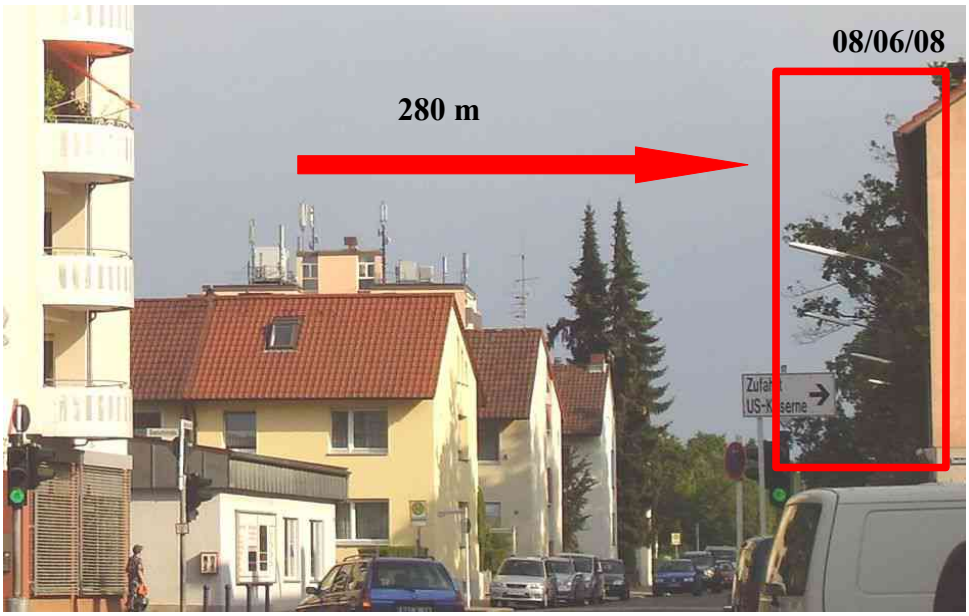
The dead branches had been cut off.
On 7 August 2010 the leaves on the left side were brown.

11/02/05

The maple tree showed even without leaves that damage had taken place.

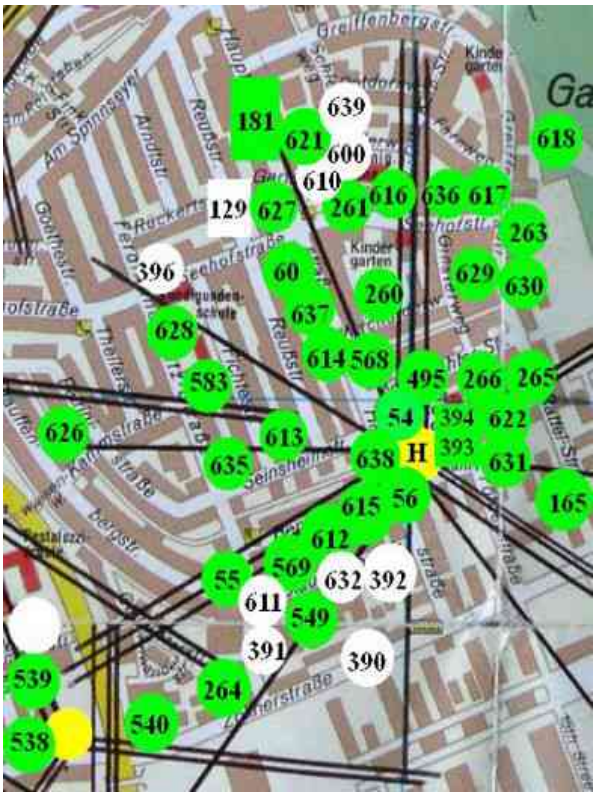
11/06/03

Road safety was not ensured anymore because of the asymmetrical shape.
In spring 2011 the maple tree was felled.



View from the crossing Hauptsmoorstraße/ Seehofstraße on the damaged maple tree to the right, mobile phone site Hauptsmoorstr. 26 a and two conifers with growth disturbance on the top. Mounting height: 26,6 m – 31,1 m, eighteen sector antennas (3 x 0°, 2 x 60°, 95°, 3 x 120°, 140°, 180°, 215°, 3 x 240°, 270°, 300°, 335°).
Around this mobile phone site numerous tree damages in gardens often beginning on the side, which was facing the antennas, were documented since 2008. All existing trees were affected: pear, cherry, walnut, birch, lime tree, beech, oak, hornbeam, field maple, tree of life, yew, sugarloaf spruce and various conifers. Only in the radio shadow of buildings one could see healthy trees.
More trees around this site: pages 80, 81, 195, 222, 252, 371-380, 498, 499, 569, 608, 623, 636.

View from the west
Unilateral damaged cherry tree in Benkertstraße with visual contact to the phone mast.



Phone mast Hauptsmoorstr.(H), sites of exposed trees (green), of trees in radio shadow (white).

Conifer, Dr.-Rattel-Straße/US-Army (2008-2016)

192 m

View from the northeast

On 8 July 2008 this unilateral damage pattern of a conifer was perplexing.

Over eight years only a slight increase of the damage appeared.

View from the east

From the conifer on the left visual contact to the phone mast Haupstsmoorstr. 26a is given.

Lime tree, Residenzstraße/Ottoplatz (2008-2013)

View from the southeast

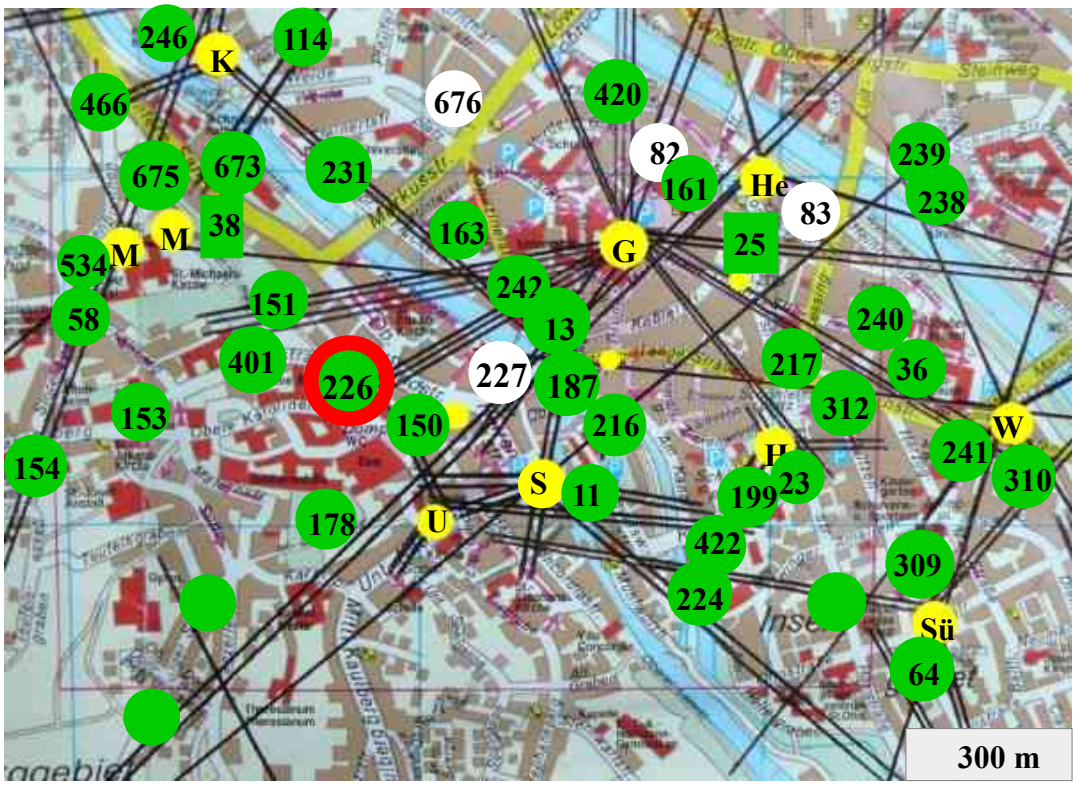
On 18 August 2008 loss of leaves and brown colouring was noticed. Only on the left green leaves were seen.

In the following time the asymmetrical damage pattern in the crown increased.

In 2011 dead branches on the eastside had been cut off. On 7 July the tree had already lost many leaves.

In 2013 the situation was similar.

From the east RF-EMF of several phone masts reach the tree (see map).



Detail from City map Bamberg with Cathedral square, Michelsberg, Concert Hall, Center, Schranne, Wilhelmsplatz and a part of the Haingebiet. The sites of the phone masts (yellow), the main beam directions of the sector antennas (black), sites of exposed trees (green) and sites of trees in the radio shadow of buildings were added (base of the map: City map Bamberg, 23. edition, Städte-Verlag E. v. Wagner & J. Mitterhuber).

View from the southwest
View from the Rosengarten over the lime tree to phone mast Grüner Markt 23.
On its westside the lime tree was still green.
Measurement on 12 July 2010: 3830 µW/m²

On 21 Sept. 2008 the lime tree in the court of the former Dominican Monastery (now Schlenkerla) had still dense foliage. The tree is shielded by the sourrounding buildings.

Poplar, Am Regnitzufer (2008-2016)

ca. 2 km

View from the north to poplar and elder. On18 August 08 the poplar was yellow on the left side. Visual contact is given to phonemast Gutenbergstr. 20 in a distance of around 2 km,

View from the northwest. On 24 Sept. 09 the poplar had lost many leaves on the left side.

On the left side branches had been cut. In the following years the crown grew asymmetrically. On 22.09.13 the elder had already lost most leaves.

Because of the asymmetrical shape road safety was not ensured anymore. In winter 2015 the poplar was felled.

Oak, Brigde in Bamberg-Bug (2008-2014)

ca. 2 km

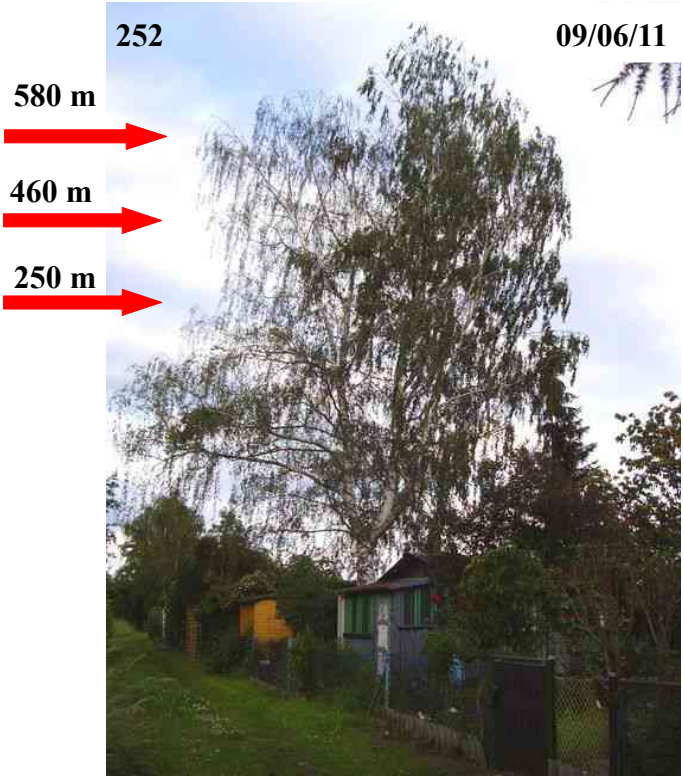
View from the northwest

In Oct. 2008 differences concerning defoliation between left and right side and between upper and lower part of the oak were noticed. From left (northeast) radiation of phone mast Gutenbergstr. 20.

In May 2010 crown transparency on the left side and on the top

In July 2014 some branches on the left side and on the top had died off.

Birch, Allotment garden Black bridge/grounds of horticultural show 2012 (2009-2015)



View from the northwest
Allotment garden Black bridge.
In June 2009 the unilaterally damaged birch was seen. More birches had already been felled.

Horticultural show 2012, Port adventure path.
RF-EMF from three phone masts in the port. reach the birch. Measurements along the path.

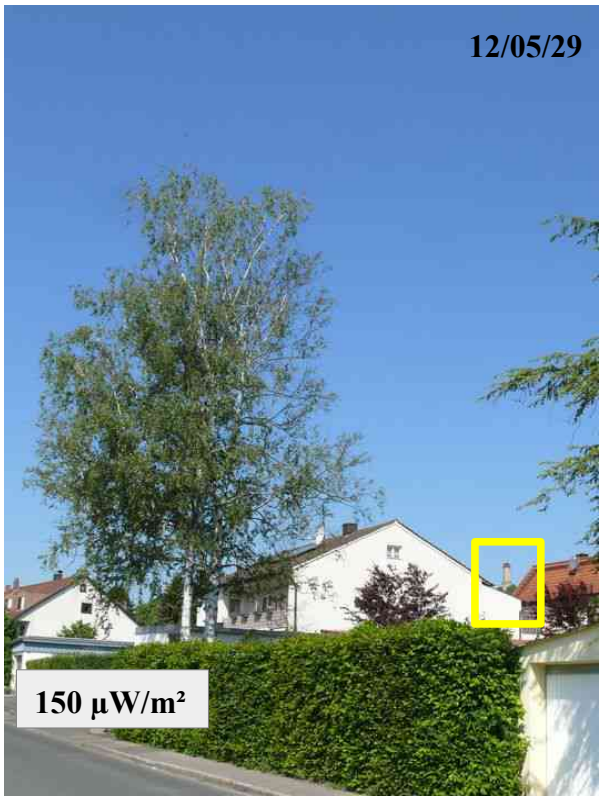
On 06 August 2014 the leaves had turned brown - probably as a result of putting into operation 4 G (LTE Long-Term Evolution).

In winter 2014/2015 the birch had been felled.

Birches, Am Hahnenweg (2009-2016)

View from the east
On 14 June 2009 a slight difference between the south and the north side of the birches was visible. The growth of the conifer was disturbed.

On 22 June 2010 the difference between the two sides was clearer. Visual contact was given to the phone mast Altenburg (810 m).



View from the southeast
On 29 May 2012 the unilateral damage and the damage of the treetop had increased.

From year to year it became worse.
In 2016 the birches had been felled.

Walnut, Schoolyard of the Gangolfschool (2009-2014)

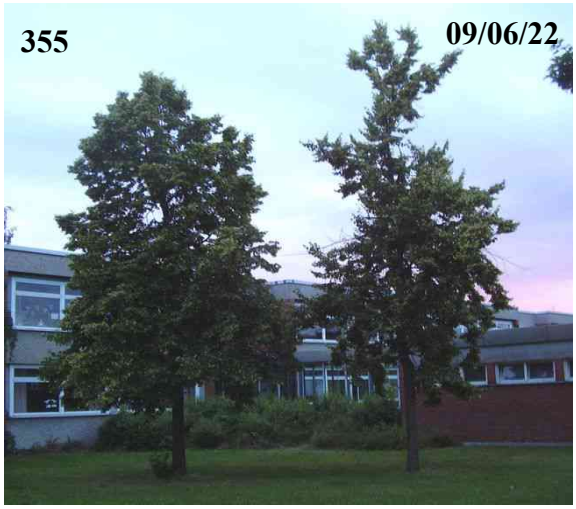
View from the southeast
In June 2009 crown damage and a difference between the left and the right side was seen.

In July 2011 branches on the right had died off.
RF-EMF from northeast (Ludwigstr. 25).

In August 2013 dead parts on the right and on top had been cut off. But the right side was leafless.

In July 2014 the walnut was felled. Phone mast Ludwigstr. 25: height 37 m, 3 (now 12) antennas.

Lime trees, Heidelsteigschool (2009-2013)



View from the southeast

In June 2009 the difference between the two lime trees on a meadow was perplexing because they stood under largely identical site conditions.

However, there is one difference: from the right RF-EMF from the phone masts Kantstr. 33 (height 43 m, 9 sector antennas) and An der Breitenau 2 (height 28 m, 21 sector antennas) reach the trees. A great amount of the electromagnetic waves is absorbed from the lime tree on the right and reflected, scattered or diffracted. Therefore the exposure of the lime tree on the left is much lower.

On 17 Sept. 13 the lime tree on the right had already lost many leaves. Measurements on 1 Nov. 15.

Birch trees on the bank of the river Regnitz (2009-2013)

Concert and Congress Hall of the „Bamberg Symphony Orchestra“ with phone mast

View from the southwest to the eastbank of Regnitz. Crown transparency at both birches. The upper half of the left birch had severe damage. From the left side (northwest) RF-EMF (main beams of two 130°- sector antennas) hit the left birch. Phone mast Concert and Congress Hall: height 25 m, 6 sector antennas.

In August 2013 the left birch was felled. Crown tranparency at the right birch.
In 2014 the phone mast on the Concert hall had been enlarged to 21 sector antennas.
In April 2016 it was shocking to see that more trees along the river had been cut down.

Hornbeam, Hainstraße/Sodenstraße (2009-2014)

95 m

535

View from the northwest

In 2007 the phone mast Hainstr. 39 started transmission.

In October 2009 a side difference at the hornbeam was seen: left side almost leafless, right side with dense foliage.

In May 2013 the tree had grown only few leaves on the left.

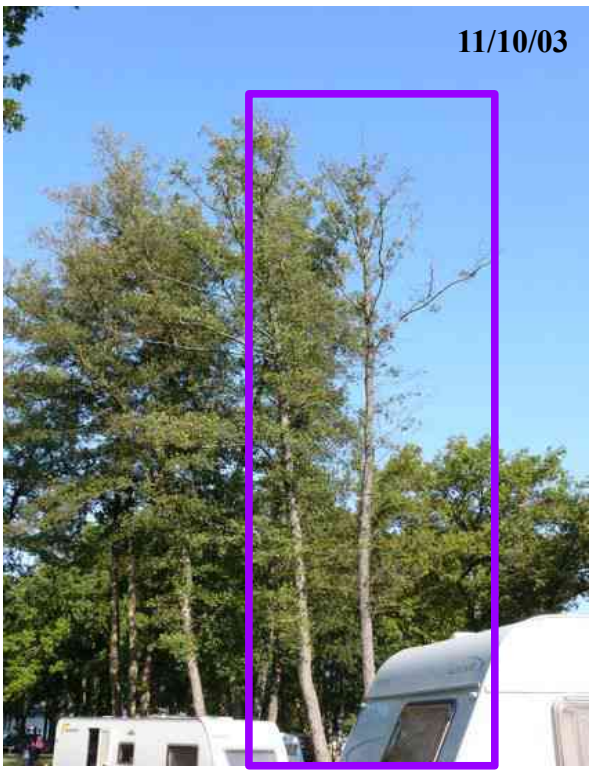
In 2014 the mobile phone site had been enlarged from 6 to 21 sector antennas.

In June 2014 branches had been cut off. Measured value: 2940 µW/m²

Alders, Campsite in Bamberg-Bug (2009-2013)

View from the south

In October 2009 two alders on the eastern side of a larger group of alders had died.
The dead alders (marked black) were felled in winter 2009/2010. From east RF-EMF are coming from the phone masts Gutenbergstr. (2,3 km) and A 73 at Strullendorf (4 km), from the television station (also DVB-T) Kälberberg (10 km) and from the radio station (DAB) Geisberg (11 km).



In the following period the next alders died (purple). In winter 2012/13 these were felled also.
Since 2004 severe tree damages occurred on the campsite. The damages increased rapidly. All tree species were affected. Numerous trees were felled (p. 170, 367, 570, 585, 605, 629).

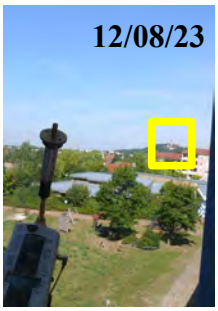
Maple trees, Playground at the Hospital (2010-2014)

View from the northeast

08/06/10

Phone mast Altenburg with 17 sector antennas and directional radio (10/10/21)

Maple trees at the playground of the hospital. On 1 July 2010 the difference between the maple trees on the right and on the left was noticed.
Visual contact is given to the phone mast Altenburg Castle in a distance of 2 km.

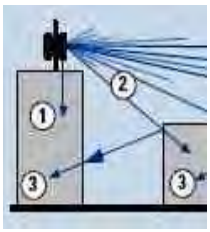


View from the Hospital over the playground to the Altenburg. Value at a window: **88 µW/m²**

On 2 August 2013 the maple tree on the right side was brown und had already lost leaves.

On 29 Aug.2014 the situation was similar. Additionally, new planted trees nearby did not grow well.

Silver maple trees, Hospital (2010-2014)



Main beam and side beams, reflection on a building. Detail from „Mobilfunk“ STMUGV (2007)

View from the northeast

Tree on the right in another perspective

Silver maples on the left of the playground above. On 1 July 10 crown tranparency at the two trees on the right, whereas the tree in the middle had dense foliage. The silver maple on the left had in turn sparse leafs. The reflections of the RF-EMF on the facade could be the cause (see figure).

On 23 August 2012 the impression was similar. Only the tree in the middle was in full leaf.

On 29 August 2014 furthermore, the trees don't develop well except the tree in the middle.

Locust trees, Don-Bosco-Straße (2010-2013)

280 m

In Oct. 2010 considerable difference between the two trees.
Locust tree on the right leafless; visual contact to phone mast.

Phone mast Margaretendamm 28
(height 26 m, 6 sector antennas)

View from the southeast
In 2011 the locust tree on the right died off and was felled.

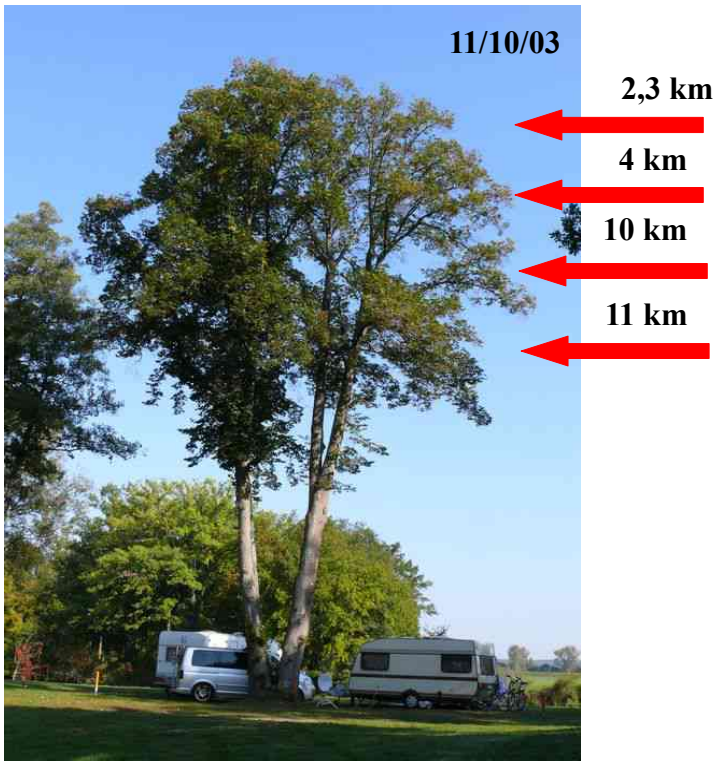
Measurement: 2920 µW/m²

The second locust tree was felled in winter 2012/2013.
Numerous trees in the radiation field of this phone mast are damaged or already felled

The phone mast was enlarged.

Lime trees, Campsite in Bamberg-Bug (2010-2014)

View from the southwest
On 12 Oct. 2010 the great contrast between the right and the left lime tree was noticed.



On 3 Oct. 2011 the lime on the right was not brown, as in the year before, but transparent.
From the east RF-EMF are coming from the phone masts Gutenbergstr. (2,3 km) and A 73 at Strullendorf (4 km), from the television station (also DVB-T) Kälberberg (10 km) and from the radio station (DAB) Geisberg (11 km).

In 2013 branches had died and broke off.

It is dangerous under the trees

Pine, Babenbergerring/Schlüsselbergerstraße (2011-2012)

170 **11/02/11**

632 m

View from the southwest
In February 2011 loss of needles on the left side. On the right side many needles were brown.

11/07/05

View from the southeast
In July 2011 the pine had lost further needles. Visual contact to phone mast Altenburg (632m).

12/05/29

View from the southwest
In May 2012 the loss of needles had increased.

12/08/23

View from the southeast
In August 2012 only a few brown needles were left. Measurement: 250 µW/m²
In 2013 the pine was felled.

Chestnuts, Beer Garden, Mahr's-Bräu (2011-2014)

View from the west

On 3 June 2011 the two chestnuts on the westside of the Beer Garden were brown. RF-EMF from the three phone masts Wilhelmsplatz, Theresienstraße and Erlichstraße interfere at this place.

On 20 Sept. 2012 the two chestnuts were leafless; the other chestnuts and a lime tree still had leafs.

On 25 August 2014 the stem of one chestnut was cut; the second chestnut was leafless.
The third chestnut began to turn brown. RF-EMF come not only from the west but also from the southeast through gaps between the buildings (distances 432 m, 622 m, 633 m).

Beech, Southern part of horticultural show 2012 (2012-2016)

View from the southwest
On 27 August 2012, during the horticultural show, crown transparency on the left side was observed.
RF-EMF from the northwest and the north (three phone masts in the port) reach the tree.

View from the west
From this perspective the difference between the north and the south side is better recognizable.

View from the west
In June 2015 crown transparency had increased.

View from the west
In July 2016 the beech was almost leafless.
In 2014/15 LTE (4 G) was added to many phone masts. A further phone mast started transmission.

Lime tree, Lange Straße/Südliche Promenade (July 2013 - April 2014)

View from the southwest
On 15 July2013 leaves turned yellow top left.

On 14 August 2013 the section top left was leafless.

On 7 Sept.2013 the whole left side had turned brown. On 30 Sept. 13 the lime had lost many leaves.

View from the south

View from the road intersection at the Schönleinsplatz to the lime tree behind the advertising pillar. In the background on the left a gap between buildings is visible.

View from the southeast

Looking from the southern end of the green area at the Schönleinsplatz to the lime tree, a part of the phone mast Grüner Markt 23 is visible.

View from the southwest

In winter 2013/2014 branches had been cut.

Maple, Babenbergerring (2014-2016)

View from the southeast
In July 2014 the upper right section showed damage. In September 2014 many leaves had fallen.

In August 2015 the damage was similar In July 2016 the damage had increased.
Visual contact is given to the phone mast Altenburg in a distance of 630 m.

Comments on the US National Toxicology Program technical reports on toxicology and carcinogenesis study in rats exposed to whole-body radiofrequency radiation at 900 MHz and in mice exposed to whole-body radiofrequency radiation at 1,900 MHz

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Abstract. During the use of handheld mobile and cordless phones, the brain is the main target of radiofrequency (RF) radiation. An increased risk of developing glioma and acoustic neuroma has been found in human epidemiological studies. Primarily based on these findings, the International Agency for Research on Cancer (IARC) at the World Health Organization (WHO) classified in May, 2011 RF radiation at the frequency range of 30 kHz-300 GHz as a 'possible' human carcinogen, Group 2B. A carcinogenic potential for RF radiation in animal studies was already published in 1982. This has been confirmed over the years, more recently in the Ramazzini Institute rat study. An increased incidence of glioma in the brain and malignant schwannoma in the heart was found in the US National Toxicology Program (NTP) study on rats and mice. The NTP final report is to be published; however, the extended reports are published on the internet for evaluation and are reviewed herein in more detail in relation to human epidemiological studies. Thus, the main aim of this study was to compare earlier human epidemiological studies with NTP findings, including a short review of animal studies. We conclude that there is clear evidence that RF radiation is a human carcinogen, causing glioma and vestibular schwannoma (acoustic neuroma). There is some evidence of an increased risk of developing thyroid cancer, and clear evidence that RF radiation is a multi-site carcinogen. Based on the Preamble to the IARC Monographs, RF radiation should be classified as carcinogenic to humans, Group 1.

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Introduction

Recently, the US National Toxicology Program (NTP) released results on the toxicology and carcinogenicity of radiofrequency (RF) radiation in rats and mice, as further discussed below. This initiated this article for the comparison of earlier human epidemiological studies with the NTP the findings, including a short review of animal studies.

NTP is an interagency program established in 1978 to coordinate toxicology research and testing across the Department of Health and Human Services. The program was also created to strengthen the science base in toxicology, develop and validate improved testing methods, and provide information about potentially toxic chemicals to health regulatory and research agencies, scientific and medical communities, and the public. NTP is headquartered at the National Institute of Environmental Health Sciences (NIEHS) (https://ntp.niehs.nih.gov/about/org/index.html).

The brain is the main target of the exposure to RF radiation during the use of handheld wireless phones; both mobile and cordless phones (1,2). Thus, an increased risk of developing brain tumors has long been a cause for concern.

Our study group has since the end of the 1990s published results from case-control studies on use of wireless phones and brain tumor risk (3). A statistically significant increased risk for ipsilateral use of mobile phones, the same side of the brain as the phone was used, was published for malignant brain tumors (4) and vestibular schwannoma (5). Further scientific evidence on the association has more recently been discussed by Carlberg and Hardell (6).

In May, 2011 the International Agency for Research on Cancer (IARC) concluded that radiofrequency (RF) radiation in the frequency range 30 kHz-300 GHz is a 'possible' human carcinogen Group 2B (7,8). The classification was based primarily on evidence that long-term users of wireless phones (mobile and cordless phones) have an increased risk for glioma and acoustic neuroma. One major reason that the rating was not a 'probable' or a 'known' risk was the lack of clear evidence from animal studies. IARC at the World Health Organization (WHO) 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/).

Unfortunately, WHO itself has constantly refused to acknowledge the carcinogenicity of RF radiation. In fact, WHO seems to rely on the conclusion of the non-governmental organization International Commission on Non-ionizing Radiation Protection (ICNIRP) instead of the IARC evaluation. That organization is even declared to be their in-house experts (9,10). ICNIRP is a private non-governmental organisation (NGO) based in Germany. New expert members can only be elected by members of the organization. Many of the ICNIRP members have ties to the industry that are dependent on the ICNIRP guidelines (11). This creates a conflict of interest, since the former leader of the WHO International Electromagnetic Field (EMF) Project is also the founder and honorary member of the ICNIRP (11). The guidelines are of huge economic and strategic importance to the military, telecom/IT and power industry. These circumstances are further discussed in a recent publication (12).

The IARC cancer classification includes all sources of RF radiation. The exposure from mobile phone base stations, DECT base stations, Wi-Fi access points, smart phones, laptops and tablets can be long-term, sometimes around the clock, at home, at the work place, at school and in the environment. For children, this risk may be accentuated due to a cumulative effect during a long lifetime use (13).

The exposure guidelines used by many agencies and countries were established in 1998 by the ICNIRP and were based only on established short-term thermal (heating) effects from RF radiation neglecting non-thermal biological effects (14). ICNIRP provides the guideline of 2 to 10 W/m^2 for RF radiation, depending on the frequency. The ICNIRP guidelines were updated in 2009; however, they still do not cover cancer and other long-term or non-thermal effects (15) [see also Hardell (10)].

In contrast to the ICNIRP, the BioInitiative Reports from 2007 and 2012 based the evaluation also on the non-thermal health effects from RF radiation (16,17). The scientific benchmark for possible health risks was defined to be 30 to 60 μW/m^2. In 2012, the Bioinitiative Working Group proposed a precautionary target level of 3-6 μW/m^2, using a safety factor of 10. 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.

The evidence of RF radiation as a carcinogen was confirmed when NTP released preliminary results of a study of long-term exposure of rats and mice to cell phone radiation (18). An increased incidence of glioma in the brain and malignant schwannoma in the heart was found. The NTP study has now been published online for public consultations (19,20) and is discussed below in relation to human epidemiological studies.

Background: Evidence from previous animal studies

There are several earlier animal studies that demonstrate the carcinogenic potential of RF radiation. Szmigielski *et al* already in 1982 published a study on the co-carcinogenic effects of RF radiation exposure and benzopyrene in mice (21). Cancer promotion was found for 2,450 MHz RF radiation at either 50 or 150 W/m^2. The results revealed an acceleration of spontaneous and chemically-induced cancers.

Non-thermal 2,450 MHz continuous-wave RF radiation has been shown to cause a biphasic effect on glioma cells (22) and lymphocytes (23). Cell proliferation was found at a specific absorption rate (SAR) of ≤50 W/kg, whereas a higher SAR suppressed DNA and RNA synthesis.

SAR ranged from 0.144 to 0.4 W/kg depending on the rats' weight in a study from 1992 on 200 rats exposed to 2,450 MHz pulsed RF radiation 21.5 h per day for 25 months (24). Compared with 200 sham-exposed rats, a statistically significant increased incidence of primary malignant diseases was found in exposed animals. Among the malignancies found in the exposed rats were malignant lymphoma and thyroid cancer. These findings are of interest since SAR values in the study were rather low compared to the ICNIRP guideline on SAR 2 W/kg to the brain for use of mobile phones (14).

A total of 100 mice were sham-exposed and 101 were exposed for two 30-min periods per day for up to 18 months to 900 MHz pulsed RF radiation with power densities 2.6-13 W/m^2 (SAR 0.008-4.2 W/kg, averaging 0.13-1.4 W/kg). The mice carried a lymphomagenic oncogene and their risk of developing lymphoma was found to be statistically significantly higher in the exposed mice than in the controls (25).

The same results were not found in the study by Utteridge *et al* (26) that has been criticized as it was not a replication study. However, the findings on lymphoma risk by Repacholi *et al* (25) and Chou *et al* (24) are of relevance in relation to the indications of an increased risk of non-Hodgkin lymphoma (NHL) in human epidemiological studies on the use of wireless phones. Thus, a statistically significant increased risk of T-Cell NHL was found in one study (27). In another study, NHL not otherwise specified was statistically significantly increased among subjects with ≥6 years duration [odds ratio (OR) =4.4 in men] for mobile phone use (28), although based on low numbers (n=7).

The thyroid gland is among the organs with the highest exposure to RF radiation during the use of the handheld wireless phone, particularly smartphones (29,30). The finding of thyroid cancer risk in the study by Chou *et al* (24), and the sharp increase in the incidence of thyroid cancer in humans during recent years (31) are of interest in that context.

In another study, mice were exposed to universal mobile telecommunications system (UMTS) fields with intensities of 0 (sham), 4.8 and 48 W/m^2 up to 24 months (32). The low-dose group, exposed to 4.8 W/m^2, was subjected to additional prenatal ethylnitrosourea (ENU) treatment. That group showed an increased lung tumor rate and an increased incidence of lung carcinomas as compared to the controls treated with ENU only. This indicated a cocarcinogenic effect of a lifelong UMTS exposure in female mice pretreated with ENU (32).

In a follow-up study, mice were exposed to RF radiation: 0 (sham), 0.04, 0.4 and 2 W/kg SAR (33). The numbers of tumors of the lungs and livers in exposed animals were statistically significantly higher than in sham-exposed controls, and the numbers of malignant lymphoma were also higher. A tumor-promoting effect of RF radiation was found at low to moderate levels (0.04 and 0.4 W/kg SAR), well below the ICNIRP exposure limits for users of mobile phones (33).

The study by the Ramazzini Institute is the largest long-term study ever performed on the health effects of RF radiation,

including 2,448 rats (34). Male and female Sprague-Dawley rats were exposed from prenatal life until natural death to a 1.8 GHz global system for mobile communication (GSM) far field of 0, 5, 25, 50 V/m with a whole-body exposure for 19 h/day. A statistically significant increase in the incidence of malignant Schwannoma in the heart was found in male rats at the highest dose, 50 V/m, corresponding to 0.66 mW/cm^2 and whole-body SAR of 0.1 W/Kg. An increased incidence of heart Schwann cell hyperplasia was observed in treated male and female rats at the highest dose (50 V/m), but was not statistically significant. In treated female rats at the highest dose (50 V/m), the incidence of malignant glial tumors was increased, although this was not statistically significant. The study revealed an increased incidence of tumor types similar to those associated with the use of wireless phones, glioma and acoustic neuroma, in human epidemiological studies.

The NTP study provides additional confirmation of the carcinogenicity of RF radiation (19,20). They showed an increased incidence of malignant schwannoma in the heart and brain glioma in male rats exposed either to GSM-modulated or code division multiple access (CDMA)-modulated cell phone RF radiation for two years. There are also increased incidences of some other tumor types and diseases. Below we discuss some of the major findings.

The results on schwannoma and glioma are of particular concern since they corroborate human epidemiological findings. Thus, it is noteworthy that similar tumors were found in the NTP study as in epidemiological studies on the human use of wireless phones; mobile phones or cordless phones (DECT). Malignant schwannoma in the heart is a similar type of tumor as vestibular schwannoma in humans, also known as acoustic neuroma, although acoustic neuroma is usually benign and rarely undergoes malignant transformation.

Below, we provide an updated evaluation of the scientific evidence of an increased risk of developing glioma and vestibular schwannoma (acoustic neuroma) associated with the use of wireless phones. It is pertinent to provide an updated presentation of the NTP reports on current evidence on cancer risks associated with the use of wireless phones.

Since the IARC evaluation in 2011, more human epidemiological studies have been published that support a causal association between RF radiation and brain and head tumors. A Danish cohort study on 'mobile phone users' (35,36) is not included herein due to serious methodological shortcomings in the study design [see Söderqvist *et al* (37)]. The study by Benson *et al* (38) is of limited value since the use of cordless phones was not included, mobile phone use was assessed only at baseline and no information on tumor laterality, including ipsilateral versus contralateral use was given. In spite of the many shortcomings, an increased risk of developing acoustic neuroma was reported. The study will not be further discussed below.

In the following, first, human epidemiological studies on specific tumor types are discussed. The NTP study findings are then presented and finally, an evaluation of the combined evidence from human and animal studies is presented.

Glioma

Human studies. Glioma is the most common malignant brain tumor and represents approximately 60% of all central nervous system (CNS) tumors. Most of these are astrocytic tumors 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 a peak incidence in the age group of 45-75 years and a median survival less than one year (39). No substantial increasing survival has been obtained in recent years. Three research groups have provided results in case-control studies on glioma, Interphone (40), Coureau *et al* (41) and the Hardell group in Sweden (42-46).

The random effects model was used for a meta-analyses of published studies, based on the test for heterogeneity in the overall group ('all mobile'), see also http://www.bioinitiative.org/report/wp-content/uploads/2017/11/Hardell-2017-Sec11-Update-Use_of_Wireless_Phones.pdf. Note that only our group also assessed the use of cordless phones. Thus, the reference category in our studies included cases and controls with no use of wireless phones, in contrast to the other studies investigating only mobile phone use. Including cordless phone use in the 'unexposed' group would bias the risk estimates towards unity (45).

In Table I, results of the highest cumulative use in hours of mobile phones are presented. All studies reported a statistically significantly increased risk of developing glioma and the meta-analysis yielded OR =1.90 and 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 exposed controls. Further support of the increased risk of glioma associated with mobile phone use has been obtained in additional analyses of parts of the Interphone study (47-49).

We previously analyzed the survival of the patients in our studies and found a shorter survival in patients with glioblastoma multiforme associated with the use of wireless phones compared with patients with no use (50). Interestingly, the mutation of the p53 gene involved in disease progression has been reported in glioblastoma multiforme in patients using mobile phones for ≥3 h per day. The mutation was statistically significantly associated with a shorter overall survival time (51).

NTP study. No increased incidence of glioma was reported in the mouse study (20).

In male rats (19), malignant glioma and glia cell hyperplasia occurred in all groups exposed to GSM-modulated cell phone RF radiation for two years. No lesions were observed in the sham controls. In female rats, glial cell hyperplasia occurred in one rat (3 W/kg), but none in the sham controls. One malignant glioma occurred in one rat in the 6 W/kg group but none in the sham controls.

In male rats exposed to CDMA-modulated cell phone RF radiation for two years, there was an increased incidence of malignant glioma with a statistically significant trend, P=0.044. In females, three malignant glioma occurred in the 1.5 W/kg group, but none in the other exposed groups or the sham control (P-value for trend =0.384). Glial cell hyperplasia was observed in most exposed groups, although this was not statistically significant (noted in text; P-value for trend not presented in NTP table).

Evaluation. Based on human epidemiological studies supported by the NTP animal study, there is clear evidence that RF radiation causes glioma in humans. There is also

Table I. 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 use in hours for mobile phone use.

	All			Ipsilateral		
Study (ref.)	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Interphone, 2010 (40)						
Cumulative use ≥1,640 h	210/154	1.40	1.03-1.89	100/62	1.96	1.22-3.16
Coureau *et al*, 2014 (41)						
Cumulative use >896 h	24/22	2.89	1.41-5.93	9/7	2.11	0.73-6.08
Hardell and Carlberg, 2015 (43)						
Cumulative use ≥1,640 h	211/301	2.13	1.61-2.82	138/133	3.11	2.18-4.44
Meta-analysis (40,41,43)						
Cumulative use ≥1,640 h[a]	445/477	1.90	1.31-2.76	247/202	2.54	1.83-3.52

[a]≥896 h used for Coureau *et al*.

Table II. 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 use in hours for mobile phone use.

	All			Ipsilateral		
Study (ref.)	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Interphone, 2010 (40)						
Cumulative use ≥1,640 h	130/107	1.15	0.81-1.62	46/35	1.45	0.80-2.61
Coureau *et al*, 2014 (41)						
Cumulative use >896 h	13/9	2.57	1.02-6.44	6/4	2.29	0.58-8.97
Carlberg and Hardell, 2015 (56)						
Cumulative use ≥1,640 h	141/301	1.24	0.93-1.66	67/133	1.46	0.98-2.17
Meta-analysis (40,41,56)						
Cumulative use ≥1,640 h[a]	284/417	1.27	0.98-1.66	119/172	1.49	1.08-2.06

[a]≥896 h used for Coureau *et al*.

evidence of an increased glioma risk in occupational studies on exposure to EMF (52-54).

Meningioma

Human studies. Meningioma is an encapsulated, well-demarked and rarely malignant tumor. It is the most common non-malignant brain tumor that accounts for approximately 30% of intracranial neoplasms. It develops from the pia and arachnoid membranes that cover the CNS. It is slow-growing and presents neurological symptoms by the compression of adjacent structures. Most common are headaches and seizures. The incidence is greater than two-fold higher in women than in men and meningioma develops mostly among middle-aged and older individuals (55). The same research groups as for glioma also included meningioma in their case-control studies with a separate publication on meningioma by Carlberg and Hardell (56). The results of the meta-analyses for cumulative exposure in highest exposure category are presented in Table II. A statistically significant increased risk was obtained for ipsilateral mobile phone use with OR =1.49, 95% CI =1.08-2.06.

NTP study. No increased incidence of meningioma was reported in rats or mice (19,20).

Granular cell tumors (GCTs)

Human studies. GCTs are uncommon tumors. They are believed to be of neuronal origin (57). They are soft tissue tumors, which are thought to be derived from Schwann cells (58). The immunoprofile of granular cell tumors has revealed nerve sheath differentiation, lending support to their neuronal origin (59). GCTs can affect any organ in the body, although approximately 50% are found in the head and neck region (60). In our case-control studies on brain tumors, all diagnoses were based on a histopathological examination; no one was diagnosed with a granular cell tumor (42-46).

NTP study. In the rat study (19), increased incidence of malignant or non-malignant granular cell tumors in the meninges, likely derived from Schwann cells, occurred in the

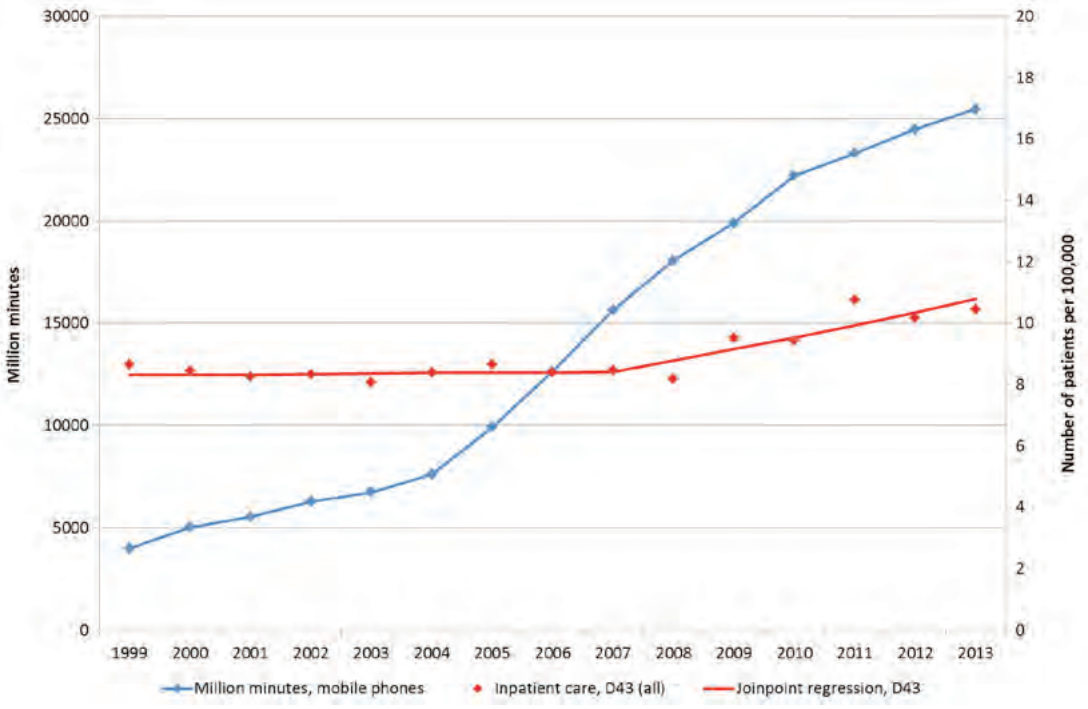

Figure 1. Number of out-going mobile phone minutes in millions during the period between 1999-2013 (http://statistik.pts.se/pts2013/download/Svensk%20Telemarknad%202013.pdf; accessed on April 1, 2015) and joinpoint regression analysis of number of patients per 100,000 inhabitants according to the Swedish National Inpatient Register for all ages during the period between 1999-2013 diagnosed with D43 = tumor of unknown type in the brain or CNS (http://www.socialstyrelsen.se/statistik/statistikdatabas/diagnoserislutenvard; accessed on April 1, 2015).

males exposed to GSM-modulated cell phone RF radiation for two years. This was not statistically significant (P-value for trend =0.343). In female rats, granular cell tumors, either malignant or non-malignant were not associated with RF radiation (P-value for trend =0.594). Since GCT is neuronal in origin, the NTP study findings in male rats add to the evidence that exposure to RF radiation damage nerve sheaths.

Evaluation. Based on human epidemiological studies and the NTP animal study, there is equivocal evidence that RF radiation causes meningeal tumors in humans (may be related to exposure).

Rate/incidence of brain tumors. The Swedish Cancer Register has not shown increasing incidence of brain tumors in a study for the time period between 1979-2008, and has been used to dismissing epidemiological evidence on risk associated with use of wireless phones (61). We have previously demonstrated that descriptive studies cannot be used to dismiss results in analytical epidemiology with individual exposure histories, such as in case-control studies. We have also published the deficiencies in the reporting of brain tumors to the Swedish Cancer Register (62). The results for more recent time periods have now been published. These articles also discuss results from studies in other countries.

We used the Swedish National Inpatient Register (IPR) and Causes of Death Register (CDR) to study the incidence of brain tumors comparing with the Swedish Cancer Register data for the time period between 1998-2013 using joinpoint regression analysis (62). In the IPR, we found a joinpoint in 2007 with Annual Percentage Change (APC) +4.25%, 95% CI +1.98, +6.57% during the period between 2007-2013 for tumors of unknown type in the brain or CNS. Fig. 1 shows time trends in IPR for brain tumors of unknown type (D43), red line, and mobile phone communication; number of out-going mobile phone minutes in millions per year (blue line). The figure shows increasing rates of brain tumors with some latency in relation to the increasing use of mobile phones.

In the CDR joinpoint regression, we found one joinpoint in 2008 with APC during the period between 2008-2013, +22.60%, 95% CI +9.68, +37.03%. These tumor diagnoses would be based on clinical examination, mainly CT and/or MRI, but without histopathology or cytology. No statistically significant increasing incidence was found in the Swedish Cancer Register during these years. We postulated that a large part of brain tumors of unknown type are never reported in the Cancer Register. Furthermore, the frequency of diagnoses based on autopsy has declined substantially due to a general decline of autopsies in Sweden, further adding to missing cases. We concluded that the Swedish Cancer Register is not reliable to be used to dismiss results in epidemiological studies on the use of wireless phones and brain tumor risk.

In Fig. 2, we present the rates per 100,000 of deaths in unknown type of brain tumor (D43), red line, and number of out-going mobile phone minutes in millions (blue line) during the period between 1999-2013. We postulate that the increasing rate of patients deceased with brain tumor may be associated with the increasing use of mobile phones.

In an updated further analysis, we used the Swedish IPR to analyze rates of brain tumors of unknown type (D43) during the period between 1998-2015 in different age groups (63). The Average Annual Percentage Change (AAPC) per 100,000 increased with +2.06%, 95% CI +1.27, +2.86% in both sexes combined. A joinpoint was found in 2007 with APC 1998-2007 of +0.16%, 95% CI -0.94, +1.28%, and 2007-2015 of +4.24%,

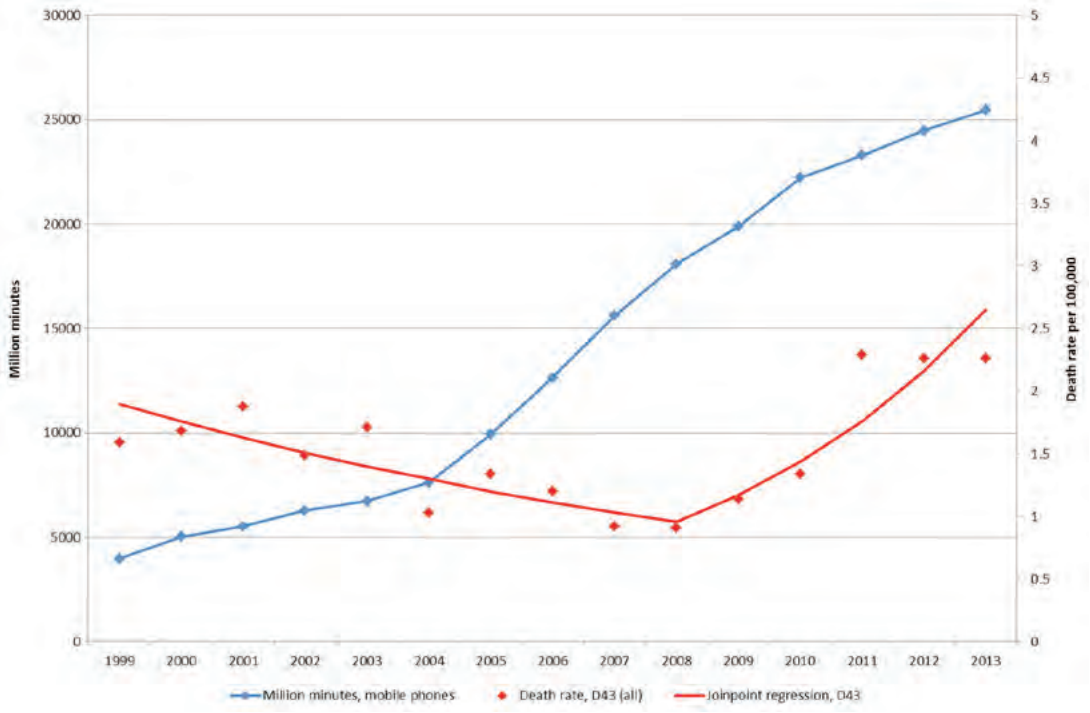

Figure 2. Number of out-going mobile phone minutes in millions during the period between 1999-2013 (http://statistik.pts.se/pts2013/download/Svensk%20Telemarknad%202013.pdf; accessed on April 1, 2015) and joinpoint regression analysis of age-standardized death rates per 100,000 inhabitants according to the Swedish Causes of Death Register for all ages during the period between 1999-2013 diagnosed with D43 = tumor of unknown type in the brain or CNS (http://www.socialstyrelsen.se/statistik/statistikdatabas/dodsorsaker).

95% CI +2.87, +5.63%. The highest AAPC was found in the age group of 20-39 years.

In the Swedish Cancer Register, the age-standardized incidence rate per 100,000 increased for brain tumors, ICD-code 193.0, during 1998-2015 with AAPC in men +0.49%, 95% CI +0.05, +0.94%, and in women +0.33%, 95% CI -0.29, +0.45% (63). The cases with brain tumor of unknown type lack morphological examination. Brain tumor diagnoses in the Cancer Register were based on cytology/histopathology in 83% for men and in 87% for women in 1980. This frequency increased to 90% in men and 88% in women in 2015. During the same time period, CT and MRI imaging techniques were introduced and morphology is not always necessary for diagnosis. If all brain tumors based on clinical diagnosis with CT or MRI had been reported to the Cancer Register the frequency of diagnoses based on cytology/histology would have decreased in the register. The results indicate underreporting of brain tumor cases to the Cancer Register. The real incidence would be higher. Thus, incidence trends based on the Cancer Register should be used with caution. Our results support mobile and cordless phones as risk factors for brain tumors with a reasonable latency period.

Fig. 3 shows joinpoint regression analyses of age-standardized incidence rates per 100,000 in men aged 60-79 years with astrocytoma grade III or IV in the Swedish Cancer Register during the period between 1998-2015, and Fig. 4 shows results in women (63).

Interestingly, a recent study demonstrated a similar increase in glioblastoma multiforme in England as in Sweden (64), '*We report a sustained and highly statistically significant ASR [age-standardized incidence rates] rise in glioblastoma multiforme (GBM) across all ages. The ASR for GBM more than doubled from 2.4 to 5.0, with annual case numbers rising from 983 to 2531. Overall, this rise is mostly hidden in the overall data by a reduced incidence of lower-grade tumours.*'

Evaluation. Increasing rates/incidences of brain tumors in Sweden, a country with among the earliest use of wireless phones in the world, have been published. Similar findings have been reported from other countries, see above and reviewed by us (62). The results have strengthened the evidence that RF radiation causes brain tumors in humans.

Acoustic neuroma (vestibular schwannoma)

Human studies. Acoustic neuroma, also known as vestibular schwannoma, is a non-malignant tumor located on the eight 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 lead to the compression of vital brain stem structures. The first symptoms of acoustic neuroma are usually tinnitus and hearing problems. The results for the use of mobile phones in the Interphone (65) and Hardell *et al* (66) studies are presented in Table III. A statistically significant increased risk was found for cumulative ipsilateral use >1,640 h yielding an OR of 2.71, 95% CI of 1.72-4.28.

The study by Moon *et al* (67) was not included in the meta-analysis, since the data on cumulative mobile phone use with numbers of cases and controls were not given. Support of an increased risk was found in the case-case part of the study (67), as also reported by Sato *et al* (68) in their case-case analysis. Pettersson *et al* made a case-control study on acoustic neuroma in Sweden not overlapping our study (69). An increased risk for the highest category of cumulative use

Table III. 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 use in hours for mobile phone use.

	All			Ipsilateral		
Study (ref.)	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Interphone, 2011 (65)						
Cumulative use ≥1,640 h	77/107	1.32	0.88-1.97	47/46	2.33	1.23-4.40
Hardell *et al*, 2013 (66)						
Cumulative use ≥1,640 h	27/301	2.40	1.39-4.16	19/133	3.18	1.65-6.12
Meta-analysis (65,66)						
Cumulative use ≥1,640 h	104/408	1.73	0.96-3.09	66/179	2.71	1.72-4.28

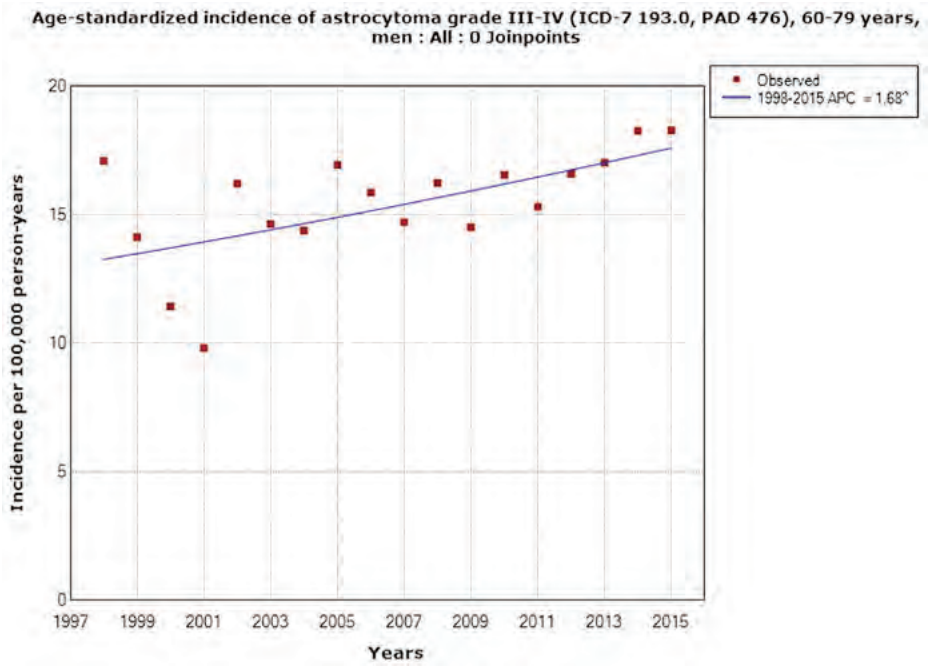

Figure 3. Joinpoint regression analysis of age-standardized incidence rates per 100,000 in men aged 60-79 years with astrocytoma grade III or IV in the Swedish Cancer Register during the period between 1998-2015. APC/AAPC +1.68%, 95% CI +0.39, +2.99% (http://www.socialstyrelsen.se/statistik/statistikdatabas/cancer).

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. We did not include that study in our meta-analysis due to the many scientific shortcomings in the study, e.g., laterality analysis was not made for cordless phone and the numbers in the laterality analysis for mobile phone are not consistent in text and tables and obviously not correct, and the 'unexposed' reference category included subjects using either mobile or cordless phone (70).

The Danish part of the Interphone study reported a mean tumor volume of 1.66 cm^3 among regular mobile phone users and 1.39 cm^3 for non-users (P=0.03) (71). We analyzed the percentage change in tumor volume per year of latency and 100 h of cumulative use (66). For all types of wireless phones, the percentage of tumor volume increased, and was statistically significant for analogue mobile phones per year of latency (P=0.02) and per 100 h of cumulative use (P=0.01). Moon *et al* (67) reported a statistically significant larger mean tumor volume for heavy users (11.32±15.43 cm^3) compared with light users (4.88±5.60 cm^3) based on the daily amount of mobile phone use (P=0.026). Similar results were found for cumulative hours of use. Taken together, these results support tumor promotion by RF radiation.

NTP study. No malignant schwannoma was reported in the mouse study (20).

In the rat study (19), there was a statistically significant increased incidence of malignant schwannoma in the heart of males exposed to GSM modulated cell phone RF radiation for 2 years; P-value for trend =0.041. The tumor was found in all exposure categories for male rats, whereas no malignant schwannoma was found in the sham controls. Endocardial hyperplastic Schwann cell lesions, that are preneoplastic, were found in one 1.5 W/kg and in two 6 W/kg males, but not in the sham control. A statistically significant trend was found in CDMA-modulated exposed males, P=0.011. Two female rats were diagnosed with malignant schwannoma in the heart

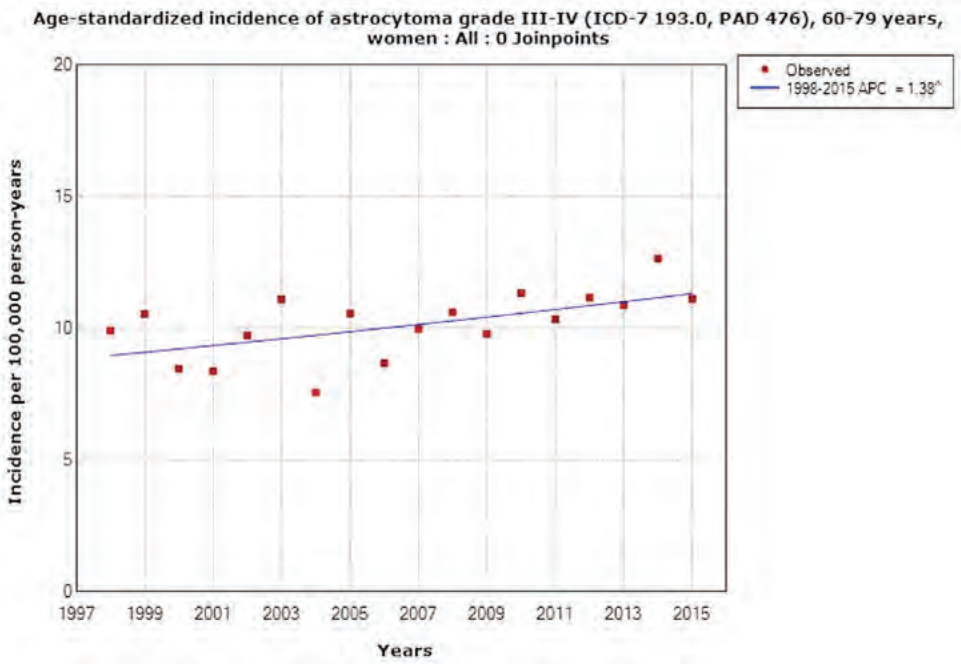

Figure 4. Joinpoint regression analysis of age-standardized incidence rates per 100,000 in women aged 60-79 years with astrocytoma grade III or IV in the Swedish Cancer Register during the period between 1998-2015. APC/AAPC +1.38%, 95% CI +0.32, +2.45% (http://www.socialstyrelsen.se/statistik/statistikdatabas/cancer).

in the 3 W/kg group, but no malignant schwannomas were found in the two other exposure groups or in the sham control, P-value for trend =0.640.

Evaluation. Based on human epidemiological studies and the NTP animal study, there is clear evidence that RF radiation causes vestibular schwannoma (acoustic neuroma) in humans.

Pituitary tumors

Human studies. In a case-control study from Japan, no statistically significant increased risks were found for the use of mobile phone (72). A somewhat increased risk was found in the highest cumulative call time in hours, OR =1.33, 95% CI =0.58-3.09. The cases were aged 30-69 years and diagnosed during the period between 2000-2004.

In a UK case-control study with patients diagnosed during the period between 2001-2005, overall no statistically significant increased risks were found (73). In the group with ≥10 years of use a somewhat increased risk was found for analog mobile phone use: OR =1.2, 95% CI =0.6-2.4, and digital mobile phone use with OR =2.5, 95% CI =0.7-9.1.

In a case-control study from China with cases diagnosed between 2006-2010, mobile phone use yielded an increased risk for pituitary tumor: OR =7.6, 95% CI =2.6-21.4 and a duration of use yielded OR =8.5, 95% CI =2.8-24.4 (74). However, no more data were provided.

The incidence of pituitary tumors increased during the time period between 2004-2009 in the USA (75). The incidence is increasing in Sweden, particularly since 2000, as shown in Fig. 5. There seems to be a decrease during the latest year, but this may be explained by a time lag in the reporting to the Swedish Cancer Register.

NTP study. In male mice (20) exposed to CDMA-modulated RF radiation for two years, two adenoma and one carcinoma occurred in the pars distalis of the pituitary gland. No carcinoma or adenoma occurred in the sham control or the other two exposure groups. No increased incidence was found in female mice.

In male rats exposed to GSM-modulated cell phone RF radiation for two years (19), an increased incidence of pituitary adenoma was found in all exposed groups, although no statistically significance was found (P-value for trend =0.301). In females, the incidence of adenoma in 1.5 and 6 W/kg was statistically significantly decreased (1.5 W/kg P=0.049; 6 W/kg P=0.038).

In male rats exposed to CDMA-modulated RF radiation for two years, an increased incidence of pituitary adenoma was found in the 1.5 W/kg (P=0.208) and 3 W/kg (P=0.030). In females there was a statistically significantly decreased incidence of adenoma or carcinoma in the 3 W/kg group (P=0.030).

Evaluation. Based on human epidemiological studies and the NTP animal study, there is equivocal evidence that RF radiation causes pituitary tumors in humans (may be related to exposure).

Thyroid cancer

Human studies. The incidence of thyroid cancer is increasing in many countries, particularly the papillary type that is the most radiosensitive type. We used the Swedish Cancer Register to study the incidence of thyroid cancer during the period between 1970-2013 using joinpoint regression analysis (31). In women, the incidence increased statistically significantly during the whole study period; AAPC +1.19% (95% CI +0.56, +1.83%). Two joinpoints were detected, 1979 and 2001, with a high increase of the incidence during the last period between 2001-2013 with an APC of +5.34% (95% CI +3.93, +6.77%).

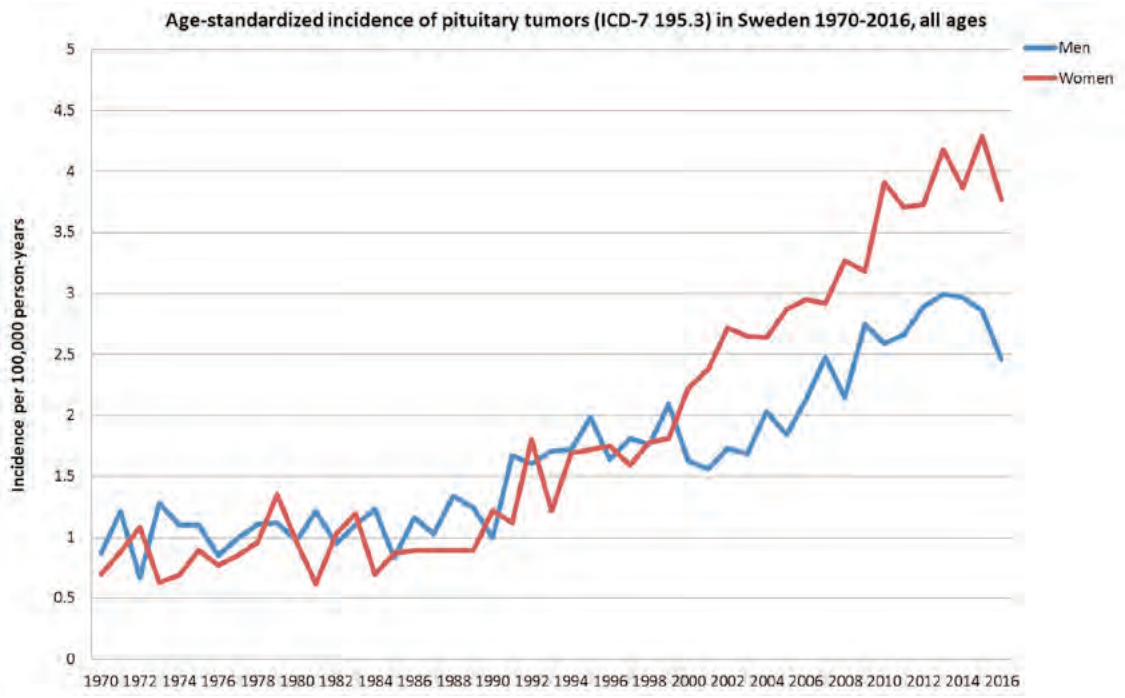

Figure 5. Age-standardized incidence of pituitary tumors (ICD-7 195.3) in Sweden between 1970-2016 for men and women, all ages, according to the Swedish Cancer Register (http://www.socialstyrelsen.se/statistik/statistikdatabas/cancer).

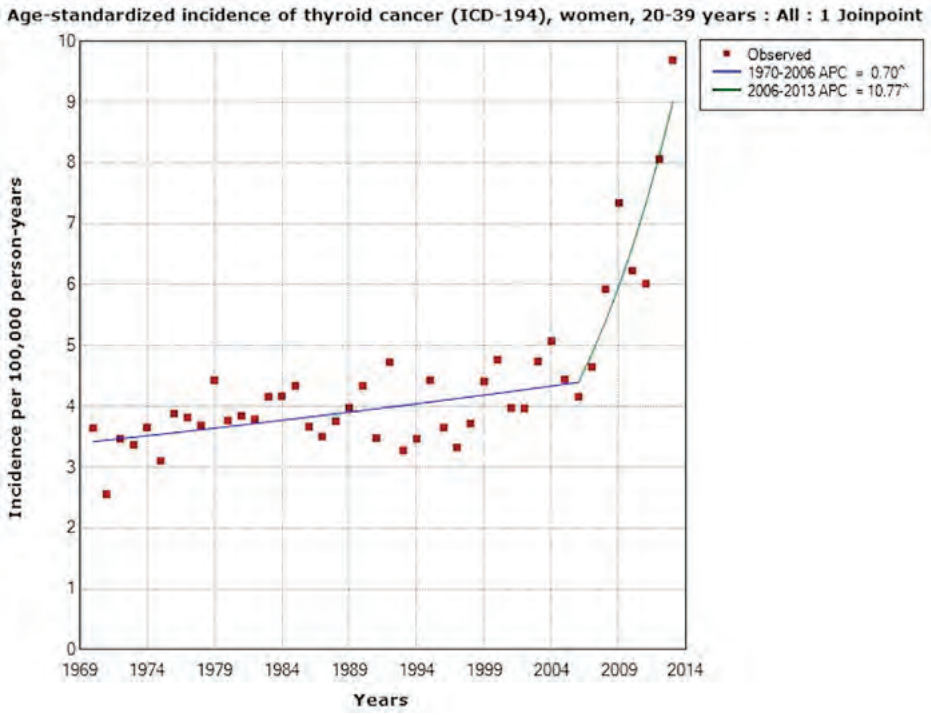

Figure 6. Joinpoint regression analysis of age-standardized incidence of thyroid cancer for women, aged 20-39 years, 1970-2013. Incidence per 100,000 inhabitants for ICD-7 code 194 according to the Swedish Cancer Register (http://www.socialstyrelsen.se/statistik/statistikdatabas/cancer).

In the age group of 20-39 years, joinpoint regression analysis of age-standardized incidence of thyroid cancer in women, aged 20-39 years, APC increased with +10.77% (95% CI +5.75, +16.04%) during the time period between 2006-2013 (Fig. 6).

Analyses based on data from the Cancer Register indicated that the increasing trend in Sweden was mainly caused by thyroid cancer of the papillary type. The incidence increased statistically significantly in women with an AAPC of +4.38% (95% CI +2.95, +5.84%) during the period between 1993-2013 (Fig. 7). One joinpoint was detected in 2006; 1993-2006 APC +1.69% (95% CI +0.32, +3.08%), 2006-2013 APC +9.58% (95% CI +5.85, +13.44%). The incidence of papillary cancer increased in men during the period between 1993-2013 with an AAPC of +3.95% (95% CI +2.20, +5.73%).

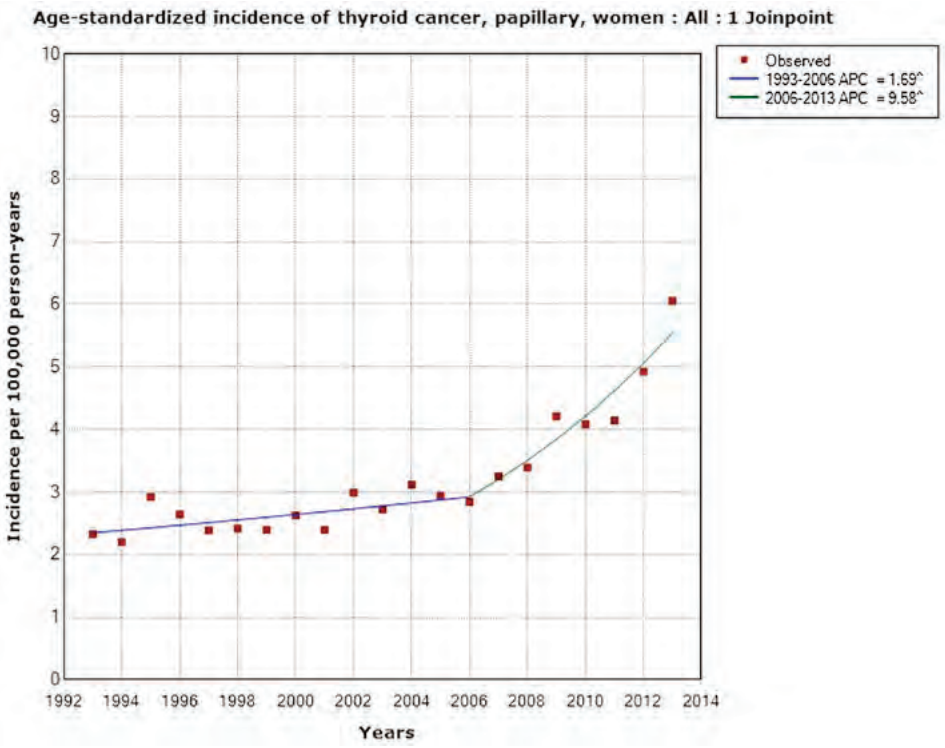

Figure 7. Joinpoint regression analysis of age-standardized incidence of papillary thyroid cancer for women, all ages, 1993-2013. Incidence per 100,000 inhabitants for ICD-7 code 194; data obtained from the Swedish Cancer Register.

AAPC for thyroid cancer in all men during the period between 1970-2013 was +0.77% (95% CI -0.03, +1.58%). One joinpoint was detected in 2005 with a statistically significant increase in incidence during the period between 2005-2013; APC +7.56% (95% CI +3.34, +11.96%). Based on the NORDCAN data, there was a statistically significant increase in the incidence of thyroid cancer in the Nordic countries during the same time period. In both women and men a joinpoint was detected in 2006. The incidence increased during 2006-2013 in women; APC +6.16% (95% CI +3.94, +8.42%) and in men; APC +6.84% (95% CI +3.69, +10.08%), thus showing similar results as in the Swedish Cancer Register (31).

We postulate that the whole increase cannot be attributed to better diagnostic procedures. In Fig. 8 data from the Nordic countries are shown on number of out-going mobile phone minutes during the period between 2001-2013 and the incidence of thyroid cancer in men (green line) and in women (red line). Clearly, with a lag time of some years after the increasing number of out-going calls, the thyroid cancer incidence is increasing.

Increasing exposure to ionizing radiation, e.g., medical CT scans, and to RF radiation should be further studied as causative factors to this emerging thyroid cancer health problem.

Fig. 9 presents three developments in the antenna design in mobile phones that may be of relevance in thyroid carcinogenesis. The second generation (2G) mobile phones appeared in the 1990s with the external retractable monopole or helical antennas. The 2G GSM band operated at a 800/900 MHz frequency band, later accompanied by a 1,800 MHz band. Around the turn of the millennium, the external antennas began to disappear, replaced with new phone models with internal planar or microstrip antennas. The first internal antenna was introduced in 1998 and the first dual-band mobile phone, with the internal antenna, was introduced on the market in 1999 (76). The internal antennas were positioned at the top of the telephone. With the emergence of the smartphones in the mid- and late 2000s, the internal antenna location started to shift from the top of the phone to the bottom. Currently, the majority of smartphone models have their antenna positioned at the bottom of the phone, thus closer to the thyroid gland (shown by grey color in Fig. 9). This would have a major impact on increasing radiation to the thyroid gland from smartphones.

Some published laboratory studies are of interest, Radiofrequency radiation at 2.45 GHz at a non-thermal level modified the morphology of the thyroid gland in a study on rats. The central and peripheral follicles presented increased in size and the thickness of peripheral septa decreased. Peripheral follicles increased in size with repeated exposure at 3 W power (77).

In another study on rats, whole body exposure to 900 MHz pulse-modulated RF radiation that was similar to that emitted by the global system for mobile communications (GSM) mobile phones caused pathological changes in the thyroid gland. The gland structure was altered and caspase-dependent pathways of apoptosis were enhanced (78).

NTP study. In mice (20) no increased incidence was reported.

In female rats (19) a statistically significant increased incidence of C-cell hyperplasia was found in the two years of GSM-exposed groups (1.5, 3 and 6 W/kg, respectively). In males, a statistically non-significant increased incidence was observed in the 1.5 W/kg exposure group (noted in text; P-value not given in NTP table).

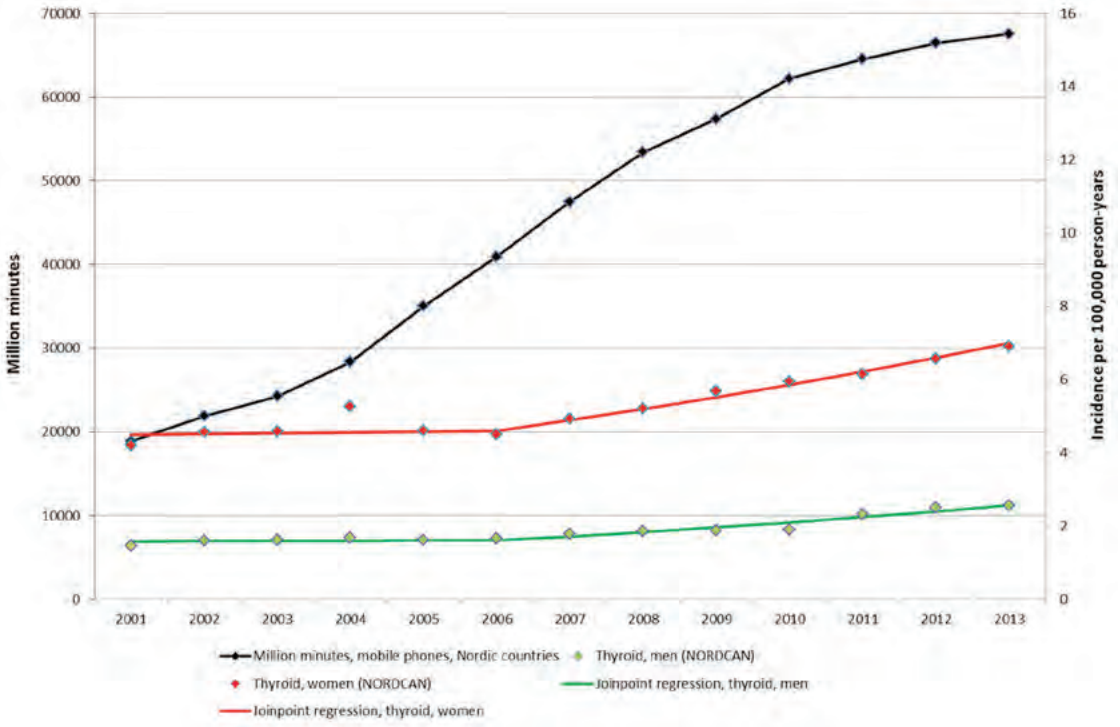

Figure 8. Number of out-going mobile phone minutes and incidence of thyroid cancer 2001-2013. Mobile phone minutes in millions in the Nordic countries (http://statistik.pts.se/PTSnordic/NordicBaltic2014/) and incidence per 100,000 person-years for all ages 2001-2013 according to NORDCAN (http://www-dep.iarc.fr/NORDCAN/english/frame.asp). Joinpoint regression analyses based on the time period between 1970-2013.

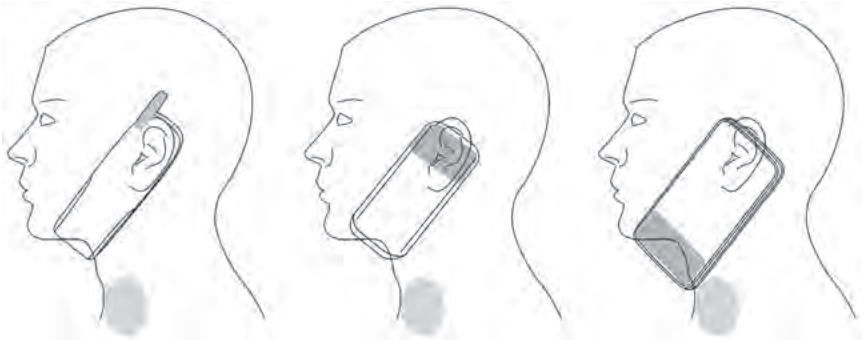

Figure 9. Mobile phone antenna placements in regard to the thyroid gland (grey). Different localizations of the antenna depending on new generations of mobile phones are shown in the panels from left to right.

Evaluation. C-cell hyperplasia as a precursor to familial medullary thyroid cancer in humans is well established. C-cell hyperplasia may be a precursor to other types of thyroid cancer but its role is not well established. Based on human cancer statistics and the NTP animal study, there is some evidence that thyroid cancer is caused by RF radiation in humans.

Malignant lymphoma

Human studies. Few studies exist on malignant lymphoma and exposure to RF radiation. In a case-control study male and female subjects aged 18-74 years living in Sweden were included during a period from December 1, 1999 to April 30, 2002 (27). Controls were selected from the national population registry. Exposure to different agents was assessed by a questionnaire. In total, 910 (91%) cases and 1,016 (92%) controls participated. NHL of the B-cell type was not associated with the use of cellular or cordless telephones. As regards T-cell NHL and the >5 year latency period, the use of analogue cellular phones yielded: OR =1.46, 95% CI =0.58-3.70; digital: OR =1.92, 95% CI =0.77-4.80; and cordless phones: OR =2.47; 95% CI =1.09-5.60. The corresponding results for certain lymphoma, e.g., of the cutaneous and leukemia types, were for analogue phones: OR =3.41, 95% CI =0.78-15.0; digital: OR =6.12, 95% CI =1.26-29.7; and cordless phones: OR =5.48, 95% CI =1.26-23.9. The results indicate an association between T-cell NHL and the use of cellular and cordless telephones; however, the study was based on low numbers and must be interpreted with caution. As regards B-cell NHL, no association was found.

A case-control study in USA used a questionnaire to assess cellular telephone use in 551 NHL cases and 462 frequency-matched population controls (28). Compared to persons who had never used cellular telephones, risks

were not increased among individuals whose lifetime use was >100 times (e.g., regular users, OR =0.9, 95% CI =0.6-1.4). Among regular users compared to those who had never used hand-held cellular telephones, risks of NHL were not statistically significantly associated with minutes per week, duration, cumulative lifetime or year of first use, although NHL was non-significantly higher in men who used cellular telephones for >8 years; OR =2.4, 95% CI =0.8-7.0. NHL not otherwise specified was statistically significantly increased in men for mobile phone use among subjects with ≥6 years duration, OR =4.4, 95% CI =1.3-14.6. There was little evidence to link the use of cellular telephones with total, diffuse large B-cell lymphoma or follicular NHL. No results were presented for T-cell lymphoma.

In the USA, primary central nervous system lymphoma (PCNSL) rates in immunocompetent men and women aged 65+ years increased statistically significantly (1.7 and 1.6% per year, respectively), but remained stable in other age groups during the period between 1992-2011 (79). Thus, the increasing rates could not be related to HIV or immune suppression in organ transplant patients.

In Sweden, the increasing incidence of PCNSL was reported for the time period between 2000-2013 in immunocompetent persons (80). With 359 identified PCNSL cases (median age, 66 years), the overall incidence was 0.26 (95% CI =0.24-0.29) per 100,000 person-years and the average annual increase 4% (P=0.002). The increasing trend was primarily observed among elderly individuals (70+ years). Similarly, an increase in incidence of all brain tumors was noted only among the elderly.

No etiological factor has clearly been defined to explain the increasing incidence of brain lymphoma. However, it has occurred during a time period when RF radiation to the brain from wireless phones has increased.

It should be noted that in transgenic mice, an increased incidence of lymphoma exposed to 900 MHz GSM RF radiation was reported; P=0.006 versus the sham group (25). No increased risk of malignant lymphoma was found in mice exposed to GSM 900 MHz in another study (26). However, the incidence in the sham exposed group was higher in the study by Utteridge *et al* (26) compared with the study by Repacholi *et al* (25) which might have influenced the results.

NTP study. In female mice exposed to GSM-modulated cell phone RF radiation for two years, there were increased incidences of malignant lymphoma in all exposed groups compared to the controls (20). The increase was statistically significant in the 2.5 W/kg (P=0.004) and 5 W/kg groups (P=0.035). In the CDMA-modulated cell phone RF radiation for two years, the incidence increased in female mice in all exposed groups compared to the controls, and was statistically significant in the 2.5 W/kg group (P=0.035).

No conclusive evidence of increased incidence of malignant lymphoma was reported in female rats (19); P-value for trend =0.537 for GSM-modulated cell phone RF radiation and P-value for trend =0.339 for CDMA-modulated cell phone RF radiation.

Evaluation. Based on human epidemiological studies and the NTP study, there is equivocal evidence that malignant lymphoma is caused by RF radiation in humans (may be related to exposure).

Skin (cutaneous tissue)

Human studies. Few studies exist on RF radiation and the risk of developing skin tumors. In a Danish cohort on mobile phone subscribers from the period between 1987-1995 followed to 2007, no increased risks of skin cancer were observed (81). The same cohort has also been used for studying brain tumor risk. Due to serious methodological problems, including the misclassification of exposure the study has been evaluated to be uninformative (8,37).

In a Swedish study on cutaneous malignant melanoma diagnosed during the period between 2000-2003, no increased risk was observed overall (82). In the shortest latency period of >1-5 years and highest cumulative use of >365 h, wireless phone use (mobile phone and/or cordless phone) yielded OR =1.6, 95% CI =0.96-2.9. For melanoma in the most exposed anatomical area during use of the handheld phone, temporal, ear, cheek, the risk increased to OR =2.1, 95% CI =1.1-3.8. The risk was overall highest for cases with first use of a wireless phone before 20 years of age, OR =2.7, 95% CI =0.6-12, although based on low numbers. No interaction was observed with known risk factors for malignant melanoma, such as hair and eye color, skin type or sunburns as a teenager.

Fig. 10 displays the rapidly increasing incidence of malignant melanoma in Sweden in both sexes. The increase is most marked from early 2000.

NTP study. The incidences of malignant fibrous histiocytoma in the skin were higher in 5 and 10 W/kg male mice exposed to GSM-modulated cell phone RF radiation for two years (20). The results were not statistically significant (5 W/kg P=0.124; 10 W/kg P=0.321). The incidences of fibrosarcoma, sarcoma or malignant fibrous histiocytoma were higher in exposed male mice compared with sham control, although border-line significant, P-value for trend =0.093. No increased incidence was observed in female mice.

Male rats exposed to GSM-modulated cell phone RF radiation for two years (19) exhibited higher incidences of fibroma, fibrosarcoma, myxosarcoma, or malignant fibrous histiocytoma in the skin (subcutaneous tissue) in all exposed groups. The increased rates were not statistically significant (P-value for =0.428). No statistically significant results were found in female rats (P-value for trend =0.551).

Evaluation. Based on human epidemiological studies and NTP animal studies there is equivocal evidence that RF radiation causes skin cancer in humans (may be related to exposure).

Concluding remarks. Based on case-control studies, as discussed above, there is a consistent finding of an increased risk of developing glioma and acoustic neuroma associated with the use of mobile phones. Similar results are found for cordless phones in the Hardell group studies. These results are supported by the results of the NTP animal studies (19,20). Malignant vestibular schwannoma is a similar tumor type as acoustic neuroma, also known as vestibular schwannoma.

The findings are less consistent for meningioma although somewhat an increased risk was observed 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 other animal studies showing

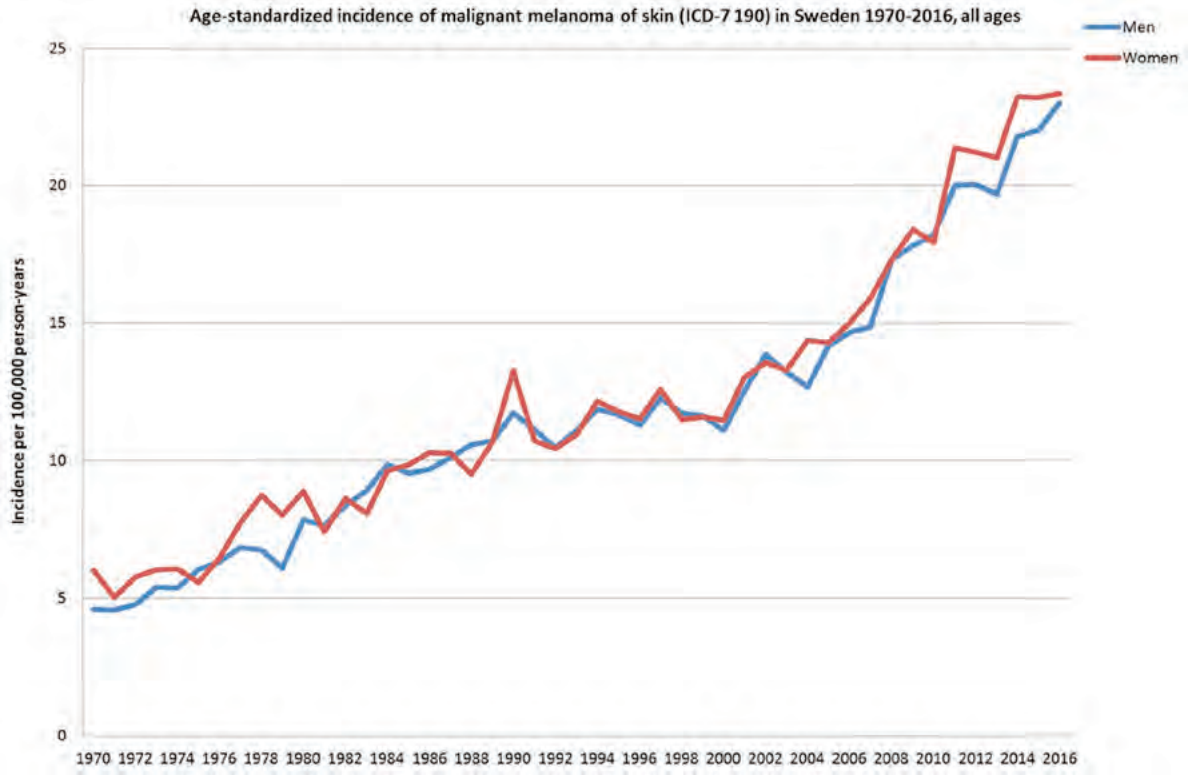

Figure 10. Age-standardized incidence of malignant melanoma (ICD-7 190) in Sweden between 1970-2016 for men and women, all ages, according to the Swedish Cancer Register (http://www.socialstyrelsen.se/statistik/statistikdatabas/cancer).

carcinogenic and/or tumor promoting effects from RF radiation (21-25,32-34). The NTP study showed genotoxicity of RF radiation in rats and mice exposed to RF radiation (83). That result supports previous findings of DNA strand breaks in rat brain cells exposed to RF radiation (84).

One mechanism in carcinogenesis may be oxidative stress with the production of reactive oxygen species (ROS), as summarized by Yakymenko *et al* (85). This could be an indirect mechanism for the increased brain and head tumor risk since ROS may lead to DNA damage (86).

By now carcinogenicity has been shown in human epidemiological studies, which has been replicated in animal studies. Laboratory studies on RF radiation have shown increased ROS production that can cause DNA damage. In 2013, we published the conclusion that RF radiation should be regarded as a human carcinogen, Group 1 according to the IARC definition, fulfilling Bradford Hill causality criteria (87). This was further supported in our updated article (6). That conclusion is reinforced by the current evaluation.

The evidence that RF radiation exposure is a risk factor for cancer is particularly worrying, taking the present deployment of the fifth generation (5G) for wireless communication. More than 200 scientists and medical doctors have asked for a moratorium until studies have been performed by independent researchers on hazards to human health and the environment (88). These millimeter waves have primarily effects on the skin and eye (89). Sweat ducts in the skin may act as helical antennas and boost RF radiation exposure (90). These findings are worrying, taking the present evaluation that present RF radiation may increase the risk of developing skin cancer.

Discussion

The NTP report uses five categories for the evaluation of RF radiation carcinogenicity as follows:

Clear evidence. Clear evidence of carcinogenic activity is demonstrated by studies that are interpreted as showing a dose-related i) increase of malignant neoplasms; ii) increase of a combination of malignant and benign neoplasms; or iii) marked increase of benign neoplasms if there is an indication from this or other studies of the ability of such tumors to progress to malignancy.

Some evidence. Some evidence of carcinogenic activity is demonstrated by studies that are interpreted as showing a test agent-related increased incidence of neoplasms (malignant, benign, or combined) in which the strength of the response is less than that required for clear evidence.

Equivocal evidence. Equivocal evidence of carcinogenic activity is demonstrated by studies that are interpreted as showing a marginal increase of neoplasms that may be test agent related.

No evidence. No evidence of carcinogenic activity is demonstrated by studies that are interpreted as showing no test agent-related increases in malignant or benign neoplasms.

Inadequate study. Inadequate evidence of carcinogenic activity is demonstrated by studies that, due to major qualitative or quantitative limitations, cannot be interpreted as valid

Table IV. National Toxicology Program (NTP) Cell Phone Radiation 2-Year Study Evaluation of Carcinogenicity of Cell Phone Radiation: NTP Draft Technical Reports (TR 595, TR 596) vs. Expert Panel Vote.[a]

Animal	Sex	Cell phone modulation	Tumor types and/or location	Evidence of carcinogenicity	
				NTP draft report	Expert panel (vote yes-no-abstention)
Rat	Male	GSMb	Heart: Schwannoma	Some evidence	Clear evidence (8-3)
Rat	Male	CDMAc	Heart: Schwannoma	Some evidence	Clear evidence (8-3)
Rat	Male	GSM	Brain: Glioma	Equivocal	Some evidence (7-4)
Rat	Male	CDMA	Brain: Glioma	Equivocal	Some evidence (6-4-1)
Rat	Male	GSM	Brain: Granular cell	Equivocal	Equivocal (11-0)
Rat	Male	GSM	Prostate gland	Equivocal	Equivocal (11-0)
Rat	Male	GSM	Pituitary gland	Equivocal	Equivocal (10-1)
Rat	Male	CDMA	Pituitary gland	Equivocal	Equivocal (11-0)
Rat	Male	GSM	Adrenal medulla	Equivocal	Some evidence (6-4-1)
Rat	Male	GSM	Pancreas	Equivocal	Equivocal (11-0)
Rat	Male	CDMA	Liver	Equivocal	Equivocal (11-0)
Rat	Female	GSM	Heart: Schwannoma	No evidence	Equivocal (9-2)
Rat	Female	CDMA	Heart: Schwannoma	No evidence	Equivocal (9-2)
Rat	Female	CDMA	Brain: Glioma	Equivocal	Equivocal (8-3) (4 voted earlier for 'some evidence')
Rat	Female	CDMA	Adrenal medulla	Equivocal	Equivocal (10-0-1)
Mouse	Male	GSM	Skin	Equivocal	Equivocal (8-3)
Mouse	Male	GSM	Lung	Equivocal	Equivocal (11-0)
Mouse	Male	CDMA	Liver	Equivocal	Equivocal (10-1)
Mouse	Female	GSM	Lymphoma	Equivocal	Equivocal (9-2)
Mouse	Female	CDMA	Lymphoma	Equivocal	Equivocal (11-0)

[a]Joel M. Moskowitz, School of Public Health, University of California, Berkeley, March 30, 2018 Electromagnetic Radiation Safety (https://www.saferemr.com/2018/01/national-toxicology-program-peer-public.html) with courtesy; [b]GSM, global system for mobile communications; [c]CDMA, code-division multiple access.

for showing either the presence or absence of carcinogenic activity.

On March 26-28, 2018, a panel of 11 external scientific experts met to evaluate carcinogenicity of the NTP carcinogenicity studies (https://factor.niehs.nih.gov/2018/4/feature/feature-2-cell-phone/index.htm). As shown in Table IV, the carcinogenicity was upgraded for seven tumor types and/or location. Thus for glioma the vote was 'some evidence' in male rats exposed to GSM or CDMA cell modulation. Evidence for heart Schwannoma was found in male rats and was equivocal in female rats, as shown in Table IV. Note that we have herein discussed carcinogenesis only for tumor types with human epidemiological data. It is of interest that animal data indicate also increased incidence for other tumor types and/or locations such as prostate gland, adrenal medulla, pancreas, liver and lung, see also https://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2018/march/actions20180328_508.pdf.

In contrast to the NTP panel, ICNIRP has made its own evaluation (https://www.icnirp.org/cms/upload/publications/ICNIRPnote2018.pdf). They discuss mainly the Schwannoma findings and ignore glial tumors. ICNIRP does not recognize the pattern of increased risk for Schwannoma and glioma in both animal studies and human epidemiology on RF radiation. They conclude that '*ICNIRP considers that the NTP (2018a, b) and Falcioni et al (2018) studies do not provide a consistent, reliable and generalizable body of evidence that can be used as a basis for revising current human exposure guidelines*.' That conclusion is not based on scientific evidence, but is rather an ad hoc statement.

A recent commentary discussed '*several unfounded criticisms about the design and results of the NTP study that have been promoted to minimize the utility of the experimental data on RFR for assessing human health risks. In contrast to those criticisms, an expert peer-review panel recently concluded that the NTP studies were well designed, and that the results demonstrated that both GSM- and CDMA-modulated RFR were carcinogenic to the heart (schwannomas) and brain (gliomas) of male rats*.' (91).

Our conclusion on RF radiation carcinogenicity is the following based on human epidemiology and supported by animal results in the NTP reports: Glioma, clear evidence; meningioma, equivocal evidence; vestibular schwannoma (acoustic neuroma), clear evidence; pituitary tumor (adenoma), equivocal evidence; thyroid cancer, some evidence; malignant lymphoma, equivocal evidence; skin

(cutaneous tissue), equivocal evidence; multi-site carcinogen, clear evidence.

There is clear evidence that RF radiation causes cancer/tumor at multiple sites, primarily in the brain (glioma) and head (acoustic neuroma). There is also evidence of an increased risk of developing other tumor types. The results are similar in both the NTP studies (19,20) and the Ramazzini Institute findings (34). Based on the IARC preamble to the monographs, RF radiation should be classified as Group 1: The agent is carcinogenic to humans.

'*This category is used when there is sufficient evidence of carcinogenicity in humans. Exceptionally, an agent may be placed in this category when evidence of carcinogenicity in humans is less than sufficient but there is sufficient evidence of carcinogenicity in experimental animals and strong evidence in exposed humans that the agent acts through a relevant mechanism of carcinogenicity.*' (http://monographs.iarc.fr/ENG/Preamble/currentb6evalrationale0706.php)

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Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

Both LH and MC participated in the conception, design and writing of the manuscript LH supervised the study. MC made all statistical calculations. Both authors have read and approved the final version.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

1. Cardis E, Deltour I, Mann S, Moissonnier M, Taki M, Varsier N, Wake K and Wiart J: Distribution of RF energy emitted by mobile phones in anatomical structures of the brain. Phys Med Biol 53: 2771-2783, 2008.
2. Gandhi OP, Morgan LL, de Salles AA, Han YY, Herberman RB and Davis DL: Exposure limits: The underestimation of absorbed cell phone radiation, especially in children. Electromagn Biol Med 31: 34-51, 2012.
3. Hardell L, Näsman A, Påhlson A, Hallquist A and Hansson Mild K: Use of cellular telephones and the risk for brain tumours: A case-control study. Int J Oncol 15: 113-116, 1999.
4. Hardell L, Mild KH and Carlberg M: Case-control study on the use of cellular and cordless phones and the risk for malignant brain tumours. Int J Radiat Biol 78: 931-936, 2002.
5. Hardell L, Hansson Mild K, Sandström M, Carlberg M, Hallquist A and Påhlson A: Vestibular schwannoma, tinnitus and cellular telephones. Neuroepidemiology 22: 124-129, 2003.
6. Carlberg M and Hardell L: Evaluation of mobile phone and cordless phone use and glioma risk using the Bradford Hill viewpoints from 1965 on association or causation. BioMed Res Int 2017: 9218486, 2017.
7. Baan R, Grosse Y, Lauby-Secretan B, El Ghissassi F, Bouvard V, Benbrahim-Tallaa L, Guha N, Islami F, Galichet L and Straif K; WHO International Agency for Research on Cancer Monograph Working Group: Carcinogenicity of radiofrequency electromagnetic fields. Lancet Oncol 12: 624-626, 2011.
8. Non-ionizing radiation, part 2: Radiofrequency electromagnetic fields. In: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol 102. International Agency for Research on Cancer Press, Lyon, 2013. http://monographs.iarc.fr/ENG/Monographs/vol102/mono102.pdf (Accessed on 4 July, 2018).
9. Starkey SJ: Inaccurate official assessment of radiofrequency safety by the advisory group on non-ionising radiation. Rev Environ Health 31: 493-503, 2016.
10. Hardell L: World Health Organization, radiofrequency radiation and health - a hard nut to crack (Review). Int J Oncol 51: 405-413, 2017.
11. Maisch D: Conflict of interest and bias in health advisory committees: A case study of the WHO's Electromagnetic Field (EMF) Task Group. J Aust Coll Nutr Environ Med 25: 15-17, 2006.
12. Belpomme D, Hardell L, Belyaev I, Ernesto Burgio E and Carpenter DO: Thermal and non-thermal health effects of non-ionizing radiation: an international perspective. Env Poll 242: 643-658, 2018.
13. Hedendahl L, Carlberg M and Hardell L: Electromagnetic hypersensitivity - an increasing challenge to the medical profession. Rev Environ Health 30: 209-215, 2015.
14. No authors listed: Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). International Commission on Non-Ionizing Radiation Protection. Health Phys 74: 494-522, 1998.
15. International Commission on Non-Ionizing Radiation Protection: ICNIRP statement on the 'Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)'. Health Phys 97: 257-258, 2009.
16. BioInitiative Working Group: BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF). Sage C and Carpenter DO (eds). Bioinitiative, 2007. Available from: http://www.bioinitiative.org/table-of-contents/ (Accessed on 4 July, 2018).
17. BioInitiative Working Group: BioInitiative Report 2012: A Rationale for a Biologically-based Exposure Standard for Electromagnetic Fields (ELF and RF). Sage C and Carpenter DO (eds). Bioinitiative, 2012. Available from: http://www.bioinitiative.org/table-of-contents/ (Accessed on 4 July, 2018).
18. Wyde M, Cesta M, Blystone C, Bucher J, Elmore S, Foster P, Hooth M, Kissling G, Malarkey D, Sills R, *et al*: Report of Partial Findings from the National Toxicology Program Carcinogenesis Studies of Cell Phone Radiofrequency Radiation in Hsd: Sprague Dawley® SD rats (Whole Body Exposure). Draft 5-19-2016. US National Toxicology Program (NTP). doi: http://dx.doi.org/10.1101/055699. Available from: http://biorxiv.org/content/biorxiv/early/2016/05/26/055699.full.pdf (Accessed on 4 July, 2018).
19. National Toxicology Program: NTP technical report on the toxicology and carcinogenesis studies in Hsd: Sprague Dawley sd rats exposed to whole-body radio frequency radiation at a frequency (900 MHz) and modulations (GSM and CDMA) used by cell phones. NTP TR 595, March 26-28, 2018. Available from: https://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2018/march/tr595peerdraft.pdf (Accessed on 4 July, 2018).

20. National Toxicology Program: NTP technical report on the toxicology and carcinogenesis studies in B6C3F1/N mice exposed to whole-body radio frequency radiation at a frequency (1,900 MHz) and modulations (GSM and CDMA) used by cell phones. NTP TR 596, March 26-28, 2018. Available from: https://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2018/march/tr596peerdraft.pdf (Accessed on 4 July, 2018).
21. Szmigielski S, Szudzinski A, Pietraszek A, Bielec M, Janiak M and Wrembel JK: Accelerated development of spontaneous and benzopyrene-induced skin cancer in mice exposed to 2450-MHz microwave radiation. Bioelectromagnetics 3: 179-191, 1982.
22. Cleary SF, Liu LM and Merchant RE: Glioma proliferation modulated in vitro by isothermal radiofrequency radiation exposure. Radiat Res 121: 38-45, 1990.
23. Cleary SF, Liu LM and Merchant RE: In vitro lymphocyte proliferation induced by radio-frequency electromagnetic radiation under isothermal conditions. Bioelectromagnetics 11: 47-56, 1990.
24. Chou CK, Guy AW, Kunz LL, Johnson RB, Crowley JJ and Krupp JH: Long-term, low-level microwave irradiation of rats. Bioelectromagnetics 13: 469-496, 1992.
25. Repacholi MH, Basten A, Gebski V, Noonan D, Finnie J and Harris AW: Lymphomas in E mu-Pim1 transgenic mice exposed to pulsed 900 MHZ electromagnetic fields. Radiat Res 147: 631-640, 1997.
26. Utteridge TD, Gebski V, Finnie JW, Vernon-Roberts B and Kuchel TR: Long-term exposure of E-mu-Pim1 transgenic mice to 898.4 MHz microwaves does not increase lymphoma incidence. Radiat Res 158: 357-364, 2002.
27. Hardell L, Eriksson M, Carlberg M, Sundström C and Mild KH: Use of cellular or cordless telephones and the risk for non-Hodgkin's lymphoma. Int Arch Occup Environ Health 78: 625-632, 2005.
28. Linet MS, Taggart T, Severson RK, Cerhan JR, Cozen W, Hartge P and Colt J: Cellular telephones and non-Hodgkin lymphoma. Int J Cancer 119: 2382-2388, 2006.
29. Lauer O, Frei P, Gosselin MC, Joseph W, Röösli M and Fröhlich J: Combining near- and far-field exposure for an organ-specific and whole-body RF-EMF proxy for epidemiological research: A reference case. Bioelectromagnetics 34: 366-374, 2013.
30. Lu M and Wu XY: Study of specific absorption rate (SAR) induced in human endocrine glands for using mobile phones. IEEE Asia-Pacific International Symposium on Electromagnetic Compatibility (APEMC): 1084-1086, 2016.
31. Carlberg M, Hedendahl L, Ahonen M, Koppel T and Hardell L: Increasing incidence of thyroid cancer in the Nordic countries with main focus on Swedish data. BMC Cancer 16: 426, 2016.
32. Tillmann T, Ernst H, Streckert J, Zhou Y, Taugner F, Hansen V and Dasenbrock C: Indication of cocarcinogenic potential of chronic UMTS-modulated radiofrequency exposure in an ethylnitrosourea mouse model. Int J Radiat Biol 86: 529-541, 2010.
33. Lerchl A, Klose M, Grote K, Wilhelm AF, Spathmann O, Fiedler T, Streckert J, Hansen V and Clemens M: Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans. Biochem Biophys Res Commun 459: 585-590, 2015.
34. Falcioni L, Bua L, Tibaldi E, Lauriola M, De Angelis L, Gnudi F, Mandrioli D, Manservigi M, Manservisi F, Manzoli I, *et al*: Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. Environ Res 165: 496-503, 2018.
35. Johansen C, Boice J Jr, McLaughlin J and Olsen J: Cellular telephones and cancer - a nationwide cohort study in Denmark. J Natl Cancer Inst 93: 203-207, 2001.
36. Schüz J, Jacobsen R, Olsen JH, Boice JD Jr, McLaughlin JK and Johansen C: Cellular telephone use and cancer risk: Update of a nationwide Danish cohort. J Natl Cancer Inst 98: 1707-1713, 2006.
37. Söderqvist F, Carlberg M and Hardell L: Review of four publications on the Danish cohort study on mobile phone subscribers and risk of brain tumors. Rev Environ Health 27: 51-58, 2012.
38. Benson VS, Pirie K, Schüz J, Reeves GK, Beral V and Green J; Million Women Study Collaborators: Mobile phone use and risk of brain neoplasms and other cancers: Prospective study. Int J Epidemiol 42: 792-802, 2013.
39. Ohgaki H and Kleihues P: Population-based studies on incidence, survival rates, and genetic alterations in astrocytic and oligodendroglial gliomas. J Neuropathol Exp Neurol 64: 479-489, 2005.
40. INTERPHONE Study Group: Brain tumour risk in relation to mobile telephone use: Results of the INTERPHONE international case-control study. Int J Epidemiol 39: 675-694, 2010.
41. Coureau G, Bouvier G, Lebailly P, Fabbro-Peray P, Gruber A, Leffondre K, Guillamo JS, Loiseau H, Mathoulin-Pélissier S, Salamon R, *et al*: Mobile phone use and brain tumours in the CERENAT case-control study. Occup Environ Med 71: 514-522, 2014.
42. Hardell L and Carlberg M: Mobile phones, cordless phones and the risk for brain tumours. Int J Oncol 35: 5-17, 2009.
43. Hardell L and Carlberg M: Mobile phone and cordless phone use and the risk for glioma - Analysis of pooled case-control studies in Sweden, 1997-2003 and 2007-2009. Pathophysiology 22: 1-13, 2015.
44. Hardell L, Carlberg M and Hansson Mild K: Pooled analysis of two case-control studies on use of cellular and cordless telephones and the risk for malignant brain tumours diagnosed in 1997-2003. Int Arch Occup Environ Health 79: 630-639, 2006.
45. Hardell L, Carlberg M and Hansson Mild K: Re-analysis of risk for glioma in relation to mobile telephone use: Comparison with the results of the Interphone international case-control study. Int J Epidemiol 40: 1126-1128, 2011.
46. Hardell L, Carlberg M and Hansson Mild K: Pooled analysis of case-control studies on malignant brain tumours and the use of mobile and cordless phones including living and deceased subjects. Int J Oncol 38: 1465-1474, 2011.
47. Cardis E, Armstrong BK, Bowman JD, Giles GG, Hours M, Krewski D, McBride M, Parent ME, Sadetzki S, Woodward A, *et al*: Risk of brain tumours in relation to estimated RF dose from mobile phones: Results from five Interphone countries. Occup Environ Med 68: 631-640, 2011.
48. Grell K, Frederiksen K, Schüz J, Cardis E, Armstrong B, Siemiatycki J, Krewski DR, McBride ML, Johansen C, Auvinen A, *et al*: The intracranial distribution of gliomas in relation to exposure from mobile phones: Analyses from the INTERPHONE study. Am J Epidemiol 184: 818-828, 2016.
49. Momoli F, Siemiatycki J, McBride ML, Parent ME, Richardson L, Bedard D, Platt R, Vrijheid M, Cardis E and Krewski D: Probabilistic multiple-bias modeling applied to the Canadian data from the INTERPHONE study of mobile phone use and risk of glioma, meningioma, acoustic neuroma, and parotid gland tumors. Am J Epidemiol 186: 885-893, 2017.
50. Carlberg M and Hardell L: Decreased survival of glioma patients with astrocytoma grade IV (glioblastoma multiforme) associated with long-term use of mobile and cordless phones. Int J Environ Res Public Health 11: 10790-10805, 2014.
51. Akhavan-Sigari R, Mazloum Farsi Baf M, Ariabod V, Rohde V and Rahighi S: Connection between cell phone use, p53 gene expression in different zones of glioblastoma multiforme and survival prognoses. Rare Tumors 6: 5350, 2014.
52. Turner MC, Benke G, Bowman JD, Figuerola J, Fleming S, Hours M, Kincl L, Krewski D, McLean D, Parent ME, *et al*: Occupational exposure to extremely low-frequency magnetic fields and brain tumor risks in the INTEROCC study. Cancer Epidemiol Biomarkers Prev 23: 1863-1872, 2014.
53. Carlberg M, Koppel T, Ahonen M and Hardell L: Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and glioma risk. Am J Ind Med 60: 494-503, 2017.
54. Peleg M, Nativ O and Richter ED: Radio frequency radiation-related cancer: Assessing causation in the occupational/military setting. Environ Res 163: 123-133, 2018.
55. Cea-Soriano L, Wallander MA and García Rodríguez LA: Epidemiology of meningioma in the United Kingdom. Neuroepidemiology 39: 27-34, 2012.
56. Carlberg M and Hardell L: Pooled analysis of Swedish case-control studies during 1997-2003 and 2007-2009 on meningioma risk associated with the use of mobile and cordless phones. Oncol Rep 33: 3093-3098, 2015.
57. Shrestha B, Khalid M, Gayam V, Mukhtar O, Thapa S, Mandal AK, Kaler J, Khalid M, Garlapati P, Iqbal S, *et al*: Metachronous granular cell tumor of the descending colon. Gastroenterol Res 11: 317-320, 2018.
58. Kim HJ and Lee MG: Granular cell tumors on unusual anatomic locations. Yonsei Med J 56: 1731-1734, 2015.
59. Rejas RA, Campos MS, Cortes AR, Pinto DD and de Sousa SC: The neural histogenetic origin of the oral granular cell tumor: An immunohistochemical evidence. Med Oral Patol Oral Cir Bucal 16: e6-e10, 2011.
60. Kamal SA and Othman EO: Granular cell tumour of the larynx. J Laryngol Otol 112: 83-85, 1998.
61. Deltour I, Johansen C, Auvinen A, Feychting M, Klaeboe L and Schüz J: Time trends in brain tumor incidence rates in Denmark, Finland, Norway, and Sweden, 1974-2003. J Natl Cancer Inst 101: 1721-1724, 2009.

62. Hardell L and Carlberg M: Increasing rates of brain tumours in the Swedish national inpatient register and the causes of death register. Int J Environ Res Public Health 12: 3793-3813, 2015.
63. Hardell L and Carlberg M: Mobile phones, cordless phones and rates of brain tumors in different age groups in the Swedish National Inpatient Register and the Swedish Cancer Register during 1998-2015. PLoS One 12: e0185461, 2017.
64. Philips A, Henshaw DL, Lamburn G and O'Carroll MJ: Brain tumours: Rise in glioblastoma multiforme incidence in England 1995-2015 suggests an adverse environmental or lifestyle factor. J Environ Public Health 7910754: 2018, 2018.
65. INTERPHONE Study Group: Acoustic neuroma risk in relation to mobile telephone use: Results of the INTERPHONE international case-control study. Cancer Epidemiol 35: 453-464, 2011.
66. Hardell L, Carlberg M, Söderqvist F and Mild KH: Pooled analysis of case-control studies on acoustic neuroma diagnosed 1997-2003 and 2007-2009 and use of mobile and cordless phones. Int J Oncol 43: 1036-1044, 2013.
67. Moon IS, Kim BG, Kim J, Lee JD and Lee WS: Association between vestibular schwannomas and mobile phone use. Tumour Biol 35: 581-587, 2014.
68. Sato Y, Akiba S, Kubo O and Yamaguchi N: A case-case study of mobile phone use and acoustic neuroma risk in Japan. Bioelectromagnetics 32: 85-93, 2011.
69. Pettersson D, Mathiesen T, Prochazka M, Bergenheim T, Florentzson R, Harder H, Nyberg G, Siesjö P and Feychting M: Long-term mobile phone use and acoustic neuroma risk. Epidemiology 25: 233-241, 2014.
70. Hardell L and Carlberg M: Long-term mobile phone use and acoustic neuroma. Epidemiology 25: 778, 2014.
71. Christensen HC, Schüz J, Kosteljanetz M, Poulsen HS, Thomsen J and Johansen C: Cellular telephone use and risk of acoustic neuroma. Am J Epidemiol 159: 277-283, 2004.
72. Takebayashi T, Varsier N, Kikuchi Y, Wake K, Taki M, Watanabe S, Akiba S and Yamaguchi N: Mobile phone use, exposure to radiofrequency electromagnetic field, and brain tumour: A case-control study. Br J Cancer 98: 652-659, 2008.
73. Schoemaker MJ and Swerdlow AJ: Risk of pituitary tumors in cellular phone users: A case-control study. Epidemiology 20: 348-354, 2009.
74. Leng L and Zhang Y: Etiology of pituitary tumors: A case control study. Turk Neurosurg 26: 195-199, 2016.
75. Gittleman H, Ostrom QT, Farah PD, Ondracek A, Chen Y, Wolinsky Y, Kruchko C, Singer J, Kshettry VR, Laws ER, *et al*: Descriptive epidemiology of pituitary tumors in the United States, 2004-2009. J Neurosurg 121: 527-535, 2014.
76. Garg R, Bhartia P, Bahl I and Ittipiboon A: Microstrip Antenna Design Handbook. Artech House, Norwood, 2001.
77. Misa-Agustiño MJ, Jorge-Mora T, Jorge-Barreiro FJ, Suarez-Quintanilla J, Moreno-Piquero E, Ares-Pena FJ and López-Martín E: Exposure to non-ionizing radiation provokes changes in rat thyroid morphology and expression of HSP-90. Exp Biol Med (Maywood) 240: 1123-1135, 2015.
78. Eşmekaya MA, Seyhan N and Ömeroğlu S: Pulse modulated 900 MHz radiation induces hypothyroidism and apoptosis in thyroid cells: A light, electron microscopy and immunohistochemical study. Int J Radiat Biol 86: 1106-1116, 2010.
79. Shiels MS, Pfeiffer RM, Besson C, Clarke CA, Morton LM, Nogueira L, Pawlish K, Yanik EL, Suneja G and Engels EA: Trends in primary central nervous system lymphoma incidence and survival in the U.S. Br J Haematol 174: 417-424, 2016.
80. Eloranta S, Brånvall E, Celsing F, Papworth K, Ljungqvist M, Enblad G and Ekström-Smedby K: Increasing incidence of primary central nervous system lymphoma but no improvement in survival in Sweden 2000-2013. Eur J Haematol 100: 61-68, 2018.
81. Poulsen AH, Friis S, Johansen C, Jensen A, Frei P, Kjaear SK, Dalton SO and Schüz J: Mobile phone use and the risk of skin cancer: A nationwide cohort study in Denmark. Am J Epidemiol 178: 190-197, 2013.
82. Hardell L, Carlberg M, Hansson Mild K and Eriksson M: Case-control study on the use of mobile and cordless phones and the risk for malignant melanoma in the head and neck region. Pathophysiology 18: 325-333, 2011.
83. Smith-Roe SL, Wyde ME, Stout MD, Winters JW, Hobbs CA, Shepard KG, Green AS, Kissling GE, Tice RR, Bucher JR, *et al*: Evaluation of the genotoxicity of cell phone radiofrequency radiation in male and female rats and mice following subchronic exposure. Environmental Mutagenesis and Genomics Society, Annual Meeting, Raleigh, North Carolina, USA, September 9-13, 2017.
84. Lai H and Singh NP: Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. Bioelectromagnetics 18: 446-454, 1997.
85. Yakymenko I, Tsybulin O, Sidorik E, Henshel D, Kyrylenko O and Kyrylenko S: Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. Electromagn Biol Med 35: 186-202, 2016.
86. Megha K, Deshmukh PS, Banerjee BD, Tripathi AK, Ahmed R and Abegaonkar MP: Low intensity microwave radiation induced oxidative stress, inflammatory response and DNA damage in rat brain. Neurotoxicology 51: 158-165, 2015.
87. Hardell L and Carlberg M: Using the Hill viewpoints from 1965 for evaluating strengths of evidence of the risk for brain tumors associated with use of mobile and cordless phones. Rev Environ Health 28: 97-106, 2013.
88. The 5G Appeal: Scientists and doctors warn of potential serious health effects of 5G. Available from: http://www.5gappeal.eu/scientists-and-doctors-warn-of-potential-serious-health-effects-of-5g/ (Accessed on 4 July, 2018).
89. Russell CL: 5 G wireless telecommunications expansion: Public health and environmental implications. Environ Res 165: 484-495, 2018.
90. Betzalel N, Ben Ishai P and Feldman Y: The human skin as a sub-THz receiver - Does 5G pose a danger to it or not? Environ Res 163: 208-216, 2018.
91. Melnick RL: Commentary on the utility of the National Toxicology Program Study on cell phone radiofrequency radiation data for assessing human health risks despite unfounded criticisms aimed at minimizing the findings of adverse health effects. Environ Res 168: 1-6, 2018.

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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.

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

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

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).

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

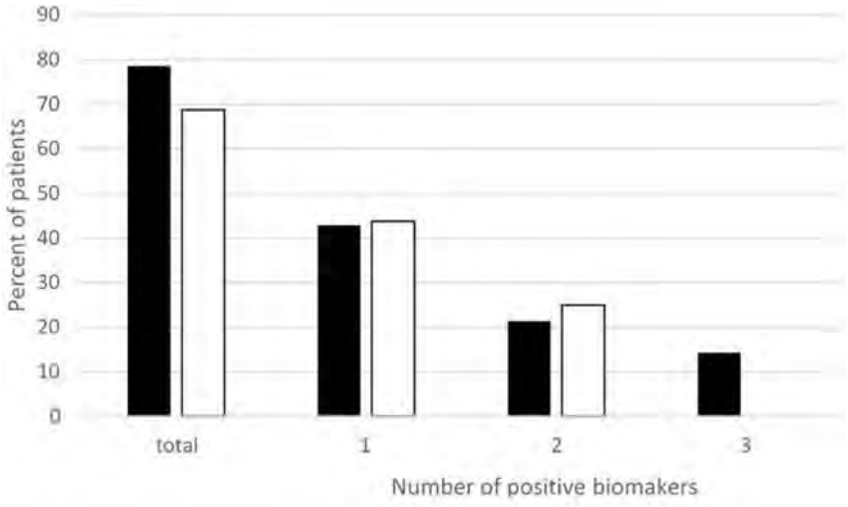

Fig. 1. Percentage of EHS self-reporting patients having positive TBARs, GSSG and/or NTT oxidative stress biomarkers measured in the peripheral blood. "Positive" biomarkers correspond to marker levels above the upper normal limit; "total" corresponds to the patients with one or more positive biomarker 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).

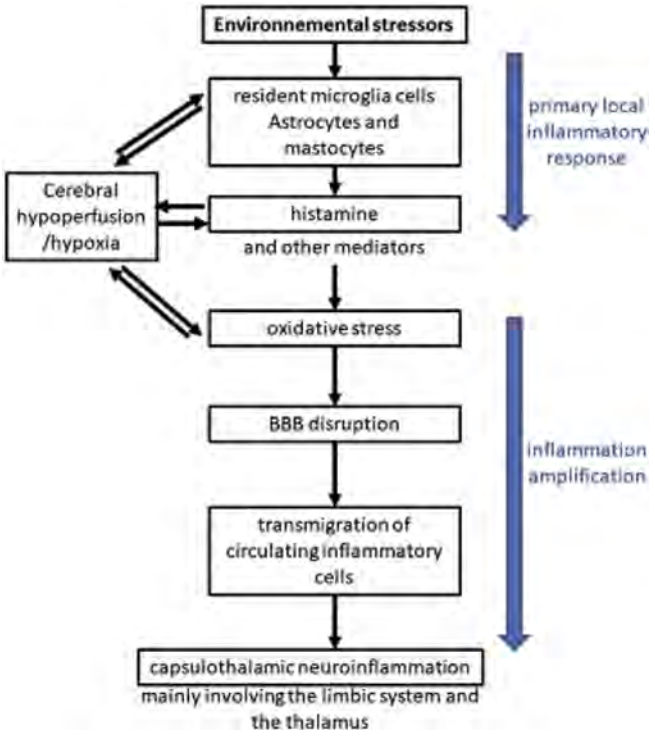

Fig. 2. Hypothetical EHS/MCS common etiopathogenic model based on neuroinflammation and oxidative/nitrosative stress-induced blood brain barrier disruption (Belpomme et al., 2015).

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

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

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.

References

Aalto, S., Haarala, C., Brück, A., Sipilä, H., Hämäläinen, H., Rinne, J.O., 2006. Mobile phone affects cerebral blood flow in humans. J. Cerebr. Blood Flow Metabol. 26, 885–890.

AAP (American Academy of Pediatrics), 2013. American Academy of Pediatrics Demands FCC Protect Children from Cell Phone & Wireless Radiation. Letter from the American Academy of Pediatrics to the FCC Regarding Radiofrequency Electromagnetic Radiation Standards. Available at: the FCC's web site at. http://bit.ly/17tQclg. http://www.saferemr.com/2013/09/american-academy-of-pediatrics-demands.html.

Adey, W.R., Bawin, S.M., Lawrence, A.F., 1982. Effects of weak amplitude-modulated microwave fields on calcium efflux from awake cat cerebral cortex. Bioelectromagnetics 3, 295–307.

Agarwal, A., Desai, N.R., Makker, K., Varghese, A., Mouradi, R., Sabanegh, E., et al., 2009. Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. Fertil. Steril. 92, 1318–1325.

AGNIR (Advisory Group of Non-Ionizing Radiation), 2012. Health Effects from Radiofrequency Electromagnetic Fields. Report of the independent advisory group on non-ionising radiation. April 2012.

Ahlbom, A., Day, N., Feychting, M., Roman, E., Skinner, J., Dockerty, J., et al., 2000. A pooled analysis of magnetic fields and childhood leukaemia. Br. J. Canc. 843, 692–698.

Akhavan-Sigari, R., Baf, M.M., Ariabod, V., Rohde, V., Rahighi, S., 2014. Connection between cell phone use, p53 gene expression in different zones of glioblastoma multiforme and survival prognoses. Rare Tumors 2014 (6), 5350. https://doi.org/10.4081/rt.2014.5350.

Aldad, T.S., Gan, G., Gao, X.B., Taylor, H.S., 2012. Fetal radiofrequency radiation exposure from 800-1900 MHz-rated cellular telephones affects neurodevelopment and behavior in mice. Sci. Rep. 2, 312.

ANSES (French Agency for Food, Environmental and Occupational Health & Safely), 2013. Radiofreqences et sante. October 2013.

ANSES (French Agency for Food, Environmental and Occupational Health & Safely), 2017. Hypersensibilite Electromagnetique Ou Intolerance Environmentale Idiopathique Attribuee Aux Champs Electromagnetiques. Pre-rapport du groupe de travail “Radiofrequence et Sante.”).

Arendash, G.W., Sanchez-Ramos, J., Mori, T., Mamcarz, M., Lin, X., Runfeldt, M., et al., 2010. Electromagnetic field treatment protects against and reverses cognitive impairment in Alzheimer's disease mice. J. Alzheim. Dis. 19, 191–210.

Augner, C., Hacker, G.W., Oberfeld, G., Florian, M., Hitzl, W., Hutter, et al., 2010. Effects of exposure to GSM mobile phone base station signals on salivary cortisol, alpha-amylase, and immunoglobulin A. Biomed. Environ. Sci. 23, 199–207.

Ayşe, I.G., Zafer, A., Sule, O., Işil, I.T., Kalkan, T., 2010. Differentiation of K562 cells under ELF-EMF applied at different time courses. Electromagn. Biol. Med. 29, 122–130.

Baan, R., Grosse, Y., Lauby-Secretan, B., El Ghissassi, F., Bouvard, V., et al., 2011. Carcinogenicity of radiofrequency electromagnetic fields. Lancet Oncol. 12, 624–626.

Balassa, T., Varró, P., Elek, S., Drozdovszky, O., Szemerszky, R., Világi, I., et al., 2014. Changes in synaptic efficacy in rat brain slices following extremely low-frequency magnetic field exposure at embryonic and early postnatal age. Int. J. Dev. Neurosci. 31, 724–730.

Balmori, A., 2005. Possible effects of electromagnetic fields from phone masts on a population of white stork (*Ciconia ciconia*). Electromagn. Biol. Med. 24, 109–119.

Balmori, A., Hallberg, O., 2007. The urban decline of the house sparrow (*Passer domesticus*): a possible link with electromagnetic radiation. Electromagn. Biol. Med. 26, 141–151.

Bas, O., Odaci, E., Kaplan, S., Acer, N., Ucok, K., Colakoglu, S., 2009. 900 MHz electromagnetic field exposure affects qualitative and quantitative features of hippocampal pyramidal cells in the adult female rat. Brain Res. 1265, 178–185.

Bassett, A., 1994. Therapeutic uses of electric and magnetidc fields in orthopaedics. In: Carpenter, D.O., Ayrapetyan, S. (Eds.), Biological Effects of Electric and Magnetic Fields, vol. 2, pp. 13–48.

Bawin, S.M., Adey, W.R., 1976. Sensitivity of calcium binding in cerebral tissue to weak environmental electric fields oscillating at low frequency. Proc. Natl. Acad. Sci. Unit. States Am. 73, 1999–2003.

Bell, R.F., Zlokovic, B.V., 2009. Neurovascular mechanisms and blood-brain barrier disorder in Alzheimer's disease. Acta Neuropathol. 118, 103–113.

Belpomme, D., Campagnac, C., Irigaray, P., 2015. Reliable disease biomarkers characterizing and identifying electrohypersensitivity and multiple chemical sensitivity as two etiopathogenic aspects of a unique pathological disorder. Rev. Environ. Health 30, 251–271.

Belyaev, I.Y., 2010. Dependence of non-thermal biological effects of microwaves on physical and biological variables: implications for reproducibility and safety standards. Eur J Oncol Library 5, 187–218.

Belyaev, I., 2015. Biophysical mechanisms for nonthermal microwave effects. In: Markov, M. (Ed.), Electromagnetic Fields in Biology and Medicine, vol. 2015. CRC Press, Boca Raton, London, New York, pp. 49–68.

Belyaev, I., 2017. Duration of exposure and dose in assessing nonthermal biological effects of microwaves. In: Dosimetry in Bioelectromagnetics. CRC Press, pp. 171–184.

Belyaev, I.Y., Alipov, Y.D., Harms-Ringdahl, M., 1997. Effects of zero magnetic field on the conformation of chromatin in human cells. Biochim. Biophys. Acta 1336, 465–473.

Belyaev, I.Y., Alipov, Y.D., Harms-Ringdahl, M., 1999. Effects of weak ELF on E. coli cells and human lymphocytes: role of genetic, physiological, and physical parameters. In: Bersani, F. (Ed.), Electricity and Magnetism in Biology and Medicine. Kluwer Academic/Plenum Publ, New York, pp. 481–484.

Belyaev, I., Dean, A., Eger, H., Hubmann, G., Jandrisovits, R., Kern, M., et al., 2016. EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. Rev. Environ. Health 31, 363–397.

Belyaev, I.Y., Koch, C.B., Terenius, O., Roxstrom-Lindquist, K., Malmgren, L.O., Sommer, W., et al., 2006. Exposure of rat brain to 915-MHz GSM microwaves induces changes in gene expression but not double stranded DNA breaks or effects on chromatin confirmation. Bioelectromagnetics 27, 295–306.

Belyaev, IYa, Kravchenko, V.G., 1994. Resonance effect of low-intensity millimeter waves on the chromatin conformational state of rat thymocytes. Z. Naturforsch. C Biosci. 49, 352–358.

Belyaev, I.Y., Markovà, E., Hillert, L., Malmgren, L.O., Persson, B.R., 2009. Microwaves from UMTS/GSM mobile phones induce long-lasting inhibition of 53BP1/gamma-H2AX DNA repair foci in human lymphocytes. Bioelectromagnetics 30, 129–141.

Belyaev, I.Y., Shcheglov, V.S., Alipov, Y.D., Polunin, V.A., 1996. Resonance effect of millimeter waves in the power range from 10(-19) to 3 x 10(-3) W/cm2 on *Escherichia coli* cells at different concentrations. Bioelectromagnetics 17, 312–321.

Belyaev, I.Y., Shcheglov, V.S., Alipov, Y.D., Radko, S.P., 1993. Regularities of separate and combined effects of circularly polarized millimeter waves on *E. coli* cells at different phases of culture growth. Bioelectrochem. Bioenerg. 31, 49–63.

Bergqvist, U., Vogel, E., Authors, 1997. Possible health implications of subjective symptoms and electromagnetic fields. In: A Report Prepared by a European Group of Experts for the European Commission, DGV. Arbete Och Hälsa, 19. Swedish National Institute for Working Life, Stockholm, Sweden. Available from: http://www2.niwl.se/forlag/en/.

Beyer, C., Christen, P., Jelesarov, I., Fröhlich, J., 2013. Experimental system for real-time assessment of potential changes in protein conformation induced by electromagnetic fields. Bioelectromagnetics 34, 419–428.

Birks, L., Guxens, M., Papadopoulou, E., Alexander, J., Ballester, F., Estarlich, M., et al., 2017. Maternal cell phone use during pregnancy and child behavioral problems in five birth cohorts. Environ. Int. 104, 122–131.

Blackman, C., 2009. Cell phone radiation. Evidence from ELF and RF studies supporting more inclusive risk identification and assessment. Pathophysiology 16, 205–216.

Blank, M., Goodman, R., 1999. Electromagnetic fields may act directly on DNA. J. Cell. Biochem. 75, 369–374.

Blank, M., Goodman, R., 2011a. Electromagnetic fields stress living cells. Pathophysiology 16, 71–78.

Blank, M., Goodman, R., 2011b. DNA is a fractal antenna in electromagnetic fields. Int. J. Radiat. Biol. 87, 409–415.

Bohr, H., Bohr, J., 2013. Microwave enhanced kinetics observed in ORD studies of a protein. Bioelectromagnetics 21, 68–72.

Burlaka, A., Tsybulin, O., Sidorik, E., Lukin, S., Polishuk, V., Tsehmistrenko, S., et al., 2013. Overproduction of free radical species in embryonal cells exposed to low

intensity radiofrequency radiation. Exp. Oncol. 35, 219–225.
Byun, Y.H., Ha, M., Kwon, H.J., Hong, Y.C., Leem, J.H., Salong, J., et al., 2017. Mobile phone use, blood lead levels, and attention deficit hyperactivity symptoms in children: a longitudinal study. PLoS One 8, e59742.
Byus, C.V., Karun, K., Pieper, S., Ady, W.R., 1988. Increased ornithine decarboxylase activity in cultured cells exposed to low energy modulated microwave fields and porbol ester tumor promoters. Canc. Res. 48, 4222–4226.
Cardis, E., Armstrong, B.K., Bowman, J.D., Giles, G.G., Hours, M., Krewski, D., et al., 2011. Risk of brain tumours in relation to estimated RF dose from mobile phones: results from five Interphone countries. Occup. Environ. Med. 68, 631–640.
Cardis, E., Deltour, I., Mann, S., Moissonnier, M., Taki, M., Varsier, N., et al., 2008. Distribution of RF energy emitted by mobile phones in anatomical structures of the brain. Phys. Med. Biol. 53, 2771–2783.
Carlberg, M., Hardell, L., 2014. Decreased survival of glioma patients with astrocytoma grade IV (glioblastoma multiforme) associated with long-term use of mobile and cordless phones. Int. J. Environ. Res. Publ. Health 11, 10790–10805.
Carlberg, M., Hardell, L., 2015. Pooled analysis of Swedish case-control studies during 1997-2003 and 2007-2009 on meningioma risk associated with the use of mobile and cordless phones. Oncol. Rep. 33, 3093–3098.
Carlberg, M., Hardell, L., 2017. Evaluation of mobile phone and cordless phone use and glioma risk using the Bradford Hill viewpoints from 1965 on association or causation. BioMed Res. Int. 2017, 9218486. https://doi.org/10.1155/2017/9218486.
Carpenter, D.O., 2006. Environmental contaminants and learning and memory. Int. Congr. 1287, 185–189.
Carpenter, D.O., 2015. The microwave syndrome or electro-hypersensitivity: historical background. Rev. Environ. Health 30, 217–222.
Carter, B., Rees, P., Hale, L., Bhattacharjee, D., Paradkar, M.S., 2016. Association between portable screen-based media device access or use and sleep outcomes: a systematic review and meta-analysis. JAMA Pediatr 170, 1202–1208.
Cea-Soriano, L., Wallander, M.A., García Rodríguez, L.A., 2012. Epidemiology of meningioma in the United Kingdom. Neuroepidemiology 39, 27–34.
Choi, K.H., Ha, M., Ha, E.H., Park, H., Kim, Y., Hong, Y.C., et al., 2017. Neurodevelopment for the first three years following prenatal mobile phone use, radiofrequent radiation and lead exposure. Environ. Res. 156, 810–817.
Choi, S.B., Kwon, M.K., Chung, J.W., Park, J.S., Chung, K., Kim, D.W., 2014. Effects of short-term radiation emitted by WCDMA mobile phones on teenagers and adults. BMC Publ. Health 14, 438.
Chrousos, G.P., Gold, P.W., 1992. The concepts of stress and stress system disorders. Overview of physical and behavioral homeostasis. JAMA 267, 1244–1252.
Coureau, G., Bouvier, G., Lebailly, P., Fabbro-Peray, P., Gruber, A., Leffondre, K., et al., 2014. Mobile phone use and brain tumours in the CERENAT case-control study. Occup. Environ. Med. 71, 514–522.
Cucurachi, S., Tamis, W.L., Vijver, M.G., Peijnenburg, W.J., Bolte, J.F., de Snoo, G.R., 2013. A review of the ecological effects of radiofrequency electromagnetic fields (RF-EMF). Environ. Int. 51, 116–140.
Dasdag, S., Akdag, M.Z., Kizil, G., Kizil, M., Cakir, D.U., Yokus, B., 2012. Effect of 900 MHz radio frequency radiation on beta amyloid protein, protein carbonyl, and malondialdehyde in the brain. Electromagn. Biol. Med. 31, 67–74.
Dasdag, S., Akdag, M.Z., Erdal, M.E., Erdal, N., Av, O.L., Ay, M.E., et al., 2015. Effects of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on microRNA expression in brain tissue. Int. J. Radiat. Biol. 91, 555–561.
Davanipour, Z., Sobel, E., 2009. Long-term exposure to magnetic fields and the risks of Alzheimer's Disease and breast cancer. Pathophysiology 16, 149–156.
De Luca, C., Thai, J.C., Raskovic, D., Cesareo, E., Caccamo, D., Trukhanov, A., et al., 2014. Metabolic and genetic screening of electromagnetic hypersensitive subjects as a feasible tool for diagnostics and intervention. Mediat. Inflamm. 2014, 924184.
Deshmukh, P.S., Megha, K., Banerjee, B.D., Ahmed, R.S., Chandna, S., Abegaonkar, M.P., Tripathi, A.K., 2013. Detection of low level microwave radiation induced deoxyribonucleic acid damage vis-a-vis genotoxicity in brain of fischer rats. Toxicol. Int. 20, 19–24.
Deshmukh, P.S., Nasare, N., Megha, K., Banerjee, B.D., Ahmed, R.S., Singh, D., et al., 2015. Cognitive impairment and neurogenotoxic effects in rats exposed to low-intensity microwave radiation. Int. J. Toxicol. 34, 284–290.
Diem, E., Schwarz, C., Adlkofer, F., Jahn, O., Rüdiger, H., 2005. Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. Mutat. Res. 583, 178–183.
Dieudonné, M., 2016. Does electromagnetic hypersensitivity originate from nocebo responses? Indications from a qualitative study. Bioelectromagnetics 37, 14–24.
Divan, H.A., Kheifets, L., Obel, C., Olsen, J., 2008. Prenatal and postnatal exposure to cell phone use and behavioral problems in children. Epidemiology 19, 523–529.
Divan, H.A., Kheifets, L., Obel, C., Olsen, J., 2012. Cell phone use and behavioural problems in young children. J. Epidemiol. Community Health 66, 524–529.
Dobes, M., Khurana, V.G., Shadbolt, B., Jain, S., Smith, S.F., Smee, R., et al., 2011. Increasing incidence of glioblastoma multiforme and meningioma, and decreasing incidence of Schwannoma (2000-2008): findings of a multicentre Australian study. Surg. Neurol. Int. 2, 176.
Dodge, C.H., 1970. Clinical and hygienic aspects of exposure to electromagnetic fields. In: Cleary, S.I. (Ed.), Biol. Effects and Health Implications of Microwave Radiation, "Symp. Proc, vols. 70–72, pp. 140–149. USDHEW, Dept. BRH/DBE.
Duan, Y., Zhang, Z., Bu, R.F., 2011. Correlation between cellular phone use and epithelial parotid gland malignancies. Int. J. Oral Maxillofac. Surg. https://doi.org/10.1016/j.ijom.2011.03.007.
Eberhardt, J.L., Persson, B.R.R., Brun, A.E., Salfor, L.G., Malmgren, L.O.G., 2008. Blood-brain barrier permeability and nerve cell damage in rat brain 14 and 28 days after exposure to microwaves for GSM mobile phones. Electromagn. Biol. Med. 27, 215–229.
Eghlidospour, M., Ghanbari, A., Mortazavi, S.M.J., Azari, H., 2017. Effects of radiofrequency exposure emitted from a GSM mobile phone on proliferation, differentiation, and apoptosis of neural stem cells. Anat Cell Biol 50, 115–123.
Eltiti, S., Wallace, D., Russo, R., Fox, E., 2015. Aggregated data from two double-blind base station provocation studies comparing individuals with idiopathic environmental intolerance with attribution to electromagnetic fields and controls. Bioelectromagnetics 36, 96–107.
Esmekaya, M.A., Ozer, C., Seyhan, N., 2011. 900 MHz pulse-modulated radiofrequency radiation induces oxidative stress on heart, lung, testis and liver tissues. Gen. Physiol. Biophys. 30, 84–89.
Etxeberrua, H., San Roman, E., Burgul, R., Guevara, M., Moreno-Iribas, C., Urbina, M.J., Ardanaz, E., 2015. Brain and central nervous system cancer incidence in Navarre (Spain), 1973-2008 and projections for 2014. J. Canc. 6, 177–183.
Falcioni, L., Bua, L., Tibaldi, M., Lauriola, L., De Angelis, F., Gnudi, F., et al., 2018. Report of final results regarding brain and heart tumors in Sparague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station. Environ. Res. 65, 496–503.
Falone, S., Grossi, M.R., Cinque, B., D'Angelo, B., Tettamanti, E., Cimini, A., et al., 2007. Fifty hertz extremely low-frequency electromagnetic field causes changes in redox and differentiative status in neuroblastoma cells. Int. J. Biochem. Cell Biol. 39, 2093–2106.
Fojt, L., Strasák, L., Vetterl, V., Smarda, J., 2004. Comparison of the low-frequency magnetic field effects on bacteria *Escherichia coli, Leclercia adecarboxylata* and *Staphylococcus aureus*. Bioelectrochemistry 63, 337–341.
Fragopoulou, A.F., Samara, A., Antonelou, M.H., Xanthopoulou, A., Papadopoulou, A., Vougas, K., et al., 2011. Brain proteome response following whole body exposure of mice to mobile phone or wireless DECT base radiation. Electromagn. Biol. Med. 31, 250–274.
Frey, A.H., 1993. Electromagnetic field interactions with biological systems. FASEB J 7, 272–281.
Friedman, J.1, Kraus, S., Hauptman, Y., Schiff, Y., Seger, R., 2007. Mechanism of short-term ERK activation by electromagnetic fields at mobile phone frequencies. Biochem. J. 405, 559–568.
Furtado-Filho, O.V., Borba, J.B., Maraschin, T., Souza, L.M., Henriques, J.A., Moreira, J.C., Saffi, J., 2015. Effects of chronic exposure to 950 MHz ultra-high-frequency electromagnetic radiation on reactive oxygen species metabolism in the right and left cerebral cortex of young rats of different ages. Int. J. Radiat. Biol. 91, 891–897.
Gandhi, O.P., Lazzi, G., Furse, C.M., 1996. Electromagnetic absorption in the human head and neck for mobile telephones at 835 and 1900 MHz. IEEE Trans. Microw. Theor. Tech. 44 (10), 1884–1897.
Gandhi, O.P., Morgan, L.L., de Salles, A.A., Han, Y.Y., Herberman, R.F., Davis, D.L., 2012. Exposure limits: the underestimation of absorbed cell phone radiation, especially in children. Electromagn. Biol. Med. 31, 34–51.
Gapeev, A.B., Iakushina, V.S., Chemeris, N.K., Fesenko, E.E., 1999a. Modulated extremely high frequency electromagnetic radiation of low intensity activates or inhibits respiratory burst in neutrophils depending on modulation frequency (in Russian). Biofizika 42, 1125–1134.
Gapeev, A.B., Iakushina, V.S., Chemeris, N.K., Fesenko, E.E., 1999b. Dependence of EHF EMF effects on the value of the static magnetic field. Dokl. Akad. Nauk. 369, 404–407.
García, A.M., Sisternas, A., Hoyos, S.P., 2008. Occupational exposure to extremely low frequency electric and magnetic fields and Alzheimer disease: a meta-analysis. Int. J. Epidemiol. 37, 329–340.
Geoffroy-Siraudin, C., Loundou, A.D., Romain, F., Achard, V., Courbiere, B., Perrad, M.H., et al., 2012. Decline of semen quality among 10932 males consulting for couple infertility over a 20-year period in Marseille, France. Asian J Andol 14, 584–490.
Goodman, R., Lin-Ye, A., Geddis, M.S., Wickramaratne, P.J., Hodge, S.E., Pantazatos, S.P., et al., 2009. Extremely low frequency electromagnetic fields activate the ERK cascade, increase hsp70 protein levels and promote regeneration in Planaria. Int. J. Radiat. Biol. 85, 851–859.
Grasso, C.M., D'Ascenzo, M., Torsello, A., Martinotti, G., Wolf, F., Cittadini, A., et al., 2004. Effects of 50 Hz electromagnetic fields on voltage-gated Ca^{2+} channels and their role in modulation of neuroendocrine cell proliferation and death. Cell Calcium 35, 307–315.
Greenland, S., Sheppard, A.R., Kaune, W.T., Poole, C., Kelsh MA for the Childhood Leukemia-EMF Study Group, 2000. A pooled analysis of magnetic fields, wire codes, and childhood leukemia. Epidemiology 11, 624–634.
Grell, K., Frederiksen, K., Schüz, J., Cardis, E., Armstrong, B., Siemiatycki, J., et al., 2016. The intracranial distribution of gliomas in relation to exposure from mobile phones: analyses from the INTERPHONE study. Am. J. Epidemiol. 184, 818–828.
Grigoriev, Y.G., Grigoriev, O.A., Ivanov, A.A., Lyaginskaya, A.M., Merkulov, A.V., Stepanov, V.S., et al., 2010. Autoimmune process after long-term low-level exposure to electromagnetic field (experimental results). Part 1. Mobile communications and changes in electromagnetic conditions for the population: need for additional substantiation of existing hygienic standards. Biophysics 55, 1041–1045.

Ha, M., Im, H., Lee, M., Kim, H.J., Kim, B.-C., Kim, B.-C., Gimm, Y.-M., Pack, J.-K., 2007. Radio-frequency radiation exposure from AM radio transmitters and childhood leukemia and brain cancer. Am. J. Epidemiol. 168, 270–279.
Hallberg, O., Oberfeld, G., 2006. Letter to the editor: will we all become electrosensitive? Electromagn. Biol. Med. 25, 189–191.
Hardell, L., 2017. World Health Organization, radiofrequency radiation and health – a hard nut to crack (Review). Int. J. Oncol. 51, 405–413.
Hardell, L., Carlberg, M., Söderqvist, F., Hansson Mild, K., 2013. Pooled analysis of case-control studies on acoustic neuroma diagnosed 1997-2003 and 2007-2009 and use of mobile and cordless phones. Int. J. Oncol. 43, 1036–1044.
Hardell, L., Carlberg, M., 2014. Long-term mobile phone use and acoustic neuroma. Epidemiology 25, 778.
Hardell, L., Carlberg, M., 2015. Mobile phone and cordless phone use and the risk for glioma – analysis of pooled case-control studies in Sweden, 1997-2003 and 2007-2009. Pathophysiology 22, 1–13.
Hardell, L., Carlberg, M., 2017. Mobile phones, cordless phones and rates of brain tumors in different age groups in the Swedish National Inpatient Register and the Swedish Cancer Register during 1998-2015. PLoS One 12 (10) e0185461. https://doi.org/10.1371/journal.pone.0185461.
Hardell, L., Näsman, Å., Påhlson, A., Hallquist, A., Hansson Mild, K., 1990. Use of cellular telephones and the risk for brain tumours: a case-control study. Int. J. Oncol. 15, 113–116.
Hansson Mild, K., Repacholi, M., van Deventer, E., Ravazzani, P. (Eds.), 2006. Electromagnetic Hypersensitivity: Proceedings, International Workshop on EMF Hypersensitivity, Prague, Czech Republic, October 25-27, 2004. Geneva (Switzerland). WHO Press, p. 16.
Havas, M., 2013. Radiation from wireless technology affects the blood, the heart, and the autonomic nervous system. Rev. Environ. Health 28, 75–84.
Hedendahl, L., Carlberg, M., Hardell, L., 2015. Electromagnetic hypersensitivity - an increasing challenge to the medical profession. Rev. Environ. Health 30, 209–215.
Heuser, G., Heuser, S.A., 2017. Functional brain MRI in patients complaining of electrohypersensitivity after long term exposure to electromagnetic fields. Rev. Environ. Health 32, 291–299.
Ho, V.K.Y., Reijneveld, J.C., Enting RHBienfait, H.P., Robe, P., Baumert, B.G., Visser, O., on behalf of the Dutch Society of Neuro-Oncology, 2014. Changing incidence and improved survival of gliomas. Eur. J. Canc. 50, 2309–2318.
Holmstrom, K.M., Finkel, T., 2014. Cellular mechanisms and physiological consequences of redox-dependent signaling. Nat. Rev. Mol. Cell Biol. 15, 411–421.
Huang, P.C., Cheng, M.T., Guo, H.R., 2018. Representative survey on idiopathic environmental intolerance attributed to electromagnetic fields in Taiwan and comparison with the international literature. Environ. Health 17, 5–12.
Huber, R., Treyer, V., Schuderer, J., Berthold, T., Buck, A., Kuster, N., et al., 2005. Exposure to pulse-modulated radio frequency electromagnetic fields affects regional cerebral blood flow. Eur. J. Neurosci. 21, 1000–1006.
Huber, R., Treyer, V., Borbély, A.A., Schuderer, J., Gottselig, J.M., Landolt, H.P., et al., 2002. Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG. J. Sleep Res. 11, 289–295.
Huss, A., Peters, S., Vermeulen, R., 2018. Occupational exposure to extremely low-frequency magnetic fields and the risk of ALS: a systematic review and meta-analysis. Bioelectromagnetics 39, 156–163.
IARC (International Agency for Research on Cancer), 2002. IARC monographs on the evaluation of carcinogenic risks to humans. In: Non-ioizing Radiation, Part 1: Static and Extremely Low-frequency (ELF) Electric and Magnetic Fields, vol. 80. IARC Press, Lyon, France, 341pp.
IARC (International Agency for Research on Cancer), 2013. IARC monographs on the evaluation of carcinogenic risks to humans. In: Non-ionization Radiation, Part 2: Radiofrequency Electromagnetic Fields, vol. 102. IARC Press, Lyon, France, 406 pp.
IEG (Independent Expert Group on Mobile Phones), 2000. Report of the Group (The Stewart Report). Available at: www.iegmp.org.uk/report/index.htm.
Interphone Study Group, 2011. Acoustic neuroma risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Cancer Epidemiol 35, 453–464.
Interphone Study Group, 2010. Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Int. J. Epidemiol. 39, 675–694.
Irigaray, P., Caccamo, D., Belpomme, D., 2018b. Oxidative stress in electrohypersensitivity self-reporting patients: results of a prospective in vivo investigation with comprehensive molecular analysis. Int. J. Mol. Med. https://doi.org/10.3892/ijmm.
Irigaray, P., Garrel, C., Houssay, C., Mantello, P., Belpomme, D., 2018a. Beneficial effects of a fermented papaya preparation for the treatment of electrohypersensitivity self-reporting patients: results of a phase I-II clinical trial with special reference to cerebral pulsation measurement and oxidative stress analysis. Funct Foods Health Dis 8, 122–144.
Irigaray, P., Lebar, P., Belpomme, D., 2018c. How ultrasonic cerebral tomosphygmography can contribute to the diagnosis of electrohypersensitivity. JBR J. Clin. Diag. Res. In press.
ISD (International Scientific Declaration on EHS & MCS), 2015. Brussels International Scientific Declaration on Electromagnetic Hypersensitivity and Multiple Chemical Sensitivity Following the 5th Paris Appeal Congress that Took Place on the 18th of May, 2015 at the Royal Academy of Medicine, Brussels, Belgium. Available from: http://eceri-institute.org/fichiers/1441982737_Statment_FR_DEFINITIF.pdf.
Jaffe, L.F., Nuccitelli, R., 1977. Electrical controls of development. Annu. Rev. Biophys. Bioeng. 6, 445–213.
Jakovljevic, M., 2014. The placebo-nocebo response: controversies and challenges from clinical and research perspective. Eur. Neuropsychopharmacol 24, 333–341.
Ji, Y., He Q,Sun, Y., Tong, J., Cao, Y., 2016. Adaptive respone in mouse bone-marrow stromal cells exposed to 900-MHz radiofrequency fields: gamma-radiation-induce DNA strand breaks and repair. J. Toxicol. Environ. Health 79, 419–426.
Johansen, C., Boice Jr., J., McLaughlin, J., Olsen, J., 2001. Cellular telephones and cancer – a nationwide cohort study in Denmark. J. Natl. Cancer Inst. 93, 203–207.
Johansson, A., Nordin, S., Heiden, M., Sandström, M., 2010. Symptoms, personality traits, and stress in people with mobile phone-related symptoms and electromagnetic hypersensitivity. J. Psychosom. Res. 68, 37–45.
Juutilainen, J., Matilainen, P., Saankoski, S., Laara, E., Suonio, S., 1993. Early pregnancy loss and exposure to 50-Hz magnetic fields. Bioelectromagnetics 14, 229–236.
Kabali, H.K., Irigoyen, M.M., Nunez-Davis, R., Budacki, J.G., Mohanty, S.H., Leister, K.P., Bonner Jr., R.L., 2015. Exposure and use of mobile media devices by young children. Pediatrics 136, 1044–1050.
Kesari, K.K., Kumar, S., Behari, J., 2011. 900-MHz microwave radiation promotes oxidation in rat brain. Electromagn. Biol. Med. 30, 219–234.
Kesari, K.K., Meena, R., Nirala, J., Kumaar, J., Verma, H.N., 2014. Effect of 3G cell phone exposure with computer controlled 2-D stepper motor on non-thermal activation of the hsp27/p38MAPK stress pathway in rat brain. Cell Biochem. Biophys. 68, 347–358.
Kheifets, L., Repacholi, M., Saunders, R., van Deventer, E., 2005. The sensitivity of children to electromagnetic fields. Pediatrics 116, e303–e313.
Koivisto, M., Revonsuo, A., Krause, C., Laarala, C., Sillanmaki, L., et al., 2000. Effects of 902 MHz electromagnetic filed emitted by cellular telephones on response times in humans. Cog Neurosci Neuropsychol 11, 413–415.
Koyu, A., Cesur, G., Ozguner, F., Akdogan, M., Mollaoglu, H., Ozen, S., 2005. Effects of 900 MHz electromagnetic field on TSH and thyroid hormones in rats. Toxicol. Lett. 137, 257–262.
Kumari, K., Kolviato, H., Viluksela, M., Paidanius, K.M.A., Maritinen, M., Hilitunen, M., et al., 2017. Behavioral testing of mice exposed to intermediate frequency magnetic fields indicates mild memory impairment. PLoS One 12, e188880.
Lai, H., Singh, N.P., 1997. Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. Bioelectromagnetics 18, 446–454.
Lai, H., Singh, N., 2004. Magnetic field-induced DNA strand breaks in brain cells of the rat. Environ. Health Perspect. 112, 687–694.
Ledoigt, G., Belpomme, D., 2013. Cancer induction molecular pathways and HF-EMF irradiation. Adv. Biol. Chem. 3, 177–186.
Lee, T.M.C., Ho, S.M.Y., Tsang, L.Y.H., Yang, S.Y.C., Li, L.S.W., Chan, C.C.H., 2001. Effect on human attention of exposure to the electromagnetic field emitted by mobile phones. Cog Neurosci Neuropsychol 12, 729–731.
Lenhart, A., 2015. Teens, social media & technology overview. Pew Research Center, 47 pages. Retrived from. http://pewinternet.org/2015/04/09/teens-social-media-technology.2015.
Leone, L., Fusco, S., Mastrodonato, A., Piacentini, R., Barbati, S.A., et al., 2014. Epigenetic modulation of adult hippocampal neurogenesis by extremely low-frequency electromagnetic fields. Mol. Neurobiol. 49, 1472–1486.
Lerchl, A., Klose, M., Grote, K., Wilhelm, A.F., Spathmann, O., Fiedler, T., et al., 2015. Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans. Biochem. Biophys. Res. Commun. 459, 585–590.
Levin, M., 2003. Bioelectromagnetics in morphogenesis. Bioelectromagnetics 24, 295–315.
Levine, H., Jorgensen, N., Martino-Andrade, A., Mendiola, J., Weksler-Derri, D., Mindlis, I., et al., 2017. Temporal trends in sperm count: a systematic review and meta-regression analysis. Hum. Reprod. Update 23, 646–659.
Li, D.K., Chen, H., Ferber, J.R., Odouli, R., Quesenberry, C., 2017. Exposure to magnetic field non-ionizing radiation and the risk of miscarriage: a prospective cohort study. Sci. Rep. 7, 17541.
Liburdy, R.P., Vanek Jr., P.F., 1987. Microwaves and the cell membrane. III. Protein shedding is oxygen and temperature dependent: evidence for cation bridge involvement. Radiat. Res. 109, 382–395.
Lin, H., Blank, M., Goodman, R., 1999. A magnetic field-responsive domain in the human HSP70 promoter. J. Cell. Biochem. 75, 170–176.
Lin, H., Blank, M., Rossol-Haseroth, K., Goodman, R., 2001. Regulating genes with electromagnetic response elements. J. Cell. Biochem. 81, 143–148.
Luo, Q., Jiang, Y., Jin, M., Xu, J., Huang, H.F., 2013. Proteomic anlaysis on the alteration of protein expression in the early-stage placental villous tissue of electromagnetic fields associated with cell phone exposure. Reprod. Sci. 20, 1055–1061.
Lyle, D.B., Schecher, P., Adey, W.R., Lundak, R.L., 1983. Suppression of T-lymphocyte cytotoxicity following exposure to sinusoidally ampltudee-modulated fields. Bioelectromagnetics 4, 281–292.
Ma, Q., Deng, P., Zhu, G., Liu, C., Zhang, L., Zhou, Z., et al., 2014. Extremely low-frequency electromagnetic fields affect transcript levels of neuronal differentiation-related genes in embryonic neural stem cells. PLoS One 9, e90041.
Maffei, M.E., 2014. Magnetic field effects on plant growth, development, and evolution. Front. Plant Sci. 5, 445. https://doi.org/10.3389/fpls.2014.00445.
Mahmoudabadi, F.S., Ziaei, S., Firoozabadi, M., Kazemnejad, A., 2015. Use of mobile

phone during pregnancy and the risk of spontaneous abortion. J Environ Health Sci Eng 13, 34. https://doi.org/10.1186/s40201-015-0193-z.
Maisch, D., 2006. Conflict of interest & bias in health advisory committees: a case study of the WHO's Electromgagnetic Field (EMF) Task Group. J Aust Coll Nutr & Env Med 25, 15–17.
Markov, M., Grigoriev, Y., 2015. Protect children from EMF. Electromagn. Biol. Med. 34, 251–256.
Markova, E., Hillert, L., Malmgren, L., Persson, B.R., Belyaev, Y., 2005. Microwaves from GSM mobile telephones affect 53BP1 and gamma-H2AZ foci in human lymphocytes from hypersensitive and healthy persons. Environ. Health Perspect. 113, 1172–1176.
Markova, E., Malmgren, L., Belyaev, I., 2010. Microwaves from mobile phones inhibit 53BP1 focus formation in human stem cells stronger than in differentiated cells: possible mechanistic link to cancer risk. Environ. Health Perspect. 118, 394–399.
Mashevich, M., 2003. Exposure of human peripheral blood lymphocytes to electromagnetic fields associated with cellular phones leads to chromosomal instability. Bioelectromagnetics 24, 82–90.
McCarty, D.E., Carrubba, S., Chesson, A.L., Frilot, C., Gonzalez-Toledo, E., Marino, A.A., 2011. Electromagnetic hypersensitivity: evidence for a novel neurological syndrome. Int. J. Neurosci. 121, 670–676.
McGill, J.J., Agarwal, A., 2014. The impact of cell phone, laptop computer, and microwave oven usage on male fertility. In: du Plessis al, S.S. (Ed.), Male Infertility: a Complete Gide to Lifestydl Ad Environmental Factors. Springer Sciece + buxiness Media, New York. https://doi.org/10.1007/978-1-4939-1040-3_11.
Medeiros, L.N., Sanchez, T.G., 2016. Tinnitus and cell phones: the role of electromagnetic radiofrequency radiation. Braz J Otorhinolaryngol 82, 97–104.
Megha, K., Deshmukh, P.S., Banerjee, B.D., Tripathi, A.K., Ahmed, R., Abegaonkar, M.P., 2015. Low intensity microwave radiation induced oxidative stress, inflammatory response and DNA damage in rat brain. Neurotoxicology 51, 158–165.
Michelozzi, P., Capon, A., Kirchmayer, U., Forastiere, F., Biggeri, A., Barca, A., Perucci, C.A., 2002. Adult and childhood leukemia near a high-power radio station in Rome. Am. J. Epidemiol. 155, 1096–1103.
Momoli, F., Siemiatycki, J., McBride, M.L., Parent, M.E., Richardson, L., Bedard, D., Platt, R., et al., 2017. Probabilistic multiple-bias modelling applied to the Canadian data from the INTERPHONE study of mobile phone use and risk of glioma, meningioma, acoustic neuroma, and parotid gland tumors. Am. J. Epidemiol. 186, 885–893.
Moon, I.S., Kim, B.G., Kim, J., Lee, J.D., Lee, W.S., 2014. Association between vestibular schwannomas and mobile phone use. Tumour Biol. 35, 581–587.
Mortavazi, S., Habib, A., Ganj-Karami, A., Samimi-Doost, R., Pour-Abedi, A., Babaie, A., 2009. Alterations in TSH and thyroid hormones following mobile phone use. Oman Med. J. 24, 274–278.
Mousavy, S.J., Riazi, G.H., Kamarel, M., Aliakbarian, H., Sattarahmady, N., Sharifizadeh, A., et al., 2009. Effects of mobile phone radiofrequency on the structure and function of normal human haemoglobin. Int. J. Biol. Macromol. 44, 278–285.
Muehsam, D., Lalezari, P., Lekhraj, R., Abruzzo, P., Boiotta, A., Marini, M., et al., 2013. Non-thermal radio frequency and static magnetic fields increase rate of haemoglobin deoxygenation in a cell-free preparation. PLoS One 8, e61752.
Nazıroğlu, M., Yüksel, M., Köse, S.A., Özkaya, M.O., 2013. Recent reports of Wi-Fi and mobile phone-induced radiation on oxidative stress and reproductive signaling pathways in females and males. J. Membr. Biol. 246, 869–875.
Needleman, H.L., Gunnoe, C.G., Leviton, A., Reed, R.R., Peresie, H., Maher, C., Barrett, P., 1979. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. N. Engl. J. Med. 300, 684–695.
Nordal, R.A., Wong, C.S., 2005. Molecular targets in radiation-induced blood-brain barrier disruption. Int. J. Radiat. Oncol. Biol. Phys. 62, 279–287.
Nordenson, I., Mild, K.H., Andersson, G., Sandström, M., 1994. Chromosomal aberrations in human amniotic cells after intermittent exposure to fifty hertz magnetic fields. Bioelectromagnetics 15, 293–301.
Nordin, S., Neely, G., Olsson, D., Sandström, M., 2014. Odor and noise intolerance in persons with self-reported electromagnetic hypersensitivity. Int. J. Environ. Res. Publ. Health 11, 8794–8805.
Novoselova, E.G., Glushkova, O.V., Khrenov, M.O., Novoselova, T.V., Lunin, S.M., et al., 2017. Extremely low-level microwaves attenuate immune imbalance induced by inhalation exposure to low-level toluene in mice. Int. J. Radiat. Biol. 93, 535–543.
Odaci, E., Hanci, H., Okinci, A., Fikret, O., Sonmez, F., Aslan, A., et al., 2016. Maternal exposure to a continuous 900-MHz electromagnetic field provokes neuronal loss and pathological changes in cerebellum of 32-day female rat offspring. J Clin Neuroanat 75, 105–110.
Ohgaki, H., Kleihues, P., 2005. Population-based studies on incidence, survival rates, and genetic alterations in astocytic and oligodendroglial gliomas. J. Neuropathol. Exp. Neurol. 64, 479–489.
Oscar, K.J., Hawkins, T.D., 1977. Microwave alteration of the blood-brain barrier system of rats. Brain Res. 126, 281–293.
Ostrom, Q.T., Gittleman, H., Fulo0, J., Liu, M., Blanda, R., Kromer, C., et al., 2015. CBTRUS statistical report: primary brain and central nervous system tumors diagnosed in the United States in 2008-2012. Neuro Oncol. 17, iv1–iv62.
Panagopoulos, D.J., Johansson, O., Carlo, G.L., 2015. Real versus simulated mobile phone exposures in experimental studies. BioMed Res. Int., 607053
Parini, M., Lepetit, J.M., Dumas, M., Tapie, P., Lemoine, J., 1984. Ultrasonic cerebral tomosphygmography. Application in 143 healthy subjects. Agressologie 25, 585–589.
Park, J.E., Seo, Y.K., Yoon, H.H., Kim, C.W., Park, J.K., Jeon, S., 2014. Electromagnetic fields induce neural differentiation of human bone marrow derived mesenchymal stem cells via ROS mediated EGFR activation. Neurochem. Int. 62, 418–424.
Pawlak, K., Seehman, B., Nieckarz, Z., 2014. Plasma thyroid hormones and corticosterone levels in blood of chicken embryos and post-hatch chickens exposed during incubation to 1800 MHz electromagnetic fields. Int. J. Occup. Med. Environ. Health 27, 114–122.
Paz de la Puente, M., Balmori, A., 2007. Addiction to cell phones: are there neurophysiological mechanisms involved? Proyecto 61, 8–12 s. 8.
Persson, B.R.R., Salford, L.G., Brun, A., 1997. Blood-brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication. Wireless Network 3, 455–461.
Pettersson, D., Mathiesen, T., Prochazka, M., Bergenheim, T., Florentzson, R., Harder, H., et al., 2014. Long-term mobile phone use and acoustic neuroma risk. Epidemiology 25, 233–241.
Philips, A., Henshaw, D.L., Lamburn, G., O'Carroll, M.J., 2018. Brain tumours: rise in glioblastoma multiforme incidence in England 1995-2015 suggests an adverse environmental or lifestyle factor. J Environ Public Health, 7910754, 10 pages.
Purlauastja, S., Sorond, P., 2012. Transcranial Doppler ultrasound: technique and application. Semin. Neurol. 32, 411–420.
Qiu, C., Fratiglioni, L., Karp, A., Winblad, B., Bellander, T., 2004. Occupational exposure to electromagnetic fields and risk of Alzheimer's disease. Epidemiology 15, 687–694.
Rea, W.J., Pan, Y., Fenyves, E.F., Sujisawa, I., Suyama, H., et al., 1991. Electromaagnetic field sensitivity. J Bioeletricity 10, 214–256.
RNCNIRP (Russian National Committee on Non-Ionizing Radiation Protection), 2011. Resolution: Electromagnetic Fields from Mobile Phones: Health Effect on Children and Teenagers. 19th April 2011. Available at: http://iemfa.org/images/pdf/RNCNIRP_Resolution_2011.pdf.
Roberts, J.A., Yaya, L.H., Manolis, C., 2014. The invisible addiction: cell-phone activities and addiction among male and female college students. J Behav Addict 3, 254–265.
Rodrequez-De la Fuente, A.O., Alcocer-Gonzalez, J.M., Heredia-Rojas, J.A., Rodriquez-Padilla, C., Rodriquez-Flores, L.E., et al., 2010. Effect of 60 Hz electromagnetic fields on the activity of hsp70 promotoer: an *in vivo* study. Cell Biol. Int. Rep. 19 e00014.
Rolland, M., Le Moal, J., Wagner, V., Royere, D., De Mouzon, J., 2013. Decline in semen concentration and morphology in a sample of 26,609 men close to general population between 1989 and 2005 in Europe. Hum. Reprod. (Eynsham) 28, 462–270.
Röösli, M., 2008. Radiofrequency electromagnetic field exposure and non-specific symptoms of ill health: a systematic review. Environ. Res. 107, 277–287.
Roshangar, L., Hamdi, B.A., Khaki, A.A., Rad, J.S., Soleimani-Rad, S., 2014. Effect of low-frequency electromagnetic field exposure on oocyte differentiation and follicular development. Adv. Biomed. Res. 3, 76.
Roux, D., Vian, A., Girard, S., Bonnet, P., Paladian, F., Davies, E., et al., 2008. High frequency (900 MHz) low amplitude (5 V m-1) electromagnetic field: a genuine environmental stimulus that affects transcription, translation, calcium and energy charge in tomato. Planta 227, 883–891.
Rubin, G.J., Hillert, L., Nieto-Hernandez, R., van Rongen, E., Oftedal, G., 2011. Do people with idiopathic environmental intolerance attributed to electromagnetic fields display physiological effects when exposed to electromagnetic fields? A systematic review of provocation studies. Bioelectromagnetics 32, 593–609.
Sadetzki, S., Chetrit, A., Jarus-Hakak, A., Cardis, E., Deutch, Y., Duvdevani, Sh, et al., 2007. Cellular phone use and risk of benign and malignant parotid gland tumors – a nationwide case-control study. Am. J. Epidemiol. 167, 457–467.
Sage, C., Burgio, E., 2017. Electromagnetic fields, pulsed radiofrequency radiation, and epigenetics: how wireless technologies may affect childhood development. Child Dev. https://doi.org/10.1111/cdev.12824.
Saili, L., Hanini, A., Smirani, C., Azzouz, I., Azzouz, A., Sakly, M., et al., 2015. Effects of acute exposure to WiFi signals (2.45GHz) on heart variability and blood pressure in albino rabbits. Environ. Toxicol. Pharmacol. 40, 600–605.
Sannino, A., Zeni, O., Sarti, M., Romeo, S., Reddy, S.B., et al., 2011. Induction of adaptive response in human blood lymphocytes exposed to 900 MHz radiofrequency fields: influence of cell cycle. Int. J. Radiat. Biol. 87, 993–999.
Sannino, A., Zeni, O., Romeo, S., Massa, R., Gialanella, G., Grossi, G., Manti, L., Vijayalaxmi, Scarfi, M.R., 2014. Adaptive response in human blood lymphocytes exposed to non-ionizing radiofrequency fields: resistance to ionizing radiation-induced damage. J. Radiat. Res. 55, 210–217.
Santini, R., Seigne, M., Bonhomme-Faivre, L., Bouffet, S., Defrasme, E., Sage, M., 2001. Symptoms experienced by users of digital cellular phones: a study of a French engineering school. Electromagn. Biol. Med. 21, 81–88.
Santini, R., Santini, P., Le Ruz, P., Danze, J.M., Seigne, M., 2003. Survey study of people living in the vicinity of cellular phone base. Electromagn. Biol. Med. 22, 41–49.
Sato, Y., Akiba, S., Kubo, O., Yamaguchi, N., 2011. A case-case study of mobile phone use and acoustic neuroma risk in Japan. Bioelectromagnetics 32, 85–93.
SCENIHR (Scientific Committee on Emerging Newly Identified Health Risk), 2009. Health Effects of Exposure to EMF. European Commission. Directorate-General for Health & Consumers, 19 January 2009.
Schwartz, C., Kratochvil, E., Pilger, A., Kuster, N., Adlkofer, F., Rudiger, H.W., 2008. Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects *in vitro* in human fibroblasts but not in lymphocytes. Int. Arch. Occup.

Environ. Health 81, 755–767.
Schüz, J., Jacobsen, R., Olsen, J.H., Boice Jr., J.D., McLaughlin, J.K., et al., 2006. Cellular telephone use and cancer risk: update of a nationwide Danish cohort. J. Natl. Cancer Inst. 98, 1707–1713.
Semin, I.A., 1995. Changes in secondary structure of DNA under the influence of electromagnetic fields. Radiats Biol Radioecol 35, 36–41.
Shahin, S., Banerjee, S., Swarup, V., Singh, S.P., Chaturvedi, C.M., 2017. 2.45 GHz microwave radiation impairs hippocampal learning and spatial memory: involvement of local stress mechanism induced suppression of iGluR/ERK/CREB signaling. Toxicol. Sci. 161, 349–374.
Sirav, B., Seyhan, N., 2009. Blood-brain barrier disruption by continuous-wave radio frequency radiation. Electromagn. Biol. Med. 28, 213–222.
Sirav, B., Seyhan, N., 2016. Effects of GSM modulated radio-frequency electromagnetic radiation on permeability of blood-brain barrier in male & female rats. J. Chem. Neuroanat. 75, 123–127.
Sly, J.L., Carpenter, D.O., 2012. Special vulnerability of children to environmental exposures. Rev. Environ. Health 27, 151–157.
Smith-Roe, S.L., Wyde, M.E., Stout, M.D., Winters, J.W., Hobbs, C.A., Shepard, K.G., et al., 2017. Evaluation of the genotoxicity of cell phone radiofrequency radiation in male and female rats and mice following subchronic exposure. In: Environmental Mutagenesis and Genomics Society, Annual Meeting, Raleigh, North Carolina, USA September 9–13.
Sobel, E., Dunn, M., Davanipour, Z., Qian, Z., Chui, H.C., 1996. Elevated risk of Alzheimer's disease among workers with likely electromagnetic field exposure. Neurology 47, 1477–1481.
Söderqvist, F., Carlberg, M., Hardell, L., 2012a. Review of four publications on the Danish cohort study on mobile phone subscribers and risk of brain tumors. Rev. Environ. Health 27, 51–58.
Söderqvist, F., Carlberg, M., Hardell, L., 2012b. Use of wireless phones and risk of salivary gland tumours: a case-control study. Eur. J. Canc. Prev. 21, 576–579.
Sonmez, O.F., Odaci, E., Bas, O., Kaplan, S., 2010. Purkinje cell number decreases in the adult female rat cerebellum following exposure to 90 MHz electromagnetic fields. Brain Res. 1356, 95–101.
Spadaro, J.A., Bergstrom, W.H., 2002. In vivo and *in vitro* effects of a pulsed electromagnetic field on net calcium flux in rat clavarial bone. Calcif. Tissue Int. 70, 496–502.
Starkey, S.J., 2016. Inaccurate official assessment of radiofrequency safety by the Advisory Group on Non-ionizing radiation. Rev. Environ. Health 31, 493–501.
State of California, 2017. How to reduce exposure to radiofrequency energy from cell phones. In: Division of Environmental and Occupational Disease Control, California Department of Public Health, December, 2017.
Sun, Z.C., Ge, J.L., Guo, B., Guo, J., Hao, M., Wu, Y.C., et al., 2016. Extremely low frequency electromagnetic fields facilitate vesicle endocytosis by increasing presynaptic calcium channel expression at a central synapse. Sci. Rep. 6, 21774.
Tice, R.R., Hook, G.G., Donner, M., McRee, D.I., Guy, A.W., 2002. Genotoxicity of radiofrequency signals. 1. Investigation of DNA damage and micronuclei induction in cultured human blood cells. Bioelectromagnetics 23, 113–128.
Tillmann, T., Ernst, H., Streckert, J., Zhou, Y., Taugner, F., Hansen, V., et al., 2010. Indication of cocarcinogenic potential of chronic UMTS-modulated radiofrequency exposure in an ethylnitrosourea mouse model. Int. J. Radiat. Biol. 86, 529–541.
Vijayalaxmi, Pridoda, T.J., 2009. Genetic damage in mammalian somatic cells exposed to extremely low frequency electro-magnetic fields: a meta-analysis of data from 87 publications (1990-2007). Int. J. Radiat. Biol. 85, 196–213.
Vijayalaxmi, Reddy AB., McKenzie, R.J., McIntosh, R.L., Prihoda, T.J., Wood, A.W., 2013. Incidence of micronuclei in human peripheral blood lymphocytes exposed to modulated and unmodulated 2450 MHz radiofrequency fields. Bioelectromagnetics 34, 542–548.
Vojisavljevic, V., Pirogova, E., Cosic, I., 2010. Review of studies on modulating enzyme activity by low intensity electromagnetic radiation. Conf Proc IEEE Eng Med Biol Soc 835–838.
Volkow, N.D., Tomasi, D., Wang, G.F., Vaska, P., Fowler, J.S., Teland, F., et al., 2011. Effects of cell phone radiofrequency signal exposure on brain glucose metabolism. J. Am. Med. Assoc. 305, 808–814.
Wang, J., Su, H., Xie, W., Yu, S., 2017. Mobile phone use and the risk of headache: a systematic review and meta-analysis of cross-sectional studies. Sci. Rep. 7, 12595.
Wei, J., Sun, J., Xu, H., Shi, L., Sun, L., Zhang, J., 2015. Effects of extremely low frequency electromagnetic fields on intracellular calcium transients in cardiomyocytes. Electromagn. Biol. Med. 34, 77–84.
Wei, L.X., Goodman, R., Henderson, A., 1990. Changes in levels of c-myc and histone H2B following exposure of cells to low frequency sinusoidal electromagnetic fields: evidence for a window effect. Bioelectromagnetics 11, 269–272.
West, J.G., Kopoor, N.S., Liao, S.-Y., Chen, J.W., Bailey, L., Nagourney, R.A., 2013. Multifocal Breast Cancer in Young Women with Prolonged Contact between Their Breast and Their Cllular Phones. Case Report Med. https://doi.org/10.1155//2013/354682.
WHO (World Health Organization, 2005. WHO Fact Sheet No. 296. Electromagnetic Fields and Public Health, Electromagnetic Hypersensitivity. Available from: http://www.who.int/peh-emf/publications/facts/fs296/en/.
WHO (World Health Organization), 2014. Electromagnetic Fields and Public Health: Mobile Phones. Fact sheet No. 193, reviewed October, 2014.
Wolf, F.I., Torsello, A., Tedesco, B., Fasanella, S., Boninsegna, A., D'Ascenzo, M., et al., 2007. 50-Hz extremely low frequency electromagnetic fields enhance cell proliferation and DNA damage: possible involvement of a redox mechanism. Biochim. Biophys. Acta 1743, 120–129.
Wyde, M., Cesta, M., Blystone, C., Elmore, S., Foster, P., Hooth, M., et al., 2016. Report of Partial Findings from the National Toxicology Program Carcinogenesis Studies of Cell Phone Radiofrequency Radiation in Hsd: Sprague Dawley® SD Rats (Whole Body Exposures). Draft 5-19-2016. US National Toxicology Program (NTP). Available online: https://doi.org/10.1101/055699 http://biorxiv.org/content/biorxiv/early/2016/05/26/055699.full.pdf (accessed on 30 July, 2017).
Yan, H.G., Agresti, M., Zhang, L.L., Yan, Y., Mathoul, H.S., 2008. Upregulation of specific mRNA levels in rat brain after cell phone exposure. Electromagn. Biol. Med. 27, 147–154.
Yang, X.S., He, G.L., Hao, Y.T., Xiao, Y., Chen, C.H., Zhang, G.B., et al., 2012. Exposure to 2.45 GHz electromagnetic fields elicits an HSP-related stress response in rat hippocampus. Brain Res. Bull. 88, 371–278.
Yang, Y., Jin, X., Yn, C., Tian, Y., Tang, J., Shen, X., 2008. Case-only study of interactions between DNA repair genes (hMLH1, APEX1, MGMT, XRCC1 and XPD) and low-frequency electromagnetic fields in childhood acute leukemia. Leuk. Lymphoma 49, 2344–2350.
Zhang, X., Liu, X., Pan, L., Lee, I., 2010. Magnetic fields at extremely low-frequency (50 Hz, 0.8 mT) can induce the uptake of intracellular calcium levels in osteoblasts. Biochem. Biophys. Res. Commun. 396, 662–666.
Zhang, Y., Li, Z., Gao, Y., Zhang, C., 2015. Effects of fetal microwave radiation exposure on offspring behavior in mice. J. Radiat. Res. 56, 261–268.

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Very high radiofrequency radiation at Skeppsbron in Stockholm, Sweden from mobile phone base station antennas positioned close to pedestrians' heads

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ABSTRACT

In urban environment there is a constant increase of public exposure to radiofrequency electromagnetic fields from mobile phone base stations. With the placement of mobile phone base station antennas radiofrequency hotspots emerge. This study investigates an area at Skeppsbron street in Stockholm, Sweden with an aggregation of base station antennas placed at low level close to pedestrians' heads. Detailed spatial distribution measurements were performed with 1) a radiofrequency broadband analyzer and 2) a portable exposimeter. The results display a greatly uneven distribution of the radiofrequency field with hotspots. The highest spatial average across all quadrat cells was 12.1 V m^{-1} (388 mW m^{-2}), whereas the maximum recorded reading from the entire area was 31.6 V m^{-1} (2648 mW m^{-2}). Exposimeter measurements show that the majority of exposure is due to mobile phone downlink bands. Most dominant are 2600 and 2100 MHz bands used by 4G and 3G mobile phone services, respectively. The average radiofrequency radiation values from the earlier studies show that the level of ambient RF radiation exposure in Stockholm is increasing. This study concluded that mobile phone base station antennas at Skeppsbron, Stockholm are examples of poor radiofrequency infrastructure design which brings upon highly elevated exposure levels to popular seaside promenade and a busy traffic street.

1. Introduction

Electromagnetic fields are known physical risk factors. When mobile phone base station antennas are installed, the immediate physical environment, including the public and the living spaces can be greatly affected by microwaves.

Measuring public exposure to radiofrequency fields is significant from public health perspective, but also for future epidemiological studies. Given the rapid development of mobile communication technologies, the radiofrequency landscape is continuously diversifying and intensifying: more frequencies are introduced to provide novel mobile phone and data services; more base station antennas are constantly installed to facilitate the increasing need for data amounts, pushed through the networks. Meanwhile, public exposure also increases.

In previous publications we have reported environmental exposure to radiofrequency (RF) electromagnetic (EMF) radiation at certain places in Stockholm in Sweden such as the Central Railway Station (Hardell et al., 2016), the Old Town (Hardell et al., 2017), with special attention to Järntorget in the Old Town (Hardell et al., 2019), and Stockholm city (Carlberg et al., 2019). Of special interest was to measure RF radiation in one Stockholm apartment with two groups of base station antennas nearby (Hardell et al., 2018). That apartment was further examined using a RF broadband analyzer and the results were compared with another Stockholm apartment with substantially much lower RF radiation but equally good wireless communication possibility (Koppel et al., 2019).

Earlier studies done in Europe show constant increase of public exposure, especially in urban environment. The increase is attributed to new mobile phone base stations installed, but also to the increased usage of corresponding mobile services. Sánchez-Montero et al. (2017) monitored urban exposure in Alcalá de Henares (Spain) for ten years and reported city mean field increase from 0.277 (203 μW m^{-2}) in 2006 to 0.395 V m^{-1} (414 μW m^{-2}) in 2015. Sánchez-Montero et al. (2017) admit that during the ten years of monitoring the number of mobile phone base

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station has doubled, but also conclude that the probability of being exposed to a high value of 14 V m^{-1} (519 mWm^{-2}) is less than 0.01% and the probability of being exposed by 28 V m^{-1} (2079 mWm^{-2}) is negligible (Sánchez-Montero et al., 2017).

It is expected, that wherever mobile phone base station antennas are installed, high exposure areas might be encountered. Although these highly exposed areas constitute a minor part of the urban environment, these should be carefully studied for the sake of the people who work and live there.

Urbinello et al. (2014) emphasized "A continuous monitoring is needed to identify high exposure areas and to anticipate critical development of RF-EMF exposure at public places", while they informed a steep RF radiation growth in public places within one year. The growth of RF radiation has been substantial in many countries, also in Sweden as exemplified in this study.

Sagar et al. (2018) conducted a literature review, looking at studies in between 2000 and 2013 of radiofrequency electromagnetic exposure in microenvironments in Europe. For outdoor microenvironments they report the mean total RF exposure to be 0.54 V m^{-1} for spot measurements. Typical exposure levels were around 0.5 V m^{-1} and rarely over 1 V m^{-1}. They report downlink contributing the most to the total RF exposure in outdoor microenvironments in all studies except one.

An updated review by Jalilian et al. (2019) on European microenvironments' studies from 2015 to 2018 found mean outdoor exposure ranging from 0.07 to 1.27 V m^{-1}. Mobile phone base stations' downlink signals were the most relevant contributor to total exposure. The review concluded a tendency for RF levels to increase with increasing urbanity. Also, the review found that all different types of studies reported mean exposure levels of less than 1 V m^{-1}; different types included spot measurement, fixed site monitoring, and personal measurement with volunteers.

The problem with most of the spot measurement studies is their inability to adequately represent spatial RF field distribution. This is due to two reasons: 1) the measurement sample is too small and does not account for highly exposed areas and/or 2) the spots where the measurements are collected do not coincide with the RF hotspots. RF hotspots occur usually around RF sources such as mobile phone base station antennas. Furthermore, RF hotspots depend on the radiation pattern of the antenna and the surrounding environment, hence the field distribution is uneven. It is not possible to visually identify RF hotspots around the antennas, this can only be done by detailed measurements or computer simulations.

For example, Aerts et al. conducted a detailed RF field mapping in Ghent, Belgium. They performed in total 650 broadband measurements in a city subarea of 1 km^2. The study found five hotspots, with max total electric field ranging from 1.3 to 3.1 V m^{-1} (Aerts et al., 2013). Their study showed, that significantly higher RF exposure levels are likely to occur than those reported by the majority of studies. In addition, they demonstrated that construction of a detailed RF heat map of the investigated area is important to characterize and outline the hotspot area.

1.1. The aim of the study

In this study we identified an area in Stockholm with an aggregation of base station antennas placed at low level, close to pedestrians' heads. The aim of this research is to point out highly exposed radiofrequency areas in the city environment and to analyze the sources and the reasons for the high exposure. We performed detailed measurements and constructed a detailed RF heat map. Such conclusions would help to better design the RF infrastructure sites with the aim of minimizing the public exposure. No ethical permission was needed since no test persons were involved.

2. Materials and methods

In this study spatial distribution of RF radiation sources was measured. The RF radiation sources were mobile phone base station antennas located at the Skeppsbron street, Stockholm, Sweden. This area is characterized by dense RF infrastructure as 15 mobile phone base station sectoral antennas from several operators are located on the same building complex, where the elevation from the street level is only few meters.

The site was selected by visually identifying radiofrequency sources, based on the dense packing of mobile phone base station antennas. Also the site is well suited for a scientific study, as it is positioned within the city center, whereas one side of the site is open to the sea where there are no RF sources nearby. The old town with old buildings is located on the other side of the street.

2.1. Study design

The measurements were conducted on a business day afternoon (January 14, 2019) with busy traffic which allows to assume higher network traffic. All measurements were done outdoor.

Field distribution was determined covering an area of 60 × 250 m, representing a street strip of old town buildings at one side and the sea (Strömmen) at the other side. The area is composed of the Skeppsbron street with busy traffic and pedestrians represented by a seaside promenade. Seaside promenade is filled with indoor and outdoor cafés, some operating throughout the year. Antennas are installed on top of those cafés. The promenade and the cafés are packed with hundreds of people on a holiday period – many of which at close range to the mobile phone base station antennas.

The area was covered by 3 × 11 quadrats, where each quadrat cell (quad) was measured with RF broadband analyzer by registering RF readings from one end of the quad to another by following North-South axis with a slow pace. For each quad, one moving measurement scan was done. Quads were drawn to both sides of the Skeppsbron street. Each quad measurement was done for about 1 min with average and maximum readings registered. The measurements were taken at the height from 1 to 1.8 m by moving the meter in circular movements along the quad. This allows covering the standing waves and detecting maximum radiation points.

RF broadband analyzer used was Narda NBM-520, with an E-field probe E0391 (Narda-Safety-Test-Solutions GmbH, Pfullingen, Germany). This meter of Narda NBM-series is capable of time and spatial averaging and determining the maximum level during the monitored period. Manufacturer's probe EF0391 is intended for base station measurements with a frequency range from 100 kHz to 3 GHz. This meter and the probe cover a large range of RF sources, including different telecommunications protocols: frequency modulation (FM) radio broadcasting; television (TV) broadcasting; TETRA emergency services (police, rescue, etc.); global system for mobile communications (GSM) second generation mobile communications; universal mobile telecommunications systems (UMTS) third generation mobile communications, 3G; long-term evolution (LTE) fourth generation mobile communications standard, 4G; digital European cordless telecommunications (DECT) cordless telephone systems standard; Wi-Fi wireless local area network protocol, 2.45 GHz; worldwide interoperability for microwave access (WIMAX) wireless communication standard for high speed voice, data and internet.

Later, the measurement readings were entered into vector mapping software 3DFIELD ver. 4.5.2.0 (by Vladimir Galouchko) and field distribution map created (in V m^{-1}). Field distribution map was based on quadrat measurement spatial averages by using kriging, which is a geostatistical calculation method.

Additionally to analyze the frequency composition the entire quadrat was in parallel also measured with an exposimeter EME Spy 200 b y Microwave Vision Group, Paris, France. The exposimeter measures 20 predefined frequency bands covering most public RF radiation emitting devices currently used in Sweden. The exposimeter covers frequencies from 88 to 5850 MHz. For FM, TV3, TETRA, TV4&5, Wi-Fi 2.4 GHz and

Wi-Fi 5 GHz the lower detection limit is 0.01 V m^{-1} (0.27 μW m^{-2}); for all other bands the lower detection limit is 0.005 V m^{-1} (0.066 μW m^{-2}). For all bands the upper detection limit is 6 V m^{-1} (95,544 μW m^{-2}; 9.5544 μW cm^{-2}). The sampling rate used in this study was every 4th second which is the fastest possible sampling rate for the given exposimeter when all bands are active. The exposimeter was held at some distance (about 0.4 m) from the body. The unit reports the exposure in a conservative manner since each reported value is the sampling outcome, where many samples are taken and statistically processed including minimum, mean, median and maximum values. The meters had valid calibration.

Based on Cellmapper.net mobile phone operators and their corresponding services, mobile bands and frequencies were determined (Table 1). A large number of base station sector antennas emit a multitude of downlink frequency spans (N = 14) covering 2G, 3G and 4G services. Service providers have their own allocated frequency spans, but some are shared.

2.2. Statistical methods

Broadband RF readings using Narda NBM-520 were collected in Volts per meter (V m^{-1}) based on quadrat measurements covering the entire area. Each quadrat produced a spatial average and maximum reading calculated on the space covered. Based on quadrat cells measurements, two samples were formed: one of spatial averages and the second of spatial maximums. For both samples minimum, quartiles, median and maximum were calculated containing all the spatial measurement values in the area, using MS Excel 2016.

Means in microWatts per square meter (μW m^{-2}) were calculated for all measured frequency bands for measurements using the exposimeter EME Spy 200. Values below the lower detection limit were treated as no (0) exposure. Total exposure was calculated as the sum of all measured frequency bands. Stata/SE 12.1 (Stata/SE 12.1 for Windows; StataCorp., College Station, TX, USA) was used for all calculations.

3. Results

The results display a greatly uneven distribution of the RF fields with hotspots. The close proximity to the RF sources creates highly elevated field levels in the immediate vicinity to the base station. Given the antennas elevation from the ground, people walking on the street are highly exposed when passing or hanging around the area.

Fig. 1 presents a boxplot of spatial RF distribution of the entire investigated area. Both spatial average and maximum readings of RF broadband analyzer are included in the graph. The fields emanated by the base station antennas overlapped at several locations, elevating the exposure to high levels. The highest spatial average across all quadrat cells was 12.1 V m^{-1} (388 mW m^{-2}), whereas the maximum recorded reading over the entire area was 31.6 V m^{-1} (2649 mW m^{-2}). These were far-field measurement results, the meter was not used in the near-field of antennas. The lowest spatial average quadrat was 1.4 V m^{-1} (5.2 mW m^{-2}) which is still relatively high, considering the levels reported by the review studies (Jalilian et al., 2019; Sagar et al., 2018) discussed in the Introduction chapter. This emphasizes that the entire microenvironment

Table 1
Mobile phone operators, their corresponding services and frequencies used at Skeppsbron, information from cellmapper.net.

Operator	Bands	Downlink frequency (MHz)
Telia	4G	806, 1815, 1832, 2660
	3G	2152, 2157
	2G	950
Telenor	4G	936, 1857, 2630, 2680
	3G	2112, 2122
Tele2	4G	936, 1857, 2630, 2680
	3G	2152, 2157, 2162

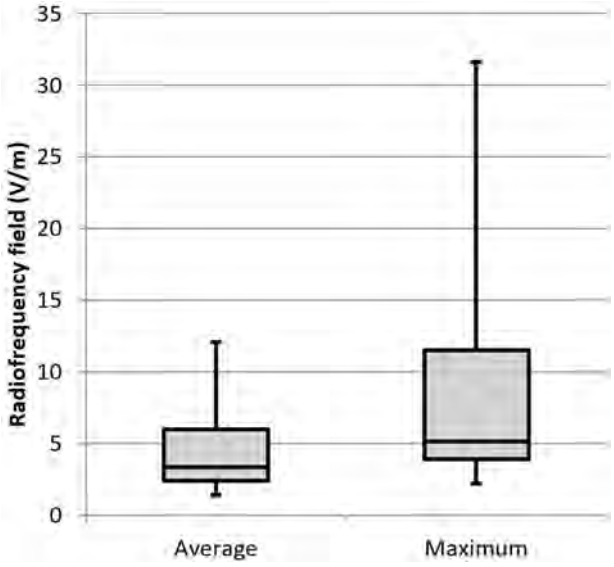

Fig. 1. Boxplot of spatial distribution of the radiofrequency field (V m^{-1}) at Skeppsbron street, based on quadrat measurements covering the entire area; sample is based on spatial averages and maximums of a quadrat cells; boxplot depicts (from bottom up) minimum, first quartile, median, third quartile and maximum of the sample containing all the spatial measurement values in the area.

in Skeppsbron street is covered with relatively high levels of radiofrequency radiation.

Fig. 2 displays a spatial distribution of the RF field at the Skeppsbron street. Exposure readings are based on spatial average of a given quadrat cell. High field levels are encountered close to the base station antennas, whereas the highest levels were not detected below the antenna, but at 26 m distance, directly on the line of the direction of sector antenna. The field decreases with increasing distance from the base station array, but is still significantly elevated at the entire 250 m length of the studied street area.

Highest field levels as registered across the street, may also refer to confounding action of building walls, as some building materials may reflect the incident waves, hence giving rise to resultant exposure level (Koppel et al., 2017a). Also the weather can play a role in microwave propagation as wet walls may increase building material microwave reflection properties (Koppel et al., 2017b).

Exposimeter measurements (mean of sample) showed that the majority of exposure was due to mobile phone downlink bands. Most dominant were 2600 and 2100 MHz bands used by 4G and 3G mobile phone services, respectively. Also 800, 900 and 1800 MHz bands were clearly elevated in the frequency spectrum, which fits the 4G profile (Table 2). The exposimeter was unable to register the highest exposure levels as the upper detection limit was exceeded repeatedly. Therefore, FM, as well as 1800 MHz, 2100 MHz, and 2600 MHz downlinks were not properly evaluated by the exposimeter measurements. Meanwhile, broadband meter measurements were able to register also the highest levels.

Table 3 compares public exposure to radiofrequency fields in Stockholm, based on authors' studies – comparing this study at Skeppsbron street to previous measurements. Comparison is done based only on exposimeter (EME Spy 200) measurements, excluding broadband meter measurements. RF field comparison reveals that Skeppsbron street is one of the highest public exposure areas in Stockholm so far measured with the maximum field level exceeding upper detection limit of the exposimeter.

Figs. 3 and 4 are photographs of the street view with some of the mobile phone base station antennas pointed out. The antennas are placed quite low, near the street level, where microwaves irradiate

Fig. 2. Spatial distribution of the radiofrequency field (values in V m $^{-1}$) at Skeppsbron street, based on spatial average of a given quadrat cell; hotspots are displayed in darker red where pedestrians are exposed at close range or rays overlap from several mobile phone base station antennas; the investigated area measures about 250 m North to South; map by Lantmäteriet, Sweden. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Exposimeter measurements of the radiofrequency field at Skeppsbron street, analysis of all data (μW m^{-2}) treating values at detection limit as 0. (Note: Exposimeter's highest detection limit (95,522.5 μW m^{-2} was constantly exceeded, therefore Max-values are likely to be much higher, as also confirmed by broadband measurements.) Total (n = 915).

Frequency band	Mean	Median	Min	Max
FM	1304.0	19.6	0.0	95,522.5
TV3	7.2	0.0	0.0	1601.4
TETRA I	0.0	0.0	0.0	1.0
TETRA II	0.0	0.0	0.0	4.7
TETRA III	2.3	0.0	0.0	403.4
TV4&5	17.4	0.6	0.0	2434.4
800 (DL)	751.3	164.5	0.7	12,978.6
800 (UL)	0.0	0.0	0.0	6.6
900 (UL)	0.0	0.0	0.0	8.6
900 (DL)	2545.3	926.5	0.4	35,473.9
1800 (UL)	71.0	8.3	0.0	3291.8
1800 (DL)	3466.6	714.5	3.6	95,522.5
DECT	367.6	0.0	0.0	36,548.9
2100 (UL)	0.1	0.0	0.0	45.5
2100 (DL)	6558.8	1237.4	1.7	95,522.5
WIFI 2G	0.4	0.0	0.0	61.3
2600 (UL)	689.5	154.1	0.0	17,275.1
2600 (DL)	11,338.3	3483.6	1.7	95,522.5
WIMax	0.2	0.0	0.0	58.9
WIFI 5G	0.4	0.0	0.0	93.8
Total	27,120.5	10,481.5	24.4	373,381.0

Table 3
Public exposure to radiofrequency field in Stockholm – this study compared authors' previous studies; exposimeter EME Spy 200 measurements; analysis of all data (μW m^{-2}) treating values at detection limit as 0.

Study	Total (n)	Mean	Median	Min	Max
Stockholm, Central Station (Hardell et al., 2016)	1669	3860.2	920.6	5.8	9206.3
Stockholm, Old Town (Hardell et al., 2017)	10,437	4292.7	534.0	0.0	173,301.8
Stockholm, City (Carlberg et al., 2019)	11,482	5494.2	3346.0	36.6	205,154.8
Stockholm, Järntorget, Old Town (Hardell et al., 2019)	792	21,354.9	12,655.3	381.7	178,928.2
Stockholm, Skeppsbron (current study)	915	27,120.5	10,481.5	24.4	373,381.0

Fig. 3. Street view on the Skeppsbron street with some of the mobile phone base station antennas pointed out with a circle; note the low placement of the antennas, where microwaves irradiate the pedestrian at close range.

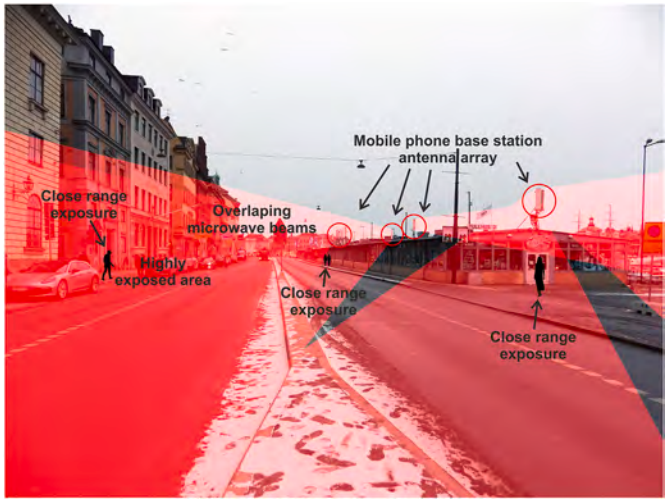

Fig. 4. Problem context of mobile phone base station antennas created high exposure at Skeppsbron street; altogether 15 antenna panels could be counted on that building, all positioned at low elevation close to the street level; the maximum RF exposure was at 31.6 V m^{-1}, registered at close range to the antennas.

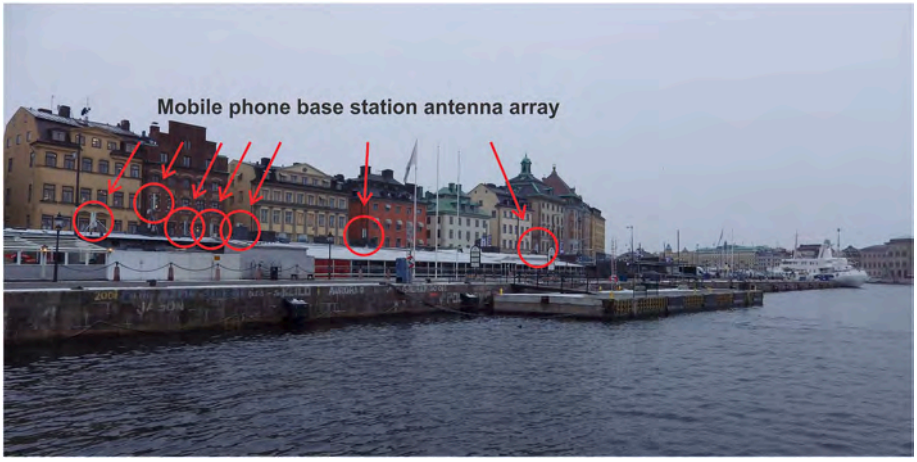

Fig. 5. The antennas are mostly facing the buildings, as the operators want to force the wave into the old town through the narrow streets. Considering the low placement of antennas and pushing all this power - creates very high exposure levels nearby.

pedestrians at close range. Fig. 5 depicts the context – very low placement of the antennas, most of which are targeting the buildings in order to push the microwave into the narrow streets and further into the old town.

4. Discussion

This study, and our previous ones, have recorded the exposure to RF radiation which will provide means for historic comparison for both public and occupational exposure. It is clear from our current study and the previous ones that the level of ambient RF radiation exposure is increasing, see Table 3. Public exposure in different places around the globe is shown in Table 4. Our average and peak RF measurement results are much higher than many of those measurements in that table, indicating a rather recent and rapid increase in radiofrequency radiation levels in city centers. To provide comparison, Bergqvist et al. (2001) measured 0,18 mW m^{-2} highest average levels in Stockholm city center in 2001 (Bergqvist et al., 2001). Swedish radiation protection authorities pointed out recently highest average levels like 720 mW m^{-2} at Järntorget (Esternberg, 2020) and 690 mW m^{-2} at Skeppsbron area (Umeå kommun 2019) in Stockholm. One possible reason for our high RF readings in 2019 was the upgrade of 4G (LTE) base stations with new antenna panels including more antenna elements for the forthcoming 5G (which started officially in Stockholm in 2020).With the development of mobile communications technologies and the widespread use of wireless services the exposure will continue to increase with substantially higher exposure levels and also ever increasing frequency bands, even though several research reports indicate health risks. These risks are relevant to those people working or living in the highly exposed places – in this study they are 1) people living in the apartments across the street from the antennas, 2) workers of the shops across the street and beneath the antennas.

This research identified an increased RF exposure risk area in the center of Stockholm city. Clearly we measured high RF radiation levels of the same magnitude at a square (Järntorget) in the old town (Hardell et al., 2019). These results may be compared with the Ramazzini Institute rat study on far field exposure to 1.8 GHz RF radiation of 0, 5, 25, 50 V m^{-1} with a whole-body exposure for 19 h/day similar to that from base stations (Falcioni et al., 2018). Increased incidence of glioma and heart tumours of the Scwannoma type were found, i.e. similar tumour types as found among people using wireless phones. A statistically significant increase in the incidence of malignant Schwannoma in the heart was found in male rats at the highest dose, 50 V m^{-1} corresponding to whole-body SAR of 0.1 W/kg. Increased non-significant incidence of heart Schwann cells hyperplasia was observed in exposed male and female rats at the highest dose. In irradiated female rats at the highest dose (50 V m^{-1}) the incidence of malignant glial tumours was increased, although not statistically significant. In the current study maximum exposure level of 31.6 V m^{-1} was measured. Thus, there is no reasonable safety limit comparing with the animal study.

Table 4
Public exposure to radiofrequency fields at different places.

Study	Investigated locations	Exposure (mean)
Joseph et al. (2010)	Europe, outdoor	372–569 μW m^{-2}
Bolte et al. (2011)	Netherlands, railway stations	304–354 μW m^{-2}
Bolte and Eikelboom (2012)	Netherlands, outdoor activities	208 μW m^{-2}
Rowley and Joyner (2012)	23 countries	730 μW m^{-2}
Urbinello et al. (2014)	Europe, Basel, Ghent, Brussels	271–892 μW m^{-2}
Verloock et al. (2014)	Belgium, public places	1020 μW m^{-2}
Estenberg and Augustsson (2014)	Stockholm city, Sweden	6700 μW m^{-2}
	Sweden, urban	1500 μW m^{-2}
	Sweden, rural	230 μW m^{-2}
Calvente et al. (2015)	Spain, Granada	799 μW m^{-2}
Gonzalez-Rubio et al. (2016)	Spain, Albecete	4,2–2102 μW m^{-2}
Choudhary and Vijay (2017)	India, Kota city residential	5452–77,840 μW m^{-2}
	industrial, commercial	2386–68,769 μW m^{-2}
	agricultural	2378–68,724 μW m^{-2}
	rural	1878–68,724 μW m^{-2}
Sánchez-Montero et al. (2017)	Spain, Alcalá de Henares	2006: 0.278 V m^{-1} (205 μW m^{-2})
		2010: 0.407 V m^{-1} (439 μW m^{-2})
		2015: 0.396 V m^{-1} (416 μW m^{-2})
Thielens et al. (2018)	Australia, Melbourne	0.05–0.89 V m^{-1} (6–2101 μW m^{-2})
Misek et al. (2018)	Ziina city, center	1.072 V m^{-1} (3048 μW m^{-2})
	residential	1.852 V m^{-1} (9097 μW m^{-2})
	rural	0.510 V m^{-1} (690 μW m^{-2})
	Visnove, rural	0.093 V m^{-1} (23 μW m^{-2})
Eeftens et al. (2018)	Europe, 5 countries	150–160 μW m^{-2}
Zeleke et al. (2018)	Australia, Melbourne	0.233 V m^{-1} (144 μW m^{-2})
Christopoulou and Karabetsos (2019)	Greece, urban	0.244 V m^{-1} (158 μW m^{-2})
	Greece, suburban	0.229 V m^{-1} (139 μW m^{-2})

Electromagnetic fields are a physical risk factor. However, current legislation does not require the mobile phone services operator to ask for approval from neighboring inhabitants, when installing RF sources. Nevertheless, when mobile phone base station antennas are installed, the immediate physical environment, including the neighborhood living environment is greatly altered by the microwaves.

Studies from recent decades have shown elevated health risk under long term exposure to such highly elevated radiofrequency fields.

A review by Khurana et al. (2010) found in 80% of the available studies neurobehavioral symptoms or cancer in populations living at distances <500 m from base stations (Khurana et al., 2010). In another review exposure from base stations and other antenna arrays showed changes in immunological and reproductive systems as well as DNA double strand breaks, influence on calcium movement in the heart and increased proliferation rates in human astrocytoma cancer cells (Levitt and Lai, 2010).

When a GSM 900 MHz base station was installed in the village Rimbach in Germany it had an influence on the neurotransmitters adrenaline, noradrenaline, dopamine and phenyletylamine (Buchner and Eger, 2011). Influence on cortisol and thyroid hormones in people living near base stations was shown in other studies (Augner et al., 2010; Eskander et al., 2012).

Dode et al. (2011 compared base station (BS) clusters and cases of deaths by neoplasia in the Belo Horizonte municipality, Minas Gerais state, Brazil, from 1996 to 2006. In their study largest electric field was 12.4 V m^{-1} and the smallest was 0.4 V m^{-1}. They found cancer-related death rates be higher close to base stations. This finding confirmed earlier findings by Eger (Eger et al., 2004).

In a study from India, genetic damage using the single cell gel electrophoresis (comet) assay was assessed in peripheral blood leukocytes of individuals residing in the vicinity of a mobile phone base station and comparing it to that in healthy controls. Genetic damage parameters of DNA migration length, damage frequency, and damage index were significantly ($p < 0.001$) elevated in the sample group compared to respective values in healthy controls (Gandhi et al., 2014).

The effect of RF radiation among 20 subjects living close to mobile phone base station compared with 20 subjects living with a distance of about 1 km was studied (Singh et al., 2016). The authors concluded that: "*It was unveiled that a majority of the subjects who were residing near the mobile base station complained of sleep disturbances, headache, dizziness, irritability, concentration difficulties, and hypertension. A majority of the study subjects had significantly lesser stimulated salivary secretion ($p < 0.01$) as compared to the control subjects.*"

Zothansiama et al. (2017) in India inspected DNA damage and antioxidant status in cultured human peripheral blood lymphocytes (HPBLs) of individuals residing in the vicinity of mobile phone base stations and compared it with healthy controls living further away. The analyses of data from the exposed group ($n = 40$), residing within a perimeter of 80 m of mobile base stations, showed statistically significantly ($p < 0.0001$) higher frequency of micronuclei when compared to the control group, residing 300 m away from the mobile base stations.

The Ramazzini Institute findings (Falcioni et al., 2018) are supported by the results in the USNTP study on rats and mice exposed to RF radiation (National Toxicology Program, 2018a, 2018b). A clear evidence of increased incidence of heart Schwannoma and some evidence for glioma and tumours in the adreanal medulla in male rats was found according to the expert panel, for further discussion see Hardell and Carlberg (2019).

4.1. Health risks associated with mobile phone radiation

RF radiation was in 2011 classified as a possible human carcinogen, Group 2B by the International Agency for Research on Cancer (IARC) at the WHO (Baan et al., 2011; IARC Working Group, 2013), After that the evidence on cancer risk has increased so that RF radiation may now be classified as a human carcinogen, Group 1 according to the IARC classification (Carlberg and Hardell, 2017).

By now there is concordance between tumours in human epidemiology (Belpomme et al., 2018; Miller et al., 2018) and animal studies (Falcioni et al., 2018; National Toxicology Program, 2018a, 2018b), that is glioma and Schwann cell tumours. These results are supported by mechanistic studies such as oxidative stress (Yakymenko et al., 2016) and DNA damage from RF radiation (Smith-Roe et al., 2020).

So far personal use of wireless phones, mobile and cordless phones (DECT), have yielded highest RF radiation exposure especially to children and to the brain (Gandhi et al., 2012). However, ambient exposure is of increasing concern and may now be of the same magnitude as for increasing cancer incidence in animal studies. This is exemplified in this study.

The BioInititative Report (2012) defines a target level of 30–60 μW m^{-2}, and for chronic exposure and sensitive people such as children one tenth of this, 3–6 μW m^{-2}, see Chapter 24 of the BioInitiative Report (Sage, and Carpenter, 2012).

Already in 2011 Yakymenko et al. stated that: *It is now becoming increasingly evident that assessment of biological effects of non-ionizing radiation based on physical (thermal) approach used in recommendations of current regulatory bodies, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, requires urgent reevaluation* (Yakymenko et al., 2011).

This view is supported by 252 EMFscientists from 43 nations www.emfscientist.org:

> "Numerous recent scientific publications have shown that EMF [electromagnetic field] affects living organisms at levels well below most international and national guidelines. 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."

5. Conclusions

This study has pointed out a highly exposed radiofrequency radiation area in the Stockholm city environment and identified the sources and reasons of high exposure. By positioning RF infrastructure to the proximity of the public the risk of health effects is increased since members of the public on the street, also inhabitants in nearby buildings are highly exposed. Mobile phone base station antennas are positioned at the height of second floor levels of adjacent buildings spreading microwaves across the street. Highly elevated exposure levels would likely be encountered in the premises next to the windows facing the mobile phone base station array.

The study concluded that Skeppsbron street mobile phone base station antennas are examples of a poor radiofrequency infrastructure design with mobile phone base station antennas positioned into close range to the general public which brings upon high exposure levels. Given the low placement of the antennas (height from the street floor), the highest exposure was often registered at pedestrian head level. Given that head is one of most vulnerable parts of the body, these placements by mobile telephony service providers put pedestrians into unnecessary risk. Position of these antennas, can pose a health risk to people at close range. This is especially critical for people at particular risk, including persons with medical implants, pregnant women or chronically ill persons.

Based on the latest scientific literature regarding RF exposure and adverse health effects, this study recommends repositioning such base station antennas to areas away from the nearby inhabitants, workers and the general public. Alternatively, very low power antennas may also be considered to reduce the exposure. Occupational exposure of people

working close to the antennas should also be considered – shop clerks, restaurant workers are likely to spend considerably longer time under high exposure, compared to the general public.

The following recommendations for radiofrequency infrastructure can be concluded from the current study.

1. Antennas should be positioned as far as possible from the general public, like locations at the high elevations or remote areas, where the antenna targeted area is not regularly/frequently visited by the members of the public.
2. Only low power output mobile phone base station antennas (<15W) should be used in the city environment.
3. To avoid hotspots, created by overlapping arrays, dense packing of many antennas at one site should be avoided.
4. Low power output antennas in the city environment should be positioned into locations where direct beam would not hit members of public closer than 50m.

The conclusions of this study will help to design safer mobile phone base station sites in the city environment, when the aim is to minimize public exposure.

Author contributions

T.K. and M.A. performed the measurements. Conception of the study, design and analyses of the material, writing of the article and approval of the final manuscript was made by all authors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Aerts, S., Deschrijver, D., Verloock, L., Dhaene, T., Martens, L., Joseph, W., 2013. Assessment of outdoor radiofrequency electromagnetic field exposure through hotspot localization using kriging-based sequential sampling. Environ. Res. 126, 184–191. https://doi.org/10.1016/j.envres.2013.05.005 PMID:23759207.

Augner, C., Hacker, G.W., Oberfeld, G., Florian, M., Hitzl, W., Hutter, J., Pauser, G., 2010. Effects of exposure to GSM mobile phone base station signals on salivary cortisol, alpha-amylase, and immunoglobulin A. Biomed. Environ. Sci. 23, 199–207. https://doi.org/10.1016/S0895-3988(10)60053-0 PMID:20708499.

Baan, R., Grosse, Y., Lauby-Secretan, B., El Ghissassi, F., Bouvard, V., Benbrahim-Tallaa, L., Guha, N., Islami, F., Galichet, L., Straif, K., 2011. WHO international agency for research on cancer monograph working group: carcinogenicity of radiofrequency electromagnetic fields. Lancet Oncol. 12, 624–626. https://doi.org/10.1016/S1470-2045(11)70147-4 PMID:21845765.

Belpomme, D., Hardell, L., Belyaev, I., Burgio, E., Carpenter, D.O., 2018. Thermal and non-thermal health effects of low intensity non-ionizing radiation: an international perspective. Environ. Pollut. 242 (Pt A), 643–658. https://doi.org/10.1016/j.envpol.2018.07.019 PMID:30025338. https://www.sciencedirect.com/science/article/pii/S0269749118310157.

Bergqvist, U., Anger, G., Birke, E., Hamnerius, Y., Hillert, L., Larsson, L.E., Christer Törnevik, C., Zetterblad, J., 2001. Exponering för radiofrekventa fält och mobiltelefoni, SSI report [exposure to radiofrequency radiation and mobile phones. In: Swedish, English Summary], 2001:09 April 2001 ISSN 0282-4434. Report.

BioInitiative Working Group, 2012. BioInitiative Report: A Rationale for Biologically-Based Exposure Standards for Low-Intensity Electromagnetic Radiation. https://bioinitiative.org/table-of-contents/. (Accessed 27 October 2021).

Bolte, J.F.B., van der Zande, G., Kamer, J., 2011. Calibration and uncertainties in personal exposure measurements of radiofrequency electromagnetic fields. Bioelectromagnetics 32, 652–663 http://doi.wiley.com/10.1002/bem.20677. https://doi.org/10.1002/bem.20677 PMID:21544843.

Bolte, J.F.B., Eikelboom, T., 2012. Personal radiofrequency electromagnetic field measurements in The Netherlands: exposure level and variability for everyday activities, times of day and types of area. Environ. Int. 48, 133–142. https://doi.org/10.1016/j.envint.2012.07.006 PMID:22906414.

Buchner, K., Eger, H., 2011. Changes of clinically important Neurotransmitters under the influence of modulated RF fields—a long-term study under real-life conditions. Umwelt-Medizin-Gesellschaft 24, 44–57.

Calvente, I., Fernández, M.F., Pérez-Lobato, R., Dávila-Arias, C., Ocón, O., Ramos, R., Ríos-Arrabal, S., Villalba-Moreno, J., Olea, N., Núñez, M.I., 2015. Outdoor characterization of radio frequency electromagnetic fields in a Spanish birth cohort. Environ. Res. 138, 136–143. https://doi.org/10.1016/j.envres.2014.12.013 PMID:25707018.

Carlberg, M., Hardell, L., 2017. Evaluation of mobile phone and cordless phone use and glioma risk using the Bradford hill viewpoints from 1965 on association or causation. BioMed Res. Int. 2017 9218486. https://doi.org/10.1155/2017/9218486 PMID:28401165.

Carlberg, M., Hedendahl, L., Koppel, T., Hardell, L., 2019. High ambient radiofrequency radiation in Stockholm city, Sweden. Oncol. Lett. 17, 1777–1783. PMID:30675237.

Choudhary, M.P., Vijay, S., 2017. Study on electromagnetic field radiation emission from mobile towers in kota city. Int. J. Innov .Res. Sci,. Engn Technoln 11, 21402–21409. https://doi.org/10.15680/IJIRSET.2017.0611061.

Christopoulou, M., Karabetsos, E., 2019. Evaluation of radiofrequency and extremely low-frequency field levels at children's playground sites in Greece from 2013 to 2018. Bioelectromagnetics 40, 602–605. https://doi.org/10.1002/bem.22220 PMID:31541484.

Dode, A.C., Leão, M.M., Tejo Fde, A., Gomes, A.C., Dode, D.C., Dode, M.C., Moreira, C. W., Condessa, V.A., Albinatti, C., Caiaffa, W.T., 2011. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. Sci. Total Environ. 409, 3649–3665. https://doi: 10.1016/j.scitotenv.2011.05.051.

Eeftens, M., Struchen, B., Birks, L.E., Cardis, E., Estarlich, M., Fernandez, M.F., Gajšek, P., Gallastegi, M., Huss, A., Kheifets, L., et al., 2018. Personal exposure to radio-frequency electromagnetic fields in Europe: is there a generation gap? Environ. Int. 121, 216–226. https://doi.org/10.1016/j.envint.2018.09.002 PMID:30216774.

Eger, H., Hagen, K.U., Lucas, B., Vogel, P., Voitet, H., 2004. Einfluss der räumlichen nähe von Mobilfunksendeanlagen Auf Die Krebsinzidenz. Umwelt-Medizin-Gesellschaft 17, 326–335 (In German, English summary).

Eskander, E.F., Estefan, S.F., Abd-Rabou, A.A., 2012. How does long term exposure to base stations and mobile phones affect human hormone profiles? Clin. Biochem. 45, 157–161. https://doi.org/10.1016/j.clinbiochem.2011.11.006 PMID:22138021.

Estenberg, J., Auguststsson, T., 2014. Extensive frequency selective measurements of radiofrequency fields in outdoor environments performed with a novel mobile monitoring system. Bioelectromagnetics 35, 227–230. https://doi.org/10.1002/bem.21830 PMID:24375568.

Esternberg, 2020. Mätrapport. Radiovågsmätningar på Järntorget i Stockholm. [Measurement report. Radiofrequency radiation at Järntorget Stockholm, in Swedish]. Swedish Radiation Safety Authority. Document: SSM2019-10309-1, 2020. ssm_jarntorget-1.pdf (stralskyddsstiftelsen.se). (Accessed 27 October 2021).

Falcioni, L., Bua, L., Tibaldi, E., Lauriola, M., De Angelis, L., Gnudi, F., Mandrioli, D., Manservigi, M., Manservisi, F., Manzoli, I., et al., 2018. Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. Environ. Res. 165, 496–503. https://doi.org/10.1016/j.envres.2018.01.037 PMID:29530389.

Gandhi, G., Morgan, L.L., de Salles, A.A., Han, Y.Y., Herberman, R.B., Davis, D., 2012. Exposure limits: the underestimation of absorbed cell phone radiation, especially in children. Electromagn. Biol. Med. 31, 34–51. https://doi.org/10.3109/15368378.2011.622827.

Gandhi, G., Kaur, G., Nisar, U., 2014. A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. Electromagn. Biol. Med. 9, 1–11. https://doi.org/10.3109/15368378.2014.933349.

Gonzalez-Rubio, J., Najera, A., Arribas, E., 2016. Comprehensive personal RF-EMF exposure map and its potential use in epidemiological studies. Environ. Res. 149, 105–112. https://doi.org/10.1016/j.envres.2016.05.010 PMID:27196609.

Hardell, L., Koppel, T., Carlberg, M., Ahonen, M., Hedendahl, L., 2016. Radiofrequency radiation at Stockholm Central Railway Station in Sweden and some medical aspects on public exposure to RF fields. Int. J. Oncol. 49, 1315–1324. https://doi.org/10.3892/ijo.2016.3657 PMID:27633090.

Hardell, L., Carlberg, M., Koppel, T., Hedendahl, L., 2017. High radiofrequency radiation at Stockholm old town: an exposimeter study including the royal castle, supreme court, three major squares and the Swedish parliament. Mol Clin. Onco.l 6, 462–476. https://doi.org/10.3892/mco.2017.1180 PMID:28413651.

Hardell, L., Carlberg, M., 2019. Comments on the US National Toxicology Program technical reports on toxicology and carcinogenesis study in rats exposed to whole-body radiofrequency radiation at 900 MHz and in mice exposed to whole-body radiofrequency radiation at 1,900 MHz. Int. J. Oncol. 54, 111–127. PMID:30365129.

Hardell, L., Carlberg, M., Hedendahl, L.K., Koppel, T., Ahonen, M., 2019. Environmental radiofrequency radiation at the Järntorget square in Stockholm old town, Sweden in may, 2018 compared with results on brain and heart tumour risks in rats exposed to 1.8 GHz base station environmental emissions. World Acad. Sci. J. 1, 47–54. https://doi.org/10.3892/wasj.2018.5.

Hardell, L., Carlberg, M., Hedendahl, L.K., 2018. Radiofrequency radiation from nearby base stations gives high levels in an apartment in Stockholm, Sweden: a case report. Oncol. Lett. 15, 7871–7883. https://doi.org/10.3892/ol.2018.8285 PMID:29725476.

IARC Working Group, 2013. IARC monographs on the evaluation of carcinogenic risks to humans. In: Non-Ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields, ume 102. International Agency for Research on Cancer, Lyon, France, 2013. http://monographs.iarc.fr/ENG/Monographs/vol102/mono102.pdf. (Accessed 27 October 2021).

Jalilian, H., Eeftens, M., Ziaei, M., Röösli, M., 2019. Public exposure to radiofrequency electromagnetic fields in everyday microenvironments: an updated systematic review for Europe. Environ. Res. 176, 108517. https://doi.org/10.1016/j.envres.2019.05.048 PMID:31202043.

Joseph, W., Frei, P., Röösli, M., Thuróczy, G., Gajsek, P., Trcek, T., Bolte, J., Vermeeren, G., Mohler, E., Juhász, P., et al., 2010. Comparison of personal radio

frequency electromagnetic field exposure in different urban areas across Europe. Environ. Res. 110, 658–663. https://doi.org/10.1016/j.envres.2010.06.009 PMID: 20638656.

Khurana, V.G., Hardell, L., Everaert, J., Bortkiewicz, A., Carlberg, M., Ahonen, M., 2010. Epidemiological evidence for a health risk from mobile phone base stations. Int. J. Occup. Environ. Health 16, 263–267. https://doi.org/10.1179/107735210799160192.

Koppel, T., Shishkin, A., Haldre, H., Toropovs, N., Vilcane, I., Tint, P., 2017a. Reflection and transmission properties of common construction materials at 2.4 GHz frequency. Energy Proc. 113, 158–165. https://doi.org/10.1016/j.egypro.2017.04.045.

Koppel, T., Vilcane, I., Mironov, V., Shiskin, A., Rubene, S., Tint, P., 2017b. Aerated concrete microwave reflection and transmission properties in a wet environment. In: Vide: Energy Procedia Environment. Technology. Resources, Rezekne, Latvia. Proceedings of the 11 International Scientific and Practical Conference, III, pp. 145–149. https://doi.org/10.17770/etr2017vol3.2619.

Koppel, T., Ahonen, M., Carlberg, M., Hedendahl, L.K., Hardell, L., 2019. Radiofrequency radiation from nearby mobile phone base stations-a case comparison of one low and one high exposure apartment. Oncol. Lett. 18, 5383–5391. https://doi.org/10.3892/ol.2019.10899 PMID:31612047.

Levitt, B., Lai, H., 2010. Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. Environ. Rev. 18 (NA), 369–395. https://doi.org/10.1139/a10-903.

Miller, A.B., Morgan, L.L., Udasin, I., Davis, D.L., 2018. Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102). Environ. Res. 167, 673–683. https://doi.org/10.1016/j.envres.2018.06.043 PMID:30196934.

Misek, J., Laukova, T., Kohan, M., Veternik, M., Jakusova, V., Jakus, J., 2018. Measurement of low-level radiofrequency electromagnetic fields in the human environment. Acta Med. Martiniana 18, 27–33. https://doi.org/10.2478/acm-2018-0010.

National Toxicology Program, 2018a. NTP technical report on the toxicology and carcinogenesis studies in B6C3F1/N mice exposed to whole-body radio frequency radiation at a frequency (1,900 MHz) and modulations (GSM and CDMA) used by cell phones. NTP TR 596. March 26-28, 2018. https://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2018/march/tr596peerdraft.pdf. (Accessed 27 October 2021).

National Toxicology Program, 2018b. NTP technical report on the toxicology and carcinogenesis studies in hsd:sprague Dawley sd rats exposed to whole-body radio frequency radiation at a frequency (900 MHz) and modulations (GSM and CDMA) used by cell phones. NTP TR 595. March 26-28, 2018. https://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2018/march/tr595peerdraft.pdf. (Accessed 27 October 2021).

Rowley, J.T., Joyner, K.H., 2012. Comparative international analysis of radiofrequency exposure surveys of mobile communication radio base stations. J. Expo. Sci. Environ. Epidemiol. 22, 304–315. https://doi.org/10.1038/jes.2012.13 PMID:22377680.

Sagar, S., Dongus, S., Schoeni, A., Roser, K., Eeftens, M., Struchen, B., Foerster, M., Meier, N., Adem, S., Röösli, M., 2018. Radiofrequency electromagnetic field exposure in everyday microenvironments in Europe: a systematic literature review. J. Expo. Sci. Environ. Epidemiol. 28, 147–160. https://doi.org/10.1038/jes.2017.13 PMID:28766560.

Sage, S., Carpenter, D., 2012. Key Scientific Evidence and Public Health Policy Recommendations (Supplement 2012). Prepared for the BioInitiative Working Group December 2012. https://www.bioinitiative.org/wp-content/uploads/pdfs/sec24_2012_Key_Scientific_Studies.pdf. (Accessed 27 October 2021).

Sánchez-Montero, R., Alén-Cordero, C., López-Espí, P.L., Rigelsford, J.M., Aguilera-Benavente, F., Alpuente-Hermosilla, J., 2017. Long term variations measurement of electromagnetic field exposures in Alcalá de Henares (Spain). Sci. Total Environ. 598, 657–668. https://doi.org/10.1016/j.scitotenv.2017.03.131 PMID:28454038.

Singh, K., Nagaraj, A., Yousuf, A., Ganta, S., Pareek, S., Vishnani, P., 2016. Effect of electromagnetic radiations from mobile phone base stations on general health and salivary function. J. Int. Soc. Prev. Community Dent. 6, 54–59. https://doi.org/10.4103/2231-0762.175413 PMID:27011934.

Smith-Roe, S.L., Wyde, M.E., Stout, M.D., Winters, J.W., Hobbs, C.A., Shepard, K.G., Green, A.S., Kissling, G.E., Shockley, K.R., Tice, R.R., et al., 2020. Evaluation of the genotoxicity of cell phone radiofrequency radiation in male and female rats and mice following subchronic exposure. Environ. Mol. Mutagen. 61, 276–290, 2020.

Thielens, A., Van den Bosschea, M., Brzozekc, C., Bhatt, C., Abramson, M., Benke, G., Martens, L., Joseph, W., 2018. Microenvironmental personal and head exposure measurements of radio-frequency electromagnetic fields in melbourne, Australia. In: Joint Annual Meeting of the Bioelectromagnetics Society and the European BioElectromagn Assoc (BioEM 2018), pp. 273–279.

Umeå Kommun, 2019. Informationsmöte Om 5G i Umeå Folkets Hus (Umeå municipality information meeting about 5G at umeå common house). Video recording. Monday 3 June. https://youtu.be/ihs13eFeBFg?t=2768. (Accessed 27 October 2021).

Urbinello, D., Joseph, W., Verloock, L., Martens, L., Röösli, M., 2014. Temporal trends of radio-frequency electromagnetic field (RF-EMF) exposure in everyday environments across European cities. Environ. Res. 134, 134–142. https://doi.org/10.1016/j.envres.2014.07.003 PMID:25127524.

Verloock, L., Joseph, W., Goeminne, F., Martens, L., Verlaek, M., Constandt, K., 2014. Assessment of radio frequency exposures in schools, homes, and public places in Belgium. Health Phys. 107, 503–513. https://doi.org/10.1097/HP.0000000000000149 PMID:25353235.

Yakymenko, I., Sidorik, E., Kyrylenko, S., Chekhun, V., 2011. Long-term exposure to microwave radiation provokes cancer growth: evidences from radars and mobile communication systems. Exp. Oncol. 33, 62–70. PMID: 21716201.

Yakymenko, I., Tsybulin, O., Sidorik, E., Henshel, D., Kyrylenko, O., Kyrylenko, S., 2016. Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. Electromagn. Biol. Med. 35, 186–202. https://doi.org/10.3109/15368378.2015.1043557 PMID:26151230. http://www.tandfonline.com/doi/full/10.3109/15368378.2015.1043557.

Zeleke, B.M., Brzozek, C., Bhatt, C.R., Abramson, M.J., Croft, R.J., Freudenstein, F., Wiedemann, P., Benke, G., 2018. Personal exposure to radio frequency electromagnetic fields among Australian adults. Int J Environ Res Public Health 15, E2234. https://doi.org/10.3390/ijerph15102234 PMID:30321997.

Zothansiama, M.Z., Zosangzuali, M., Lalramdinpuii, M., Jagetia, G.C., 2017. Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. Electromagn. Biol. Med. 36, 295–305. https://doi.org/10.1080/15368378.2017.1350584 PMID:28777669.

Measurements of radiofrequency electromagnetic fields, including 5G, in the city of Columbia, SC, USA

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Abstract. The present study aimed to characterize the wireless infrastructure and public exposure to radiofrequency (RF) electromagnetic fields, including the sub-millimeter wave 5G, in the city center of Columbia, SC, USA. A downtown measurement route was designed to cover popular outdoor areas, including business, recreational and shopping areas. The route was measured five times during different days and times. An exposimeter, was used to cover all the main civilian wireless broadcasting and downlink sources in frequencies 88-5,850 MHz. The measurement route at the streets and squares calculated 1.240 V/m as a mean exposure (total as a sum of all frequency bands) and 6.867 V/m as all times maximum. The most common contributors to the exposure budget were bands FM US, 14DL, 27DL, 25DL and 66DL - mainly indicating 4G. The exposure levels were found to be 12-16% lower during weekends as compared to business hours ($P<0.001$). The spatial analysis of the field distribution revealed 15-20 hotspot areas. A number of hotspots were found where cell phone base station antennas were mounted on top of the utility poles and therefore positioned at low levels, close to street level. On the whole, the findings of the present study suggest that cell phone base station antennas should be distinct and noticeable, as this would assist individuals who need to limit their exposure by distancing themselves from RF sources.

Introduction

The city of Columbia is the capital of the US state of South Carolina with a population of 131 thousand individuals (2019 estimate) (1). South Carolina is a southern state located in South East US, at the coast of Atlantic Ocean. The city has a well-developed wireless connectivity infrastructure with services provided by all major cell phone service providers. As a central hub for the state, the city of Columbia entails offices for large corporations and small businesses, government and city municipality departments. The city is also home to a number of colleges, including the University of South Carolina, Benedict College, Columbia College, Columbia International University, Fortis College, South University, Allen University and Lutheran Theological Southern seminary.

In previous studies, the authors investigated public and occupational radiofrequency (RF) exposure in European cities, including both outdoor and indoor exposure. For example, in June and August, 2017, RF level measurements were conducted in city center of Stockholm, Sweden. That study is analogous to the present study as it covered a central city area, including business district, shopping and tourist areas, together with popular leisure streets and squares. In Stockholm the total (of all frequency bands) mean exposure level was 5,494 μW/m^2 (1.439 V/m), whereas the major contributions were downlinks from LTE 800 (4G), GSM + UMTS 900 (3G), GSM 1800 (2G), UMTS 2100 (3G) and LTE 2600 (4G) (2). In another detailed investigation into RF exposure levels in Stockholm, the authors performed a spatial exposure map of Järntorget square, where the mean exposure value was 5.2 V/m (median, 5.0 V/m; range, 1.2-11.6 V/m), indicating one of the highest exposure areas in the old town (3). The previous Stockholm Old Town measurement in 2016, covering six different areas, including squares and streets determined that the mean level of the total RF radiation was 4,293 μW/m^2 (1.27 V/m) and max 173,302 μW/m^2 (8.08 V/m) (4).

In recent studies, the authors compared indoor living places in the city of Stockholm, where a maximum exposure at 6 V/m was encountered at the attic apartment, located at the same elevation and only some 6 m away from the base station antennas (5). In another indoor exposure study, the authors conducted exposimeter measurements in Swedish schools. The mean exposure to RF radiation ranged from 1.1 to 66.1 μW/m^2 (0.02 to 0.16 V/m), whereas the highest mean level was 396.6 μW/m^2 (0.39 V/m) and maximum peaks reached 82,857 μW/m^2 (5.59 V/m) (6). In another densely packed indoor area, Stockholm central railway station, the mean total RF radiation level varied between 2,817 to 4,891 μW/m^2 (1.03 to 1.36 V/m) for different measurement and maximum

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levels close to a wall mounted cell phone base station yielding >95,544 μW/m^2 (6.0 V/m) (7).

Herein, the findings of other authors in similar studies are briefly discussed below. Jalilian *et al* (8) performed a review of exposure studies across European cities, finding mean outdoor exposure to range from 0.07 to 1.27 V/m for downlink signals, as from mobile phone base stations were highest contributors. Their study concluded that everyday exposure during the pre-5G era, from 2012 to 2018 had not noticeably risen.

Sagar *et al* (9) also conducted a review of RF exposure in 8 European cities. Of note, the majority of studies studies report mean RF EMF exposure values, whereas others report median values (for details, please see each publication in the aforementioned study). For outdoor microenvironments, great variability has been reported, ranging from 0.11 V/m (France) (10) to 1.59 V/m (Sweden) (11).

In another study by Sagar *et al* (12), microenvironments were compared, including outdoor places in several cities in different countries, namely Switzerland, Ethiopia, Nepal, South Africa, Australia and the US. Los Angeles was included from the US where city center mean exposure levels were reported to be 1.24 V/m (12). City centers in other countries reported the following values: Switzerland, 0.48 V/m; Nepal, 0.75 V/m; South Africa, 0.85 V/m; Ethiopia, 1.21 V/m; Australia, 1.46 V/m [please see Table 1 in the aforementioned study by Sagar *et al* (12)].

Thielens *et al* (13) investigated different microenvironments in Melbourne, Australia. They recorded the highest mean total 0.89 V/m RF-EMF exposure in Melbourne's central business district (13) Misek *et al* (14) performed RF EMF exposure anayses and measured 1.07 V/m in the city center, Andrej Hlinka Square, Zilina, Slovakia. Iyare *et al* (15) measured GSM900, GSM1800 and UMTS bands in Leuven, Belgium using spectrum analyzer measurements at 60 locations. They calculated the maximum field value of 2.53 V/m (total exposure), whereas GSM900 was the main contributor (15).

Cansiz *et al* (16) conducted exposimeter measurements in the cities of Diyarbakir and Batikent, Turkey. The highest field level recorded was 7.18 V/m, where the main contributor was the Universal Mobile Telecommunications System (UMTS) band (16). Also in Turkey, in the Altınordu district of Ordu, Kurnaz and Mutlu (17) measured city center RF exposure in 2016 and 2017, and recorded the average level to be 0.79 V/m and the highest 5.86 V/m. Tang *et al* (18). also performed measurements in the densely populated city of Xiamen, China, finding that the integrated electric field intensity ranged from 0.32 to 1.70 V/m, whereas the power density levels of 2G were higher than 3G and 4G.

The aforementioned studies by other authors have followed different methodologies, producing different parameters, which render comparisons difficulties at best. It should be emphasized that there is a need to report all the relevant statistical indicators (mean, median, min, max) and to provide detailed background information on the locations and times the measurements were obtained. The authors have developed a methodology to characterize any city and an example of a city is provided below.

The present study was performed to physically characterize the wireless infrastructure and determine public exposure to RF electromagnetic fields, including the sub-millimeter wave 5G, in the city environment of Columbia, SC, USA. The present study is particularly applicable to the emergence of 5G cell phone systems and the installment of corresponding base station antennas by the cell phone service operators.

This study is part of ongoing measurements of RF fields in public places. The aim was to provide reliable measurement data, characterizing the RF exposure levels on the dawn of the 5G mobile communications era, using high-quality measurement devices and following rigorous scientific methods. The results also provide the means of comparing public exposure to other cities worldwide. The findings of the present study may hence prove to be meaningful for public health and safety discourse. From the perspective of public RF exposure, Apart from the study by Sagar *et al* (12), no such public exposure surveys have been performed in the US for three decades, at least to the best of our knowledge. The authors aim to continue with further studies investigating other US cities.

Materials and methods

Characterizing the exposure of a city downtown area. A measurement route was planned in the downtown area of Columbia, taking into account central locations for various activities, such as business, shopping, dining and recreation. The authors have previously measured several European cities and have developed a method to characterize public exposure to RF electromagnetic fields (2-5,7). By this method, four types of common places are included in the city environment where the public comes into contact with these physical fields: i) City streets, including downtown business district(s), shopping areas, recreational hotspots with cafes and other outdoor recreational places, and historic and tourist locations; ii) city squares; iii) green areas, such as parks, promenades or others, depending on the geographical placement of the city; and iv) public transport hubs, such as railways station, bus stations or others, depending on the infrastructure of the given city. By accounting the aforementioned locations, typical exposure levels for any city can be confidently registered and displayed.

Measurements were conducted at least five times, following the same measurement route; however, they were conducted on different days, including business days and weekends, and at different times of day, from morning to evening. The temporal distribution allows for the identification of the times at which the exposure is the highest.

Measurement route in the city of Columbia, SC. The route represents the downtown area of the city of Columbia. The route was designed to cover the popular public areas, including recreational and commonly visited areas. The route was designed to include major public hotspots; hence, the route is representative of public exposure in this city.

The measurement route for city streets and squares consisted of 12 markers, designating the different street strips or squares included in the measured public objects. The route includes the three main downtown streets of the city: i) Assembly Street, a business street where several offices reside. This is one of the busiest streets, the arterial road of the city; ii) Main Street which is a popular shopping street, with a number of pedestrians either walking, sitting in cafes or shopping (Fig. 1); iii) Gervais Street; iv) Greene Street; and v) Lincoln Street. Gervais Street represents a typical area

Table I. Frequency bands present and measured in Columbia, SC, USA.

Band	Transmitted by	Bandwidth (MHz)	Frequency span (MHz)
FM US	Radio broadcasting	20	88-108
TV UHF	Television broadcasting	145	470-615
71 DL	4G, 5G base station	35	617-652
12 DL	4G base station	17	729-746
17 DL	4G base station	12	734-746
13 DL	4G base station	10	746-756
14 DL	4G base station	10	758-768
27 DL	4G base station	17	852-869
26 DL	3G, 4G base station	35	859-894
ISM	Short range applications	26	902-928
DECT 6	Cordless phones	10	1920-1930
25 DL	4G base station	65	1930-1995
66 DL	4G base station	90	2110-2200
30 DL	4G base station	100	2305-2405
W 2G	Public or private WLAN	10	2437-2447
41TDD	4G, 5G base station/cell phone	194	2496-2690
7 DL	4G base station	70	2620-2690
22 DL	4G, 5G base station	80	3510-3590
43 TDD	4G, 5G base station/cell phone	200	3600-3800
W 5G	Public or private WLAN	700	5150-5850

DL, cellular download band; TDD, cellular band servicing both upload and download traffic; ISM, industrial, scientific, and medical frequency bands; DECT, digital European cordless telecommunications.

Figure 1. Main Street (Columia, SC, USA): A popular shopping and leisure area with several cafes and small shops.

comprised of small shops and businesses. The area is also popular with small cafes, bars and diners. The buildings in this area are mostly one- and two-story buildings, no high-rise buildings are present at the strip included in the measurements. The Gervais Street area represents the oldest business district part of Columbia, as several of the buildings were built 100 years ago. The route also accounts for Pendleton, Sumter and Laurel Streets, along the Main Street; the route accounts detailed measurements from Boyd plaza. Lincoln Street contains both old historic buildings and relatively modern buildings, constructed over the past few decades. Lincoln Street in the proximity of Gervais Street contains a historical

Figure 2. Horseshoe Park (Columia, SC, USA) located at the heart of the campus; this park is popular amongst students.

leisure area with popular bars and pubs in the construction style of the beginning of the last century. The southern part of Lincoln Street includes the city's main free time locations, including a conference center, arena and other features.

The route starts and ends at the University of South Carolina campus and continues along the city center, passing several central buildings, including FedEx, Wells Fargo Bank, Optus bank, Synovus bank, South Carolina Secretary of State, State House, Supreme Court, Sheraton Columbia Downtown, Marriott Columbia, Columbia Museum of Art, Columbia City Hall, US Social Security Administration, Federal building, Courthouse, United States Postal Service, Richland county main library, the South Carolina Department of Transportation, Colonial Life Arena and the Carolina Coliseum.

In additional to the street route, the present study measured RF levels at Columbia's train street (850 Pulaski Street, Columbia). Public parks included i) State House Park, Assembly Street; ii) Horseshoe Park, Sumter Street (Fig. 2); and iii) Finlay Park, 930 Laurel Street. For the parks and the train station, only one measurement round was conducted. All aforementioned locations are presented in Fig. 3.

Additionally, another measurement route was planned for parks and the railway station, which was conducted independently from the aforementioned route.

The meter was held at arm's length which is ~50 cm from the body, to minimize the shielding effect of the operator's body. The measurement was activated and a preset route was followed for each measurement round. All the measurement rounds were conducted at a steady pace, maintaining a constant speed. The city squares were measured using a spiral movement pattern, covering the square by evenly distributed layout; this allows for spatial representation and the calculation of the mean exposure level.

Spatial distribution of the field. Other series of measurements were conducted to analyze the spatial distribution of the radiofrequency field exposure. An area of 0.89x1.0 miles (1.4x1.60 km) was selected, where all streets were measured using the grid mapping method. The spatial measurement was performed once, unlike the aforementioned representative route measurements which were performed five times. An exposimeter (EME SPY Evolution; MVG) was used for the measurements together with a GPS logger for obtaining geographical coordinates from GPS. During the measurements, the GPS accuracy was 1-3 meters, allowing for good spatial accuracy to prepare a field distribution vector map. Vector mapping 3D Field software ver. 4.6.1.0 was used to conduct the calculations, where the kriging method 'Natural neighbors II' was applied and the number of gradients set to 20. To clearly illustrate the elevated exposure areas i.e., hotspots, the highest gradient was set at 2.0 V/m, whereas all the values above that were treated at the same color (dark red). Spot measurement data were fed to the contour map software 3DFIELD ver. 4.5.2.0 (by Vladimir Galouchko) and spatial field distribution maps were drawn.

Measurement device. The EME SPY Evolution was used, a latest model exposimeter (MVG). EME Spy Evolution is a selective, isotropic and portable electromagnetic field meter for measuring various communication standards between 80 MHz and 6 GHz, such as (frequency modulation) radio broadcasting; television (TV) broadcasting; Terrestrial Trunked Radio (formerly known as the Trans-European Trunked Radio; TETRA) emergency services (police, rescue, etc.); global system for mobile communications (GSM) second generation mobile communications; universal mobile telecommunications systems (UMTS) third generation mobile communications, 3G; long term evolution (LTE) fourth generation mobile

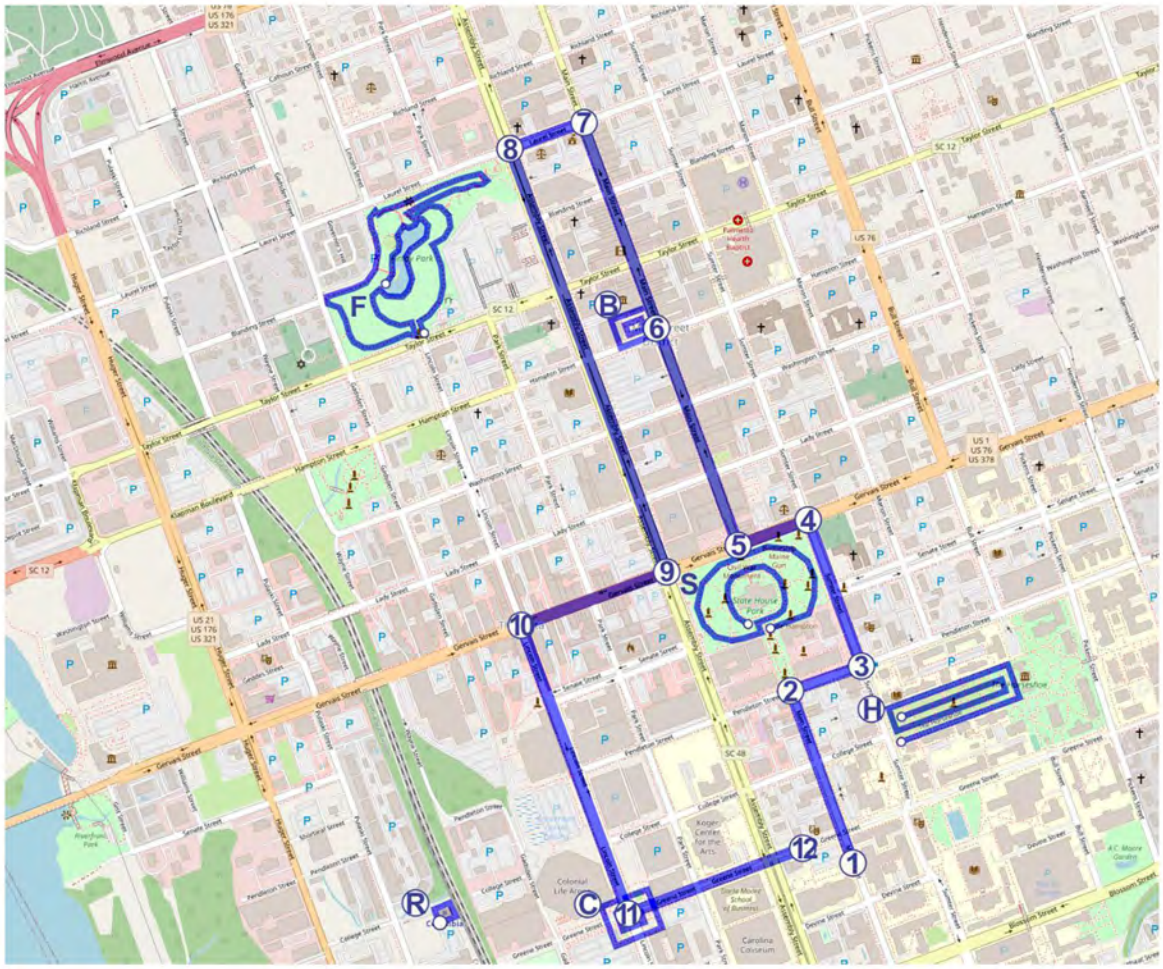

Figure 3. Measurement routes (Columia, SC, USA) characterizing public exposure to radiofrequency in the downtown area. H, Horseshoe Park; F, Finlay Park; B, Boyd Plaza; C, Colonial Life area square; R, railway station; S, State House Park. © OpenStreetMap contributors, the data are available under the Open Database License; base map and data were from OpenStreetMap and OpenStreetMap Foundation (openstreetmap.org).

communications standard, 4G; digital European cordless telecommunications (DECT) cordless telephone systems standard; Wi-Fi wireless local area network protocol. EME Spy Evolution allows for the recording of field levels with a user set period and recording duration. The lower detection limit of the meter is 0.05 V/m (2.7-6 GHz) and 0.02 V/m (0.08-2.7 GHz). The upper detection limit is 6 V/m for all bands. The meter can store 166,000 measurement samples for 20 band scenarios. For each band, the meter monitors the frequency bandwidth for a specific time and registers (records) either an average or median depending on the band (signal type).

For this measurement task, EME SPY Evolution was configured to measure the maximum number of frequency bands and at sampling rate of 6 sec (shortest for the given number of bands).

Frequency bands. EME SPY Evolution software includes 85 preset frequency bands covering all European, American and Asian cellphone bands, as well as other civilian RF sources. Prior to the measurements, a configuration must be set to select desired bands. The device was configured to measure mostly download (DL) bands, as the interest of the study was to characterize the exposure from cell phone base station antennas. Cellular bands are designated as b1 … b79 and can be duplex bands, meaning one for upload and the other for download, e.g. b26UL and b26DL. Some cellular bands have both the upload and download traffic within the same band, meaning sharing the same frequencies e.g., 5G band b41.

Other, non-cellular exposure sources were also included, constituting for the entire civilian RF infrastructure, including TV, radio, industrial, scientific, and medical frequency bands (ISM), DECT and TETRA. The frequencies used in the US were preconfigured and set to the meter. USA TETRA is permitted in the 450-470 MHz and 809-824/854-869 MHz business/industrial land transportation (B/ILT) band (19). TETRA is a standardized trunked radio system (20). TETRA is used by a number of professional services, including government, emergency, police, rescue, ambulance and railway services. The Federal Communications Commission (FCC) has set regulations for permitting intentional radiators in the 902-928 MHz ISM band; ISM bands near 900 MHz and 2.4 GHz are allowed to be used in the US (21). The preparatory measurements did not detect any transmitters at 450-470 MHz; thus, this was omitted from the frequency table. In the US and Canada, DECT is permitted at frequencies 1,920-1,930 MHz (22). DECT (23) is most often familiar by cordless telephones, baby monitors, but is also used for door opener remotes and traffic.

Table II. Radiofrequency levels at specific areas in Columbia, SC, USA.

Location	Map marker	Length of measured strip (ft/m)	n	Mean (V/m)	Median (V/m)	Min (V/m)	Maximum (V/m)
Gervais Street (west)	9-10	1,048/319	64	1.750	0.870	0.150	6.867
Main Street (middle)	5-6	1,664/507	80	1.624	1.096	0.261	5.903
Pendleton Street	2-3	537/163	21	1.568	1.368	0.566	3.728
Greene Street	11-12	1,294/394	59	1.548	1.319	0.228	4.917
Sumter Street	3-4	1,084/330	41	1.280	1.158	0.548	2.880
Assembly Street	8-9	3,125/953	127	1.243	0.928	0.116	3.772
Main Street (south)	1-2	1,239/378	77	1.072	0.984	0.089	2.444
Boyd plaza	B	1,023/312	48	0.997	0.809	0.197	2.195
Lincoln Street	10-11	2,107/642	78	0.956	0.654	0.250	5.490
Laurel Street	7-8	506/154	26	0.923	0.548	0.240	2.849
Main Street (north)	6-7	1,476/450	64	0.871	0.544	0.168	3.164
Colonial Life Arena square	C	1,685/513	82	0.858	0.680	0.242	2.771
Gervais Street (east)	4-5	553/168	28	0.785	0.669	0.381	3.275
State House Park	S	3,788/1,150	223	0.740	0.581	0.174	2.093
Finlay Park	F	5,233/1,600	267	0.688	0.614	0.187	1.409
Horseshoe Park	H	3,989/1,220	232	0.475	0.410	0.212	1.210
Railway Street	R	395/120	39	0.341	0.260	0.143	0.755
Streets and squares altogether	-	14,626/4,458[a]	795	1.240	0.859	0.089	6.867
Parks altogether	-	NA	722	0.645	0.530	0.174	2.093

The total exposure of all measured frequency bands and the analysis of all data (V/m) across all measurement rounds is shown, treating values at lower detection limit as 0. [a]Length of measured strip TOTAL (m/ft) is calculated by adding street strip lengths, excluding squares, parks and Railway Street; n, number of measurement points per each strip, average across all measurement rounds; maximum indicates highest of all measurement rounds; NA, data not available or computable.

Prior to the measurements, a literature search was conducted, accounting for the public sources revealing the cellular bands used in the corresponding city or area. In addition, multiple measurement test runs were conducted in the area to identify and confirm the cellular bands used in the city. The aim was to cover all relevant sources of public exposure from the civilian RF infrastructure, including GSM 2G, 3G, LTE 4G and 5G submillimeter wave bands (<6 GHz). The selected bands do not include most cell phone upload bands, as this level is highly dependent to the proximity of people using cell phones and was not within the scope of this study.

Statistical analysis. The mean, median, minimum and maximum values in V/m were calculated to characterize the following: i) Amplitudes of different frequency bands; ii) total exposure at different downtown areas; and iii) total exposure across different weekdays and times of day. The means were calculated as quadratic means. Total exposure was calculated as the sum of all measured frequency bands. Readings at the lower detection limit were treated as zero level (0.00 V/m) exposure. One-way analysis of variance (ANOVA) was conducted to assess whether there was a statistically significant difference in RF public exposure when measured at different weekdays and times. Tukey's test for multiple comparisons was used for post hoc tests of all pairwise combinations of measurement times. Statistical analyses were performed using IBM SPSS software (ver. 26) (IBM Corp.). A value of $P<0.05$ was considered to indicate a statistically significant difference.

Results

Measurements. The measurements in the present study were conducted in the city of Columbia, SC, USA in the period of June 6 to 13, 2021. The measurement route length was calculated 2.8 M (4.5 km), with the average duration of a measurement being 1 h and 10 min. On the whole, 3,943 single measurements were conducted all over the downtown area, distributed over five measurement days; each measurement entailed an amplitude analysis of 20 frequency bands (see Table I).

The highest exposure readings were registered close to cell phone base station antennas that were placed at a low level near the street level. These were cylinders mounted on top of utility poles, street lamps, traffic lights or other arbitrary posts. The antennas were surrounded by a cylindrical cover rendering these unnoticeable for the bystanders.

Analysis of different downtown areas. The area-specific results of the RF exposure measurements averaged across all five measurement rounds are presented in Table II. For parks and the railway, only one measurement round was conducted. The exposure is presented as a total of the 2.8 M (4.5 km) route and also as route legs representing exposure at each measured

Table III. Band specific radiofrequency exposure levels based on all five measurement rounds in the city streets and squares in Columbia, SC, USA.

Band	Mean (V/m)	Median (V/m)	Min (V/m)	Maximum (V/m)
FM US	**0.687**	0.355	0.000	**3.242**
TV UHF	0.021	0.000	0.000	0.165
71 DL	0.101	0.026	0.000	0.895
12 DL	0.000	0.000	0.000	0.000
17 DL	0.000	0.000	0.000	0.000
13 DL	0.191	0.052	0.000	1.867
14 DL	**0.293**	0.082	0.000	**2.653**
27 DL	**0.216**	0.053	0.000	**3.037**
26 DL	0.076	0.000	0.000	0.916
ISM	0.036	0.000	0.000	0.451
DECT 6	0.024	0.000	0.000	0.286
25 DL	**0.513**	0.260	0.021	**5.196**
66 DL	**0.781**	0.388	0.000	**6.001**
30 DL	0.062	0.000	0.000	0.478
W 2G	0.013	0.000	0.000	0.193
41TDD	0.031	0.000	0.000	0.470
7 DL	0.027	0.000	0.000	0.338
22 DL	0.001	0.000	0.000	0.033
43 TDD	0.002	0.000	0.000	0.052
W 5G	0.006	0.000	0.000	0.104

The analysis of all data (V/m) was performed treating values at the detection limit as 0. Values in bold font indicate the highest values. DL, cellular download band; TDD, cellular band servicing both upload and download traffic; ISM, industrial, scientific, and medical frequency bands; DECT, digital European cordless telecommunications.

Table IV. Pairwise post hoc comparisons between all measurement times.

Comparison between different times[a]	Mean difference (V/m)	P-value[b]
2106091700 vs. 2106061329	0.18	<0.001
2106101550 vs. 2106061329	0.11	0.01
2106112010 vs. 2106061329	0.02	0.98
2106121340 vs. 2106061329	0.05	0.51
2106101550 vs. 2106091700	-0.07	0.19
2106112010 vs. 2106091700	-0.16	<0.001
2106121340 vs. 2106091700	-0.13	0.002
2106112010 vs. 2106101550	-0.09	0.04
2106121340 vs. 2106101550	-0.06	0.44
2106121340 vs. 2106112010	0.04	0.83

[a]The times are in the format of year/month/day/time (hhmm). [b]P-values were obtained using Tukey's test for multiple comparisons following ANOVA.

street strip. The presentation of street strip data helps to identify highly exposed areas in the city, as well as areas with lower exposure levels. In Table II, the column labeled 'Length of measured strip' presents the length of each measured street strip in feet and meters. In squares and parks, the strip length indicates the total length of a spiral-like route pattern which was taken at each area. 'Nr of measurement points' indicates how many measurement points (single measurements) were taken in each corresponding street strip or area.

Based on the measurements collected at locations around the city, the analysis of the means indicates the highest exposure areas (beginning from the highest) at Gervais Street (west), Main Street (middle) and Pendleton Street and Greene Street. The upper detection limit of the meter was repeatedly exceeded at Gervais Street, where also the maximum exposure level of all rounds was registered.

Analysis of frequency bands. Frequency analysis (Table III) revealed that the majority of contributors to the exposure budget were bands 'FM US', '14DL', '27DL', '25DL' and '66DL', whereas the latter two had the highest single measurements recorded throughout the city and over all the measurement bands. The highest exposure places for the bands were accordingly: 1.243 V/m 'FM US' at Main Street (middle); 0.734 V/m '14DL' at Greene Street; 0.616 V/m '27DL' at Laurel Street; 0.847 '25DL' at Pendleton Street; and 1.422 V/m '66DL' at Gervais Street (west); the values indicate the mean exposure of several measurement points at the location, and averaged over all five measurement rounds.

Comparing total exposure across different days. The measurements, following the same route, were conducted on five different weekdays: 2106061329, 2106091700, 2106101550, 2106112010 and 2106121340 [the format year/month/day/time (hhmm) designates the end time of a measurement round]. In Fig. 4, a boxplot chart is presented, demonstrating the total exposure, indicating temporal fluctuations across different days and times of day. Temporal variations across different weekdays and times of day are minimal in Columbia with respect to public exposure. The mean exposures over the entire route were measured as follows (in descending order) as follows: i) highest 1.149 V/m on 2106091700, Wednesday afternoon; ii) 1.075 V/m on 2106101550, Thursday afternoon; 1.02 V/m on 2106121340, Saturday midday; 0.985 V/m on 2106112010, Friday evening; and the lowest 0.965 V/m on 2106061329, Sunday midday.

The exposure levels in downtown area were 12-16% lower on weekend times as compared to business hours. The results of the statistical analysis using ANOVA revealed a statistically significant difference (P<0.001). Pairwise post hoc tests showed statistically significantly different exposure levels for 2106091700 compared to 2106061329 (mean difference, 0.18 V/m; P<0.001), for 2106101550 compared to 2106061329 (mean difference 0.11, V/m; P=0.01), for 2106112010 compared to 2106091700 (mean difference, -0.16 V/m; P<0.001), for 2106121340 compared to 2106091700 (mean difference, -0.13 V/m; P=0.002) and for 2106112010 compared to 2106101550 (mean difference, -0.09 V/m; P=0.04) (Table IV). The exposure was lower on weekend times (Friday evening through Sunday) as compared to business times. Additionally,

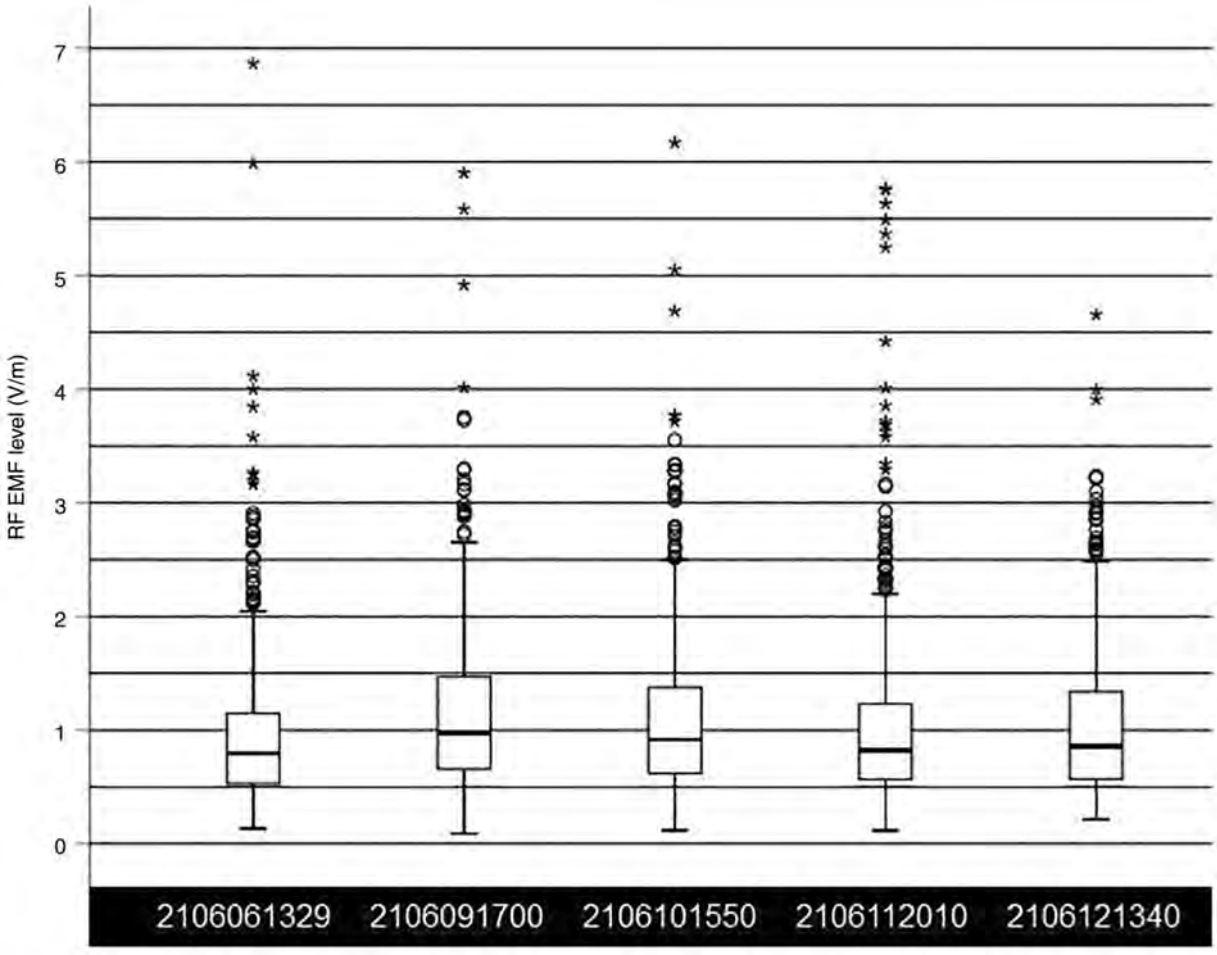

Figure 4. Boxplot of the total exposure on city the streets and squares in V/m. The measurements, following the same route, were conducted on five different weekdays: 2106061329, 2106091700, 2106101550, 2106112010 and 2106121340 [in the format year/month/day/time (hhmm)] in Columbia, SC, USA. The median 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 the 1.5x interquartile range. Points represent outliers.

the effect size [partial eta squared (η2p)] characterized that 0.9% of RF level variability accounted for different measurement times.

Spatial distribution of the field. During the field spatial mapping, 1,448 single measurements were conducted. The total field exposure (sum of all measured frequency bands) at the downtown area was as follows: Mean, 0.879; median, 0.703; min, 0.127; max, 5.507 V/m (meter's upper detection limit was reached). The measurement covered altogether 14.8 miles (23.7 km). The results of spatial field distribution in downtown Columbia, SC are depicted in Fig. 5, where ~15-20 hotspots of elevated exposure could be identified. For example, a number of smaller-scale hotspots could be identified in Gervais Street where cell phone base station antennas are mounted on top of the utility poles and therefore positioned low, close to the street level. However, these are relatively low-powered transmitters, and also due to the low positioning, the elevated field does not reach far. Hotspots that cover larger areas are caused by the transmitters of higher power, which are located on top of the tall buildings. A histogram of the spatial field distribution measurements is depicted in Fig. 6. The highest exposure levels were caused by cell phone base station antennas that were positioned low close to the street level (Figs. 7 and 8).

Discussion

Base stations nearby street level yielded the highest exposure. This is demonstrated by measurements which calculated the highest exposure for Gervais Street, where also the maximum exposure of the entire study was registered. Unlike the other streets measured, Gervais Street can be distinguished by two features: i) New 5G base stations were installed and; ii) the majority of the base station antennas were installed at a low level, close to the street level. Hence, the present study demonstrated that the installment of 5G base station antennas was the reason for the highest exposure areas in the city. The reason for the high exposure levels is the need to bring base stations close to the subscriber devices.

Pedestrians walking on the city streets may notice radio and TV transmitters placed on top of high-rise buildings; however, they are unlikely to suspect that cylindrical objects on top of utility poles, street lamps and traffic lights could be cell phone antennas, particularly considering these are painted the same color as the pole they are mounted on top of. Furthermore, cell phone antennas are not always clearly visible, and thus individuals are unaware of their presence; perhaps this is due to purposes of conforming with any relevant city ordinance, such as aesthetics.

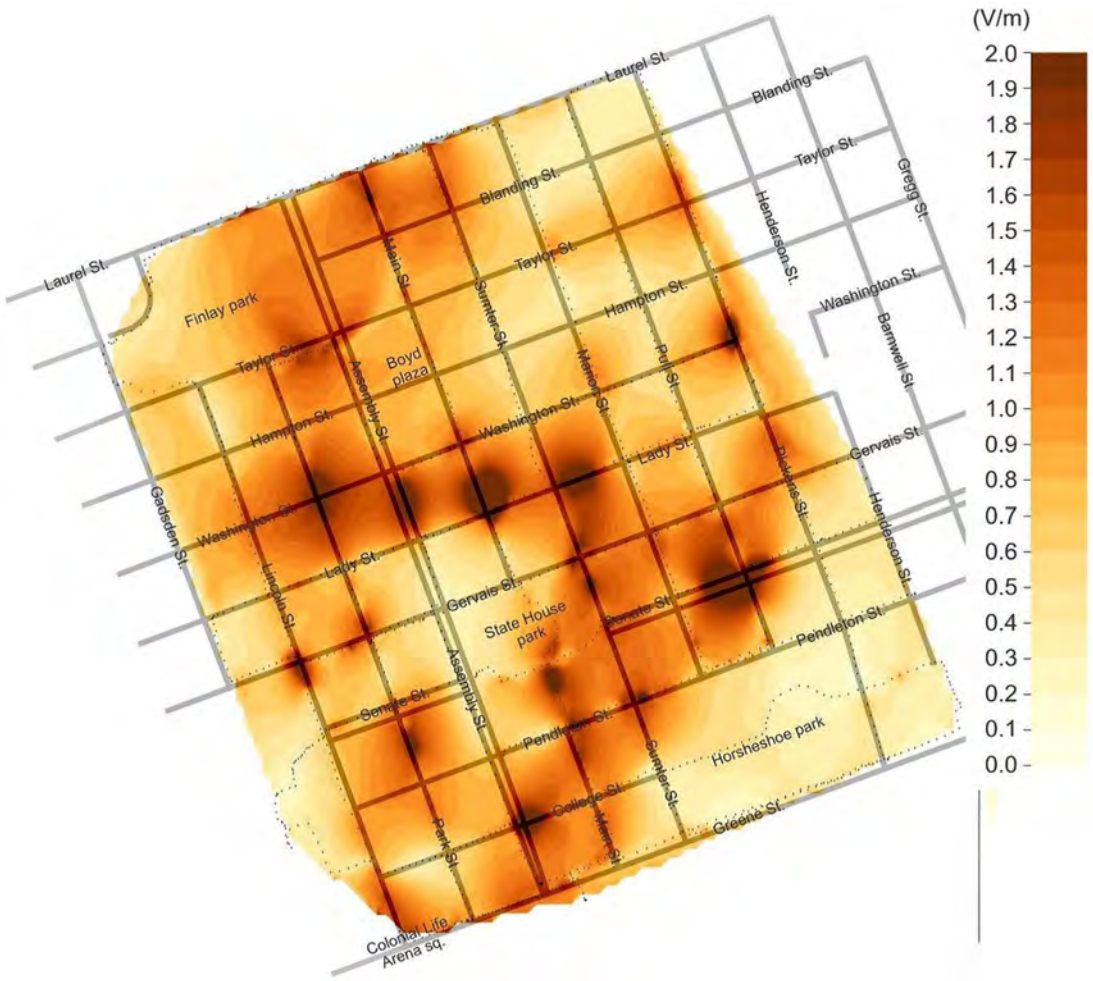

Figure 5. Radiofrequency electromagnetic field (V/m) spatial distribution in the city of Columbia, SC, USA downtown area of 0.89x1.0 miles (north is on the top). Small individual black dots indicate locations of single measurements (n=1,448).

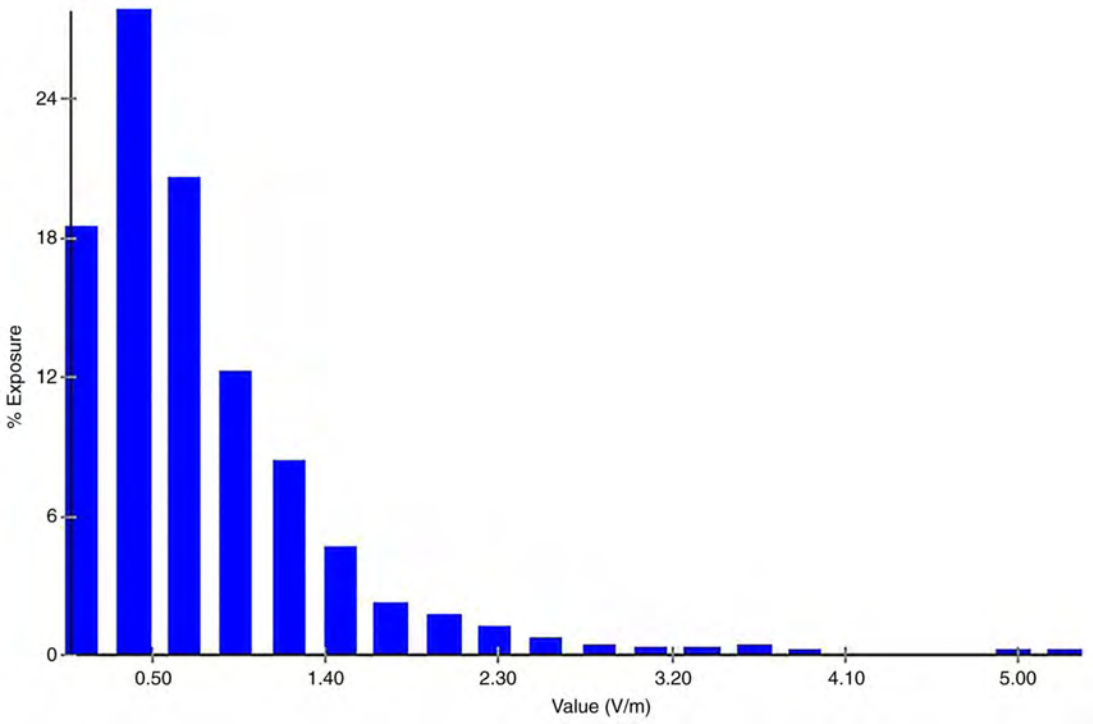

Figure 6. Histogram of spatial field distribution measurements shows that majority of the readings are ~0.5 V/m, whereas high readings of 5 V/m or more were only obtained five times. The histogram characterizes the percentages (%) of exposure values (V/m) in 20 bins.

Figure 7. Gervais Street: Cell phone base station antenna placed close to street level and causing high exposure to pedestrians and nearby café visitors (exposure scenario illustration). The antenna appears camouflaged and seemingly part of a utility pole. The measurer only discovered the antenna due to the high radiofrequency levels in the vicinity.

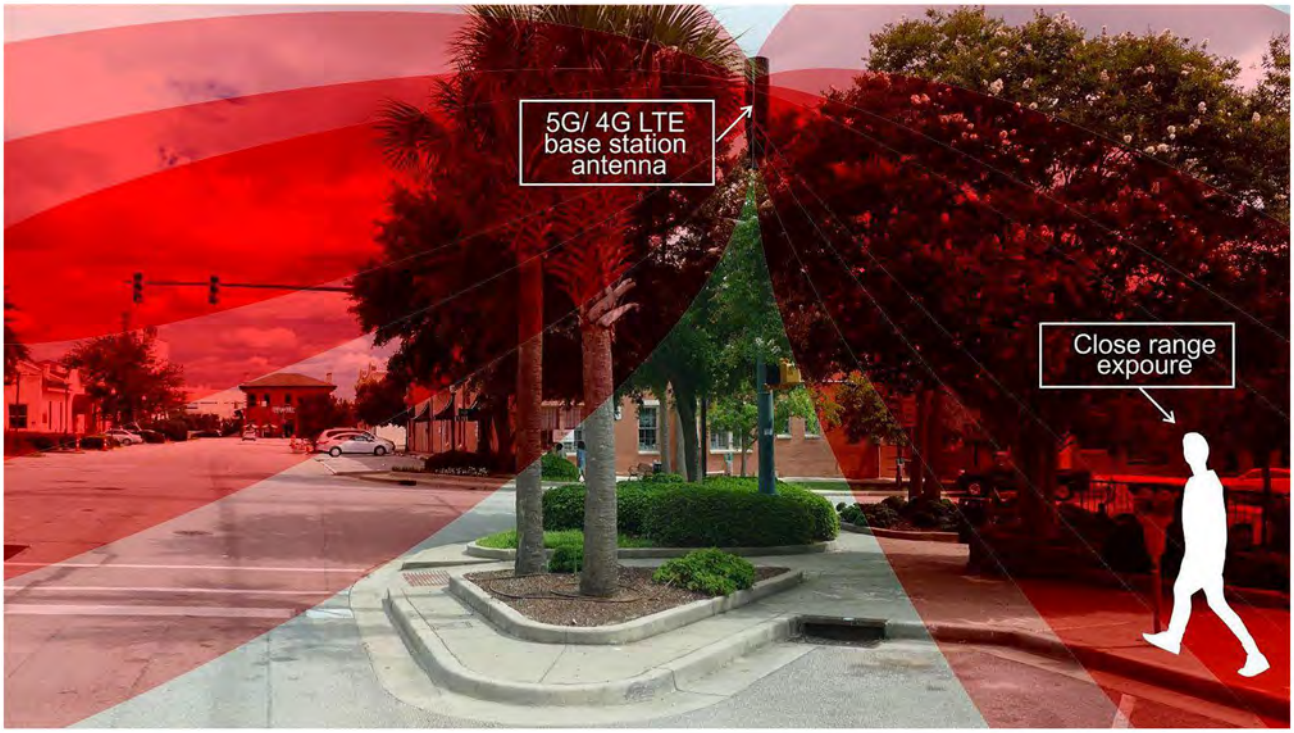

Figure 8. Gervais Street: Another cell phone base station antenna close to street level and causing high exposure to pedestrians (exposure scenario illustration). Note the antenna appears undistinguishable from the utility pole an unnoticeable between the trees.

Temporal analysis revealed that there was a statistically significant difference in exposure levels in the downtown area when comparing total exposure across different days and times. The public exposure varied during different times and days.

In the present study we conducted different assessment methods to characterize city center exposure levels by i) repetitive route measurements (mean 1,240 V/m) compared to ii) grid measurement (mean 0.879 V/m). The difference of means can be expected due to the following reasons: i) the grid measurement covers a wider city center area, including areas of a lower population density; ii) the route approach focuses more at the city center area, where there are more RF

EMF sources. Therefore, the city center route method results in ~30% higher mean than the grid measurement method. In addition, the temporal variation of 16% between means from different days needs to be accounted for. When comparing mean exposures from different cities, higher exposure levels may be obtained, if these differ by ≥2-fold.

The present study measured RF exposure levels in Columbia. In Columbia, SC, the measurement route, which was conducted five times, calculated at the streets and squares 1,240 V/m as a mean exposure (total as a sum of all frequency bands) and 6.867 V/m as all times maximum (Table II).

The majority of previous studies discussed above in the 'Introduction' reported similar results in European cities. An analogous study by the authors in Stockholm, Sweden, following the same method, calculated 1,439 V/m as the mean exposure (2). The highest exposure levels that were measured in a detailed measurements in Stockholm, Järntorget square, resulted in 11.6 V/m as the maximum (3).

Jalilian *et al* (8), in their review article, reported the mean outdoor exposure level of European cities to range from 0.07 to 1.27 V/m. This together with the readings from Stockholm places the mean of Columbia city (1,240 V/m) on top of the European scale.

In conclusion, in the city of Columbia, SC, USA, the present study determined that the highest exposure areas were due to two reasons: i) Cell phone base station antennas on top of high-rise buildings provide good cell coverage reaching far away, but creating elevated public exposure to the RF RMFs at the immediate vicinity; and ii) cell phone base station antennas installed on top of the utility poles have placed the radiation source closer to humans walking on the street level.

RF exposure levels from mobile phone base station antennas near the street level reached high levels. It is thus recommended, that all such close proximity transmitters should be labeled with relevant signs to warn of high RF exposure in the area (24). Cell phone base station antennas should be distinct and noticeable so that people who need to limit their exposure, have been given a chance to do so by distancing themselves from the RF sources. Considering the current trend of cell phone service providers expanding their 5G network, more utility pole base station antennas are expected. Consequently, the public exposure is also likely to increase in the coming years.

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Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

TK performed the measurements. The conception of the study, the design and analyses of the material, the writing of the article and the approval of the final manuscript was made by both authors (TK and LH). Both authors confirm the authenticity of all the raw data. Both authors have read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

LH is an Editorial Advisor of the journal, but had no personal involvement in the reviewing process, or any influence in terms of adjudicating on the final decision, for this article. The author TK declares that he has no competing interests.

References

1. United States Census Bureau. City of Columbia. QuickFacts-Columbia City, South Carolina. 2021. https://www.census.gov/quickfacts/columbiacitysouthcarolina. Accessed November 19, 2021.
2. Carlberg M, Hedendahl L, Koppel T and Hardell L: High ambient radiofrequency radiation in Stockholm city, Sweden. Oncol Lett 17: 1777-1783, 2019.
3. Hardell L, Carlberg M, Hedendahl LK, Koppel T and Ahonen M: Environmental radiofrequency radiation at the Järntorget Square in Stockholm Old Town, Sweden in May, 2018 compared with results on brain and heart tumour risks in rats exposed to 1.8 GHz base station environmental emissions. World Acad Sci J 1: 47-54, 2019.
4. Hardell L, Carlberg M, Koppel T and Hedendahl L: High radiofrequency radiation at Stockholm Old Town: An exposimeter study including the Royal Castle, Supreme Court, three major squares and the Swedish Parliament. Mol Clin Oncol 6: 462-476, 2017.
5. Koppel T, Ahonen M, Carlberg M, Hedendahl LK and Hardell L: Radiofrequency radiation from nearby mobile phone base stations-a case comparison of one low and one high exposure apartment. Oncol Lett 18: 5383-5391, 2019.
6. Hedendahl LK, Carlberg M, Koppel T and Hardell L: Measurements of radiofrequency radiation with a body-borne exposimeter in Swedish schools with Wi-Fi. Front Public Health 5: 279, 2017.
7. Hardell L, Koppel T, Carlberg M, Ahonen M and Hedendahl L: Radiofrequency radiation at Stockholm Central Railway Station in Sweden and some medical aspects on public exposure to RF fields. Int J Oncol 49: 1315-1324, 2016.
8. Jalilian H, Eeftens M, Ziaei M and Röösli M: Public exposure to radiofrequency electromagnetic fields in everyday microenvironments: An updated systematic review for Europe. Environ Res 176: 108517, 2019.
9. Sagar S, Dongus S, Schoeni A, Roser K, Eeftens M, Struchen B, Foerster M, Meier N, Adem S and Röösli M: Radiofrequency electromagnetic field exposure in everyday microenvironments in Europe: A systematic literature review. J Expo Sci Environ Epidemiol 28: 147-160, 2018.
10. Viel FJ, Clerc S, Barrera C, Rymzhanova R, Moissonnier M and Cardis E: Residential exposure to radiofrequency fields from mobile phone base stations, and broadcast transmitters: A population-based survey with personal meter. Occup Environ Med 6: 550-556, 2009.
11. Estenberg J and Augustsson T: Extensive frequency selective measurements of radiofrequency fields in outdoor environments performed with a novel mobile monitoring system. Bioelectromagn 35: 227-230, 2014.

12. Sagar S, Adem SM, Struchen B, Loughran SP, Brunjes ME, Arangua L, Dalvie MA, Croft RJ, Jerrett M, Moskowitz JM, *et al*: Comparison of radiofrequency electromagnetic field exposure levels in different everyday microenvironments in an international context. Env Int 114: 297-306, 2018.
13. Thielens A, Van den Bosschea M, Brzozekc C, Bhatt C, Abramson M, Benke G, Martens L and Joseph W: Microenvironmental personal and head exposure measurements of radio-frequency electromagnetic fields. In: Joint Annual Meeting of the Bioelectromagnetics Society and the European BioElectromagn Assoc (BioEM 2018). Melbourne, pp273-279, 2018.
14. Misek J, Laukova T, Kohan M, Veternik M, Jakusova V and Jakus J: Measurement of low-level radiofrequency electromagnetic fields in the human environment. Acta Med Martiniana 18: 27-33, 2018.
15. Iyare RN, Volskiy V and Vandenbosch GA: Study of the electromagnetic exposure from mobile phones in a city like environment: The case study of Leuven, Belgium. Environ Res 175: 402-413, 2019.
16. Cansiz M, Abbasov T, Kurt MB and Celik AR: Mapping of radio frequency electromagnetic field exposure levels in outdoor environment and comparing with reference levels for general public health. J Expo Sci Environ Epidemiol 28: 161-165, 2018.
17. Kurnaz C and Mutlu M: Comprehensive radiofrequency electromagnetic field measurements and assessments: A city center example. Environ Monit Assess 192: 334, 2020.
18. Tang C, Yang C, Cai RS, Ye H, Duan L, Zhang Z, Shi Z, Lin K, Song J and Huang X: Analysis of the relationship between electromagnetic radiation characteristics and urban functions in highly populated urban areas. Sci Total Environ 654: 535-540, 2019.
19. Federal Communications Commission. A Rule by the Federal Communications Commission on 10/10/2012. 2012. https://www.federalregister.gov/documents/2012/10/10/2012-24792/private-land-mobile-radio-rules. Accessed November 19, 2021.
20. ETSI EN 300 392-2 V3.2.1 (2007-09), European standard, Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI). 2007. https://www.etsi.org/deliver/etsi_en/300300_300399/30039202/03.02.01_60/en_30039202v030201p.pdf. Accessed November 19, 2021.
21. Loy M, Karingattil R and Williams L (eds). ISM-Band and Short Range Device Regulatory Compliance Overview, Application Report, Texas Instruments. 2003, http://www.ti.com/lit/pdf/swra048. Accessed November 19, 2021.
22. Federal Communications Commission. Unlicensed Personal Communications Service Devices in the 1920-1930 MHz Band. A Rule on 07/23/2012. 77 FR 4300. 2012. https://www.federalregister.gov/documents/2012/07/23/2012-17793/unlicensed-personal-communications-service-devices-in-the-1920-1930-mhz.band. Accessed November 19, 2021.
23. European Telecommunications Standards Institute. Digital Enhanced Cordless Telecommunications (DECT); A High Level Guide to the DECT Standardization, ETSI TR 101 178 V1.5.1 (2005-02) Technical Report. 2005. http://www.etsi.org/deliver/etsi_tr/101100_101199/101178/01.05.01_60/tr_101178v010501p.pdf. Accessed November 19, 2021.
24. Recommendation 13 (page 16) of the State of New Hampshire report: 'Commission to Study The Environmental and Health Effects of Evolving 5G Technology'. http://www.gencourt.state.nh.us/statstudcomm/committees/1474/reports/5G%20final%20report.pdf.

Senator Markey Letter September 18, 2018
Senator Markey Letter, July 26, 2017

ENVIRONMENTAL HEALTH TRUST

FACTSHEET: ENVIRONMENTAL HEALTH TRUST ET AL. V. FCC

FCC's Lack of Adequate Review for Wireless Radiation Exposure Limits

LANDMARK FEDERAL COURT RULING AGAINST THE FCC

On August 13, 2021 the U.S. Court of Appeals for the D.C. Circuit ruled the Federal Communications Commission (FCC) ignored scientific evidence and failed to provide a reasoned explanation for its determination that its 1996 regulations adequately protect the public against all the harmful effects of wireless radiation.

FCC'S REFUSAL TO UPDATE 1996 LIMITS

The legal case challenged the FCC's 2019 decision not to update its 1996 regulations regarding allowable exposures of radiofrequency radiation (RF) from wireless technologies - including 5G, cell phones, cell towers, Wi-Fi, and wireless networks.

EVIDENCE OF BIOLOGICAL EFFECTS BELOW FCC LIMITS

FCC limits are based on the outdated belief that heating is the only proven harm from RF. Over 11,000 pages of evidence - 447 exhibits in 27 Volumes - was submitted to the Court documenting biological effects and illness from wireless radiation exposure at non-heating levels. Research has found brain damage, headaches, memory problems, reproduction damage, synergistic effects, nervous system impacts, brain cancer, genetic damage, as well as harm to trees, birds, bees, and wildlife.

THE COURT FINDINGS

The Court found that the FCC did not provide evidence of properly examining record evidence indicating non-cancer harm such as:

- impacts to children
- testimony of persons injured by wireless radiation
- impacts to the developing brain
- impacts to the reproductive system
- impacts to wildlife and the environment

THE COURT ORDER

The Court ordered the FCC to provide a reasoned determination as to whether the evidence warrants a change to 1996 RF limits especially in regards to:

- children's vulnerability
- long-term exposure
- environmental impacts
- new technological developments and the ubiquity of wireless
- how FCC's cell phone tests only measure heat and allow a space between the phone and body.

"The factual premise—the non-existence of non-thermal biological effects—underlying the current radiofrequency (RF) guidelines may no longer be accurate."

-2021 EHT et al. v. FCC RULING

TIMELINE

1980s: EPA tasked to develop RF safety limits for heating and biological effects.

1996: EPA is fully defunded and halts all research on RF. The FCC adopts RF limits developed by industry-tied groups- based on heating.

1999: FDA requests the National Toxicology Program (NTP) study RF because of the lack of safety data on long-term exposure.

2008/2009 Congressional Hearings

2012: GAO Report recommends rules be reassessed to reflect current use patterns and recent science.

2013-2019: FCC opens record on RF limits - gets over 1000 submissions.

2018: NTP releases $30M animal study concluding "clear evidence" of cancer. FDA rejects the findings.

2019: FCC closes record, decides not to update its 1996 wireless RF limits.

2020: Cases filed against FCC.

2021: Ruling against FCC.

ENVIRONMENTAL HEALTH TRUST

FACTSHEET: ENVIRONMENTAL HEALTH TRUST ET AL. V. FCC

FCC's Lack of Adequate Review for Wireless Radiation Exposure Limits

THE BOTTOM LINE

FCC Compliance Does Not Ensure Safety

Most of the public assumes that current FCC safety limits for cell phones, cell towers, Wi-Fi, 5G, and wireless networks are based upon an up to date robust review of all relevant research. This assumption of safety is now clearly documented to be erroneous.

Lack of Oversight by Health and Environmental Agencies

The ruling reveals a lack of accountability with our federal health agencies regarding wireless radiation. The EPA, CDC, NIOSH, and NCI did not submit any reports to the Court, revealing that none of these agencies has reviewed the science on health effects to ensure safety for the public. The U.S. has no pre-market safety testing for health effects, no post-market surveillance, no environmental monitoring, and no meaningful interagency coordination.

FDA's Dismissal of Harm Deemed Insufficient

The Court states the FCC improperly relied on the FDA's conclusions that RF limits did not need an update. The FDA's submissions were described by the Court as "cursory" and "insufficient." Although the FDA later released a literature review, it was only focused on cancer, further confirming the fact that the FDA and U.S. safety agencies have failed to evaluate the numerous health effects documented in scientific studies, such as brain and reproductive system impacts. A US government review of the full body of recent science has simply never been done.

Children's Vulnerability Ignored by the FCC

The Court states the FCC "dismissed" the American Academy of Pediatrics recommendations for strengthened regulations that ensure children and pregnant women would be protected. The Court found the FCC failed to explain why it ignored research indicating children were more vulnerable to wireless: their developing brains are more sensitive, they absorb higher levels of RF deeper into their brains, and they will have a lifetime of exposure.

Wildlife Remains Unprotected

FCC's limits were designed in 1996 to protect only humans, not flora or fauna. The Court found that the FCC had "completely failed" to address the "substantive evidence of potential environmental harms" on the record, which included science showing serious impacts to birds, bees, trees, and plants.

"In the Department of the Interior's expert view, the Commission's RF radiation limits "continue to be based on thermal heating, a criterion now nearly 30 years out of date and inapplicable today."

-2021 EHT et al. v. FCC

PETITIONERS

Environmental Health Trust (EHT), Consumers for Safe Cell Phones, Elizabeth Barris, and Theodora Scarato.

Children's Health Defense (CHD), Michelle Hertz, Petra Brokken, Dr. David Carpenter, Dr. Toril Jelter, Dr. Paul Dart, Dr. Ann Lee, Virginia Farver, Jennifer Baran, and Paul Stanley M.Ed. CHD's case was consolidated with EHT's.

Briefs and evidence were jointly filed.

Go to EHTrust.org for links to the ruling, briefs, and the latest science.

April 21, 2022

The Honorable Jessica Rosenworcel, Chairwoman
Federal Communications Commission
45 L Street NE
Washington, DC 20554

RE: August 13, 2021 judgment by the U.S. Court of Appeals for the District of Columbia Circuit, in Environmental Health Trust et al. v. the FCC

Dear Chairwoman Rosenworcel,

In response to the judgment by the U.S. Court of Appeals in the Environmental Health Trust case, I am requesting that appropriate actions be taken immediately to wireless radiofrequency radiation levels. I request that the FCC ensure an up to date examination of its wireless radiofrequency radiation regulations by reopening Docket 13-84 ("Reassessment of FCC Radiofrequency Exposure Limits and Policies") to refresh the record before issuing its final response to the judgment.

The current scientific research must be immediately reviewed and acted upon in a timely manner so that the health and safety of our citizens is prioritized. Consumers must have accurate information related to the benefits and risks of the products and services available to them. Policies should be reflective of current scientific research performed in accordance with utilization. It is impossible for consumers to make educated decisions without accurate information; therefore, I am requesting that you take immediate action as directed by the courts to review the research and update any policies as necessary for the health and wellbeing of all citizens, including the most vulnerable, our children.

Sincerely,

Mark Gordon
Governor of Wyoming

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SANTA FE NEW MEXICAN

Report says wireless radiation may harm wildlife

- By Scott Wyland swyland@sfnewmexican.com

- Feb 5, 2022 Updated Feb 7, 2022

Timeline for wireless radiation oversight

1980s to 1996: The Environmental Protection Agency measures levels of wireless radiation in the U.S. and is tasked with developing safety limits. The agency issues findings in a 1984 report on biological effects and a 1986 report on environmental exposure levels.

1995: The EPA meets with the Federal Communications Commission and presents its plan to develop safety limits for the potentially harmful electromagnetic fields that wireless technologies produce.

1996: The EPA's research on EMFs is defunded. The agency

2 of 3

A cell tower off I-25 on Jan. 31.
Luis Sánchez Saturno/The New Mexican

Health researchers raised concerns in the 1990s about the possible harmful effects of wireless radiation from cellphones and towers,

closes is project measuring EMF levels in U.S. cities.The FCC adopts wireless radiation rules and safety limits proposed by industry-connected groups.

1999: The Food and Drug Administration asks the National Toxicology Program to study cellphone radiation because of the lack of safety data on the health effects from long-term exposure.

2008: The National Research Council issues a report called "The Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communications Devices." Congress holds a hearing on the health effects of cellphone use.

2009: The U.S. Senate holds hearings on the health effects of cellphones' wireless radiation.

2012: A Government Accountability Office report recommends cellphone test procedures be reassessed to ensure they reflect real world use and are based on the latest science.

2013: The FCC opens an official inquiry asking if wireless radiation limits should be updated.Thousands of pages of scientific evidence are submitted and their warnings met pushback from telecommunications companies on the verge of growing a mega-industry.

Industry-backed researchers assured federal agencies health concerns — especially those centered on the possibility of low-level microwaves causing cancer — lacked conclusive evidence.

Regulators accepted their assessments, and the alarm bells went silent.

Now a trio of researchers have compiled a report saying the widespread installation of cell towers and antennas is generating electromagnetic fields — EMFs for short — that could be physiologically harmful.

The report focuses on potential impacts on wildlife, trees, plants and insects, such as bees, because there are no regulations protecting them from EMFs emanating from wireless antennas. Wildlife protections are becoming more vital as this radiation — known more specifically as radiofrequency EMFs — escalates through 5G technologies, the researchers warn.

"There needs to be regulatory standards to address EMFs affecting wildlife," said Albert Manville, a retired U.S. Fish and Wildlife Service biologist and one of the paper's authors.

Manville also is an adjunct science professor at Johns Hopkins University.

Santa Fe New Mexican, Report says wireless radiation may harm wildlife by Scott Wyland 2/07/2022

to the FCC for its inquiry.

2019: The FCC issues a decision not to update the 1996 standards.

2020: The Environmental Health Trust files a petition against the FCC arguing the 2019 decision was not based on an adequate review of the data submitted.

2021: The U.S Court of Appeals in Washington, D.C., rules the FCC must review its 1996 guidelines and justify why they shouldn't be updated.

Source: Environmental Health Trust

He said he provided the Federal Communications Commission with some research on how the electromagnetic pollution can hurt wildlife and the steps that could be taken to lessen the impacts.

But the FCC has been unresponsive, Manville said, arguing the agency tends to accommodate the industry it's supposed to regulate.

"That's unfortunate, but that's just the way it is," he said.

The FCC did not respond to questions about whether it would consider making efforts to reduce animals' EMF exposure.

The three authors drew from 1,200 peer-reviewed studies to compile a three-part, 210-page report titled "Effects of non-ionizing electromagnetic fields on flora and fauna." It was published in the journal *Reviews on Environmental Health*.

Science journalist Blake Levitt, lead author of the report, said they dug up overlooked studies that contained compelling research on how living organisms react to low-level EMFs. Their compilation invalidates any claims that the EMFs don't cause biological effects, she said.

"We just blew the whole thing out of the water and took it to the ecosystem level, which is really where it needed to go," Levitt said. "Nobody had done that before. We need a whole lot more scrutiny put to the low-intensity stuff."

Ambient EMFs have risen exponentially in the past quarter-century, as cellphones were widely adopted, to become a ubiquitous and continuous environmental pollutant, even in remote areas, the

report said, adding studies indicate EMFs can affect animals' orientation, migration, food finding, reproduction, nest building, territorial defense, vitality, longevity and survival.

EMFs' toxic effects on an animal's cells, DNA and chromosomes have been observed in laboratory specimens — and thus would apply to wildlife, according to the report.

Many types of wildlife are exposed to EMFs from wireless sources, such as deer, seals, whales, birds, bats, insects, amphibians and reptiles, the report said. Many species have been found more sensitive to EMFs than humans in some ways.

The report recommends new laws that include the redesign of wireless devices and infrastructure to reduce the rising ambient levels.

It comes several months after a federal court in Washington, D.C., ordered the FCC to review its guidelines for wireless radiation and justify why it should retain them, as the standards haven't been updated since 1996. This radiation should not be confused with radioactivity, the court noted, adding microwaves used in transmitting signals are low enough to not heat tissues in what are known as "thermal effects."

But medical studies suggest the lower-level radiation could cause cancer, reproductive problems, impaired learning and motor skills, disrupted sleep and decreased memory.

These studies and others were submitted to the FCC after it opened a notice of inquiry in 2013 under the administration of former President Barack Obama to probe the adequacy of the 1996 guidelines, which were geared toward avoiding thermal effects, the court said.

In 2019, the Trump administration's FCC deemed the inquiry unnecessary, saying the 1996 rules were sufficient and required no revision.

Two judges called that FCC action "arbitrary and capricious," saying the FCC made the decision out of hand, ignoring all the science presented and offering no reasonable, fact-based argument to back it up.

Santa Fe New Mexican, Report says wireless radiation may harm wildlife by Scott Wyland 2/07/2022

The agency also failed to look at the technological developments in the past 25 years and how they've changed the degree of exposure, the judges wrote. And they said it refused to examine possible health effects from EMFs that fall below the threshold set in 1996.

"When an agency in the commission's position is confronted with evidence that its current regulations are inadequate or the factual premises underlying its prior judgment have eroded, it must offer more to justify its decision to retain its regulations than mere conclusory statements," the judges wrote.

"Rather, the agency must provide 'assurance that [it] considered the relevant factors,' " they added.

The FCC's reluctance to ensure wireless transmissions are safe for human health extends to wildlife, even as 5G technology gains momentum, said Theodora Scarato, executive director of the Environmental Health Trust, a nonprofit think tank that led the petition against the FCC.

Scarato said her group is promoting the wildlife report to fill a crucial gap in wireless oversight.

She plans to submit the report to the FCC as it conducts its new review of wireless radiation, with the hope the report will go on the record and be considered when crafting future rules.

Regulators need to determine how much EMFs must be curbed to safeguard flora and fauna, she said.

"What is a limit for a person is going to be different" than for animals, Scarato said.

The study notes EMFs can disrupt the Earth's natural magnetic fields that birds, cats, fish and other animals use to navigate and orient themselves.

Towers keep the EMFs away from people on the ground but leave birds vulnerable because they fly near the transmitters and even perch on them, Scarato said.

"Air needs to be designated as habitat," she said. "And EMFs need to be regulated like other pollutants."

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The transmissions can disorient bees, causing them to become lost, not return to their hives and die, Manville said.

The bees are already threatened by pesticides and climate change, he said. “It’s death by a thousand cuts.”

If they have a mass die-off, it could be disastrous for growers that depend on them to pollinate crops, he added.

Manville said as a federal biologist, he pushed to get the Interior Department to establish an environmental review that covered how new sources of wireless radiation would affect wildlife. Interior officials were receptive in 2014, but his proposal stalled at the Commerce Department, which was in charge of internet technology, he said. Then later, the Trump administration scrapped it.

Scarato said this “landmark paper” could be the catalyst for creating wildlife guidelines.

“The challenge before us is there isn’t an environmental agency who’s even looking at the science at this time,” she said. The study’s authors “make the case for regulations that we need.”

Scott Wyland
Reporter

Wildlife Review Scientific References

Levitt BB, Lai HC, Manville AM. Effects of non-ionizing electromagnetic fields on flora and fauna, Part 3. Exposure standards, public policy, laws, and future directions. Rev Environ Health. 2021 Sep 27. doi: 10.1515/reveh-2021-0083. Epub ahead of print. PMID: 34563106.

Levitt BB, Lai HC, Manville AM. Effects of non-ionizing electromagnetic fields on flora and fauna, part 1. Rising ambient EMF levels in the environment. Rev Environ Health. 2021 May 27. doi: 10.1515/reveh-2021-0026. Epub ahead of print. PMID: 34047144.

Levitt BB, Lai HC, Manville AM. Effects of non-ionizing electromagnetic fields on flora and fauna, Part 2 impacts: how species interact with natural and man-made EMF. Rev Environ Health. 2021 Jul 8. doi: 10.1515/reveh-2021-0050. Epub ahead of print. PMID: 34243228.

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Federal Court Instructs FCC to Review Electromagnetic Radiation Standards

By Barbara Koeppel

FOR 25 YEARS—THROUGH FIVE DEMOCRATIC AND Republican administrations—the Federal Communications Commission has refused to revise the regulations it set in 1996 that address what level of radiation from cell phones should be considered safe. Labeled radio-frequency radiation (RFR), these emissions are discharged from all wireless devices, Wi-Fi networks, and the thousands of towers stretched across the United States that transmit and receive the signals.

The FCC's power is promethean. It is the sole U.S. agency that determines the acceptable RFR exposure from wireless devices for people of all ages, wildlife, and the environment. And it insists its original 1996 limits are fine.

However, scientists who've reviewed hundreds of studies published over the last two decades claim the FCC ignores critical findings that show a "statistically significant" link between heavy cell phone use (10 or more years) and brain and thyroid tumors, especially on the side of the head where people hold their phones. Professional groups such as the American Academy of Pediatrics and the California Medical Association have asked the FCC to update its numbers.

Photo by BearFotos

The scientists and physicians worry that the FCC simply repeats the industry's line that all is well—which is particularly troubling since millions more people around the world are exposed each year. In the United States, for example, only 44 million people had cell phones in 1996; today, the number has soared to about 300 million, and that doesn't include the tablets, watches, and other wireless products that increase RFR exposure exponentially.

Thus, in 2019, the Environmental Health Trust (EHT), Consumers for Safe Cell Phones, Children's Health Defense, and 11 other petitioners sued the FCC. They argued that although the U.S. Government Accountability Office told the FCC in 2013 to review its 1996 limits in light of new research, six years later, the FCC was still repeating its all-is-safe mantra. In a 2019 press release, the FCC said that "after a thorough review of the record, we find it appropriate to maintain the existing radiofrequency limits, which are among the most stringent in the world for cell phones."

At the least, this assurance is doubtful. The lawsuit against the FCC argues precisely the opposite: that the Commission has *not* reviewed "the record." Also, researchers point out that countries such as Italy, Switzerland, France, Israel, China, India, and Russia have more stringent limits than the United States regarding the use of Wi-Fi in schools and day care centers, and on acceptable levels of radiation emissions from cell towers. In addition, some have banned all cell phone ads pitched to children.

The lawsuit notes that the FCC even ignored the landmark 10-year, $30 million National Toxicology Program study carried out under the National Institutes of Health—which produced unequivocal results in 2019. Having exposed rats and mice to cell phone radiation for two years, the NTP researchers reported "clear evidence of cancer in the male rats' heart cells, some evidence of increased brain gliomas (brain cancer), and adrenal gland tumors, DNA damage in the brains of male and female rats and mice, and lower birth weights of female rats' offspring."

Two years after the suit was filed, the U.S. Court of Appeals of the D.C. Circuit ruled in August 2021 that the FCC had to reexamine the research to determine if its regulations should be updated. Further, the court called the commission's behavior "arbitrary and capricious," since it had ignored evidence of the harm to children's brains (which are not fully developed) and to

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male and female reproductive systems. It also ruled that because the FCC never produced regulations about radiofrequency radiation's effects on wildlife, it had "completely failed" to address the evidence of potential environmental harm.

However, the court did not set a date for the FCC to comply—which meant the commission could retain its old regulations indefinitely. Also, the court did not address the issue of whether RFR exposures cause cancer; instead it said the FCC had passed the "minimum legal requirement" to assure it had evaluated the research on cancer and radiation exposure. Thus, scientists are concerned that the FCC will again find ways to defer serious examination of the voluminous literature on the subject.

How could this be, given the NTP findings and other research? To bolster its no-cancer claims, the FCC points to a letter the U.S. Food and Drug Administration wrote the commission, which claimed the NTP results weren't relevant to humans since the study was done on rats and mice (although 10 years earlier, the FDA itself had approved the animal study). Dr. Joel Moskowitz, director of the Center for Family and Community Health at the University of California, Berkeley and a leading authority on radiofrequency radiation, says, "The FDA wrote a biased review of the research regarding cancer risk from cell phone radiation."

[Dr. Joel Moskowitz:] "The FDA wrote a biased review of the research regarding cancer risk from cell phone radiation."

Also, the FCC cited reports from organizations that have undeclared conflicts of interest (ties to the wireless industry), which contest the cancer links. Dr. Ronald Melnick, the lead designer of the NTP study, has published two articles stating that the results from these groups' reports were "unfounded."

In fact, the FCC failed on several fronts. Besides ignoring the NTP study, the commission dismissed the American Academy of Pediatrics' request for regulations that reflect the special effects RFR have on children and pregnant women. It never explained why it ignored research that showed children's brains absorb higher levels of the radiation. Instead, it has insisted for 20-plus years that RFR is only harmful if it overheats the human body by at least one degree centigrade. This is a red herring, since wireless devices don't emit the kind of radiation that produces higher temperatures. Also, the FCC didn't consider the effects of long-term exposures.

Many researchers insist these links have been proven. As noted in an earlier article in this journal ("Wireless Hazards," *Washington Spectator*, December 2020), studies over the past 20 years have found strong evidence of brain tumors and leaks in the blood-brain barrier, acoustic neuromas (tumors on the nerves leading from the inner ear to the brain), thyroid tumors, and cognitive impairment. They also showed a link to male infertility: when men carried phones in their pants' pockets, their sperm were weakened and reduced. Also, physicians and scientists found that some individuals are particularly sensitive to RFR radiation, which can cause tinnitus, vertigo, headaches, fatigue, and loss of memory. Early this month, some experts studying the U.S. diplomats' and CIA agents' "Havana Syndrome" symptoms suggested they could be related to radiofrequency radiation.

The latest evidence

Theodora Scarato, the executive director of the Environmental Health Trust, says that since the FCC had not yet responded to the court's August ruling by last November, the EHT asked the commission to consider additional studies that were completed after 2019, when the suit was filed.

For example, in late 2019, the European Parliamentary Research Service said that electromagnetic fields (EMFs) emitted by 2G, 3G, and 4G cell phones (which operate at 450 to 6,000 megahertz) are "probably carcinogenic for humans," particularly in causing gliomas, acoustic neuromas, and meningiomas (slow-growing, mostly nonmalignant brain tumors).

In 2020, Yoon-Jung Choi and Joel Moskowitz (the lead authors) and three other scientists reviewed 46 "case-controlled studies" and published their findings in "Cellular Phone Use and Risk of Tumors: Systematic Review and Meta-Analysis," in the November *International Journal of Environmental Research and Public Health*. Moskowitz says, "This study updated our earlier analysis published in 2009." Evidence from the new study, he says, links cell phone use to increased tumor risk. The researchers' numbers are compelling: 1,000 or more hours of cell phone use, or about 17 minutes a day over 10 years, was associated with a statistically significant 60 percent increase in brain tumor risk.

Also in 2020, Devra Davis (an epidemiologist and co-founder of the Environmental Health Trust), Aaron Pilarcik (a biophysicist at the Worcester Polytechnic Institute), and Anthony Miller (an epidemiologist specializing in cancer etiology and

an adviser to the World Health Organization) reviewed data on colon and rectal cancer from the U.S. Centers for Disease Control, the U.S. SEER Program at the National Cancer Institute, and the Iranian National Cancer Registry. They found that the colon cancer risk for adults born in the 1990s had doubled and the rectal cancer risk had increased fourfold by the time they were 24 years old—when compared to those born 60 years ago. They hypothesized that cell phone radiation could play a role in the increased risk and recommended the FCC set limits to reduce the exposure. Their study, "Increased Generational Risk of Colon and Rectal Cancer in Recent Birth Cohorts Under Age 40—the Hypothetical Role of Radiofrequency Radiation from Cell Phones," was published in the *Annals of Gastroenterology and Digestive Disorders.*

In 2020, Henry Lai (a retired University of Washington scientist) reviewed the research on genetic effects and found that exposure to RFR can break DNA strands and affect the central nervous system. The review, "Genetic Effects of Non-Ionizing Electromagnetic Fields" was published in the December 2020 issue of *Electromagnetic Biology and Medicine.*

In 2021, Henry Lai, with Albert Manville (a biologist formerly at the U.S. Fish and Wildlife Service) and Blake Levitt (an environmental journalist), studied the effects of cell phone towers in various countries, comparing data from the 1980s to the present. They found that the toxic effects of EMFs on cells and genes had altered "the wildlife's orientation and migration patterns, their ability to find food, mate, reproduce, build nests and dens, and maintain and defend their territory." Yet the FCC has still set no standards for long-term, low-level EMF exposure on wildlife. The scientists' three-part research was published in *Reviews on Environmental Health,* "Effects of Non-Ionizing Electromagnetic Fields (EMF) on Flora and Fauna."

Also in 2021, the journal *Andrologia* published a study by Iranian scientists who found DNA fragmentation in sperm and recommended that men keep cell phones "away from the pelvis as much as possible."

Further, from 2015 to the present, the French government has tested the radiation from cell phones when people hold them next to their bodies. Their findings are dramatic: They reported exposures to RFR up to 11 times higher than those approved in FCC guidelines. Thus, the government passed a ministerial order in 2019 urging the public to limit children's cell phone use and "keep the phones away from the belly of pregnant women and the lower abdomen of adolescents."

Moreover, the National Institutes of Health and the American Cancer Society funded a study in 2019 and 2020 at Yale University that found increased thyroid cancer among heavy cell phone users.

The accompanying table enumerates many of the ways that doctors and vigilant public jurisdictions have identified to help people reduce the health risks that could be associated with exposure to RFR and cell phone radiation emissions.

The EHT's Scarato reminds readers concerned about RFR emissions exposure to "contact their senators and representatives to raise the issues with the committees." In the Senate, the Committee on Commerce, Science, and Transportation, along with its Subcommittee on Communications, Media, and Broadband oversees the FCC. In the House, the FCC reports to the Energy and Commerce Committee and its Communications and Technology Subcommittee. Public pressure on the members of these committees will help to prod the FCC to review the research and respond to the ruling of the Court of Appeals. ■

Barbara Koeppel is a Washington, D.C.-based investigative reporter who covers social, economic, political, and foreign policy issues.

PROTECT YOURSELF FROM WIRELESS RADIATION

The California Department of Public Health recommends these precautions:

- **Use headsets—not ear buds—but remove them when not talking, since even headsets release small amounts of radiation when not in use.**
- **Text instead of talk.**
- **Carry phones away from your body in backpacks, tote bags, handbags, and briefcases.**
- **Keep phones away from your head when streaming.**
- **Download movies instead of streaming them.**
- **Don't use cell phones when reception is poor and they show just one or two bars—in subways, cars, basements, or rural areas. Under such circumstances cell phones often need vastly more energy to communicate with cell towers and other phones, and radiation levels intensify.**
- **Men should not carry phones in pants' pockets. Cleveland Clinic Center for Male Fertility researchers found this weakened and reduced sperm, which can cause infertility.**

Go to page 8 for more information

(Continued from page 3)

PROTECT YOURSELF FROM WIRELESS RADIATION

Countries must adopt tough laws

- Belgium and France banned companies from designing phones to appeal to children.
- Israel and Cyprus banned Wi-Fi in day care centers and kindergartens, requiring connections be wired. Israel limited Wi-Fi use in first and second grades to three hours a week.
- France ordered cities to map the locations of antennae, measure their radiation levels, and tell the public. Also, it banned ads showing people holding phones next to their heads and ordered companies to list phones' exposure levels. If they don't, they can be fined up to 75,000 euros.
- India ordered companies to remove towers located near hospitals and schools.
- Israel ordered companies to list phones' radiation levels.
- Geneva (Switzerland) placed a moratorium on the rollout of 5G.

Scientists also recommend these steps:

- Use corded landlines at home, but put satellite or cordless handsets on speakerphone, since they emit even more radiation than cell phones.
- Push for laws to protect children.
- Get states to create expert commissions to study radiation emissions' effects. New Hampshire's commission recommended that towers and antennae be placed farther from schools and homes.

November 24, 2021

The Honorable Jessica Rosenworcel, Commissioner
Acting Chairwoman
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Dear Chairwoman Rosenworcel,

We write to you as scientists and public health experts deeply committed to protecting public health and the environment. As authors of numerous publications and reports in the field we urge that the FCC ensure a robust review of the latest science and expert recommendations in the FCC's upcoming reexamination of its Inquiry on human exposure limits for wireless radiation. The major scientific developments of the last two years must be included in the FCC review- especially in the new 5G environment where wireless is ubiquitous.

We request the FCC reopen Docket #13-84 "Reassessment of FCC Radiofrequency Exposure Limits and Policies" and Docket #03-137 'Proposed Changes to the Commission Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields" in order to refresh the record before issuing a final response to the recent August 13, 2021 judgment by the U.S. Court of Appeals for the District of Columbia Circuit, in Environmental Health Trust et al. v. the FCC.

Furthermore, as the FCC does not have expertise in interpreting scientific studies, it relies on input from federal health agencies and knowledgeable expert organizations to evaluate the scientific evidence and the adequacy of FCC limits. However the relevant US health and safety agencies have not reviewed the research on impacts to flora and fauna; long-term exposures from cell towers; children's unique vulnerability; and health effects such as damage to the brain and reproduction. The court noted that the "silence" of federal agencies such as the National Cancer Institute, the Environmental Protection Agency, the Centers for Disease Control and Prevention, and the National Institute for Occupational Safety and Health does not mean these agencies agree with the FCC's 1996 limits. In fact, none of these agencies has systematically reviewed the totality of science in their respective area of expertise both to develop safety standards and to offer an analysis of the adequacy of FCC's 1996 wireless exposure limits.

Accordingly, we recommend that the FCC record be reopened with ample time to allow for new substantive comments. U.S. safety limits for cell phones and cell towers must rest on sound science to ensure the public and wildlife are protected.

Importantly, we also recommend a full environmental impact review to evaluate 5G and the rapid proliferation of 4G wireless antennas in the USA. A three part review published in Reviews in Environmental Health found the scientific evidence showing adverse effects is sufficient to trigger new regulatory action to protect wildlife, yet the US does not have regulations that were ever designed to protect flora and fauna (1). Instead, the FCC is fast tracking small cell deployment and opening new

spectrum disregarding recent research which finds, for example, that the higher frequencies of 5G can result in higher absorption rates into the bodies of pollinators.

In addition, experts are warning that 5G will contribute to climate change and have documented the exponentially increasing energy demands of 5G networks, "smart" wireless devices, and other new communication technologies. As the FCC has projected hundreds of thousands of new wireless facilities, we recommend a full environmental assessment for the 5G rollout and 4G wireless network densification.

The scientific evidence has substantially increased over the last two years (2). In 2020 scientists of the National Institute of Environmental Health Sciences National Toxicology Program published their animal-study findings of "significant increases in DNA damage" in groups of mice and rats after just 14 to 19 weeks of exposure to cell phone radiation (3). A 2021 analysis published by the Environmental Working Group concluded FCC limits should be 200 to 400 times more protective than the whole-body exposure limit set by the FCC in 1996 (4). Unaware of the scientists calling for caution, school districts nationwide are deploying high-capacity Wi-Fi networks in school buildings, testing out 5G networks with students, and signing leases with companies to install cell towers on school property, relying on these outdated FCC limits. As the American Academy of Pediatrics and numerous other specialists have noted, children are uniquely vulnerable to wireless radiation (5).

Health risks should be assessed by experts with no conflicts of interest. The FCC should not rely on the International Commission on Non-Ionizing Radiation Protection (ICNIRP), a small 14 member privately constituted invite only Commission lacking in transparency whose self-appointed membership has conflicts of interest and industry ties (6). ICNIRP has rejected the NTP and Ramazzini Institute animal studies with unfounded criticisms (7). Further, ICNIRP has not shown any systematic review of the totality of the research such as impacts to the developing brain and damage to reproduction. It has never conducted a comprehensive evaluation of human health and environmental risks associated with RF radiation. Their exposure guidelines are based solely on protecting against heating effects, with no change of concept since 1998, two years after the FCC adopted human exposure guidelines in 1996.

Broadband internet provides the connectivity that enables Americans to do their jobs, to participate equally in school learning and health care, and to create a fairer playing field by eliminating the digital divide. The United States must bridge the digital divide with a "future-proof" broadband infrastructure with wired *rather than wireless* connections to and through homes, schools and businesses that is affordable, reliable, high-speed, and sustainable.

Wherever possible, we urge that the broadband system rely on wired connections, rather than wireless connections. Wired connections are safer, faster, more secure, more energy efficient, and more reliable. Wired connections are especially important for schools and other institutions where they will save money and reduce exposure to wireless radiation.

Our experts stand ready to provide more detailed information to you on this important issue, including elaborating on materials and assistance with evaluating the science and impacts on humans, climate, animals, and wilderness.

Sincerely,

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References

1. Levitt BB, Lai HC, Manville AM. (2021) Effects of non-ionizing electromagnetic fields on flora and fauna, part 1. Rising ambient EMF levels in the environment. Rev Environ Health May 27; Levitt BB, Lai HC, Manville AM. (2021) Effects of non-ionizing electromagnetic fields on flora and fauna, Part 2 impacts: how species interact with natural and man-made EMF. Rev Environ Health. Jul 8; Levitt BB, Lai HC, Manville AM. (2021) Effects of non-ionizing electromagnetic fields on flora and fauna, Part 3. Exposure standards, public policy, laws, and future directions. Rev Environ Health. Sep 27.
2. Luo, J., et al.(2020) Genetic susceptibility may modify the association between cell phone use and thyroid cancer: A population-based case-control study in Connecticut, Environmental Research, Volume 182; Choi Yoon-Jung et al., (2020) Cellular Phone Use and Risk of Tumors: Systematic Review and Meta-Analysis. International Journal of Environmental Research and Public Health. 17(21), 8079; Bertagna et al (2021) Effects of electromagnetic fields on neuronal ion channels: a systematic review. Annals of the New York Academy of Sciences. 2021 Sep;1499(1):82-103; Lai H. (2021) Genetic effects of non-ionizing electromagnetic fields. Electromagn Biol Med. 2021 Apr 3;40(2):264-273; Schuermann, David, and Meike Mevissen (2021) "Manmade Electromagnetic Fields and Oxidative Stress—Biological Effects and Consequences for Health" International Journal of Molecular Sciences 22, no. 7: 3772; Maluin SM et al., (2021) Effect of Radiation Emitted by Wireless Devices on Male Reproductive Hormones: A Systematic Review. Front Physiol. Sep 24;12:732420 ;
3. Smith-Roe, SL., et al. (2020) "Evaluation of the genotoxicity of cell phone radiofrequency radiation in male and female rats and mice following subchronic exposure." Environmental and molecular mutagenesis, Feb;61(2):276-290
4. Uche, U.I., Naidenko, O.V. (2021) "Development of health-based exposure limits for radiofrequency radiation from wireless devices using a benchmark dose approach." Environmental Health 20, 84 (2021)

5. American Academy of Pediatrics Letter to the FCC on "Reassessment of Exposure to Radiofrequency Electromagnetic Fields Limits and Policies"August 29, 2013; Fernández, C., de Salles, A., Sears, M., Morris, R., & Davis, D. (2018). "Absorption of wireless radiation in the child versus adult brain and eye from cell phone conversation or virtual reality." Environmental Research, 167, 694-699. https://doi.org/10.1016/j.envres.2018.05.013
6. James C. Lin. Science, Politics, and Groupthink [Health Matters]. IEEE Microwave Magazine. 22(5):24-26.May 2021; Lennart Hardell, Michael Carlberg, Health risks from radiofrequency radiation, including 5G, should be assessed by experts with no conflicts of interest. Oncol Lett. 2020 Oct;20(4):15.; Lennart Hardell, Mona Nilsson, Tarmo Koppel, Michael Carlberg. Aspects on the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2020 Guidelines on Radiofrequency Radiation. J Cancer Sci Clin Ther. 2021; 5(2): 250-285; Hardell L. "World Health Organization, radiofrequency radiation and health – a hard nut to crack (Review)" Int J Oncol 51 (2017): 405-413; Hans van Scharen, Tomas Vanheste, Erik Lambert for European Members of Parliments Michèle Rivasi and Dr. Klaus Buchner "The International Commission on Non-Ionizing Radiation Protection: Conflicts of Interest, Corporate Capture and the Push for 5G." (PDF)
7. Melnick R. "ICNIRP'S Evaluation of the National Toxicology Program's Carcinogenicity Studies on Radiofrequency Electromagnetic Fields" Health Phys. 2020 Jun;118(6):678-682; Melnick RL. "Commentary on the utility of the National Toxicology Program study on cell phone radiofrequency radiation data for assessing human health risks despite unfounded criticisms aimed at minimizing the findings of adverse health effects" . Environ Res. 2019;168:1–6

November 19, 2021

The Honorable Jessica Rosenworcel
Chairwoman
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554

Dear Chairwoman Rosenworcel,

The Environmental Working Group, a nonprofit public health research and advocacy organization with offices in Washington, D.C, Minneapolis, and Sacramento, Calif., requests that the Federal Communications Commission reopen Docket #13-84, "Reassessment of FCC Radiofrequency Exposure Limits and Policies," and Docket #03-137, "Proposed Changes to the Commission Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields," to allow robust review and consideration of scientific evidence published in the past two years and in response to the court ruling in *Environmental Health Trust et al. v. the FCC*.

Since 2009, the Environmental Working Group has extensively researched the topic of the human and environmental health impacts of radiofrequency radiation emitted from wireless communication devices. EWG also closely follows regulatory approaches and recommendations on radiofrequency radiation made by authoritative health agencies around the world. The World Health Organization states on its website:

> *… during the 20th century, environmental exposure to man-made sources of EMF steadily increased due to electricity demand, ever-advancing wireless technologies and changes in work practices and social behaviour. Everyone is exposed to a complex mix of electric and magnetic fields at many different frequencies, at home and at work, and concern continues to grow over possible health effects from overexposure*.[1]

Extensive research literature points to the potential health risks of radiofrequency radiation, particularly for the developing child. Peer-reviewed studies show that the

[1] World Health Organization, web page not dated, "Supporting the development of national policies on electromagnetic fields". https://www.who.int/activities/supporting-the-development-of-national-policies-on-electromagnetic-fields Accessed Nov. 16, 2021.

bodies of children absorb more radiofrequency radiation, compared to adults, putting children at greater health risk as a result to such exposure.[2]

Scientists and public health advocates have raised concerns for decades about the adverse health effects of exposure to electromagnetic radiation. Recent research publications highlight the severity of these impacts, especially among vulnerable populations, and the need for more stringent health-based exposure standards. In 2011, the International Agency for Research on Cancer (IARC), an agency of the World Health Organization, classified radiofrequency electromagnetic fields as "possibly carcinogenic to humans."[3]

For today's generation of children, exposure to radiofrequency radiation from wireless communication devices starts from the fetal development period as a result of wireless devices in the pregnant person's everyday environment. Following birth, today's children will be exposed to radiofrequency radiation throughout their lives – an exposure scenario that is drastically different from the very limited consumer use and exposure to wireless radiation of the 1980s and 1990s, when the basis for current FCC standards was established.

This comment letter highlights two key considerations that point to the need for the FCC to reassess existing radiofrequency exposure limits and policies:

1. A 2021 peer-reviewed publication we authored that uses Environmental Protection Agency methodology to determine protective health-based exposure limits for radiofrequency radiation, based on the U.S. government's landmark 2018 laboratory study; and
2. Recent literature that documents a range of effects of non-ionizing electromagnetic radiation on different body systems that current FCC standards do not take into account.

1. Health-based limits developed with consideration for children's health

[2] Fernández C, de Salles AA, Sears ME, Morris RD, Davis DL. Absorption of wireless radiation in the child versus adult brain and eye from cell phone conversation or virtual reality. Environ Res. 2018; 167:694-699. https://doi.org/10.1016/j.envres.2018.05.013; Gandhi OP, Morgan LL, de Salles AA, Han YY, Herberman RB, Davis DL. Exposure limits: the underestimation of absorbed cell phone radiation, especially in children. Electromagn Biol Med. 2012; 31(1):34-51. https://doi.org/10.3109/15368378.2011.622827

[3] International Agency for Research on Cancer. IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans. Press Release N: 208. 2011. https://www.iarc.who.int/wp-content/uploads/2018/07/pr208_E.pdf Accessed Nov. 16, 2021.

A peer-reviewed article published by our organization in 2021 (Uche & Naidenko, 2021)[4] documented how the current FCC exposure limit for radiofrequency radiation is not sufficient to protect the general population, especially children, against the adverse impacts associated with radiofrequency radiation exposure. The current limit, last revised a quarter-century ago – well before wireless devices became ubiquitous – needs to be updated with the latest science to be fully health protective for all users of wireless communication technologies.

Our study, published in the journal *Environmental Health*, recommends strict, lower health-based exposure standards for both children and adults for radiofrequency radiation emitted from wireless devices. This recommendation draws on data from a landmark 2018 study from the National Toxicology Program, one of the largest long-term laboratory studies on the health effects of radiofrequency radiation exposure.[5]

EWG's study used an approach similar to the methodology that the U.S. EPA developed to assess human health risks arising from toxic chemical exposures. EWG study recommends a whole-body specific absorption rate (SAR) limit of 0.2 to 0.4 mW/kg for children, which is 200 to 400 times lower than the current federal whole-body exposure limit. For adults, EWG recommends a whole-body specific absorption rate limit of 2 to 4 mW/kg, which is 20 to 40 times lower than the federal limit (Uche & Naidenko, 2021).[4]

EWG's analysis and recommendation for a much stricter limit for radiofrequency radiation exposure is a step toward advancing a re-evaluation of the existing federal limit for radiofrequency radiation exposure while reviewing the latest research on radiofrequency radiation exposure.

2. Wide range of potential impacts of non-ionizing electromagnetic radiation on human health not accounted for in the current FCC standard

[4] Uche UI, Naidenko OV. Development of health-based exposure limits for radiofrequency radiation from wireless devices using a benchmark dose approach. Environ Health. 2021; 20(1):84. https://doi.org/10.1186/s12940-021-00768-1

[5] National Toxicology Program. 595: NTP Technical Report on the Toxicology and Carcinogenesis Studies in Hsd: Sprague Dawley SD Rats Exposed to Whole-Body Radio Frequency Radiation at a Frequency (900 MHz) and Modulations (GSM and CDMA) Used by Cell Phones. National Toxicology Program, US Department of Health and Human Services. 2018. https://ntp.niehs.nih.gov/ntp/htdocs/lt_rpts/tr595_508.pdf?utm_source=direct&utm_medium=prod&utm_campaign=ntpgolinks&utm_term=tr595

The current FCC standard was based on the 1986 recommendations of the National Council on Radiation Protection and Measurements[6] and 1991 recommendations of the Institute of Electrical and Electronics Engineers,[7] which chose an exposure level based on behavioral changes observed in laboratory animals exposed to radiofrequency radiation for a duration of minutes to hours in studies conducted in the 1970s and 1980s. With extensive current research linking radiofrequency exposure to adverse impacts, even at exposure levels below the current federal limit, the FCC needs to review the latest science and update the allowable exposure limits.

Among the reported biological effects of electric and magnetic fields are harm to fetal growth and development (Ozgur et al., 2013);[8] changes in brain activity (Wallace and Selmaoui, 2019);[9] changes in heart rate variability (Wallace et al., 2020);[10] DNA damage (Smith-Roe et al., 2020);[11] cognitive effects (Azimzadeh and Jelodar);[12] and increased risk of cancer, including gliomas,[3] parotid gland tumors (Sadetzki et al., 2008),[13] thyroid cancers (Luo et al., 2019).[14] These adverse health effects may be associated with different mechanistic pathways, such as changes in the activity of voltage-gated calcium

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[6] National Council on Radiation Protection and Measurements. Biological effects and exposure criteria for radiofrequency electromagnetic fields: NCRP Report No. 86; 1986. Available from: https://ncrponline.org/shop/reports/report-no-086-biological-effects-and-exposure-criteria-for-radiofrequency-electromagnetic-fields-1986/

[7] Institute of Electrical and Electronics Engineers. (Revision of ANSI C95.1–1982). IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz. IEEE Std C95. 1991. https://doi.org/10.1109/IEEESTD.1992.101091

[8] Ozgur E, Kismali G, Guler G, Akcay A, Ozkurt G, Sel T, et al. Effects of prenatal and postnatal exposure to GSM-like radiofrequency on blood chemistry and oxidative stress in infant rabbits, an experimental study.
Cell Biochem Biophys. 2013;67(2):743–51. https://doi.org/10.1007/s12013- 013- 9564-1

[9] Wallace J, Selmaoui B. Effect of mobile phone radiofrequency signal on the alpha rhythm of human waking EEG: a review. Environ Res. 2019; 175:274–86. https://doi.org/10.1016/j.envres.2019.05.016

[10] Wallace J, Andrianome S, Ghosn R, Blanchard ES, Telliez F, Selmaoui B.Heart rate variability in healthy young adults exposed to global system for mobile communication (GSM) 900-MHz radiofrequency signal from mobile phones. Environ Res. 2020; 191:110097. https://doi.org/10.1016/j.envres.2020.110097

[11] Smith-Roe SL, Wyde ME, Stout MD, Winters JW, Hobbs CA, Shepard KG, et al. Evaluation of the genotoxicity of cell phone radiofrequency radiation in male and female rats and mice following subchronic exposure. Environ Mol Mutagen. 2020; 61(2):276–90. https://doi.org/10.1002/em.22343

[12] Azimzadeh M, Jelodar G. Prenatal and early postnatal exposure to radiofrequency waves (900 MHz) adversely affects passive avoidance learning and memory. Toxicol Ind Health. 2020;36(12):1024–30. https://doi.org/10.1177/0748233720973143

[13] Sadetzki S, Chetrit A, Jarus-Hakak A, Cardis E, Deutch Y, Duvdevani S, et al. Cellular phone use and risk of benign and malignant parotid gland tumors – a nationwide case-control study. Am J Epidemiol. 2008;167(4):457–67. https://doi.org/10.1093/aje/kwm325

[14] Luo J, Deziel NC, Huang H, Chen Y, Ni X, Ma S, et al. Cell phone use and risk of thyroid cancer: a population-based case–control study in Connecticut. Ann Epidemiol. 2019; 29:39–45. https://doi.org/10.1016/j.annepidem.2018.10.004

channels (Blackman et al., 1991);[15] changes in the concentrations of reactive oxygen species and redox homeostasis (Ertilav et al., 2018);[16] changes in intracellular enzymes and gene expression (Fragopoulou et al.,2018);[17] and changes in membrane permeability (Perera et al., 2018).[18]

Table 1. Extensive research points to effects of non-ionizing electromagnetic radiation on individual body systems that are not considered by the current FCC standards for cell phone radiation.

Reported health effects	**Key studies**
Elevated risk of brain cancer, breast cancer, parotid gland tumors, and thyroid cancer	Choi YJ, Moskowitz JM, Myung SK, Lee YR, Hong YC. Cellular Phone Use and Risk of Tumors: Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2020; 17(21):8079. West JG, Kapoor NS, Liao SY, Chen JW, Bailey L, Nagourney RA. Multifocal Breast Cancer in Young Women with Prolonged Contact between Their Breasts and Their Cellular Phones. Case Rep Med. 2013; 2013:354682 Sadetzki S, Chetrit A, Jarus-Hakak A, Cardis E, Deutch Y, Duvdevani S, et al. Cellular phone use and risk of benign and malignant parotid gland tumors – a nationwide case-control study. American journal of epidemiology 2008; 167(4):457-67. Luo J, Li H, Deziel NC, Huang H, Zhao N, Ma S, et al. Genetic susceptibility may modify the association between cell phone

[15] Blackman C, Benane S, House D. The influence of temperature during electric-and magnetic-field-induced alteration of calcium-ion release from in vitro brain tissue. Bioelectromagnetics. 1991;12(3):173–82. https://doi.org/10.1002/bem.2250120305

[16] Ertilav K, Uslusoy F, Ataizi S, Nazıroğlu M. Long term exposure to cellphone frequencies (900 and 1800 MHz) induces apoptosis, mitochondrial oxidative stress and TRPV1 channel activation in the hippocampus and dorsal root ganglion of rats. Metab Brain Dis. 2018;33(3):753–63. https://doi.org/10.1007/s11011-017-0180-4

[17] Fragopoulou AF, Polyzos A, Papadopoulou MD, Sansone A, Manta AK, Balafas E, et al. Hippocampal lipidome and transcriptome profile alterations triggered by acute exposure of mice to GSM 1800 MHz mobile phone radiation: an exploratory study. Brain Behavior. 2018; 8(6):e01001. https://doi.org/10.1002/brb3.1001

[18] Perera PGT, Nguyen THP, Dekiwadia C, Wandiyanto JV, Sbarski I, Bazaka O, et al. Exposure to high-frequency electromagnetic field triggers rapid uptake of large nanosphere clusters by pheochromocytoma cells. Int J Nanomed. 2018;13:8429. https://doi.org/10.2147/IJN.S183767

	use and thyroid cancer: A population-based case-control study in Connecticut. Environmental Research. 2020; 182:109013.
Eye strain, damage to eye tissues cataracts	Bormusov E, P Andley U, Sharon N, Schächter L, Lahav A, Dovrat A. Non-thermal electromagnetic radiation damage to lens epithelium. Open Ophthalmol J. 2008; 2:102-6
Cardiomyopathy, heart rate variability	National Toxicology Program. 2018. Technical Report on the Toxicology and Carcinogenesis Studies in Hsd: Sprague Dawley SD Rats Exposed to Whole-Body Radio Frequency Radiation at a Frequency (900 MHz) and Modulations (GSM and CDMA) Used by Cell Phones. Wallace J, Andrianome S, Ghosn R, Blanchard ES, Telliez F, Selmaoui B. Heart rate variability in healthy young adults exposed to global system for mobile communication (GSM) 900-MHz radiofrequency signal from mobile phones. Environmental Research 2020; 191:110097
Damage to sperm, decreased male fertility	Kesari KK, Agarwal A, Henkel R. Radiations and male fertility. Reprod Biol Endocrinol. 2018; 16(1):118
Changes in brain activity Changes in blood-brain barrier	Volkow ND, Tomasi D, Wang G-J, Vaska P, Fowler JS, Telang F, et al. Effects of cell phone radiofrequency signal exposure on brain glucose metabolism. JAMA 2011; 305(8):808-13 Wallace J, Selmaoui B. Effect of mobile phone radiofrequency signal on the alpha rhythm of human waking EEG: A review. Environmental research. 2019; 175:274-86
Changes in the immune system function	Piszczek P, Wójcik-Piotrowicz K, Gil K, Kaszuba-Zwoińska J. Immunity and electromagnetic fields. Environ Res. 2021; 200:111505.

As documented in Table 1, exposure to non-ionizing electromagnetic fields can harm a variety of organs and body systems, highlighting the urgency of a public-health-focused reassessment of existing exposure limits for radiofrequency radiation. Further, exposure to non-ionizing electromagnetic fields during pregnancy has been associated with an

increased risk of miscarriage (Li et al., 2017)[19] and an increased frequency of hyperactivity and inattention during early childhood (Birks et al., 2017).[20]

In conclusion, the Environmental Working Group urges the FCC to open its record for a more comprehensive evaluation of radiofrequency radiation and update its standard to ensure the safety of wireless radiation devices for everyone, especially young children.

Submitted on behalf of the Environmental Working Group,

Uloma Igara Uche, Ph.D.
Environmental Health Science Fellow
Environmental Working Group

Olga V. Naidenko, Ph.D.
Vice President, Science Investigations
Environmental Working Group

[19] Li DK, Chen H, Ferber JR, Odouli R, Quesenberry C. Exposure to Magnetic Field Non-Ionizing Radiation and the Risk of Miscarriage: A Prospective Cohort Study. Sci Rep. 2017; 7(1):17541. https://doi.org/10.1038/s41598-017-16623-8

[20] Birks L, Guxens M, Papadopoulou E, Alexander J, Ballester F, Estarlich M, Gallastegi M, Ha M, Haugen M, Huss A, Kheifets L, Lim H, Olsen J, Santa-Marina L, Sudan M, Vermeulen R, Vrijkotte T, Cardis E, Vrijheid M. Maternal cell phone use during pregnancy and child behavioral problems in five birth cohorts. Environ Int. 2017; 104:122-131. https://doi.org/10.1016/j.envint.2017.03.024

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November 9, 2021

The Honorable Jessica Rosenworcel, Commissioner
Acting Chairwoman
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Dear Chairwoman Rosenworcel,

I am writing to request that the FCC re-open Docket #13-84 "Reassessment of FCC Radiofrequency Exposure Limits and Policies" and Docket #03-137" Proposed Changes to the Commission Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields- in order to refresh the record before responding to the mandate of the August 13, 2021 judgment by the U.S. Court of Appeals for the District of Columbia Circuit, in Environmental Health Trust et al. v. the FCC.

I am Professor and Chair Emeritus at the University of New Hampshire Department of Electrical & Computer Engineering and served on the New Hampshire State Commission on 5G Technology. After a year of investigation we issued our final report on November 1, 2020.

I want to ensure the fifteen recommendations of the expert New Hampshire State Commission are considered by the FCC. If the FCC does not re-open the record, the Report will not be available to the Commission as it was finalized in 2020.

Sincerely

Kent Chamberlin

Digitally signed by Kent Chamberlin
Date: 2021.11.09 21:21:17 -05'00'

Kent Chamberlin, PhD
Professor & Chair Emeritus

New Hampshire State Commission on 5G Technology Final Report Recommendations

RECOMMENDATION 1

Propose a resolution of the House to the US Congress and Executive Branch to require the Federal Communication Commission (FCC) to commission an independent review of the current radiofrequency (RF) standards of the electromagnetic radiation in the 300MHz to 300GHz microwave spectrum as well as a health study to assess and recommend mitigation for the health risks associated with the use of cellular communications and data transmittal.

RECOMMENDATION 2

Require that the most appropriate agency (agencies) of the State of New Hampshire include links on its (their) website(s) that contain information and warnings about RF-radiation from all sources, but specifically from 5G small cells deployed on public rights-of-way as well as showing the proper use of cell phones to minimize exposure to RF-radiation, with adequate funding granted by the Legislature. In addition, public service announcements on radio, television, print media, and internet should periodically appear, warning of the health risks associated with radiation exposure. Of significant importance are warnings concerning the newborn and young as well as pregnant women.

RECOMMENDATION 3

Require every pole or other structure in the public rights of- way that holds a 5G antenna be labeled indicating RF-radiation being emitted above. This label should be at eye level and legible from nine feet away.

RECOMMENDATION 4

Schools and public libraries should migrate from RF wireless connections for computers, laptops, pads, and other devices, to hardwired or optical connections within a five-year period starting when funding becomes available.

RECOMMENDATION 5

Signal strength measurements must be collected at all wireless facilities as part of the commissioning process and as mandated by state or municipal ordinances. Measurements are also to be collected when changes are made to the system that might affect its radiation, such as changes in the software controlling it. Signal strength is to be assessed under worst-case conditions in regions surrounding the tower that either are occupied or are accessible to the public, and the results of the data collection effort is to be made available to

the public via a website. In the event that the measured power for a wireless facility exceeds radiation thresholds, the municipality is empowered to immediately have the facility taken offline. The measurements are to be carried out by an independent contractor and the cost of the measurements will be borne by the site installer.

RECOMMENDATION 6

Establish new protocols for performing signal strength measurements in areas around wireless facilities to better evaluate signal characteristics known to be deleterious to human health as has been documented through peer-reviewed research efforts. Those new protocols are to take into account the impulsive nature of high-data-rate radiation that a growing –body of evidence shows as having a significantly greater negative impact on human health than does continuous radiation. The protocols will also enable the summative effects of multiple radiation sources to be measured.

RECOMMENDATION 7

Require that any new wireless antennas located on a state or municipal right-of-way or on private property be set back from residences, businesses, and schools. This should be enforceable by the municipality during the permitting process unless the owners of residences, businesses, or school districts waive this restriction.

RECOMMENDATION 8

Upgrade the educational offerings by the NH Office of Professional Licensure and Certification (OPLC) for home inspectors to include RF intensity measurements.

RECOMMENDATION 9

The State of New Hampshire should begin an effort to measure RF intensities within frequency ranges throughout the state, with the aim of developing and refining a continually updated map of RF exposure levels across the state using data submitted by state-trained home inspectors.

RECOMMENDATION 10

Strongly recommend all new cell phones and all other wireless devices sold come equipped with updated software that can stop the phone from radiating when positioned against the body.

RECOMMENDATION 11

Promote and adopt a statewide position that would strongly encourage moving forward with the deployment of fiber optic cable connectivity, internal wired connections, and optical wireless to serve all commercial and public properties statewide.

RECOMMENDATION 12

Further basic science studies are needed in conjunction with the medical community outlining the characteristics of expressed clinical symptoms related to radio frequency radiation exposure.The majority of the Commission feels the medical community is in the ideal position to clarify the clinical presentation of symptoms precipitated by the exposure to radio frequency radiation consistent with the Americans with Disabilities Act (ADA) which identifies such a disability. The medical community can also help delineate appropriate protections and protocols for affected individuals. All of these endeavors (basic science, clinical assessment, epidemiological studies) must be completely independent and outside of commercial influence.

RECOMMENDATION 13

Recommend the use of exposure warning signs to be posted in commercial and public buildings. In addition, encourage commercial and public buildings, especially healthcare facilities, to establish RF-radiation free zones where employees and visitors can seek refuge from the effects of wireless RF emissions.

RECOMMENDATION 14

The State of New Hampshire should engage agencies with appropriate scientific expertise, including ecological knowledge, to develop RF-radiation safety limits that will protect the trees, plants, birds, insects, and pollinators.

RECOMMENDATION 15

The State of New Hampshire should engage our Federal Delegation to legislate that under the National Environmental Policy Act (NEPA) the FCC do an environmental impact statement as to the effect on New Hampshire and the country as a whole from the expansion of RF wireless technologies.

November 24, 2021

The Honorable Jessica Rosenworcel
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Dear Chairwoman Rosenworcel,

I am a physician in France and for the past fifteen years I have been working on the documented health issues related to cell phone radiation as well as the cell phone SAR test procedures.

In regards to the recent U.S. DC Circuit Court of Appeals' ruling in EHT v FCC, we are writing to request that the FCC re-open Dockets #13-84 and #03-137 to allow new, significant policy developments and research be included for consideration because of it's relevance to the FCC examining its cell phone SAR testing procedures.

I am President of the Phonegate Alerte Association, formed in 2018 and our efforts to ensure transparency have led to the French government's actions to withdraw or update at least 23 models of cell phones from different manufacturers (Xiaomi, Nokia, Huawei, Wiko, Alcatel, etc.) because they were found to exceed European Union regulatory SAR limits for human exposure to radiofrequency radiation.

Similar to the FCC's regulations on cell phone test procedures, European Union regulations allow manufacturers to test cell phones at 5 mm separation distance from the body. They do not force companies to test cell phones or wireless devices at positions that are directly against the body (0 mm separation distance) *despite the reality that billions of people are using cell phones close to the body.*

The French Government is Requesting 0 mm Cell Phone Radiation Testing

In late 2019, the French government health agency ANSES issued a report[1] on the possible health effects associated with high radiation from mobile telephones carried close to the body and recommended that cell phones be tested at 0 millimeters, instead of 5 mm as the European Commission regulations require. Subsequently, France submitted a formal objection[2] to the European Commission in regards to the

[1] https://www.anses.fr/en/content/exposure-mobile-telephones-carried-close-body
[2] https://ec.europa.eu/docsroom/documents/43448

current compliance test separation distance requirements of only 5 mm. The authorities have requested that compliance test distances be revised to 0 mm

> "*Developments in the use of mobile telephones have led to a wide variety of situations in which telephones are no longer exclusively held close to a person's ear in order to hold a conversation, since they are now also used to send and receive data through various applications for listening to music, playing video games or making video calls, which means that the equipment is used in ways which were not previously foreseen. There is also a growing trend for telephones to be networked with numerous connected objects, such as headsets or watches, which tend to result in lengthy connections between a telephone and the mobile network without the telephone being held in the hand, since it is often carried in clothing and is therefore closer to – or in contact with – the trunk.*
>
> *For this reason, the French authorities believe that it is necessary to revise the harmonised standard EN 50566: 2017 concerning measurements of the SAR of devices that are hand-held or body-mounted in close proximity to the human body so that a maximum distance of 0 mm from the body is taken into consideration."*

The FCC should ensure that cell phones are tested in body contact positions at 0 mm.

For background, in 2016, the French National Frequency Agency (ANFR) officially tested various models of cell phones and found that the majority exceeded regulatory limits when tested in body contact positions - with 0 mm between the phone and simulated body testing device (aka "phantom").

Cell Phones Violate Radiation Limits

Since December 4, 2019 ANFR has posted *143 new cell phone SAR test reports*. Despite the fact that the European Union strengthened their requirements to ensure cell phones were tested at 5 mm from the body, many cell phone models are still violating the limit of 2.0 W/kg for trunk SAR when tested by ANFR (10 g of tissue). All of the test results are posted online[3].

Examples of smartphones that **violated the EU limits of 2.0 W/kg as well as the FCC limit of 1.6 W/kg when SAR radiation tested by the ANFR at 5mm include:**

- February 26, 2020: Sony Xperia 5 violated the limit at 2.64 W/kg.
- November 12, 2020: Essential Heyou 40 violated the limit at 2.54 W/kg[4]
- September 9, 2020: Essential Heyou 60 violated the limit at 2.86 W/kg[5]
- February 26, 2020: Xiaomi Mi Note 10 violated the limit at 2.45 W/kg[6]

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[3] https://data.anfr.fr/explore/dataset/das-telephonie-mobile/table/?disjunctive.marque&disjunctive.modele&dataChart=eyJxdWVyaWVzIjpbeyJjb25maWciOnsiZGF0YXNldCI6ImRhcy10ZWxlcGhvbmllLW1vYmlsZSIsIm9wdGlvbnMiOnsiZGlzanVuY3RpdmUubWFycXVlIjp0cnVlLCJkaXNqdW5jdGl2ZS5tb2RlbGUiOnRydWV9fSwiY2hhcnRzIjpbeyJ0eXBlIjoibGluZSIsImZ1bmMiOiJBVkciLCJ5QXhpcyI6ImRhc190ZXRlX25vcm1lX25mX2VuXzUwMzYwIiwic2NpZW50aWZpY0Rpc3BsYXkiOnRydWUsImNvbG9yIjoiIzY2YzJhNSJ9XSwieEF4aXMiOiJkYXRlX2R1X2NvbnRyb2xlX3Bhcl9sX2FuZnIiLCJtYXhwb2ludHMiOiIiLCJ0aW1lc2NhbGUiOiJ5ZWFyIiwic29ydCI6IiJ9XX0%3D&sort=das_tronc_au_contact

[4] https://www.anfr.fr/das/COM054200035

[5] https://www.anfr.fr/das/COM054200035

[6] https://www.anfr.fr/das/COM006200006/

Examples of smartphones **that would be compliant with the EU limit but would violate the FCC limits of 1.6 W/kg when SAR radiation tested by the ANFR at 5mm include:**

- September 16, 2020 Logicom Le Fleep 178 violated FCC's limit at 1.94 W/kg[7]
- September 16, 2020: Sky 55 Konrow violated FCC's limit at 1.91 W/kg[8]
- September 30, 2020: Wiki Lubi 5 Plus violated FCC's limit at 1.9 W/kg [9]
- September 29, 2020: Nokia 5.1 violated FCC's limit at 1.82 W/kg[10]
- April 8, 2021: Wiko F 300 violated FCC's limit at 1.8 W/kg[11]

As European Union and FCC test procedures utilize different averaging volumes, one cannot directly compare the measurements. However, FCC test procedures could result in even higher SAR violations (Gandhi 2019)[12].

Unfortunately ANFR no longer tests cell phones in body contact positions with 0 mm distance from the phone to the body phantom. If they did, far more of the 143 cell phones tested in the last two years would violate FCC and EU limits because every millimeter can significantly increase exposure. Further, due to the averaging volume differences between the FCC and EU limits, several of the phones that ANFR finds are compliant with the 1.6 W/kg limit would violate the FCC's test procedures.

The FCC presently allows manufacturers to SAR test cell phones with a separation distance between the phone and body (which can be up to approximately one inch from the body in some models of phones still in use in the USA) inaccurately measuring SAR levels into the body. Actual SAR exposure in direct body contact positions would be much higher than FCC test measurements.

New Research on Metal and Radiation Levels

Studies on SAR in human tissue published since 2019 related to cell phone test procedures need to be included in the FCC re-examination. Metal can reflect and refocus cellular radiation, resulting in much higher absorption rates. The FCC, states, "Electrically conductive objects in or on the body may interact with sources of RF energy in ways that are not easily predicted. Examples of conductive objects in the body include implanted metallic objects. Examples of conductive objects on the body include eyeglasses, jewelry, or metallic accessories."

- In January 2021 the study "Experimental Validation for Temperature Rise in Human Tissue Due to Implanted Metal Plates with Screw Holes Using Translucent Solid Phantom" was published in 2020 International Symposium on Antennas and Propagation (ISAP), Osaka, Japan IEEE, 2021 and found increases in SAR enhancement due to the implanted metallic plates observed at specific frequencies. [13]
- On December 2020, the study The effect of metal objects on the SAR and temperature increase in the human head exposed to dipole antenna (numerical analysis) published in Case Studies in Thermal Engineering found "the presence of metal objects in proximity to the head alters SAR and temperature increase within the tissues. In most cases, metal objects redistribute the EM

[7] https://www.anfr.fr/das/COM044200035
[8] https://www.anfr.fr/das/COM044200036
[9] https://www.anfr.fr/das/COM046200002
[10] https://www.anfr.fr/das/COM085200003
[11] https://www.anfr.fr/das/COM057210009
[12] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8688629
[13] https://ieeexplore.ieee.org/document/9391129

> field incident upon them to a smaller region increasing power absorption, thereby increasing SAR and temperature in that region. The power absorption in head layers is found to be sensitive to metal object's size and shape, and distance of the antenna from the objects".[14]

These are just *a few* of the published studies on radiation levels will not be included in the FCC's examination of cell phone test procedures *unless the FCC refreshes the record.*

Investigative Reports on Telecom Influence

In September 2020, the editor-in-chief of the Program 66 minutes interviewed Chicago Tribune journalist and Pulitzer Prize winner Sam Roe and myself discussing how FCC's cell phone test procedures allow violations of FCC limits because they do not requite cell phones to be tested at 0 mm.[15]

On November 12, 2020, France Télévisions Complément d'Investigation "5G A Wave of Doubt" directed by investigative journalist Nicolas Vescovacci was broadcast on France 2[16]. The investigation described how cell phones exceed radiation thresholds when tested against the body and how cell phones are being taken off the market in response. Importantly, the industry ties of members of International Commission on Non-Ionizing Radiation Protection (ICNIRP) were revealed. In June 2020, a report released by European Members of Parliment Michèle Rivasi (Europe Écologie) and Dr. Klaus Buchner (Ökologisch-Demokratische Partei) found that ICNIRP has long ignored the science on non thermal effects[17].

This 2020 investigative research must be included in the FCC's record review so that the FCC does not inadvertently allow the wireless industry to influence its review of the record and decision.

There is Not a 50-Fold Safety Factor for Cell Phone Local SAR

Furthermore, we would like to importantly note that after we questioned ICNIRP President Rodney Croft and Vice President Eric Van Rongen, we received confirmation that there is not a 50 fold safety factor when it comes to ICNIRP's cell phone local SAR limit.

Here is what Mr. Van Rongen wrote about this:

> "Anyone who states that a reduction factor of 50 applies to local exposures obviously misinterprets the guidelines, although the 1998 guidelines might not have been very clear in that respect the 2020 ones provide more clear information."

On December 17, 2019 Environmental Health Trust and Phonegate Association write members of Congress a letter[18] and Background and Facts document[19] on the urgent need for a hearing regarding cell phone radiation test procedures, due to the excessive radiation the phone can expose the user to in body contact positions.

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[14] https://www.sciencedirect.com/science/article/pii/S2214157X20305311?via%3Dihub
[15] Phonegate : entretien avec le journaliste américain et prix Pulitzer Sam Roe
[16] https://www.francetvinfo.fr/replay-magazine/france-2/complement-d-enquete/complement-d-enquete-5g-londe-dun-doute_4152949.html
[17] https://ehtrust.org/wp-content/uploads/ICNIRP-report-FINAL-JUNE-2020.pdf
[18] https://ehtrust.org/wp-content/uploads/Signed-Letter-to-US-Congress-phonegate-.pdf
[19] Background and Facts Documenting PhoneGate and Our Call for Congressional Action https://ehtrust.org/wp-content/uploads/Background-and-Facts-on-PhoneGate-1-1.pd

We have a significant amount of new data on SAR test methods from 2020 and 2021 to share with the FCC in order to ensure the protection of cell phone users, especially children. SAR tests are thermally based and they are an inadequate measurement to ensure safety. Stronger regulations which protect users from thermal and non-thermal effects are needed.

New Law To Require Radiation Testing of Wi-Fi Laptops, Router and Electronics

In addition, there has been new legislation regarding transparency on wireless radiation in France. Starting in July 2020, the wireless industry must label tablets, laptops, Wi-Fi routers, DECT phones and other wireless connected electronics with the radiofrequency radiation SAR exposure levels for consumers **at point of sale and for all advertising**. This includes the SAR for the head, trunk and extremities. All equipment used close to the head, hand-held or carried close to the body is potentially covered. From the SAR Regulation Guide provided by ANFR, you can find a non-exhaustive list of equipment qualified as radio equipment that required SAR testing.

Note: For years France law[20] has ensured cell phones were SAR radiation labeled, banned the sale of cell phones designed for young children, prohibited advertising to children under 14 years of age[21] and warned[22] users to keep devices away from the body.

It is imperative that the two above-mentioned dockets are re-opened to allow recent developments to be submitted for a proper assessment of FCC's testing protocol.

Sincerely,

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A book on Phonegate was published by Massot Editions on this international health scandal. An English version is planned and we will be sure to send it to you when it is released in the United States.

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[20] Article 183 - LOI n° 2010-788 du 12 juillet 2010 portant engagement national pour l'environnement (1)

[21] **Law on sobriety, transparency, information and consultation for exposure to electromagnetic waves**

[22] **Order of November 15, 2019 relating to the display of the specific absorption rate of radioelectric equipment and to consumer information NOR: SSAP1834792A**

November 18, 2021

The Honorable Jessica Rosenworcel, Commissioner
Acting Chairwoman
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Dear Chairwoman Rosenworcel,

We are writing to request that the FCC re-open the relevant Dockets to ensure the latest science be included in the FCC's reexamination of the adequacy of its human exposure limits and regulations for radiofrequency radiation exposures.

We urge the Commission to look at new scientific evidence published since December 4, 2019. Of 39 new genetic effect studies, 79 % (31 studies) showed effects and 21 % (8 studies) did not show significant effects. Of 33 new neurological effect studies, 85 % (28 studies) showed effects and 15 % (5 studies) did not show significant effects. Of 30 new oxidative effect studies, 93% (28 studies) showed effects and 7 % (2 studies) did not show significant effects. The preponderance of scientific research on RFR continues on an upward trend.

There is a broad consensus among those in the scientific research community who are knowledgeable on the published literature, that new, biologically-based public safety limits for chronic exposure to radiofrequency radiation (RFR) are warranted now. The available evidence for health risks due to low intensity radiofrequency radiation exposures from wireless technology applications is sufficient and compelling. Research published over the last two years has added significant additional weight to the body of evidence which indicates that FCC public safety exposure limits are grossly inadequate to protect public health given the proliferation of RFR-emitting devices now in common usage.

The evidence for health risks comes directly from hundreds of published scientific and public health studies reporting that low-intensity RFR is capable of producing health harm across very large populations of exposed people.

The BioInitiative Working Group has been gathering and evaluating hundreds of such studies since 2006, and has published two large reports detailing this evidence. The group concluded that the scientific evidence was more than sufficient in 2007, and certainly in 2012 (www.bioinitiative.org) to establish new biologically-based exposure safety standards. Further, we have submitted numerous comments to the FCC since 2013 advising that the Commission has not struck the right balance between the wireless technologies rollout and managing resulting health impacts for Americans, particularly for children. The increased risk for cancers, neurological diseases, fertility and reproduction, immune disfunction, memory and learning impairment, and other serious medical problems associated with exposure to low-intensity RF are documented and analyzed for the Commission to review at: https://bioinitiative.org/research summaries/

When the cumulative body of evidence is assessed over the last decades of research, the overall picture for studies on radiofrequency radiation effects shows clear and consistent patterns of effects on living tissues. Chronic RFR exposures at environmental levels common today can reasonably be presumed to produce health harm at and below current FCC safety limits for humans and should be substantially lowered.

Genetic effects: Effect= 67% (259 studies); No Effect= 33% (129 studies) (literature up to November 12, 2021)

Neurological effects: Effect= 74% (271 studies); No Effect= 26% (97 studies) (literature up to November 12, 2021)

Oxidative effects: Effect= 9***2***% (258 studies); No Effect= 8% (23) studies) (literature up to November 12, 2021)

Respectfully submitted on behalf of the BioInitiative Working Group by:

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Consumers for Safe Cell Phones

November 24, 2021

The Honorable Jessica Rosenworcel
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Dear Chairwoman Rosenworcel,

As one of the petitioners who recently sought the DC Circuit Court of Appeal's review of the FCC's December 4th, 2019 decision to maintain their outdated 25 year old wireless exposure guidelines, we write to urge the Commission to follow the Court's directive to properly review the evidence that had been submitted into Dockets #13-84 and #03-137. A proper review requires that the two dockets be re-opened to allow newly published research and documents (made public over the past 2 years) to be included in the analysis. This will provide the FCC with up-to-date information to use in undertaking the Court's required thorough analysis.

The Court's ruling stated that the Commission "*must, in particular, (i) provide a reasoned explanation for its decision to retain its testing procedures for determining whether cell phones and other portable electronic devices comply with its guidelines*…"

Of particular concern to the Court is the failure of the FCC to review the evidence in the record related to assessing their inadequate cell phone testing guidelines. Since the GAO released their 2012 report[1] stating, "*The Federal Communications Commission's (FCC) RF energy exposure limit may not reflect the latest research, and testing requirements may not identify maximum exposure in all possible usage conditions… Some consumers may use mobile phones against the body, which FCC does not currently test, and could result in RF energy exposure higher than the FCC limit."* - we have been calling on the FCC to test phones directly against the body with zero separation to simulate the manner in which they are typically used by consumers.

[1] "Telecommunications: Exposure and Testing Requirements for Mobile Phones Should Be Reassessed" - GAO-12-77: Published: Jul 24, 2012

FCC's current testing protocol allows a separation distance between the phone and the torso simulating use in a holster or belt clip, enabling a phone to pass the FCC compliance test when in fact, the exposure from phones used in real life usage positions will likely exceed the federal "safety" limit. This is because it is commonplace for today's consumer to carry a transmitting phone in a pants or breast pocket or tucked into a bra with no separation between the antennas and the body.

Here are some examples of the RF warnings for wireless devices currently on the market in 2021:

- The Apple iPhone 13 Pro Max RF Exposure statement[2] reads, *"iPhone is evaluated in positions that simulate uses against the head, with no separation, and when worn or carried against the torso of the body, with 5mm separation."* [Users will likely carry and use transmitting phones in pockets and bras against their body unaware because the RF "safety" warning is located in the small print of the legal section deep within menus on the phone where it is not likely to be found.]
- The Miku Pro Smart Baby Monitor manual states[3], "*RF EXPOSURE WARNING: ….This equipment should be installed and operated with minimum distance 20cm between the radiator and your body.*" [Yet many parents will locate these RF transmitting monitors close to the crib or in a child's playroom unaware that these RF warnings are in the manual.]
- The AT&T DECT 6.0 Home Cordless Phone manual[4] states, "*The telephone base shall be installed and used such that parts of the user's body other than the hands are maintained at a distance of approximately 20 cm (8 inches) or more*." [Yet many people install the base unit on the desk just inches from their head or on their bedside table unaware of these instructions.]

Key evidence has been published in the past two years that indicates cell phones directly in body contact (as when worn and used in a pants or shirt pocket or sports bra) are associated with an increased risk for breast tumors and sperm damage.

As examples, these 2020 and 2021 published studies referenced below must be included in a thorough FCC assessment of their cell phone testing protocol in order to perform a more "reasonable analysis" of the testing protocol:

I. "The Association Between Smartphone Use and Breast Cancer Risk Among Taiwanese Women: A Case-Control Study" - Cancer Manag Res 2020 Oct 29;12:10799-10807 doi: 10.2147/CMAR.S267415.

> Results: "*Participants who carried their smartphone near their chest or waist-abdomen area had significantly increased 5.03-fold and 4.06-fold risks of breast cancer*"

II. "Effects of mobile phone usage on sperm quality - No time-dependent relationship on usage: A systematic review and updated meta-analysis" - 2021 Nov; 202:111784. doi: 10.1016/j.envres.2021.111784. Epub 2021 Jul 30

> Results: "*Exposure to mobile phones is associated with reduced sperm motility, viability, and concentration*." 18 studies were evaluated including 4280 samples.

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[2] https://www.apple.com/legal/rfexposure/iphone14,3/en/
[3] https://cdn.shopify.com/s/files/1/2621/9254/files/mikucare.com_quick_setup-guide.pdf?v=1589825520
[4] https://att.vtp-media.com/products/CL/CL82X07/CL82X07_WEBCIB_i5.0_20201217.pdf

If the past two years of important research and evidence are not allowed to be included in the re-assessment of the FCC's cell phone testing protocol, it is certain that the public's distrust of the safety of phones and other wireless consumer devices will become even more widespread. The public's trust is dependent upon the FCC's thorough evaluation of the current, up to date body of research, especially with the advent of the novel and more powerful exposures expected with 5G.

Respectfully submitted,

Cynthia Franklin, Director
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Radiofrequency radiation injures trees around mobile phone base stations

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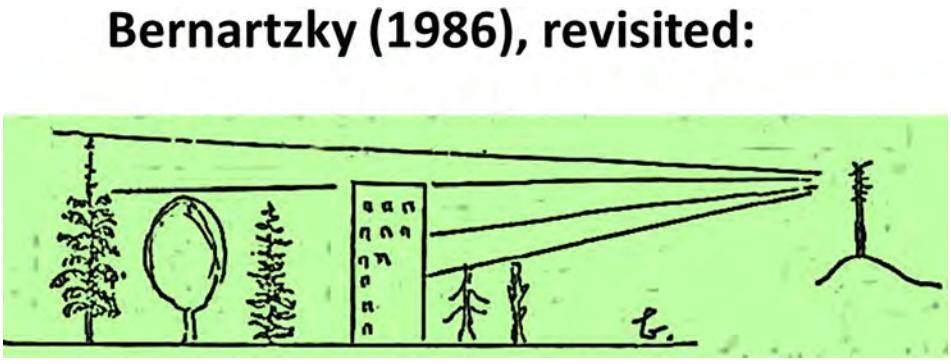
HIGHLIGHTS

- High frequency nonionizing radiation is becoming increasingly common.
- This study found a high level of damage to trees in the vicinity of phone masts.
- Deployment has been continued without consideration of environmental impact.

GRAPHICAL ABSTRACT



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ABSTRACT

In the last two decades, the deployment of phone masts around the world has taken place and, for many years, there has been a discussion in the scientific community about the possible environmental impact from mobile phone base stations. Trees have several advantages over animals as experimental subjects and the aim of this study was to verify whether there is a connection between unusual (generally unilateral) tree damage and radiofrequency exposure. To achieve this, a detailed long-term (2006–2015) field monitoring study was performed in the cities of Bamberg and Hallstadt (Germany). During monitoring, observations and photographic recordings of unusual or unexplainable tree damage were taken, alongside the measurement of electromagnetic radiation. In 2015 measurements of RF-EMF (Radiofrequency Electromagnetic Fields) were carried out. A polygon spanning both cities was chosen as the study site, where 144 measurements of the radiofrequency of electromagnetic fields were taken at a height of 1.5 m in streets and parks at different locations. By interpolation of the 144 measurement points, we were able to compile an electromagnetic map of the power flux density in Bamberg and Hallstadt. We selected 60 damaged trees, in addition to 30 randomly selected trees and 30 trees in low radiation areas (n = 120) in this polygon. The measurements of all trees revealed significant differences between the damaged side facing a phone mast and the opposite side, as well as differences between the exposed side of damaged trees and all other groups of trees in both sides. Thus, we found that side differences in measured values of power flux density corresponded to side differences in damage. The 30 selected trees in low radiation areas (no visual

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contact to any phone mast and power flux density under 50 μW/m^2) showed no damage. Statistical analysis demonstrated that electromagnetic radiation from mobile phone masts is harmful for trees. These results are consistent with the fact that damage afflicted on trees by mobile phone towers usually start on one side, extending to the whole tree over time.

1. Introduction

For many years, there has been a discussion in the scientific community about whether artificial radiofrequency radiation has harmful effects on living organisms and, more specifically, on the environmental impact from mobile phone base stations (Panagopoulos et al., 2016). Trees have several advantages over animals as experimental subjects: they are continuously exposed to radiation in a constant orientation in the electromagnetic field due to their inability to move (Vian et al., 2016). Additionally, it is possible to easily document changes over time, such as disturbed growth, dying branches, and premature colour change of leaves. Moreover, the damage to trees is objective and cannot be attributed to psychological or psychosomatic factors.

Plants are specialized in the interception of electromagnetic radiation (light) but radiofrequency radiation impact on plants, which is becoming common in the environment because of the exponential use of mobile phone technology, has received little attention and his physiological effect has long been considered negligible.

Since the mid-twentieth century, several researchers have investigated the effects of electromagnetic radiation on plants, both in the laboratory (Kiepenheuer et al., 1949; Brauer, 1950; Harte, 1950, 1972; Jerman et al., 1998; Lerchl et al., 2000; Sandu et al., 2005; Roux et al., 2006, 2008; Sharma et al., 2009; Tkalec et al., 2005, 2009; Beaubois et al., 2007; Kundu and IEEE, 2013; Pesnya and Romanovsky, 2013; Cammaerts and Johansson, 2015; Grémiaux et al., 2016; Vian et al., 2016), and in nature (field observations) (Bernatzky, 1986; Volkrodt, 1987, 1991; Selga and Selga, 1996; Balodis et al., 1996; Haggerty, 2010). Both kinds of study have frequently found pernicious effects.

Around the world, phone masts have been deployed in the last two decades everywhere. Preliminary published studies have indicated deleterious effects of radiofrequency radiation on trees (Balmori, 2004; Van't Wout, 2006; Schorpp, 2011; Waldmann-Selsam, 2007; Waldmann-Selsam and Eger, 2013), cautioning that research on this topic is extremely urgent (Balmori, 2015). However, these early warnings have had no success and deployment has been continued without consideration of environmental impact.

In a review of the effects of environmental microwaves on plants (Jayasanka and Asaeda, 2013), it was indicated that effects depend on the plant family and the growth stage, as well as the exposure duration, frequency, and power density. This review concluded that most studies that address the effects of microwaves on animals and plants have documented effects and responses at exposures below limits specified in the electromagnetic radiation exposure guidelines and it is therefore necessary to rethink these guidelines (Jayasanka and Asaeda, 2013).

Since 2005, on the occasion of medical examinations of sick residents living near mobile phone base stations, changes in nearby trees (crown, leaves, trunk, branches, growth…) were observed at the same time as clinical symptoms in humans occurred. Since 2006 tree damages in the radiation field of mobile phone base stations were documented (http://kompetenzinitiative.net/KIT/KIT/baeume-in-bamberg/). In the radio shadow of buildings or that one of other trees, the trees stayed healthy.

Additionally, unilateral crown damage, beginning on the side facing an antenna, pointed to a possible link between RF-EMF (Radiofrequency Electromagnetic Fields) and tree damage. We carried out measurements on both sides of unilaterally damaged trees. Most of the trees had been exposed to RF-EMF for at least five years. Each time we found considerable differences between the measured values on the damaged and on the healthy side.

The aim of the present study was to verify whether there is a connection between unusual (generally unilateral) tree damage and radiofrequency exposure.

2. Materials and methods

The official information of 65 mobile phone sites in the neighbouring cities Bamberg and Hallstadt was extracted from the EMF database (EMF-Datenbank) of the German Federal Network Agency (Bundesnetzagentur, in March 2011 and October 2015). Each site certificate ("Standortbescheinigung") provides information on the mounting height of antennas, the number and main beam direction of the sector antennas, the number of omnidirectional antennas (ND), the number of other transmitters, as well as the horizontal and vertical safety distances. The current specifications of the transmission facilities are available at: http://emf3.bundesnetzagentur.de/karte/Default.aspx

On most of the 65 mobile phone sites several sector antennas emitting RF-EMF with differences in frequency, modulation and other physical characteristics are installed (GSM 900, GSM 1800, UMTS, LTE (4th generation), TETRA). In 2011 there was a total of 483 sector antennas, in 2015 a total of 779 sector antennas.

Numerical code, address and UTM 32N coordinates for the 65 Mobile phone (base stations) sites in Bamberg and Hallstadt are shown in Table 1.

Between 2006 and 2015 there was observation and documentation of tree damages. There were some preliminary measurements on both sides of unilaterally damaged trees and approximately 700 trees in Bamberg and Hallstadt were visited. The condition of numerous trees has been documented in photographs. The photographs record the state of trees showing damage patterns not attributable to diseases, pests, drought or other environmental factors in order to monitor damage and growth over several years (in 2006, Olympus FE-100 was used; since 2007, Panasonic DMC-FZ50 was used).

In 2015 we selected a polygonal study site, with an approximate area of 30 km^2, which includes partial municipalities of Bamberg and Hallstadt (70 km^2). The study area with the location of the phone masts in the layer of natural areas and municipalities is shown in Fig. 1. In this area, different measurements (see below) were done both for having a radiation map and for knowing which are the incident power densities beside different trees. In spite of the fact that measurements are changing continuously, they do not show significant differences between times (own data, see below).

In this polygon, we performed 144 measurements of the radiofrequency electromagnetic fields at a height of 1.5 m at different points in the city. These measurements were taken in streets and parks and allowed the preparation of an electromagnetic map of Bamberg and Hallstadt with their interpolation. The measurements were carried out with an EMF-broadband analyzer HF 59B (27–3300 MHz) and the horizontal-isotrope broadband antenna UBB27_G3, (Gigahertz Solutions). Measurements of the sum peak values of power flux density were in μW/m^2, which can be converted in V/m.

In general, a sector antenna covers an angle of 120° and the radiation of the sector antennas is distributed in main and secondary beams, bundled vertically and horizontally. The high-frequency emissions are reflected/diffracted and/or absorbed by buildings and trees. Therefore,

Table 1
Official information of the 65 mobile phone base stations in Bamberg and Hallstadt.

Code number	Adress in Bamberg and Hallstadt	X	Y	Code number	Adress in Bamberg and Hallstadt	X	Y
1	Altenburg	634268	5527019	34	Ludwigstr. 25 (Post)	636318	5529177
2	Am Borstig 2	636070	5531636	35	Luitpoldstr. 51	636241	5529232
3	Am Hirschknock	637511	5532267	36	Mainstraße, Ladekai 2	633924	5530319
4	An der Breitenau 2	637253	5530650	37	Mainstraße, Ladekai 3	633816	5530130
5	(An der Breitenau, P&R) ca.	637259	5526912	38	Margaretendamm 28	635341	5529331
6	(Artur-Landgraf-Straße)	635183	5526912	39	Memmelsdorfer Straße (Post) ca.	637769	5531392
7	Breitäckerstr. 9	632965	5529621	40	Memmelsdorfer Str. 208a	637568	5531191
8	Coburger Str. 6a	635877	5529951	41	Memmelsdorfer Str. 208a	634861	5528541
9	Coburger Str. 35	635252	5530468	42	Mußstr. 1	634949	5528827
10	Erlichstr. 47/51	637291	5527903	43	Pödeldorfer Str. 144	637828	5529305
11	Franz-Ludwig-Str. 7	635843	5528490	44	Rheinstr. 16 ca.	632910	5530367
12	Geisfelder Str. 30	637689	5528020	45	Robert-Bosch-Str. 40	637767	5528292
13	Grüner Markt 1	635624	5528370	46	Schildstr. 81	637049	5529049
14	Grüner Markt 23	635640	5528565	47	Schranne 3	635511	5528166
15	Gutenbergstr. 20	638448	5527180	48	Schützenstr. 23	636197	5527961
16	Hainstr. 4	635945	5528229	49	Schwarzenbergstr. 50	636762	5528732
17	Hainstr. 39	636341	5527550	50	Siemensstr. 37-43	638091	5528505
18	Hauptsmoorstr. 26a	638223	5530558	51	Theresienstr. 32	637487	5527866
19	Hauptsmoorwald, Pödeldorfer Straße	639683	5529635	52	Unterer Kaulberg 4	635350	5528084
20	Hauptsmoorwald, Geisfelder Straße	639890	5528022	53	Von-Ketteler-Str. 2	637905	5527553
21	Heiliggrabstr. 15	636054	5529240	54	Wilhelmsplatz 3	636316	5528259
22	Heinrichsdamm 1	635849	5528723	55	Zollnerstr. 181	637772	5530133
23	Heinrichsdamm 33a, P&R	636748	5527529	56	Heganger 18	634327	5530982
24	Hohenlohestr. 7	634794	5526480	57	Biegenhofstr. 13	633963	5531045
25	Kantstr. 33	637161	5530333	58	Seebachstr. 1	634399	5531764
26	Katzenberg	635374	5528266	59	Landsknechtstr.	634800	5531918
27	Kirschäckerstr. 37	636649	5530756	60	Lichtenfelser Str.	634864	5532621
28	(Kloster-Langheim-Str. 8)	637190	5529182	61	Michelinstr. 130 ca.	635629	5532106
29	Kronacher Str. 50	636722	5531496	62	Margaretendamm	634991	5529497
30	Lagerhausstr. 4-6	634850	5529871	63	Mainstr. 36a/Kiliansplatz	634326	5532386
31	Lagerhausstr. 19	634304	5530136	64	Bamberger Straße	635964	5526050
32	(Laurenziplatz 20)	635207	5527404	65	Würzburger Str. 76	635359	5526709
33	Ludwigstr. 2	635207	5529103				

due to existing obstacles there is an inhomogeneous radiofrequency field distribution. Buildings and vegetation (trees and foliage) can shield and reduce radiation and thus affect the quality of signal propagation (e.g. Meng and Lee, 2010). Living material is not a perfect dielectric object and interferes with high frequency electromagnetic fields in a way that depends upon several parameters, including the general shape, conductivity, and density of the tissue, and the frequency and amplitude of the electromagnetic radiation (Vian et al., 2016).

In the polygon mentioned before we selected 60 trees showing unilateral damage. The selection was limited by the fact that we were able to measure with the telescopic rod only up to a height of 6 m. Many trees (*Tilia, Betula, Quercus, Populus, Picea*) showing damage above the

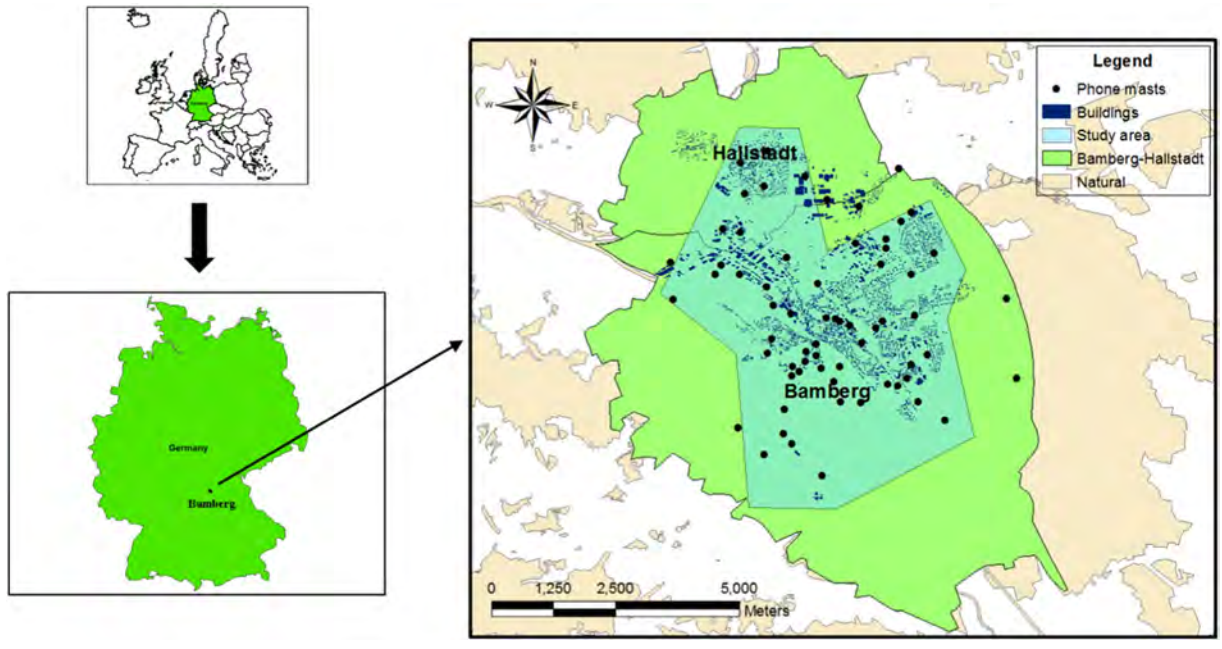


Fig. 1. The study area with the location of the phone masts in the layer of natural areas, buildings, and municipalities.

height of 6 m could not be included. The measurements at the trees were done between April and October 2015. *Acer platanoides*, *Carpinus betulus*, *Tilia* sp., *Taxus baccata* and *Thuja occidentalis* are widely spread in Bamberg and Hallstadt and can be reached for measurements. Therefore they are the most represented species.

The selected 60 trees from the study polygon show damage patterns that are not usually attributable to harmful organisms, such as diseases (fungi, bacteria, viruses) and pests (insects, nematodes) or other environmental factors (water stress, heat, drought, frost, sun, compaction of the soil, air and soil pollutants).

The main features of damage from this source are:

- Trees are mainly affected on one side (showing side differences and unilateral damage) and can appear in any orientation. The damage only originates on one side.
- Damage appears without external indications that the tree is infested with insects, nematodes, fungi, bacteria or viruses.
- Damage appears on trees, which have previously grown well. Damage appears on once healthy trees within one or two years after Antennas were put into operation.
- Damage increases from the outside to the inner part of the crown over time.
- Trees of different species in the same location also show damage.
- Damage appears in favourable (gardens, parks) as well as in unfavourable locations.
- Trees in the same location, but that are shielded by buildings or other trees, are healthy.

For these damaged trees, we used 13 damage codes that may be recognised with the naked eye (for explanations, see Table 2). In order to explain each type of damage visually, a photograph was added for each damage code.

Table 2
Tree damage codes.

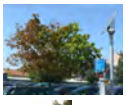
01 Damage only on one side: The tree shows damage only on one side. The damage can be recognized with the naked eye.	
02 Crown transparency (sparse leaves or needles): The number of leaves or needles is reduced. The crown transparency increases from year to year.	
03 Brown leaves (start at leaf margins): The leaves begin to turn brown in june. The browning starts at the leaf margins. It looks similar to effects by salt.	
04 Colour change of leaves prematurely: Leaves become yellow, red or brown (in the whole) early in the year.	
05 Tree leaves fall prematurely: The leaves begin to fall already from june on.	
06 Dead branches: Over a period of some years it can be observed how little and big branches die.	
07 Tip of the main guide dried.	
08 Irregular growth. The growth of deciduous and coniferous trees can be disturbed in different manners. One observation is that trees bend to a side.	
09 Not grow in height: Trees often stop to grow in height. The height was not measured. Only the visual impression was valuated.	
10 Colour change of needles. Needles can change their colour to yellow, red or brown.	
11 Dead parts were trimmed down: When bigger branches die, it becomes necessary to remove these parts for the sake of security of people passing.	
12 Damage on different sides: The trees show damages on different sides.	
13 No damage: The tree shows the typical habitus of its species. With the naked eye no damage can be seen.	

Table 3
144 selected points in Bamberg and Hallstadt with their measurements and UTM coordinates.

Number	Streets and parks in Bamberg and Hallstadt	Measurement μW/m²	X	Y	Number	Streets and parks in Bamberg and Hallstadt	Measurement μW/m²	X	Y
1	Wassermannpark	2300	637395	5530345	73	Ludwigstraße/Zollnerstraße	50	636228	5529444
2	Memmelsdorfer Str. 209	1830	637581	5531113	74	Landratsamt, Ludwigstraße, Einfahrt	670	636422	5529044
3	Holunderweg	10	638125	5530967	75	Wilhelmsplatz, Mitte	460	636250	5528263
4	Hauptsmoorstraße/Seehofstraße	3600	638039	5530857	76	Amalienstr. 16	16570	636303	5528086
5	Greifffenbergstr. 79	4210	638349	5530855	77	Otttostr. 7a	120	636133	5527878
6	Heimfriedweg 16	870	638393	5530621	78	Schönbornstr. 3	3640	636251	5527696
7	AWO, Innenhof, Parkplatz	3920	638223	5530584	79	Hainspielplatz	1530	636229	5527403
8	Ferdinand-Tietz-Str. 40	2600	637883	5530616	80	P&R Heinrichsdamm, Parkplatz bei Kirschen	3400	636706	5527667
9	Ferdinand-Tietz-Str. 38	80	637889	5530601	81	P&R Heinrichsdamm, südöstlich des Senders, Eichen	1690	636755	5527504
10	Petrinistr. 20	1340	637797	5530514	82	Luisenhain, Höhe Wasserwerk	260	636895	5526482
11	Petrinistr. 32	4700	637891	5530449	83	Kapellenstraße	2120	637050	5528148
12	Zollnerstraße 181	9300	637773	5530102	84	Geisfelder Str. 9, Gärtnerei	740	637410	5528164
13	Wassermannstr. 14	540	637424	5530125	85	Gereuthstr. 8	30	637621	5527424
14	Feldkirchenstraße/Kantstraße	2620	636803	5530069	86	Distelweg, Innenhof	15	637881	5527160
15	Breslaustr. 20	3890	637392	5530431	87	Am Sendelbach BSC 1920	30	637331	5526877
16	Berliner Ring	16920	637188	5530786	88	Am Sendelbach, Kleingartenanlage	10	637542	5526222
17	Rodezstr. 3	3780	637044	5530765	89	Robert-Bosch-Straße	2060	637504	5528200
18	Am Spinnseyer 3	880	637545	5530764	90	Ludwigstraße/Memmelsdorfer Straße	1000	635974	5529708
19	Kirschäckerstr. 24	4290	636655	5530857	91	Coburger Straße, Neubau Studentenwohnheim	3460	635867	5529878
20	Kammermeisterweg	810	636283	5530282	92	Coburger Straße, junge Platane	3400	635835	5529941
21	Eichendorff-Gymnasium, Hof	6340	637194	5529084	93	Gundelsheimer Str. 2	9000	635783	5529680
22	Starkenfeldstraße/Pfarrfeldstraße	3660	637092	5529138	94	Hallstadter Straße	12	635232	5530212
23	Parkplatz auf der Westseite der Polizei	9020	636921	5528970	95	Gerberstraße/Benzstraße	1280	635108	5530546
24	Starkenfeldstraße, Höhe Polizei	1120	636975	5529061	96	Coburger Straße, Einfahrt Fitnesszentrum	2000	635326	5530508
25	Starkenfeldstr. 2	860	637527	5529216	97	Kleintierzuchtanlage	890	635380	5530622
26	Pödeldorfer Str., Haltestelle	2180	636965	5529217	98	Margaretendamm, Eingang ehemaliges Hallenbad	1300	635455	5529178
27	Kindergarten St. Heinrich, Eingang	6450	637712	5529364	99	Margaretendamm/Europabrücke	1890	635200	5529365
28	Pödeldorfer Straße, Haltestelle Wörthstraße	1620	637654	5529433	100	Margartendamm 38, nahe Sendeanlage	5560	635003	5529497
29	Pödeldorfer Str. 142, Nordseite	30	637840	5529437	101	Hafenstraße/Regnitzstraße	7610	634719	5529740
30	Pödeldorfer Str. 142, Südseite	17060	637824	5529410	102	Lagerhausstraße	210	634556	5530102
31	Berliner Ring, Höhe Pödeldorfer Str. 144	4480	637900	5529380	103	Hafenstr. 28, Bayerischer Hafen	3200	634192	5530370
32	Schwimmbad Bambados, Vorgarten mit Bambus	1620	638074	5529315	104	Laubanger 29	160	634202	5530561
33	Schwimmbad Bambados, Parkplatz, Feldahorn	2540	638202	5529346	105	Heganger	1400	634341	5530812
34	Carl-Meinelt-Str.	5360	638043	5529094	106	Emil-Kemmer-Str. 2	5000	633822	5530863
35	Volkspark, FC Eintracht, Ostseite	120	638343	5529065	107	Emil-Kemmer-Str. 14	2500	634342	5531099
36	Michelsberger Garten, Teil Streuobst	5450	634831	5528673	108	Dr. Robert-Pfleger-Straße 60	90	634448	5530978
37	Michelsberger Garten, Terrassengarten, bei Eibe	2500	634988	5528508	109	Friedhof Gaustadt, Haupteingang	13100	632981	5529677
38	Michelsberger Garten, Südostecke, bei Holunder	910	635036	5528455	110	Friedhof Gaustadt, Ahornpaar	1400	632929	5529728
39	Michelsberg, Aussichtsterrasse, oberhalb Weinberg	1260	634924	5528463	111	Herzog-Max-Str. 21	1600	636245	5528071
40	Michelsberg, Aussichtsterrasse, Aussichtspunkt	780	634911	5528537	112	Gaustadter Hauptstr. 116	10	634042	5529457
41	Michelsberg, Nordostecke, bei jungen Linden	390	634874	5528565	113	Landesgartenschaugelände, Hafenerlebnispfad	2000	633789	5529894
42	Storchsgasse/Michelsberg	200	634725	5528415	114	Landesgartenschau, junge Baumgruppe	1270	633949	5529718
43	St. Getreu-Kirche, Südseite	55	634518	5528405	115	Würzburger Str.	340	635283	5527151
44	Villa Remeis, Garten	390	634295	5528203	116	Würzburger Straße/Arthur-Landgraf-Straße	1380	635355	5526862
45	Villa Remeis, Treppe	300	634400	5528237	117	Hohe-Kreuz-Straße/Würzburger Straße, Haltestelle	590	635383	5526733
46	Maienbrunnen 2	3920	634744	5528838	118	Hohe-Kreuz-Straße	10950	635469	5526729
47	Am Leinritt	2140	635071	5528617	119	Am Hahnenweg 6	3420	635332	5526729
48	Abtsberg 27	130	634526	5528935	120	Am Hahnenweg/Viktor-von-Scheffel-Straße	640	635307	5526710
49	Welcome Hotel, Garten	3200	634788	5529012	121	Am Hahnenweg 28 a	145	635028	5526654
50	Mußstraße, eingang Kindergarten	1670	634864	5529011	122	Schlüsselberger Straße	200	634712	5526534
51	Mußstraße/Schlüsselstraße	710	634846	5529034	123	Schlüsselberger Str./Haltestelle Hezilostr., Parkdeck	460	634749	5526549
52	Nebingerhof	2040	635069	5528901	124	Hezilostr. 13	70	634604	5526563
53	Graf-Stauffenberg-Platz	100	635120	5529009	125	Sückleinsweg, junge Hainbuchenhecke	75	634512	5526654
54	Don-Bosdo-Straße, Innenhof	10	635176	5529056	126	Rößleinsweg, oberes Ende	300	634708	5526789
55	Pfeuferstraße/Weide	1100	635222	5528820	127	Große Wiese	1500	634874	5526810

Table 3 (*continued*)

Number	Streets and parks in Bamberg and Hallstadt	Measurement µW/m²	X	Y	Number	Streets and parks in Bamberg and Hallstadt	Measurement µW/m²	X	Y
56	Weidendamm/Don-Bosco-Straße	1860	635166	5529195	128	Suidgerstraße	195	634508	5526409
57	Katzenberg/Karolinenstraße	1720	635316	5528239	129	Waizendorfer Straße	280	635317	5525864
58	Vorderer Bach	450	635305	5528141	130	Waizendorfer Straße, Einfahrt Gärtnerei	210	635326	5525582
59	Obere Brücke	8000	635565	5528289	131	Klinikum, Nähe Spielplatz	175	635732	5525672
60	Judenstraße	6	635479	5528040	132	Klinikum Weiher	100	635759	5525520
61	Tourist Information	4920	635674	5528172	133	Buger Straße/Bamberger Straße	2730	635829	5526082
62	Universität, Am Kranen 14, Innenhof	10	635501	5528535	134	Dunantstraße	470	635848	5526176
63	Fleischstraße	10	635703	5528683	135	Buger Straße/Paradiesweg	90	635743	5526286
64	ZOB	600	635882	5528541	136	Buger Straße/Abzweigung Münchner Ring	470	635528	5526499
65	Schönleinsplatz, Ostseite	900	636004	5528300	137	Hallstadt, Markplatz, bei Linde	2000	634582	5532426
66	Friedrichstraße, Parkplatz	165	635984	5528360	138	Hallstadt, Markplatz 21, Innenhof	8	634632	5532488
67	Franz-Ludwig-Straße/Luisenstraße	1720	636158	5528410	139	Hallstadt, Lichtenfelser Str. 12	4000	634659	5532474
68	Franz-Ludwig-Str, Strassenbauamt	90	636246	5528408	140	Hallstadt, Lichtenfelser Str. 8	9000	634720	5532516
69	Heiliggrabstraße, Nähe Sender	4740	636072	5529245	141	Hallstadt, Am Gründleinsbach/Kemmerner Weg	200	634743	5532784
70	Heiliggrabstr. 29, Landesjustizkasse	20	636063	5529399	142	Hallstadt, Valentinstraße/Seebachstraße	2200	634232	5532237
71	Heiliggrabstr. 57, Aussichtspunkt Schiefer Turm	4500	635797	5529410	143	Hallstadt, Johannisstr. 6	5000	634805	5532078
72	Bahnhof, ParkplatzWestseite	1600	636300	5529374	144	Hallstadt, Bamberger Straße/Michael-Bienlein-Straße	1860	634805	5531969

For each selected tree, the types of damage and the Universal Transversal Mercator (UTM) coordinates were recorded. In addition, two measurements were recorded: on the side showing damage and on the side without damage, generally corresponding to opposite sides of each tree. On both sides, the measurements were carried out at a variable height of 1–6 m (depending on the height of the tree), using a telescopic rod, a ladder, and the broadband radiofrequency meter.

Most measurements were done in the afternoon or in the evening on different days between April and October 2015. But the measurements on the two sides of each single tree were done one after another immediately on the same day and at the same time. The measurements took about 5 min on each side. When we stood on the ground or on a ladder we measured the peak values. When we used the telescopic rod we measured the peak hold values. Using the telescopic rod and measuring peak hold values it took longer, because the measurements had to be repeated often in cases where RF-EMF emitting cars or passengers disturbed the results. At each single tree the two measurements were done in the height where the damage had appeared. Because the height of the 120 trees differed, it was necessary to do the measurements at different heights.

In theory, although measurements are changing continuously there is no evidence about significant changes in power densities of electromagnetic radiation produced by phone masts over time. One study carried over one year in the city of Madrid showed no changes in terms of radiation intensity between the three rounds of measurements

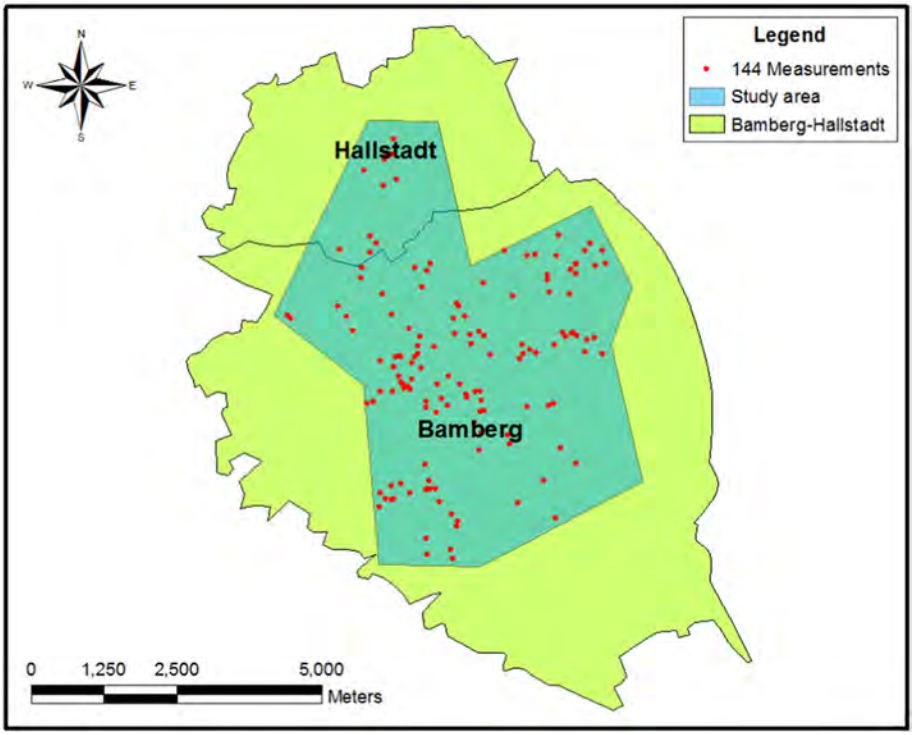


Fig. 2. Location of the 144 measurements points in Bamberg and Hallstadt in the study area.

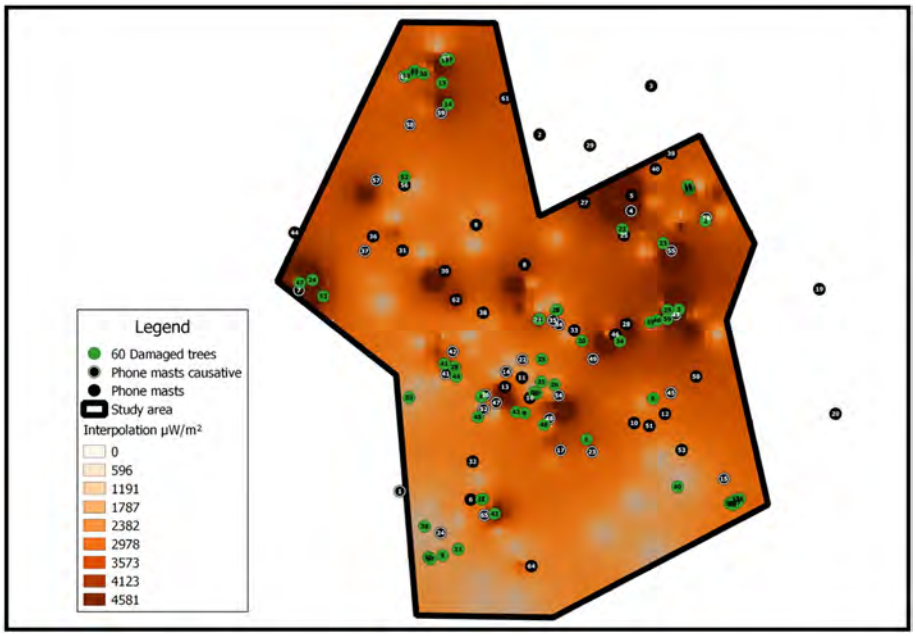


Fig. 3. Map showing the 60 damaged trees and phone masts (both with code numbers) over the interpolation electromagnetic map of the 144 measurement points.

performed in about 200 sampling points (own data). Repeatability analysis checked this. Despite the fact that the increase in sector antennas (observed between 2011 and 2015) would have probably increased the radiation in the environment of the study area, measurements used in this study were mostly done in 2015.

In an attempt to link the electromagnetic radiation measured at every tree to specific phone masts, the distances to the three nearest antennas that could be mainly responsible for the radiation measurements at each tree were calculated in meters with Geographical Information System (GIS) programs, following the general approach criteria of proximity. However, it must be taken into account that buildings and vegetation diminish radiation intensity and, in many cases, the nearest phone mast or masts may be obscured by obstacles. In other cases, the phone mast is in direct line of sight from the tree and the radiation can reach the tree directly.

Additionally, 30 random points were generated inside the polygonal study area and outside a layer of buildings, downloaded from: http://www.mapcruzin.com/free-germany-arcgis-maps-shapefiles.htm using a Random Points tool of QGIS 2.6.0-Brighton (QGIS Development Team, 2014) allowing create random points inside a specific layer. Therefore the points were randomly situated in specific places in the study area outside buildings but not frequently concur with the location of trees. That is why measurements were taken from the nearest tree for each random point, generating a random tree group. Measurements and damage characteristics were scored in the same way as with 60 damaged trees explained above, measuring the maximum value of radiation corresponding to opposite sides of each tree.

In areas of the city with low measurements of electromagnetic radiation (no visual contact to any phone mast and power flux density <50 µW/m^2), we scored another 30 trees in the same way as with 60 damaged trees and 30 random points. The UTM coordinates and the three nearest phone masts of each tree in these last two groups (random and low radiation trees) were also recorded.

To generate electromagnetic maps, we used ArcGis 9.3 (ESRI, 2008) and QGIS 2.6.0-Brighton (QGIS Development Team, 2014). To check possible differences between groups of data and taking into account that there were two measures made in each tree, repeated measures analysis of variance were applied, considering a repeated measures factor (within-subjects) and another between-subjects. The post hoc Bonferroni test was used in all cases to elucidate significant differences. Statistics were performed using STATISTICA 7 program (StatSoft, Inc, 2004).

3. Results

The results of radiation measurements obtained at 144 points in Bamberg and Hallstadt at a height of 1.5 m were between 6 µW/m^2 (0.047 V/m) and 17,060 µW/m^2 (2.53 V/m) (for measurements and UTM coordinates, see Table 3). The measured values are far below the current limit values (41 V/m for GSM system and 61 V/m for UMTS; ICNIRP, 1998).

The locations of these points in the study area are shown in Fig. 2. By interpolation of the 144 measurements points (Table 3), we prepared a map of the power flux density in Bamberg and Hallstadt (Fig. 3). This map is theoretical and approximate, since many factors affect the true electromagnetic values. However, the map is useful to provide approximate differences in exposure (electromagnetic pollution) throughout the city.

The 60 selected trees showing damage patterns not attributable to diseases, pests or other environmental factors are presented in Table 4. In this Table, we added the tree code number, the scientific name, the UTM coordinates, the measurements (power flux density) on both sides of each tree, and the distances (meters) and code numbers to the three nearest antennas for each tree, which may be mainly responsible for the electromagnetic radiation measured. We also included the orientation of the tree damage and the number of main (nearest) phone mast(s) in direct line of sight, whose lobe of radiation most directly affected each tree. Finally, we included the codes of damage observed in the 60 trees.

From all 60 selected trees, one or more phone mast(s) could be seen, with no obstacles between the phone mast and damaged tree. In many cases, one of the three closest antennas caused the main radiation on the tree surface. In ten trees (codes: 4, 7, 9, 10, 15, 26, 27, 31, 35, and 50), another antenna in direct line of sight caused the measured radiofrequency exposure. This was determined using topography and existing buildings (Table 4 and Fig. 3).

The 60 damaged trees (with their code number) and the phone masts are overlaid on the electromagnetic map prepared by interpolation of the 144 measurements points (Fig. 3). The likely antenna or

antennas causing radiation damage to each tree are also shown (Fig. 3). The measurements at all selected trees revealed significant differences between the damaged side facing a phone mast and the intact (or less damaged) opposite side. On the side facing a phone mast, the measured values were 80–13,000 μW/m^2 (0.173–2.213 V/m). On the opposite side the values were 8–720 μW/m^2 (0.054–0.52 V/m).

Table 4
60 selected trees showing damage patterns not attributable to diseases, drought or other environmental factors.

														Effect codes												
														1	2	3	4	5	6	7	8	9	10	11	12	13
N°	Scientific name	X	Y	Side antenna measurement μW/m²	Opposite side measurement μW/m²	Number of Phone Mast 1	Distance a 1	Number of Phone Mast 2	Distance a 2	Number of Phone Mast 3	Distance a 3	Direction of damage	Number of main phone mast(s) causing the radiation	Damage only on one side	Sparse leaves or needles (crown transparency)	Brown leaves (start at leaf margins)	Colour change of leaves prematurely	leaves fall prematurely	Dead branches (Peak branches dried).	Tip of the main guide dried	Irregular growth	Not grow in eight	Color change of needles	Dead parts were trimmed down	damage on different sides	no damage
1	*Acer platanoides*	636298	5529366	970	130	35	145,6	34	190,1	21	274,6	S, SW	35,34,21	+	+	+		+	+	+		+				
2	*Acer platanoides*	638211	5530518	680	80	18	41,76	55	583,9	40	930,8	N	18	+	+	+		+	+			+		+		
3	*Acer platanoides*	637868	5529371	2100	290	43	77,18	28	703,9	55	768	S	43	+	+	+		+	+	+		+				
4	*Acer platanoides*	635316	5528245	2300	130	26	61,68	52	164,6	47	210,4	E, S	26,52,47, 14	+	+	+		+	+	+		+		+		
5	*Acer platanoides*	636677	5527688	3600	290	23	174,1	17	363,2	48	552,2	S	23	+	+	+		+	+	+		+		+		
6	*Acer platanoides*	637536	5528219	700	140	45	242,3	12	251	51	356,4	E	45	+	+	+		+	+	+						
7	*Acer platanoides*	635339	5526919	270	30	6	156,2	65	211	32	502,6	W	1	+		+		+	+	+		+		+		
8	*Acer platanoides*	635876	5528029	80	10	16	211,6	48	328,1	47	389,9	W	47	+	+	+		+								
9	*Acer platanoides*	634819	5526187	160	20	24	294,1	65	751,1	6	811,2	N	24, 1		+	+		+	+					+		
10	*Acer platanoides*	634638	5526163	180	55	24	353,3	65	904,4	6	926,3	N	24, 1		+	+		+	+							
11	*Acer platanoides*	635022	5526270	95	20	24	310	65	553,4	6	661,9	NW	24	+	+			+								
12	*Acer platanoides*	634854	5532596	11800	400	60	26,93	63	568,2	59	680,1	N	60	+	+	+		+	+	+		+				
13	*Acer platanoides*	634455	5532438	9900	620	63	139,1	60	448,1	59	624	W	63	+			+							+		
14	*Acer platanoides*	634890	5532028	3380	500	59	142,1	58	557,5	60	593,6	SW	59	+	+	+		+	+	+		+		+		
15	*Acer platanoides*	634815	5532307	1050	50	60	317,8	59	389,3	63	495,3	SW	58	+	+	+		+	+	+		+		+		
16	*Carpinus betulus*	638001	5530928	1210	120	18	431,5	40	506,6	39	518,8	S	18	+	+	+		+	+							
17	*Carpinus betulus*	637996	5530945	2520	150	18	448,7	40	493,7	39	501,3	S	18	+	+	+		+	+							
18	*Carpinus betulus*	637987	5530959	890	90	18	465,3	40	478,9	39	484,8	S	18	+	+	+		+								
19	*Carpinus betulus*	637984	5530970	670	10	40	471,1	39	473,6	18	476,3	S	18	+	+	+		+								
20	*Carpinus betulus*	636619	5528966	1000	200	33	169,6	49	274,2	34	367,6	SE	49		+	+		+	+			+		+		
21	*Carpinus betulus*	636068	5529245	430	20	21	14,87	35	173,5	34	259,1	W	21	+	+	+		+				+		+		
22	*Carpinus betulus*	637138	5530413	4340	110	25	83,24	4	263,4	5	450,6	NE	4	+	+	+		+	+	+		+				
23	*Carpinus betulus*	637664	5530231	990	60	55	145,8	25	513,2	4	586,9	E	55	+	+	+		+	+							
24	*Carpinus betulus*	633137	5529754	2700	50	7	217,4	44	653,7	37	776,2	E	37	+	+	+		+	+							
25	*Tilia sp.*	636098	5528729	870	150	22	249,1	11	349,5	14	486,5	W	22	+	+	+		+	+							
26	*Tilia sp.*	636261	5528398	410	20	54	149,5	16	358,4	11	428	W	14	+		+		+								
27	*Tilia sp.*	636030	5528283	680	160	16	100,7	11	279	54	287	S	48	+	+		+	+	+					+		
28	*Tilia sp.*	634972	5528626	660	170	41	139,8	42	202,3	26	539,6	SW	41	+	+	+		+	+	+		+		+		
29	*Tilia sp.*	636283	5529365	2450	160	35	139,5	34	191,2	21	260,9	SW	35, 34, 21	+		+		+				+		+		
30	*Tilia sp.*	634573	5532422	3800	420	63	249,6	60	352,5	59	552,8	NE	60	+	+	+		+	+					+		
31	*Tilia sp.*	635319	5526914	380	120	6	136	65	208,9	32	502,6	W	1	+	+		+	+	+	+						
32	*Quercus robur*	638598	5526911	860	130	15	308	53	944,7	12	1434	NW	15		+			+	+							
33	*Quercus rubra*	637501	5529207	1340	120	28	312	43	341,4	46	478,8	E	43	+	+			+	+							
34	*Quercus rubra*	637107	5528961	1650	250	46	105,4	28	236,1	49	414,1	SW	49	+	+				+							
35	*Aesculus hippocastanum*	636092	5528434	400	20	16	252,3	11	255,2	54	284,3	W	14	+	+	+		+	+	+		+				
36	*Robinia pseudoacacia*	638653	5526920	1300	40	15	331,1	53	979,9	12	1463	NW	15	+			+		+	+		+				

Table 4 *(continued)*

37	*Robinia pseudoacacia*	638619	5526874	660	240	15	350,5	53	985,3	12	1476	NW	15	+			+		+					+		
38	*Sorbus occuparia*	634587	5526564	84	8	24	223,4	1	555,7	6	690,2	N	1	+	+	+		+	+	+		+				
39	*Acer negundo*	637722	5529366	3060	310	43	122,3	28	562,9	46	743,9	SE	43	+	+			+	+			+		+		
40	*Acer saccharinum*	637852	5527078	840	180	53	477,9	15	604,7	51	868,4	E	15	+	+			+								
41	*Juglans regia*	634841	5528669	4500	590	41	129,6	42	191,4	26	668,2	N, E	42	+	+			+	+	+	+	+				
42	*Taxus baccata*	635767	5528046	300	70	16	255,3	47	282,7	13	354,2	NW	47	+	+				+					+	+	
43	*Taxus baccata*	635491	5526727	8970	190	65	133,2	6	359,3	32	734,2	W	65	+	+				+					+	+	
44	*Taxus baccata*	634997	5528506	2500	240	41	140,4	42	324,6	26	446,9	N,E,W	41,42		+				+					+	+	
45	*Taxus baccata*	635272	5527980	2700	70	52	130	47	302,8	26	303,6	NE	52	+	+				+					+	+	
46	*Taxus baccata*	637586	5529231	1520	190	43	253,1	28	399	46	567	E	43	+	+									+	+	
47	*Thuja occidentalis*	632975	5529719	910	30	7	98,51	44	651,3	37	936,1	S	7	+	+				+					+		
48	*Thuja occidentalis*	636128	5527881	120	10	48	105,6	16	393,2	17	393,6	S	17	+	+				+					+		
49	*Thuja occidentalis*	634900	5532611	13000	520	60	37,36	63	616,5	59	700,2	NW	60	+	+				+					+		
50	*Thuja occidentalis*	634387	5528232	290	50	41	565,8	42	818,5	52	974,3	S	1	+	+				+	+				+		
51	*Picea pungens*	638525	5526863	770	90	15	326,2	53	927,6	12	1427	NE	15	+	+				+					+		
52	*Picea pungens*	634328	5531086	3080	310	56	104	57	367,3	58	681,7	W	57		+				+				+	+		
53	*Picea pungens*	633280	5529546	1350	200	7	323,8	37	792,7	44	900,5	W	7	+	+				+		+			+		
54	*Pinus sylvestris*	638542	5526861	790	50	15	332,6	53	940,5	12	1439	NE	15		+				+		+	+		+		
55	*Pinus sylvestris*	634461	5532462	5300	130	63	154,9	60	433,2	59	641	SW	63	+	+									+		
56	*Pseudotsuga menziesii*	638560	5526844	1720	60	15	354,2	53	965,2	12	1463	NE	15	+	+				+	+		+		+		
57	*Juniperus communis*	634664	5526141	160	20	24	363,1	65	897,6	6	929,4	N	24	+	+				+					+		
58	*Corylus avellana 'Contorta'*	634355	5532399	420	80	63	31,78	60	555,3	58	636,5	W	63	+	+	+		+	+							
59	*Corylus avellana*	637720	5529249	3880	720	43	121,7	28	534,2	46	700,2	N	43	+	+	+		+							+	
60	*Symphoricarpos albus*	636002	5528299	1200	320	16	90,27	11	248,5	54	316,5	E	54	+	+			+	+						+	

In the five most represented species ($n \geq 4$) among the 60 affected trees, most trees showed damage only on one side: unilateral damage (Damage code 1, Tables 2 and 4). By species and percentages: *Acer platanoides* (86%), *Carpinus betulus* (88%), *Tilia* sp. (100%), *Taxus baccata* (80%) and *Thuja occidentalis* (100%). On the seven trees not given code 1, the damage spread over the whole tree, but trees still showed side differences. Most of these trees were characterized with sparse leaves or needles (crown transparency) (Damage code 2, Tables 2 and 4). By species and percentages: *Acer platanoides* (86%), *Carpinus betulus* (100%), *Taxus baccata* (100%) and *Thuja occidentalis* (100%). In many of the trees with the one-sided damage, the leaves turned prematurely yellow or brown in June – this always began at the leaf margins (Damage code 3, Tables 2 and 4). The species with higher percentages were: *Acer platanoides* (86%) and *Carpinus betulus* (100%). In many trees leaves fall prematurely: *Acer platanoides* (93%), *Carpinus betulus* (100%) and *Tilia sp.* (100%) (Damage code 5, Tables 2 and 4). Many trees of the species *Acer platanoides* (80%), *Taxus baccata* (80%) and *Thuja occidentalis* (100%) had dead branches (Peak branches dried) (Damage code 6, Tables 2 and 4). All the trees of the species *Taxus baccata* (100%) and *Thuja occidentalis (100%)* exhibited color change of the needles (Damage code 10, Tables 2 and 4). Finally, in all trees of the species *Taxus baccata*, dead parts were trimmed (Damage code 11, Tables 2 and 4). Some trees stopped growing in height while, in others, the main guide died (see Tables 2 and 4).

The 30 randomly selected trees are presented in Table 5 with the tree code number, the scientific name, the UTM coordinates, the measurements (power flux density) on both sides of each tree, the distance (meters) to the three nearest antennas, their code number and the damage codes. Trees in these locations may be in areas with either high or low radiation. Seventeen trees in this group were situated in places with low radiation and showed no signs of damage. The measurements were 8–50 μW/m^2 (0.054–0.137 V/m) and showed no difference between the two opposite sides. Thirteen trees stood in the radiation field of one or more phone mast. Six of these had damage only on the side facing a phone mast, and five had damages on other sides. The measurements on the exposed sides were 40–4600 μW/m^2 (0.122–1.316 V/m).

The 30 trees selected in areas with low radiation (radio shadow of hills, buildings or trees) are presented in Table 6 with the tree code number, scientific name, UTM coordinates, measurements (power flux density) on both sides of each tree, distance (meters) to the three nearest antennas, their code number and the damage codes. All trees selected in low radiation areas showed no damage (code 13). The power flux density values measured were 3–40 μW/m^2 (0.033–0.122 V/m) and no significant differences were found between the two opposite sides.

The trees in random points and the trees in areas of low radiation are represented In Fig. 4 over the electromagnetic map prepared by interpolation of the 144 measurements points.

We performed a Repeated Measures ANOVA analysis in order to include the measurements of the exposed and shielded side of each tree (R1 = within subjects factor) in the three groups of trees (damaged, random, and low radiation), and to avoid pseudoreplication. The comparisons of all factor levels revealed significant differences, including the interaction between factors. A post hoc Bonferroni comparisons test, recommended for different sized groups of samples, revealed significant differences between measurements from the exposed side of damaged trees and all other groups (Table 7). Fig. 5 shows the measurements (mean and standard error) in all groups.

In the "Random points" group of trees, we performed another Repeated Measures ANOVA (R1 = within subjects factor) for trees damaged and undamaged within this group (Table 8). The results showed significant differences in both factors, including the interaction, which means that depending on the group of tree (damaged or undamaged),

Table 5
Results of the tree measurements at the 30 random points.

												Effect codes												
												1	2	3	4	5	6	7	8	9	10	11	12	13
N°	Scientific name	X	Y	Side antenna measurement µW/m²	Opposite side measurement µW/m²	Number of Phone Mast 1	Distance a 1	Number of Phone Mast 2	Distance a 2	Number of Phone Mast 3	Distance a 3	Damage only on one side	Sparse leaves or needles (crown transparency)	Brown leaves (start at leaf margins)	Colour change of leaves prematurely	leaves fall prematurely	Dead branches (Peak branches dried).	Tip of the main guide dried	Irregular growth	Not grow in eight	Color change of needles	Dead parts were trimmed down	damage on different sides	no damage
1	*Salix viminalis*	634095	5532455	10	10	63	241,1	58	754,9	60	786,7													+
2	*Thuja occidentalis*	634760	5532680	500	120	60	119,6	63	524,2	59	763		+				+	+			+		+	
3	*Abies alba*	634030	5530490	2200	900	36	201,2	37	418,8	31	447,7		+				+			+	+		+	
4	*Acer campestre*	634545	5530739	890	320	56	326,5	31	649,4	57	657,5	+	+				+							
5	*Acer platanoides*	634557	5530005	4600	1100	31	284,9	30	322,2	62	668,1	+	+	+		+						+		
6	*Picea abies*	635311	5530644	1900	210	9	185,6	8	894,8	30	900									+	+			
7	*Thuja occidentalis*	635635	5529879	10	10	8	252,5	38	621,9	9	702,6													+
8	*Acer platanoides*	635693	5529848	2600	310	8	210,9	38	625,5	21	707,1	+	+			+	+					+		
9	*Cornus sanguinea*	636415	5530248	40	30	27	559,3	8	614,5	25	750,8													+
10	*Acer pseudoplatanus*	637525	5530896	50	50	5	270,5	40	298,1	4	366,7													+
11	*Syringa*	638111	5531436	10	10	39	344,8	40	595,7	18	885,1													+
12	*Acer platanoides 'Globorum'*	637928	5530541	30	30	18	295,5	55	436,8	4	683,7													+
13	*Acer platanoides*	637159	5529361	20	15	28	181,7	46	330,8	43	671,3													+
14	*Quercus rubra*	638342	5528994	1480	570	50	549,7	43	600,8	45	907,4		+			+	+					+	+	
15	*Thuja occidentalis*	638359	5528569	25	20	50	275,5	45	653,6	12	866,2													+
16	*Tilia sp*	637412	5527922	460	320	51	93,6	10	122,5	12	293,8											+		
17	*Quercus robur*	637363	5527807	45	33	10	120	51	137,3	12	389,4													+
18	*Larix decidua*	637804	5527628	4400	3170	53	125,8	51	396,4	12	408,5		+				+		+				+	
19	*Acer pseudoplatanus*	637919	5527135	760	120	53	418,2	15	530,9	51	849,1	+	+			+	+	+				+		
20	*Acer negundo*	637329	5526888	190	30	23	865,1	53	879,8	51	990,7	+										+		
21	*Quercus robur*	637115	5527423	46	26	23	382	10	511,2	51	578,5													+
22	*Thuja occidentalis*	637315	5526260	40	13	64	1367	23	1390	53	1421	+									+			
23	*Salix matsudana 'Tortuosa'*	635403	5525413	15	12	64	848,8	24	1229	65	1297													+
24	*Populus tremula*	635410	5525828	15	9	64	596,8	65	882,5	24	897													+
25	*Salix matsudana 'Tortuosa'*	634981	5526161	41	23	24	369,8	65	665,7	6	777,7													+
26	*Prunus sp.*	634829	5526050	28	21	24	431,4	65	845,7	6	931,9													+
27	*Picea pungens*	634791	5526809	470	340	24	329	6	405,3	1	563,6		+				+		+				+	
28	*Cornus sanguinea*	635164	5527863	15	15	52	288,9	26	454,4	47	460,7													+
29	*Cornus sanguinea*	634905	5528779	20	20	42	65,12	41	242	26	695,1													+
30	*Acer negundo*	634202	5529092	8	8	42	792,6	41	859	62	886,9													+

significant or non-significant respectively differences between the measurements of the two sides are seen (Fig. 6). A post hoc Bonferroni comparisons test showed significant differences between the measurements from the exposed side of damaged trees and all other groups in the random points group (Table 8).

Of the 120 trees, those with lower mean distance to the three closest antennas have usually higher values of radiation (Fig. 7). However, screening is common in cities due to a large amount of buildings, thus some trees that are close to antennas show lower radiation values than expected. This means that radiation measurements at points close to antennas are variable (high and low) while trees farther from antennas always have low values.

A dossier with documentation gathered over the years and the examples of tree damages is presented in: http://kompetenzinitiative.net/KIT/KIT/baeume-in-bamberg/

4. Discussion

In the present study it was useful, that tree damages in the vicinity of phone masts in Bamberg and Hallstadt had been documented starting 2006. We found a high level of damage to trees in the vicinity of phone masts. The damage encountered in these trees is not attributable to harmful organisms, such as diseases, pests or other environmental factors. These would impact upon the entire tree, whereas damage to trees in the present study was only found on parts of the tree and only on one side (unilateral). Therefore, these factors cannot explain the damage documented here. Generally in all trees of this study, damage is higher in areas of high radiation and occurs on the side where the nearest phone mast is located (Table 4 and Fig. 3). Moreover, areas with more antennas have more levels of radiation and damaged trees are found most often in these high electromagnetic polluted areas. These results showed that side differences in damage corresponded to side differences in measured values of power flux density. This paper look at the effects on trees, but also provides information on how electromagnetic radiation is distributed in a city (interpolation map and Fig. 7).

In this study deciduous and coniferous trees were examined under the real radiofrequency field conditions around phone masts in Bamberg and Hallstadt. From most phone masts a broad band of frequencies with different modulations and pulse frequencies and fluctuating power densities is emitted (GSM 900, GSM 1800, UMTS, LTE, TETRA). Different signals may have different effects due to their physical parameters (Belyaev, 2010; IARC, 2013). We do not discriminate between these different signals and cannot answer the question which part of the

Table 6
Results of the tree measurements in the 30 points with low radiation.

												Effect codes												
												1	2	3	4	5	6	7	8	9	10	11	12	13
Nº	Scientific name	X	Y	Side antenna measurement µW/m²	Opposite side measurement µW/m²	Number of Phone Mast 1	Distance a 1	Number of Phone Mast 2	Distance a 2	Number of Phone Mast 3	Distance a 3	Damage only on one side	Sparse leaves or needles (crown transparency)	Brown leaves (start at leaf margins)	Colour change of leaves prematurely	leaves fall prematurely	Dead branches (Peak branches dried).	Tip of the main guide dried	Irregular growth	Not grow in eight	Color change of needles	Dead parts were trimmed down	damage on different sides	no damage
1	*Acer platanoides*	636741	5529855	26	20	25	636,3	33	784,1	35	798,8													+
2	*Carpinus betulus*	634853	5529041	10	8	42	234,5	62	476,4	41	500,1													+
3	*Carpinus betulus*	638311	5528439	12	10	50	229,7	45	563,5	12	750													+
4	*Carpinus betulus*	636753	5529880	8	8	25	609,6	33	811,5	28	823,5													+
5	*Carpinus betulus*	637817	5527130	15	12	53	432,1	15	633	51	806,6													+
6	*Carpinus betulus*	634931	5526731	15	15	24	286	6	310,3	65	428,6													+
7	*Tilia sp.*	636500	5529673	8	8	35	511,4	34	528,3	33	570,3													+
8	*Tilia sp.*	636824	5529794	17	9	25	635,7	28	713,1	33	755,3													+
9	*Quercus robur*	636455	5526130	9	8	64	497,5	65	1240	17	1425													+
10	*Quercus robur 'Fastigiata'*	636178	5528932	10	10	34	282,2	35	306,5	21	332													+
11	*Aesculus hippocastanum*	636828	5529780	10	10	25	645,5	28	699	33	744,2													+
12	*Aesculus carnea*	636463	5529709	12	12	35	526,1	34	551,4	33	608,6													+
13	*Robinia pseudoacacia*	635507	5528534	15	15	14	136,6	13	201,5	26	299,2													+
14	*Robinia pseudoacacia*	634720	5532783	8	8	60	216,7	63	559,3	59	868,7													+
15	*Acer campestre*	635697	5528689	40	30	14	136,5	22	155,8	11	246,8													+
16	*Acer campestre*	636486	5526116	6	6	64	526,2	65	1273	23	1437													+
17	*Juglans regia*	635744	5528667	20	15	22	119	14	145,7	11	202,8													+
18	*Platanus hispanica*	635496	5528529	17	15	14	148,4	13	204,1	26	289,9													+
19	*Prunus avium*	637958	5530874	10	8	18	412,4	40	502,6	39	551,4													+
20	*Prunus sp.*	636079	5528463	10	10	11	237,5	16	269,7	54	312,7													+
21	*Taxus baccata*	638407	5528502	5	5	50	316	45	673,6	12	864,8													+
22	*Taxus baccata*	638222	5531032	10	10	18	474	39	578,6	40	673,1													+
23	*Thuja occidentalis*	636518	5529853	9	9	8	648,4	35	680	34	705													+
24	*Thuja occidentalis*	635318	5528784	20	15	42	371,5	14	389,4	13	514,8													+
25	*Picea pungens*	636512	5529735	17	17	35	571,4	34	590,8	33	632													+
26	*Juniperus communis*	636549	5529756	8	8	35	607,8	34	623,4	33	653,7													+
27	*Cornus sanguinea*	638167	5529098	8	6	43	397,2	50	597,9	45	899,8													+
28	*Sambucus nigra*	635529	5525601	5	5	64	625,2	65	1121	24	1146													+
29	*Corylus avellana*	636422	5526181	5	3	64	476,4	65	1187	17	1371													+
30	*Corylus avellana*	636625	5529834	6	6	35	714	34	725,2	25	732,3													+

radiation has caused the damage. Nevertheless broad bands of frequencies, modulation, pulse frequencies, interferences and other physical characteristics may play an important role, since in some cases, damage already appears at low intensities. This can be a shortcoming of the study.

The aim of the present study was to find out whether there is a causal relationship between the unilateral tree damages, which had been observed since 2006, and the RF-EMF emitted from phone masts and a preliminary observation to find out whether various species react differently to RF exposure.

The selection of the 60 unilaterally damaged trees was limited by the fact that we could do measurements only up to a height of 6 m. Trees with damages above the height of 6 m could not be included.

Many factors can affect the health of trees: Air and soil pollutants, heat, frost, drought, as well as composition, compaction and sealing of the soil, road salts, root injury due to construction work, diseases and pests. Most of these factors do not affect a tree only on one side over a period of >5 years. Industrial air pollutants could eventually cause unilateral damage in direction to an industrial emitter. But the observed unilateral damages appeared in all directions and were not oriented to the incineration plant or other industrial plants. Root injury due to construction work can produce damage on one side of a tree, but 24 of the 60 selected trees were situated in gardens, parks or on the cemetery where they could not be affected by construction damages.

From the damaged side there was always visual contact to one or more phone mast (s). In each case measurements of the power flux density on the damaged side which was facing a phone mast and on the opposite side without (or with less) damage were carried out and the difference between the measured values on both sides was significant (Fig. 5), as well as between the exposed side of damaged trees and all other groups. In all 60 trees the gradient of damage corresponded to a gradient of measured values. The attenuation of the RF-EMF within the treetop offers an explanation: a part of the RF-EMF is absorbed by leaves or needles and another part is reflected, scattered and diffracted.

In the randomely selected group of 30 trees, 17 trees were situated on places with low radiation. These 17 trees showed no damages, the measured values were below 50 µW/m^2 (0.137 V/m) and there was no difference between opposite sides as in the low radiation group. On the other hand, 13 trees grew in the radiation field of one or more phone mast (s). These trees showed unilateral damage or damage on different sides. The measured values at damaged trees showed differences between both sides as in the previous group above.

In the group of 30 trees in areas with low radiation (radio shadow of hills, buildings or trees and without visual contact to phone masts)

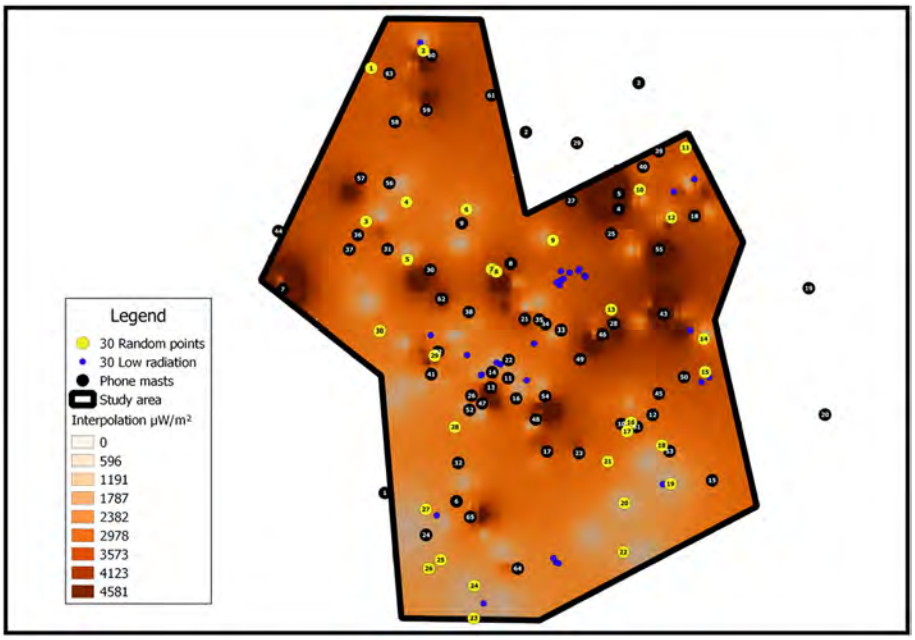


Fig. 4. Map showing the 30 trees at random points and the 30 trees in areas of low radiation (both with code numbers) over the interpolation electromagnetic map of the 144 measurement points. Phone masts (with code numbers) are also represented.

there were no unilateral damages. The measured values were below 50 µW/m^2 (0.137 V/m) and there was no difference between opposite sides. These results in the three groups point to a connection between unilateral tree damage and RF exposure.

In the electromagnetic field of all mobile phone base stations visited numerous tree damages were observed. The damage occurred in temporal relation with the putting into operation of new mobile phone base stations. Woody plants of all species are affected (deciduous and coniferous trees as well as shrubs).

In the five most represented species ($n \geq 4$) among the 60 damaged trees (*Acer platanoides*, *Carpinus betulus*, *Tilia* sp., *Taxus baccata* and *Thuja occidentalis*), most trees showed damage only on one side (Damage code 1, Tables 2 and 4). Most of these trees were characterized with sparse leaves or needles (crown transparency) (Damage code 2, Tables 2 and 4). In many of the trees with the one-sided damage, the leaves turned prematurely yellow or brown in June – this always began at the leaf margins (Damage code 3, Tables 2 and 4). In many trees leaves fall prematurely (Damage code 5, Tables 2 and 4) or had dead branches (Peak branches dried) (Damage code 6, Tables 2 and 4). Some trees stopped growing in height while, in others, the main guide died (see Tables 2 and 4).

The differences in susceptibility of different species could be related to radiofrequency energy absorption properties of the trees (e.g., dielectric property). Perhaps this study cannot answer questions about these differences, however it is quite possible that differences are related to the electrical conductivity, related also with the density of the wood (species of fast or slow growth) and particularly with the percentage of water in the tissues. Poplars and aspen that grow near rivers and water bodies in Spain seem to be particularly sensitive to the effects of radiation. But the waves reflection in the water could also influence.

The results presented here lead us to conclude that damage found in the selected trees is caused by electromagnetic radiation from phone

Table 7
Repeated measures ANOVA analysis and Bonferroni post hoc comparisons ($p < 0.01$ values with *) in the three types of trees (damaged, random, and low radiation). Measurement Side 1/2 correspond to the maximum/minumum value of radiation respectively for the opposite sides of each tree.

	SS	Degr. of	MS	F	p
Intercept	62663309	1	62663309	25.81460	0.000001*
Type of tree	52931692	2	26465846	10.90280	0.000046*
Error	284010086	117	2427437		
R1	33197069	1	33197069	18.28694	0.000039*
R1*Type of tree	44608664	2	22304332	12.28656	0.000014*
Error	212395158	117	1815343		

	Type of tree	R1	{1}	{2}	{3}	{4}	{5}	{6}
1	Damaged	Measurement Side1		0.000000*	0.001829*	0.000001*	0.000000*	0.000000*
2	Damaged	Measurement Side2	0.000000*		1.000000	1.000000	1.000000	1.000000
3	Random	Measurement Side1	0.001829*	1.000000		1.000000	1.000000	1.000000
4	Random	Measurement Side2	0.000001*	1.000000	1.000000		1.000000	1.000000
5	Low radiation	Measurement Side1	0.000000*	1.000000	1.000000	1.000000		1.000000
6	Low radiation	Measurement Side2	0.000000*	1.000000	1.000000	1.000000	1.000000	

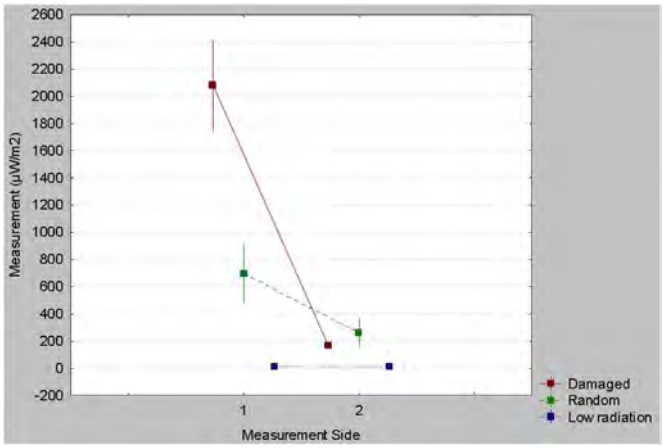


Fig. 5. Differences between measurements in both sides for the three different tree groups: damaged, random, and low radiation. Measurement Side 1/2 correspond to the maximum/minumum value of radiation respectively for the opposite sides of each tree. The bars represent means ± standard errors. The central point represents the mean and the straight line ± 0.95*SE.

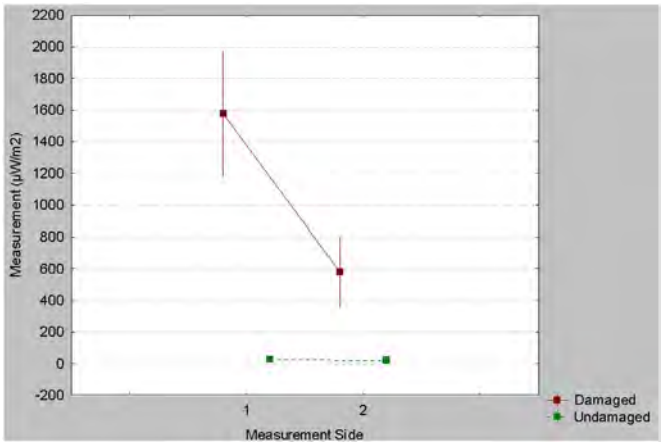


Fig. 6. Differences between measurements in both sides for the damaged and undamaged trees within the random trees group. Measurement side 1/2 correspond to the maximum/minumum value of radiation respectively for the opposite sides of each tree. The bars represent means ± standard errors. The central point represents the mean and the straight line ± 0.95*SE.

masts, as we proposed in previous studies (Balmori, 2004; Waldmann-Selsam, 2007; Waldmann-Selsam and Eger, 2013; Balmori, 2014). Interested parties are able to locate the damaged trees found in this work in Bamberg and Hallstadt with their UTM coordinates. However, trees with code numbers 20, 38 and 48 (Table 4) have been cut down and removed.

Research on the effects of radiation from phone masts is advancing rapidly. In February 2011 the first symposium on the effects of electromagnetic radiation on trees took place in Baarn, Netherlands (Schorpp, 2011 - http://www.boomaantastingen.nl/), where similar effects and results to those found in the current paper were presented.

Although there are some related experiments that show no effect of long-term exposure (3,5 years), 2450-MHz (continous wave) and power flux densities from 0.007 to 300 W/m^2 on crown transparency, height growth and photosynthesis of young spruce and beech trees (Schmutz et al., 1996), this result may not be transferred to modulated 2450-MHz or to other pulsed and modulated frequencies. In addiction, an increasing number of studies have highlighted biological responses and modifications at the molecular and whole plant level after exposure to high frequency electromagnetic fields (Vian et al., 2016). Plants can perceive and respond to various kinds of electromagnetic radiation over a wide range of frequencies. Moreover, a low electric field intensity (5 V/m) was sufficient to evoke morphological responses (Grémiaux et al., 2016). Electromagnetic radiation impacts at physiological and ecological levels (Cammaerts and Johansson, 2015), and evokes a multitude of responses in plants. The effects of high frequency electromagnetic fields can also take place at the subcellular level: it can alter the activity of several enzymes, including those of reactive oxygen species (ROS) metabolism, a well-known marker of plant responses to various kinds of environmental factors; it evokes the expression of specific genes previously implicated in plant responses to wounding (gene expression modifications), and modifies the growth of the whole plants (Vian et al., 2016). It could be hypothesized that membrane potential variations in response to electromagnetic radiation exposure may initiate electrical waves of depolarization (AP and/or VP) that could initiate immediate or delayed growth responses (Grémiaux et al., 2016). It has been proposed that electromagnetic fields act similarly in plants and in animals, with the probable activation of calcium channels via their voltage sensor (Pall, 2016).

Electromagnetic radiation (1800 MHz) interferes with carbohydrate metabolism and inhibits the growth of *Zea mays* (Kumar et al., 2015). Furthermore, cell phone electromagnetic radiation inhibits root growth of the mung bean (*Vigna radiata*) by inducing ROS-generated oxidative stress despite increased activities of antioxidant enzymes (Sharma et al., 2009). Germination rate and embryonic stem length of *Triticum aestivum* was also affected by cell phone radiation (Hussein and El-Maghraby, 2014). After soybeans were exposed to weak microwave radiation from the GSM 900 mobile phone and base station, growth of

Table 8
Repeated measures ANOVA analysis and Bonferroni post hoc comparisons ($p < 0.01$ values with *) in the random trees group. Measurement Side 1/2 correspond to the maximum/minumum value of radiation respectively for the opposite sides of each tree.

	SS	Degr. of	MS	F	p
Intercept	17829607	1	17829607	16.60985	0.000343*
13 code	16391606	1	16391606	15.27023	0.000538*
Error	30056202	28	1073436		
R1	3701923	1	3701923	16.73250	0.000329*
R1*13 code	3627579	1	3627579	16.39647	0.000368*
Error	6194761	28	221241		

	13 code	R1	{1}	{2}	{3}	{4}
1	Undamaged	Measurement Side 1		1.000000	0.002129*	0.416303
2	Undamaged	Measurement Side 2	1.000000		0.000034*	0.927155
3	Damaged	Measurement Side 1	0.002129*	0.000034*		0.000055*
4	Damaged	Measurement Side 2	0.416303	0.927155	0.000055*	

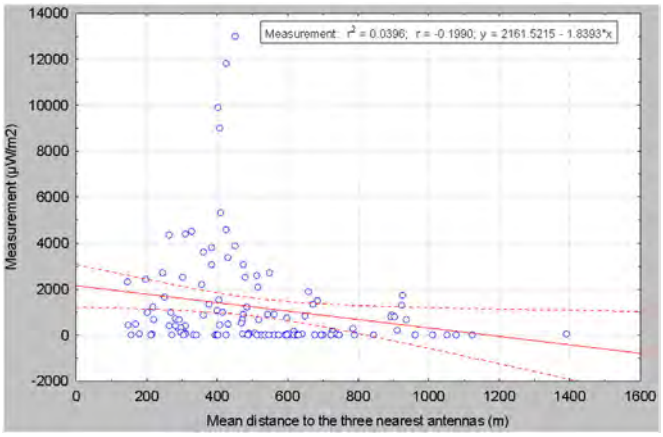


Fig. 7. Scatterplot showing the correlation between measurements from each of the 120 trees and the mean distance to the three nearest antennas. Dashed lines represent the 0.95 confidence interval.

epicotyl and hypocotyl was reduced, whereas the outgrowth of roots was stimulated. These findings indicate that the observed effects were significantly dependent on field strength as well as amplitude modulation of the applied field (Halgamuge et al., 2015). Phone mast radiation also affects common cress (*Lepidium sativum*) seed germination (Cammaerts and Johansson, 2015). In *Arabidopsis thaliana*, the long term exposure to non ionizing radiation causes a reduction in the number of chloroplasts as well as the decrease of stroma thylakoids and the photosynthetic pigments (Stefi et al., 2016). Finally, low-intensity exposure to radiofrequency fields can induce mitotic aberrations in root meristematic cells of *Allium cepa*; the observed effects were markedly dependent on the frequencies applied as well as on field strength and modulation (Tkalec et al., 2009).

In general, polarization from man-made electromagnetic radiation appears to have a greater bioactive effect than natural radiation, and significantly increases the probability for initiation of biological or health effects (Panagopoulos et al., 2015).

Tree damages as in Bamberg and Hallstadt were documented by the authors in several countries: Spain (Valladolid, Salamanca, Madrid, Palencia, León), Germany (Munich, Nürnberg, Erlangen, Bayreuth, Neuburg/Donau, Garmisch-Partenkirchen, Murnau, Stuttgart, Kassel, Fulda, Göttingen, biosphere reserve Rhön, Tegernsee Valley and in several small towns), Austria (Graz), Belgium (Brussels) and Luxemburg.

Each phone mast can harm many trees and each tree can be affected by several phone masts belonging to the same or different base stations. Damaged trees seem to exist around each antenna and the several million phone masts in the world could potentially be damaging the growth and health of millions of trees. This can occur not only in cities, but also in well-preserved forests, and in natural and national parks, where base stations are being installed without the necessary prior environmental impact studies, due to a lack of knowledge of the problem. For this reason, it is essential for an assessment on the environmental impact of any new base station prior to implementation.

Additionally, phone masts can cause a drop in timber productivity in plantations of pine, poplar, etc., as well as fruits, nuts, etc. Thus, the industry must be required to pay damages to plantation owners. Similarly, as trees are a common social good, the industry should compensate for damaged and dead trees around the world due to radiation. Further, the money spent by municipalities to repair or replace damaged trees should enter into the computation of costs/benefits of this technology. For installation of any new technology, the burden of proof should be to the industry that requires demonstration of safety prior to deployment.

Electromagnetic radiation from telecommunication antennas affected the abundance and composition of wild pollinators in natural habitats and these changes in the composition of pollinator communities associated with electromagnetic smog may have important ecological and economic impacts on the pollination service that could significantly affect the maintenance of wild plant diversity, crop production and human welfare (Lázaro et al., 2016).

Evidence for plant damage due to high frequency electromagnetic radiation was not taken into account in determining the current statutory regulations (the limit values). Once the problem becomes evident, the guidelines of radiation emitted by the antennas should be reviewed. Proper risk assessment of electromagnetic radiation should be undertaken to develop management strategies for reducing this pollution in the natural environment (Kumar et al., 2015).

Moreover, due to the lack of recognition, certain modern projects with interesting ideas for decreasing environmental pollution could have opposite effects than expected. For example, in the Netherlands, the TreeWiFi project (http://treewifi.org/), which aims to motivate people to use bikes and public transport in order to reduce the [NO2] pollution providing free WiFi when air quality improves, could be favoring electromagnetic pollution with even more harmful effects as it has been demonstrated in this manuscript (see also: http://www.greenpeace.org/canada/fr/Blog/le-wi-fi-tuerait-les-ar-bres/blog/33569/).

In addition, the number of sector antennas has increased in Bamberg and this increase appears to be accelerating: 483 sector antennas in 2011 and 779 sector antennas in 2015. Both radiation and damaged trees represent a loss of quality of life for citizens. This study began after finding that patients who claimed to be affected by phone masts, referred to as radiation, live in areas where affected trees and plants are located. Evidence of radiation damage was even found in potted plants inside patient homes (Waldmann-Selsam and Eger, 2013). Thus, this study is certainly complementary to the study by Eger and Jahn (2010) and other research that has shown effects on the health of people by phone masts located in their vicinity (Santini et al., 2002; Eger et al., 2004; Wolf and Wolf, 2004; Abdel-Rassoul et al., 2007; Khurana et al., 2010; Dode et al., 2011; Gómez-Perretta et al., 2013; Shahbazi-Gahrouei et al., 2014; Belyaev et al., 2015).

In the introduction to the International Seminar on "Effects of Electromagnetic Fields on the Living Environment" in 1999 in Ismaning, Germany, organized by WHO, ICNIRP and German Federal Office for Radiation Protection (BfS), M. Repacholi, head of the International EMF Project of the WHO, said: "By comparison, influences of these fields on plants, animals, birds and other living organisms have not been properly examined. Given that any adverse impacts on the environment will ultimately affect human life, it is difficult to understand why more work has not been done. There are many questions that need to be raised: …" and "…it seems that research should focus on the long-term, low-level EMF exposure for which almost no information is available. Specific topics that need to be addressed include: … EMF influences on agricultural plants and trees" (Matthes et al., 2000).

5. Conclusions

In this study we found a high-level damage in trees within the vicinity of phone masts. Preliminary laboratory studies have indicated some deleterious effects of radiofrequency radiation. However, these early warnings have had no success and deployment has been continued without consideration of environmental impact.

We observed trees with unilateral damage in the radiation field of phone masts. We excluded the possibility that root injury due to construction work or air pollutants could have caused the unilateral damage. We found out that from the damaged side there was always visual contact to one or more phone mast (s).

Statistical analyses demonstrated that the electromagnetic radiation from cellphone towers is harmful to trees. Results show that the measurements in the most affected sides of damaged trees (i.e. those that withstand higher radiation levels) are different to all other groups. These results are consistent with the fact that damage inflicted on

trees by cellphone towers usually start on one side, extending to the whole tree over time.

The occurrence of unilateral damage is the most important fact in our study and an important argument for a causal relationship with RF-EMF, as it supplies evidence for non-thermal RF-EMF effects. This constitutes a danger for trees worldwide. The further deployment of phone masts has to be stopped. Scientific research on trees under the real radiofrequency field conditions must continue.

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References

Abdel-Rassoul, G., El-Fateh, O.A., Salem, M.A., Michael, A., Farahat, F., El-Batanouny, M., Salem, E., 2007. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology 28, 434–440.

Balmori, A., 2004. Pueden afectar las microondas pulsadas emitidas por las antenas de telefonía a los árboles y otros vegetales? Ecosistemas 13, 79–87.

Balmori, A., 2014. Electrosmog and species conservation. Sci. Total Environ. 496, 314–316.

Balmori, A., 2015. Anthropogenic radiofrequency electromagnetic fields as an emerging threat to wildlife orientation. Sci. Total Environ. 518, 58–60.

Balodis, V.G., Brumelis, K., Kalviskis, O., Nikodemus, D., Tjarve, V.Z., 1996. Does the Skrunda Radio Location Station disminish the radial growth of pine trees? Sci. Total Environ. 180, 57–64.

Beaubois, E., Girard, S., Lallechere, S., Davies, E., Paladian, F., Bonnet, P., Ledoit, G., Vian, A., 2007. Intercellular communication in plants: evidence for two rapidly transmitted systemic signals generated in response to electromagnetic field stimulation in tomato. Plant Cell Environ. 30, 834–844.

Belyaev, I., 2010. Dependence of non-thermal biological effects of microwaves on physical and biological variables: implications for reproducibility and safety standards. In: Giuliani, L., Soffritti, M. (Eds.), European Journal of Oncology - Library Non-thermal effects and mechanisms of interaction between electromagnetic fields and living matterAn ICEMS Monograph vol. 5. RAMAZZINI INSTITUTE, Bologna, Italy (http://www.icems.eu/papers.htm?f=/c/a/2009/12/15/MNHJ1B49KH.DTL).

Belyaev, I., Dean, A., Eger, H., Hubmann, G., Jandrisovits, R., Johansson, O., Moshammer, H., Kern, M., Kundi, M., Lercher, P., Mosgoller, W., Moshammer, H., Muller, K., Oberfeld, G., Ohnsorge, P., Pelzmann, P., Scheingraber, C., Thill, R., 2015. EUROPAEM EMF Guideline 2015 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. Rev. Environ. Health 30, 337–371.

Bernatzky, A., 1986. Elektromagnetischer Smog – Feind des Lebens. Der Naturarzt 11, 22–25 (http://www.diewellenbrecher.de/pdf/bernatzky.pdf).

Brauer, I., 1950. Experimentelle Untersuchungen über die Wirkung von Meterwellen verschiedener Feldstärke auf das Teilungswachstum der Pflanzen. Chromosoma 3, 483–509 (http://www.springerlink.com/content/kqn177g8g5114787/, letzter Zugriff: 30.5.2013).

Cammaerts, M.C., Johansson, O., 2015. Effect of man-made electromagnetic fields on common Brassicaceae *Lepidium sativum* (cress d'Alinois) seed germination: a preliminary replication study. Fyton 84, 132–137.

Dode, A.C., Leão, M.M., de AF Tejo, F., Gomes, A.C., Dode, D.C., Dode, M.C., Caiaffa, W.T., 2011. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. Sci. Total Environ. 409, 3649–3665.

Eger, H., Uwe, K., Hagen, B., Lucas, P., Vogel, P., Voit, H., 2004. Einfluss der räumlichen Nähe von Mobilfunksendeanlagen auf die Krebsinzidenz. Umwelt Med. Ges. 17, 326–332.

Eger, H., Jahn, M., 2010. Specific symptoms and radiation from mobile basis stations in Selbitz, Bavaria, Germany: evidence for a dose-effect relationship (original article in German). Umwelt Med. Ges. 23, 130–139.

ESRI (Environmental Systems Research Institute), 2008. ArcMap 9.3 (Build 1770). ESRI® ArcGIS, 9, 1999–2008.

Gómez-Perretta, C., Navarro, E.A., Segura, J., Portolés, M., 2013. Subjective symptoms related to GSM radiation from mobile phone base stations: a cross-sectional study. BMJ open 3 (12), e003836.

Grémiaux, A., Girard, S., Guérin, V., Lothier, J., Baluška, F., Davies, E., Bonnet, P., Vian, A., 2016. Low-amplitude, high-frequency electromagnetic field exposure causes delayed and reduced growth in Rosa hybrid. J. Plant Physiol. 190, 44–53.

Haggerty, K., 2010. Adverse influence of radio frequency background on trembling aspen seedlings: preliminary observations. Int. J. For. Res. 2010, 836278.

Halgamuge, M.N., Yak, S.K., Eberhardt, J.L., 2015. Reduced growth of soybean seedlings after exposure to weak microwave radiation from GSM 900 mobile phone and base station. Bioelectromagnetics 36, 87–95.

Harte, C., 1950. Mutationsauslösung durch Ultrakurzwellen. Chromosoma 3, 140–147.

Harte, C., 1972. Auslösung von Chromosomenmutationen durch Meterwellen in Pollenmutterzellen von Oenothera. Chromosoma 36, 329–337 (http://www.springerlink.com/content/x32049jrnm4u7858/).

Hussein, R.A., El-Maghraby, M.A., 2014. Effect of two brands of cell phone on germination rate and seedling of wheat (*Triticum aestivum*). J. Environ. Pollut. Human Health 2, 85–90.

IARC, 2013. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields vol. 102. IARC Press, Lyon, France (http://monographs.iarc.fr/ENG/Monographs/vol102/mono102.pdf).

I. C. N. I. R. P., 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Phys. 74 (4), 494–522.

Jayasanka, S.M.D.H., Asaeda, T., 2013. The significance of microwaves in the environment and its effect on plants. Environ. Rev. 22, 220–228.

Jerman, I., Berden, M., Ruzic, R., Skarja, M., 1998. Biological effects of TV set electromagnetic fields on the growth of spruce seedlings. Electromagn. Biol. Med. 17, 31–42.

Kiepenheuer, K.O., Brauer, I., Harte, C., 1949. Über die Wirkung von Meterwellen auf das Teilungswachstum der Pflanzen. Naturwissenschaften 36, 27.

Kundu, A., IEEE, 2013. Specific Absorption Rate evaluation in apple exposed to RF radiation from GSM mobile towers. IEEE Applied Electromagnetics Conference (AEMC). IEEE, pp. 1–2 (ISBN 978-1-4799-3266-5).

Khurana, V.G., Hardell, L., Everaert, J., Bortkiewicz, A., Carlberg, M., Ahonen, M., 2010. Epidemiological evidence for a health risk from mobile phone base stations. Int. J. Occup. Environ. Health 16, 263–267.

Kumar, A., Singh, H.P., Batish, D.R., Kaur, S., Kohli, R.K., 2015. EMF radiations (1800 MHz)-inhibited early seedling growth of maize (*Zea mays*) involves alterations in starch and sucrose metabolism. Protoplasma 1–7.

Lázaro, A., Chroni, A., Tscheulin, T., Devalez, J., Matsoukas, C., Petanidou, T., 2016. Electromagnetic radiation of mobile telecommunication antennas affects the abundance and composition of wild pollinators. J. Insect Conserv. 1–10 http://dx.doi.org/10.1007/s10841-016-9868-8.

Lerchl, D., Lerchl, A., Hantsch, P., et al., 2000. Studies on the effects of radio-frequency fields on conifers, Kurzmitteilung auf der Tagung der Bioelectromagnetics Society in München. http://www.boomaantastingen.nl/EMF_and_conifers%5B1%5D.pdf.

Matthes, R., Bernhardt, J.H., Repacholi, M.H., 2000. Effects of electromagnetic fields on the living environment. Proceedings International Seminar on Effects of Electromagnetic Fields on the Living Environment – Ismaning, Germany, October 4 and 5, 1999, ICNIRP 10/2000.

Meng, Y.S., Lee, Y.H., 2010. Investigations of foliage effect on modern wireless communication systems: a review. Prog. Electromagn. Res. 105, 313–332.

Pall, M., 2016. Electromagnetic fields act similarly in plants as in animals: probable activation of calcium channels via their voltage sensor. Curr. Chem. Biol. (http://benthamscience.com/journals/current-chemical-biology/article/141390/).

Panagopoulos, D.J., Johansson, O., Carlo, G.L., 2015. Polarization: a key difference between man-made and natural electromagnetic fields, in regard to biological activity. Sci. Rep. 5, 14914. http://dx.doi.org/10.1038/srep14914.

Panagopoulos, D.J., Cammaerts, M.C., Favre, D., Balmori, A., 2016. Comments on environmental impact of radiofrequency fields from mobile phone base stations. Crit. Rev. Environ. Sci. Technol. http://dx.doi.org/10.1080/10643389.2016.1182107.

Pesnya, D.S., Romanovsky, A.V., 2013. Comparison of cytotoxic and genotoxic effects of plutonium-239 alpha particles and mobile phone GSM 900 radiation in the *Allium cepa* test. Mutat. Res. Genet. Toxicol. Environ. Mutagen. 750, 27–33.

QGIS Development Team, 2014. Quantum GIS geographic information system version 2.6.0-Brighton [Internet]. http://qgis.osgeo.org.

Roux, D., Vian, A., Girard, S., Bonnet, P., Paladian, F., Davies, E., Ledoigt, G., 2006. Electromagnetic fields (900 MHz) evoke consistent molecular responses in tomato plants. Physiol. Plant. 128, 283–288.

Roux, D., Vian, A., Girard, S., Bonnet, P., Paladian, F., Davies, E., Ledoigt, G., 2008. High frequency (900 MHz) low amplitude (5 V m − 1) electromagnetic field: a genuine environmental stimulus that affects transcription, translation, calcium and energy charge in tomato. Planta 227, 883–891.

Sandu, D.D., Goiceanu, C., Ispas, A., Creanga, I., Miclaus, S., Creanga, D.E., 2005. A preliminary study on ultra high frequency electromagnetic fields effect on black locust chlorophylls. Acta Biol. Hung. 56, 109–117.

Santini, R., Santini, P., Danze, J.M., Le Ruz, P., Seigne, M., 2002. Study of the health of people living in the vicinity of mobile phone base stations: I. Influences of distance and sex. Pathol. Biol. 50, 369–373.

Schmutz, P., Siegenthaler, J., Stäger, C., Tarjan, D., Bucher, J.B., 1996. Long-term exposure of young spruce and beech trees to 2450 MHz microwave radiation. Sci. Total Environ. 180, 43–48.

Schorpp, V., 2011. Tree damage from chronic high frequency exposure. The effect of electromagnetic radiation on trees, First symposium February 18, 2011, Lecture, Baan, Netherlands (http://www.puls-schlag.org/download/Schorpp-2011-02-18.pdf).

Selga, T., Selga, M., 1996. Response of *Pinus sylvestris* L. needles to electromagnetic fields. Cytological and ultrastructural aspects. Sci. Total Environ. 180, 65–73.

Shahbazi-Gahrouei, D., Karbalae, M., Moradi, H.A., Baradaran-Ghahfarokhi, M., 2014. Health effects of living near mobile phone base transceiver station (BTS) antennae: a report from Isfahan, Iran. Electromagn. Biol. Med. 33, 206–210.

Sharma, V.P., Singh, H.P., Kohli, R.K., Batish, D.R., 2009. Mobile phone radiation inhibits *Vigna radiata* (mung bean) root growth by inducing oxidative stress. Sci. Total Environ. 407, 5543–5547.

StatSoft, Inc, 2004. STATISTICA (data analysis software system), version 7. www.statsoft.com.

Stefi, A.L., Margaritis, L.H., Christodoulakis, N.S., 2016. The effect of the non ionizing radiation on cultivated plants of *Arabidopsis thaliana* (Col.). Flora 223, 114–120.

Tkalec, M., Malarić, K., Pevalek-Kozlina, B., 2005. Influence of 400, 900, and 1900 MHz. electromagnetic fields on *Lemna minor* growth and peroxidase activity. Bioelectromagnetics 26, 185–193.

Tkalec, M., Malarić, K., Pavlica, M., Pevalek-Kozlina, B., Vidaković-Cifrek, Ž., 2009. Effects of radiofrequency electromagnetic fields on seed germination and root meristematic cells of *Allium cepa* L. Mutat. Res. Genet. Toxicol. Environ. Mutagen. 672, 76–81.

Van't Wout, N., 2006. Unkown tree damage. http://www.boomaantastingen.nl.

Vian, A., Davies, E., Gendraud, M., Bonnet, P., 2016. Plant responses to high frequency electromagnetic fields. Biomed. Res. Int. 2016, 1830262. http://dx.doi.org/10.1155/2016/1830262.

Volkrodt, W., 1987. Wer ist am Waldsterben schuld? Mikrowellensmog der Funk- und Nachrichtensysteme. Raum Zeit 26, 53–62.

Volkrodt, W., 1991. Droht den Mikrowellen ein ähnliches Fiasko wie der Atomenergie? Wetter-Boden-Mensch 4, 16–23.

Waldmann-selsam, C., 2007. Mikrowellensyndrom – ein neues Krankheitsbild, Vortrag, 6. Rheinland-Pfälzisch-Hessisches Mobilfunksymposium, 14.4.2007, BUND Rheinland-Pfalz, Mainz. http://www.bund-rlp.de/publikationen/tagungsbaende/mobilfunksymposium/6_mobilfunksymposium/.

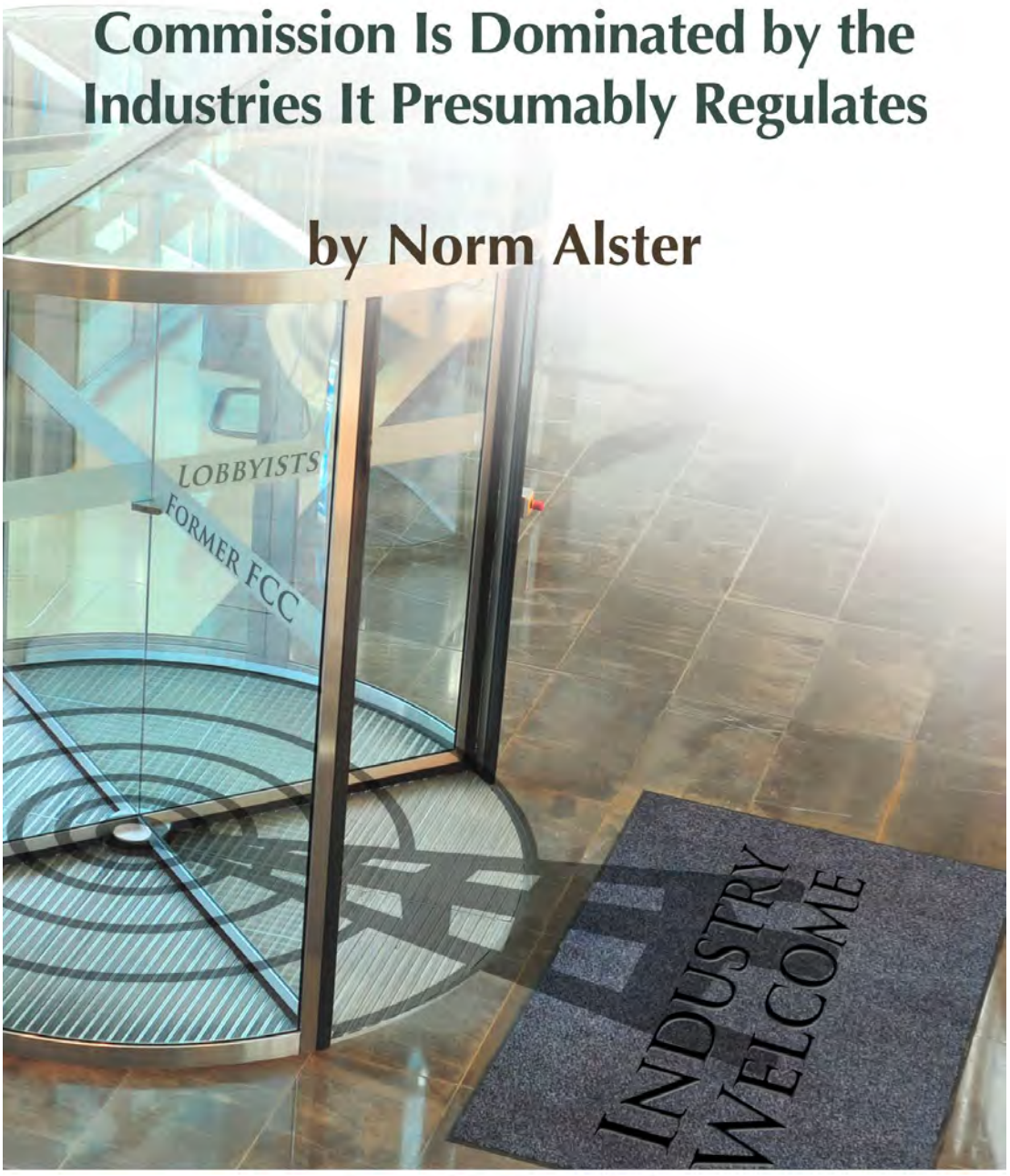
Waldmann-Selsam, C., Eger, H., 2013. Baumschäden im Umkreis von Mobilfunksendeanlagen. Umwelt Med. Ges. 26, 198–208 (http://kompetenzinitiative.net/KIT/wp-content/uploads/2016/06/Tree-damages-in-the-vicinity-of-mobile-phone-base-stations.pdf).

Wolf, R., Wolf, D., 2004. Increased incidence of cancer near a cell-phone transmitter station. Int. J. Cancer 1, 123–128.

Captured Agency:

How the Federal Communications Commission Is Dominated by the Industries It Presumably Regulates

by Norm Alster



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CONTENTS

Chapter One: The Corrupted Network

Renee Sharp seemed proud to discuss her spring 2014 meeting with the Federal Communications Commission.

As research director for the non-profit Environmental Working Group, Sharp doesn't get many chances to visit with the FCC. But on this occasion she was able to express her concerns that lax FCC standards on radiation from wireless technologies were especially hazardous for children.

The FCC, however, should have little trouble dismissing those concerns.

Arguing that current standards are more than sufficient and that children are at no elevated risk from microwave radiation, wireless industry lobbyists don't generally have to set up appointments months in advance. They are at the FCC's door night and day.

Indeed, a former executive with the Cellular Telecommunications Industry Association (CTIA), the industry's main lobbying group, has boasted that the CTIA meets with FCC officials "500 times a year."[1]

Sharp does not seem surprised. "There's no question that the government has been under the influence of industry. The FCC is a captured agency," she said.[2]

Captured agency.

That's a term that comes up time and time again with the FCC. Captured agencies are essentially controlled by the industries they are supposed to regulate. A detailed look at FCC actions—and non-actions—shows that over the years the FCC has granted the wireless industry pretty much what it has wanted. Until very recently it has also granted cable what it wants. More broadly, the FCC has again and again echoed the lobbying points of major technology interests.

Money—and lots of it—has played a part. The National Cable and Telecommunications Association (NCTA) and CTIA have annually been among Washington's top lobbying spenders. CTIA alone lobbied on at least 35 different Congressional bills through the first half of 2014. Wireless market leaders AT&T and Verizon work through CTIA. But they also do their own lobbying, spending nearly $15 million through June of 2014, according to data from the Center for Responsive Politics (CRP). In all, CTIA, Verizon, AT&T, T-Mobile USA, and Sprint spent roughly $45 million lobbying in 2013. Overall, the Communications/Electronics sector is one of Washington's super heavyweight lobbyists, spending nearly $800 million in 2013-2014, according to CRP data.

But direct lobbying by industry is just one of many worms in a rotting apple. The FCC sits at the core of a network that has allowed powerful moneyed interests with limitless access a variety of ways to shape its policies, often at the expense of fundamental public interests.

As a result, consumer safety, health, and privacy, along with consumer wallets, have all been overlooked, sacrificed, or raided due to unchecked industry influence. The cable industry has consolidated into giant local monopolies that control pricing while leaving consumers little choice over content selection. Though the FCC has only partial responsibility, federal regulators have allowed the Internet to grow into a vast hunting grounds for criminals and commercial interests: the go-to destination for the surrender of personal information, privacy and identity. Most insidious of all, the wireless industry has been allowed to grow unchecked and virtually unregulated, with fundamental questions on public health impact routinely ignored.

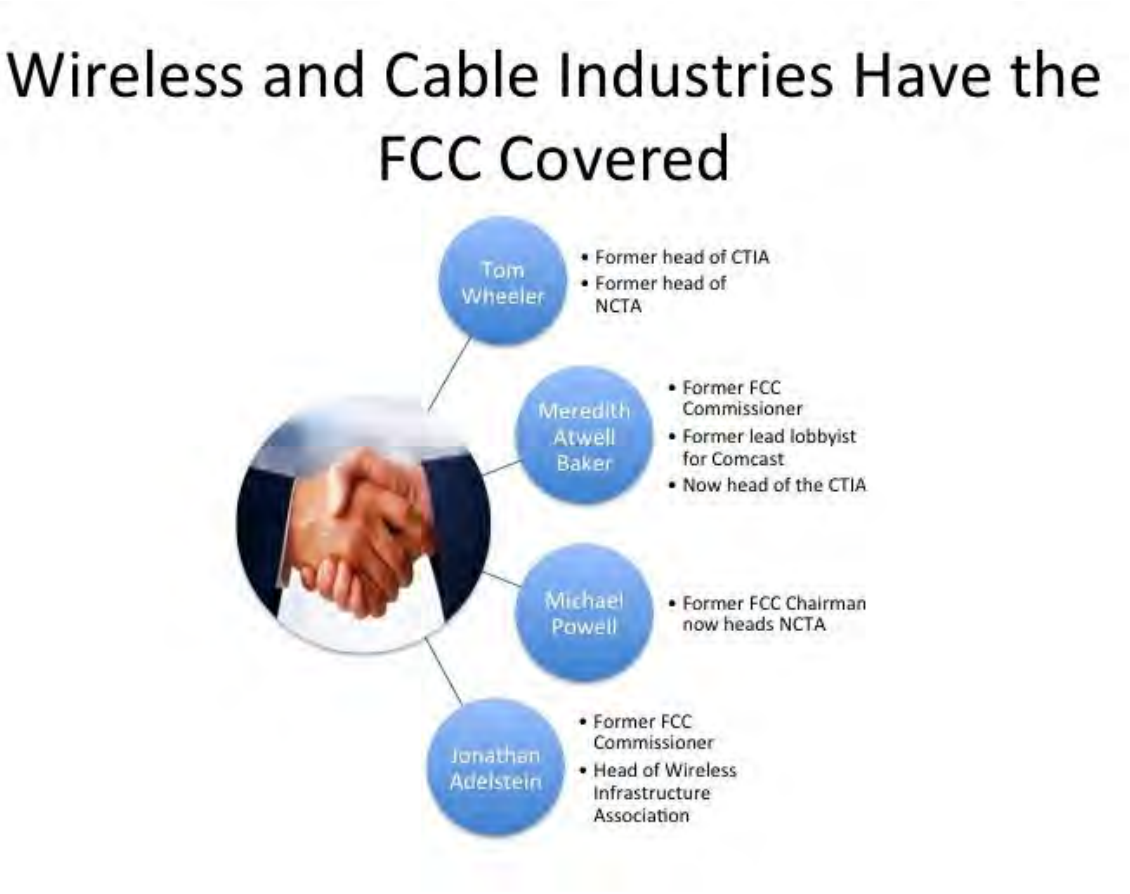
Industry controls the FCC through a soup-to-nuts stranglehold that extends from its well-placed campaign spending in Congress through its control of the FCC's Congressional oversight committees to its persistent agency lobbying. "If you're on a committee that regulates industry you'll be a major target for industry," said Twaun Samuel, chief of staff for Congresswoman Maxine Waters.[3] Samuel several years ago helped write a bill aimed at slowing the revolving door. But with Congress getting its marching orders from industry, the bill never gained any traction.

Industry control, in the case of wireless health issues, extends beyond Congress and regulators to basic scientific research. And in an obvious echo of the hardball tactics of the tobacco industry, the wireless industry has backed up its economic and political power by stonewalling on public relations and bullying potential threats into submission with its huge standing army of lawyers. In this way, a coddled wireless industry intimidated and silenced the City of San Francisco, while running roughshod over local opponents of its expansionary infrastructure.

On a personal level, the entire system is greased by the free flow of executive leadership between the FCC and the industries it presumably oversees. Currently presiding over the FCC is Tom Wheeler, a man who has led the two most powerful industry lobbying groups: CTIA and NCTA. It is Wheeler who once supervised a $25 million industry-funded research effort on wireless health effects. But when handpicked research leader George Carlo concluded that wireless radiation did raise the risk of brain tumors, Wheeler's CTIA allegedly rushed to muffle the message. "You do the science. I'll take care of the politics," Carlo recalls Wheeler saying.[4]

Wheeler over time has proved a masterful politician. President Obama overlooked Wheeler's lobbyist past to nominate him as FCC chairman in 2013. He had, after all, raised more than $700,000 for Obama's presidential campaigns. Wheeler had little trouble earning confirmation from a Senate whose Democrats toed the Presidential line and whose Republicans understood Wheeler was as industry-friendly a nominee as they could get. And while Wheeler, at the behest of his Presidential sponsor, has taken on cable giants with his plans for net neutrality and shown some openness on other issues, he has dug in his heels on wireless.

Newly ensconced as chairman of the agency he once blitzed with partisan pitches, Wheeler sees familiar faces heading the industry lobbying groups that ceaselessly petition the FCC. At CTIA, which now calls itself CTIA - The Wireless Association, former FCC commissioner Meredith Atwell Baker is in charge.

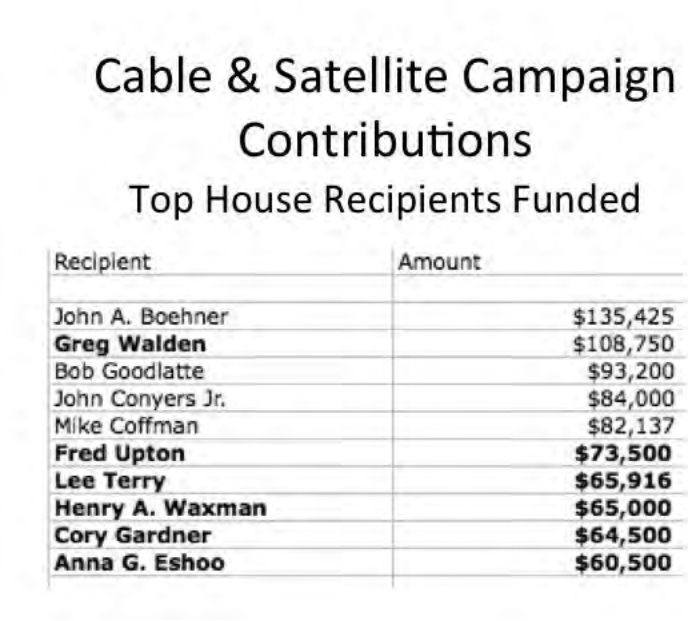


And while cell phone manufacturers like Apple and Samsung, along with wireless service behemoths like Verizon and AT&T, are prominent CTIA members, the infrastructure of 300,000 or more cellular base stations and antenna sites has its own lobbying group: PCIA, the Wireless Infrastructure Association. The President and CEO of PCIA is Jonathan Adelstein, another former FCC commissioner. Meanwhile, the cable industry‘s NCTA employs former FCC chairman Michael Powell as its president and CEO. Cozy, isn‘t it?

FCC commissioners in 2014 received invitations to the Wireless Foundation‘s May 19th Achievement Awards Dinner. Sounds harmless, but for the fact that the chief honoree at the dinner was none other than former wireless lobbyist but current FCC Chairman Tom Wheeler. Is this the man who will act to look impartially at the growing body of evidence pointing to health and safety issues?

The revolving door also reinforces the clout at another node on the industry-controlled influence network. Members of congressional oversight committees are prime targets of

industry. The cable industry, for example, knows that key legislation must move through the Communications and Technology Subcommittee of the House Energy and Commerce Committee. Little wonder then that subcommittee chairman Greg Walden was the second leading recipient (after Speaker John Boehner) of cable industry contributions in the last six years (through June 30, 2014). In all, Walden, an Oregon Republican, has taken over $108,000 from cable and satellite production and distribution companies.[5] But he is not alone. Six of the top ten recipients of cable and satellite contributions sit on the industry's House oversight committee. The same is true of senators on the cable oversight committee. Committee members were six of the ten top recipients of campaign cash from the industry.[6]



Cellular Industry Campaign Contributions

Top House Recipients Funded

Recipient	Amount
Henry A. Waxman	**$41,500**
Scott H. Peters	$40,300
Greg Walden	**$35,750**
Fred Upton	**$32,250**
Bob Goodlatte	$31,250
Lee Terry	**$29,600**
Anna G. Eshoo	**$27,000**
Doris O. Matsui	**$25,500**
John Shimkus	**$24,000**
Peter J. Roskam	$21,100

Cable & Satellite Campaign Contributions

Top Senate Recipients Funded

Recipient	Amount
Edward J. Markey	**$320,500**
Kirsten E. Gillibrand	$194,125
Mitch McConnell	$177,125
Harry Reid	$175,600
Charles E. Schumer	$175,450
Mark L. Pryor	**$172,950**
Michael F. Bennet	$159,000
Richard Blumenthal	**$148,800**
Claire McCaskill	**$138,185**
Mark Udall	$136,625

Cellular Industry Campaign Contributions

Top Senate Recipients Funded

Recipient	Amount
Edward J. Markey	**$155,150**
Mark R. Warner	$74,800
Harry Reid	$73,600
Mark L. Pryor	**$71,900**
Roy Blunt	**$57,400**
John McCain	$56,261
Charles E. Schumer	$53,300
Roger F. Wicker	$51,300
Barbara Boxer	$49,578
Kelly Ayotte	$43,333

The compromised FCC network goes well beyond the revolving door and congressional oversight committees. The Washington social scene is one where money sets the tone and throws the parties. A look at the recent calendar of one current FCC commissioner shows it would take very disciplined and almost saintly behavior on the part of government officials to resist the lure of lavishly catered dinners and cocktail events. To paraphrase iconic investigative journalist I.F. Stone, if you're going to work in Washington, bring your chastity belt.

All that free liquor, food and conviviality translates into the lobbyist's ultimate goal: access. "They have disproportionate access," notes former FCC commissioner Michael Copps. "When you are in a town where most people you see socially are in industry, you don't have to ascribe malevolent behavior to it," he added.[7]

Not malevolent in motive. But the results can be toxic. And blame does not lie solely at the feet of current commissioners. The FCC's problems predate Tom Wheeler and go back a long way.

Indeed, former Chairman Newton Minow, enduringly famous for his 1961 description of television as a "vast wasteland," recalls that industry manipulation of regulators was an issue even back then. "When I arrived, the FCC and the communications industry were both regarded as cesspools. Part of my job was to try to clean it up."[8]

More than 50 years later, the mess continues to pile up.

Chapter Two: Just Don't Bring Up Health

Perhaps the best example of how the FCC is tangled in a chain of corruption is the cell tower and antenna infrastructure that lies at the heart of the phenomenally successful wireless industry.

It all begins with passage of the Telecommunications Act of 1996, legislation once described by South Dakota Republican senator Larry Pressler as ―the most lobbied bill in history." Late lobbying won the wireless industry enormous concessions from lawmakers, many of them major recipients of industry hard and soft dollar contributions. Congressional staffers who helped lobbyists write the new law did not go unrewarded. Thirteen of fifteen staffers later became lobbyists themselves.[9]

Section 332(c)(7)(B)(iv) of the Act remarkably—and that adverb seems inescapably best here—wrests zoning authority from local governments. Specifically, they cannot cite health concerns about the effects of tower radiation to deny tower licenses so long as the towers comply with FCC regulations.

Congress Silences Public

Section 332(c)(7)(B)(iv) of the Communications Act provides:

> No State or local government or instrumentality thereof may regulate 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 Commission's regulations concerning such emissions.

In preempting local zoning authority—along with the public's right to guard its own safety and health— Congress unleashed an orgy of infrastructure build-out. Emboldened by the government green light and the vast consumer appetite for wireless technology, industry has had a free hand in installing more than 300,000 sites. Church steeples, schoolyards, school rooftops, even trees can house these facilities.

Is there any reason to believe that the relatively low level radiofrequency emissions of these facilities constitute a public health threat? Certainly, cell phones themselves, held close to the head, have been the focus of most concern on RF emissions. Since the impact of RF diminishes with distance, industry advocates and many scientists dismiss the possibility that such structures pose health risks.

But it's not really that simple. A troubling body of evidence suggests exposure to even low emission levels at typical cellular frequencies between 300 MHz and 3 GHz can have a wide range of negative effects.

In a 2010 review of research on the biological effects of exposure to radiation from cell tower base stations, B. Blake Levitt and Henry Lai found that "some research does exist to warrant caution in infrastructure siting."[10] They summarized the results on one 2002 study that compared the health of 530 people living at various distances within 300 meters of cell towers with a control group living more than 300 meters away. "Results indicated increased symptoms and complaints the closer a person lived to a tower. At <10 m, symptoms included nausea, loss of appetite, visual disruptions, and difficulties in moving. Significant differences were observed up through 100 m for irritability, depressive tendencies, concentration difficulties, memory loss, dizziness, and lower libido."[11]

A 2007 study conducted in Egypt found similar results. Levitt and Lai report, "Headaches, memory changes, dizziness, tremors, depressive symptoms, and sleep disturbance were significantly higher among exposed inhabitants than controls."[12]

Beyond epidemiological studies, research on a wide range of living things raises further red flags. A 2013 study by the Indian scientists S. Sivani and D. Sudarsanam reports: "Based on current available literature, it is justified to conclude that RF-EMF [electro magnetic fields] radiation exposure can change neurotransmitter functions, blood-brain barrier, morphology, electrophysiology, cellular metabolism, calcium efflux, and gene and protein expression in certain types of cells even at lower intensities."[13]

The article goes on to detail the effects of mobile tower emissions on a wide range of living organisms: "Tops of trees tend to dry up when they directly face the cell tower antennas. . . . A study by the Centre for Environment and Vocational Studies of Punjab University noted that embryos of 50 eggs of house sparrows were damaged after being exposed to mobile tower radiation for 5-30 minutes. . . . In a study on cows and calves on the effects of exposure from mobile phone base stations, it was noted that 32% of calves developed nuclear cataracts, 3.6% severely."[14]

Does any of this constitute the conclusive evidence that would mandate much tighter control of the wireless infrastructure? Not in the estimation of industry and its captured agency. Citing other studies—often industry-funded—that fail to establish health effects, the wireless industry has dismissed such concerns. The FCC has typically echoed that position.

Keep in mind that light regulation has been one factor in the extraordinary growth of wireless—CTIA says exactly that in a Web post that credits the Clinton Administrations light regulatory touch.

July 25, 2013

CTIA BLOG

CTIA is an international nonprofit trade association that has represented the wireless communications industry since 1984.

But our position as the world's leader was no accident. It started with the Clinton Administration that had the foresight to place a "light regulatory touch" on the wireless industry, which was in its infancy at the time. That light touch has continued through multiple Administrations.

Obviously, cellular technology is wildly popular because it offers many benefits to consumers. But even allowing for that popularity and for the incomplete state of science, don't some of these findings raise enough concern to warrant some backtracking on the ham-fisted federal preemption of local zoning rights?

In reality, since the passage of the 1996 law, the very opposite has occurred. Again and again both Congress and the FCC have opted to stiffen—rather than loosen—federal preemption over local zoning authority. In 2009, for example, the wireless industry convinced the FCC to impose a "shot clock" that requires action within 90 days on many zoning applications. "My sense is that it was an industry request," said Robert Weller, who headed up the FCC's Office of Engineering and Technology when the shot clock was considered and imposed.[15]

And just last November, the FCC voted to further curb the rights of local zoning officials to control the expansion of antenna sites Again and again, Congress and the FCC have extended the wireless industry carte blanche to build out infrastructure no matter the consequences to local communities.

The question that hangs over all this: would consumers' embrace of cell phones and Wi-Fi be quite so ardent if the wireless industry, enabled by its Washington errand boys, hadn't so consistently stonewalled on evidence and substituted legal intimidation for honest inquiry? (See Appendix for online study of consumer attitudes on wireless health and safety.)

Document searches under the Freedom of Information Act reveal the central role of Tom Wheeler and the FCC in the tower siting issue. As both lobbyist and FCC chairman, Wheeler has proved himself a good friend of the wireless industry.

In January of 1997, CTIA chieftain Wheeler wrote FCC Wireless Telecommunications Bureau Chief Michele C. Farquhar citing several municipal efforts to assert control over siting. Wheeler, for example, asserted that one New England state had enacted a law requiring its Public Service Commissioner to issue a report on health risks posed by wireless facilities.[16] He

questions whether such a study—and regulations based on its results—would infringe on FCC preemption authority.

FCC bureau chief Farquhar hastily reassured Wheeler that no such study could be consulted in zoning decisions. "Therefore, based on the facts as you have presented them, that portion of the statute that directs the State Commissioner to recommend regulations based upon the study's findings would appear to be preempted,"[17] the FCC official wrote to Wheeler. She emphasized that the state had the right to do the study. It just couldn't deny a siting application based on anything it might learn.

The FCC in 1997 sent the message it has implicitly endorsed and conveyed ever since: study health effects all you want. It doesn't matter what you find. The build-out of wireless cannot be blocked or slowed by health issues.

Now let's fast forward to see Wheeler on the other side of the revolving door, interacting as FCC chairman with a former FCC commissioner who is now an industry lobbyist.

A March 14, 2014 letter[18] reveals the chummy relationship between Wheeler and former commissioner Jonathan Adelstein, now head of PCIA, the cellular infrastructure lobbying group. It also references FCC Chairman Wheeler seeking policy counsel from lobbyist Adelstein:

Wheeler Still Willing to Help

From: Jonathan Adelstein [mailto:adelstein@pcia.com]
Sent: Friday, March 14, 2014 12:24 PM
To: [redacted]
Cc: Renee Gregory; Jonathan Campbell
Subject: How to Spur Wireless Broadband Deployment

Tom – It was great to see you the other night at the FCBA event, and wonderful to see how much fun you're having (if that's the right word). I know I enjoyed my time there (thanks to your help with Daschle in getting me that role in the first place!).

Thanks for asking how we think the FCC can help spur wireless broadband deployment. The infrastructure proceeding perfectly tees up many of the top issues the FCC needs to address. As you requested, I've summarized briefly in the attached letter some of the key steps you can take now.

"Tom – It was great to see you the other night at the FCBA event, and wonderful to see how much fun you're having (if that's the right word). I know I enjoyed my time there (thanks to your help with Daschle in getting me that role in the first place!)."

"Thanks for asking how we think the FCC can help spur wireless broadband deployment," the wireless lobbyist writes to the ex-wireless lobbyist, now running the FCC.

Adelstein's first recommendation for FCC action: *"Amend its rules to categorically exclude DAS and small deployments* [Ed. note: these are compact tower add-ons currently being widely deployed] *from environmental and historic review."* Adelstein outlined other suggestions for further limiting local antenna zoning authority and the FCC soon did its part. Late last year, the agency proposed new rules that largely (though not entirely) complied with the antenna industry's wish list.

James R. Hobson is an attorney who has represented municipalities in zoning issues involving the FCC. He is also a former FCC official, who is now of counsel at Best, Best and Krieger, a Washington-based municipal law practice. "The FCC has been the ally of industry," says Hobson. Lobbyist pressure at the FCC was intense even back in the 70s, when he was a bureau chief there. "When I was at the FCC, a lot of my day was taken up with appointments with industry lobbyists." He says of the CTIA that Wheeler once headed: "Their reason for being is promoting the wireless industry. And they've been successful at it."[19]

The FCC's deferential compliance has allowed industry to regularly bypass and if necessary steamroll local authorities. Violation of the FCC-imposed "shot clock," for example, allows the wireless license applicant to sue.

The FCC's service to the industry it is supposed to regulate is evidently appreciated. The CTIA web site, typically overflowing with self-congratulation, spreads the praise around in acknowledging the enabling contributions of a cooperative FCC. In one brief summation of its own glorious accomplishments, CTIA twice uses the word "thankfully" in describing favorable FCC actions.

In advancing the industry agenda, the FCC can claim that it is merely reflecting the will of Congress. But the agency may not be doing even that.

Remember the key clause in the 96 Telecom Act that disallowed denial of zoning permits based on health concerns? Well, federal preemption is granted to pretty much any wireless outfit on just one simple condition: its installations must comply with FCC radiation emission standards. In view of this generous carte blanche to move radiation equipment into neighborhoods, schoolyards and home rooftops, one would think the FCC would at the very least diligently enforce its own emission standards. But that does not appear to be the case.

Indeed, one RF engineer who has worked on more than 3,000 rooftop sites found vast evidence of non-compliance. Marvin Wessel estimates that "10 to 20% exceed allowed radiation standards."[20] With 30,000 rooftop antenna sites across the U.S. that would mean that as many as 6,000 are emitting radiation in violation of FCC standards. Often, these emissions can be 600% or more of allowed exposure levels, according to Wessel.

Antenna standards allow for higher exposure to workers. In the case of rooftop sites, such workers could be roofers, painters, testers and installers of heating and air conditioning

equipment, to cite just a few examples. But many sites, according to Wessel, emit radiation at much higher levels than those permitted in occupational standards. This is especially true of sites where service providers keep adding new antenna units to expand their coverage. "Some of these new sites will exceed ten times the allowable occupational radiation level," said Wessel.[21] Essentially, he adds, this means that nobody should be stepping on the roof.

"The FCC is not enforcing its own standard," noted Janet Newton, who runs the EMF Policy Institute, a Vermont-based non-profit. That group several years ago filed 101 complaints on specific rooftop sites where radiation emissions exceeded allowable levels. "We did this as an exercise to hold the FCC's feet to the fire," she said. But the 101 complaints resulted in few responsive actions, according to Newton.[22]

Former FCC official Bob Weller confirms the lax—perhaps negligible is the more appropriate word—FCC activity in enforcing antenna standards. "To my knowledge, the enforcement bureau has never done a targeted inspection effort around RF exposure," he said.[23] Budget cuts at the agency have hurt, limiting the FCC's ability to perform field inspections, he added. But enforcement, he adds, would do wonders to insure industry compliance with its limited regulatory compliance requirements. "If there were targeted enforcement and fines issued the industry would pay greater attention to ensuring compliance and self-regulation," he allowed.

Insurance is where the rubber hits the road on risk. So it is interesting to note that the rating agency A.M. Best, which advises insurers on risk, in 2013 topped its list of "emerging technology-based risks" with RF Radiation:

> *"The risks associated with long-term use of cell phones, although much studied over the past 10 years, remain unclear. Dangers to the estimated 250,000 workers per year who come in close contact with cell phone antennas, however, are now more clearly established. Thermal effects of the cellular antennas, which act at close range essentially as open microwave ovens can include eye damage, sterility and cognitive impairments. While workers of cellular companies are well trained on the potential dangers, other workers exposed to the antennas are often unaware of the health risks. The continued exponential growth of cellular towers will significantly increase exposure of these workers and others coming into close contact with high-energy cell phone antenna radiation,"* A.M. Best wrote.[24]

So what has the FCC done to tighten enforcement? Apparently, not very much. Though it does follow up on many of the complaints filed against sites alleged to be in violation of standards it takes punitive actions very rarely. (The FCC did not provide answers to written questions on details of its tower enforcement policies.)

The best ally of industry and the FCC on this (and other) issues may be public ignorance.

An online poll conducted for this project asked 202 respondents to rate the likelihood of a series of statements.[25] Most of the statements were subject to dispute. Cell phones raise the risk of certain health effects and brain cancer, two said. There is no proof that cell phones are harmful, another declared. But among the six statements there was one statement of indisputable fact: "The U.S. Congress forbids local communities from considering health effects when deciding whether to issue zoning permits for wireless antennae," the statement said.

Though this is a stone cold fact that the wireless industry, the FCC and the courts have all turned into hard and inescapable reality for local authorities, just 1.5% of all poll respondents replied that it was "definitely true."

Public ignorance didn't take much cultivation by the wireless industry on the issue of local zoning. And maybe it doesn't matter much, considering the enormous popularity of wireless devices. But let's see how public ignorance has been cultivated and secured—with the FCC's passive support—on the potentially more disruptive issue of mobile phone health effects.

Chapter Three: Wireless Bullies and the Tobacco Analogy

Issues of cable and net neutrality have recently attracted wide public attention (more on that in Chapter Six). Still, the bet here remains that future judgment of the FCC will hinge on its handling of wireless health and safety issues.

And while the tower siting issue is an egregious example of an industry-dominated political process run amuck, the stronger health risks appear to reside in the phones themselves. This is an issue that has flared up several times in recent years. Each time, industry has managed to beat back such concerns. But it's worth noting that the scientific roots of concern have not disappeared. If anything, they've thickened as new research substantiates older concerns.

The story of an FCC passively echoing an industry determined to play hardball with its critics is worth a further look. The CTIA's own website acknowledges the helpful hand of government's "light regulatory touch" in allowing the industry to grow.[26]

Former congressman Dennis Kucinich ventures one explanation for the wireless industry's success in dodging regulation: "The industry has grown so fast its growth has overtaken any health concerns that may have gained attention in a slow growth environment. The proliferation of technology has overwhelmed all institutions that would have attempted safety testing and standards," Kucinich said.[27]

But the core questions remain: Is there really credible evidence that cell phones emit harmful radiation that can cause human health problems and disease? Has the FCC done an adequate job in protecting consumers from health risks? Or has it simply aped industry stonewalling on health and safety issues?

Before wading into these questions, some perspective is in order.

First, there's simply no denying the usefulness and immense popularity of wireless technology. People depend on it for safety, information, entertainment and communication. It doesn't take a keen social observer to know that wireless has thoroughly insinuated itself into daily life and culture.

The unanswered question, though, is whether consumers would embrace the technology quite so fervently if health and safety information was not spun, filtered and clouded by a variety of industry tactics.

To gain some insight into this question, we conducted an online survey of 202 respondents, nearly all of whom own cell phones, on Amazon's Mechanical Turk Web platform (see Appendix). One striking set of findings: many respondents claim they would change behavior—reduce wireless use, restore landline service, protect their children—if claims on health dangers of wireless are true.

It is not the purpose of this reporter to establish that heavy cell phone usage is dangerous. This remains an extremely controversial scientific issue with new findings and revised scientific conclusions repeatedly popping up. Just months ago, a German scientist who had been outspoken in denouncing the view that cell phones pose health risks reversed course. In an April 2015 publication, Alexander Lerchl reported results confirming previous research on the tumor-promoting effects of electromagnetic fields well below human exposure limits for mobile phones. ―Our findings may help to understand the repeatedly reported increased incidences of brain tumors in heavy users of mobile phones," the Lerchl team concluded.[28] And in May 2015, more than 200 scientists boasting over 2,000 publications on wireless effects called on global institutions to address the health risks posed by this technology.

But the National Cancer Institute still contends that no cell phone dangers have been established. A representative of NCI was the sole known dissenter among the 30 members of the World Health Organization's International Agency for Research on Cancer (IARC) when it voted to declare wireless RF ―possibly carcinogenic."[29] If leading scientists still can't agree, I will not presume to reach a scientific conclusion on my own.

IARC RF working group: Official press release

International Agency for Research on Cancer

World Health Organization

PRESS RELEASE
N° 208

31 May 2011

IARC CLASSIFIES RADIOFREQUENCY ELECTROMAGNETIC FIELDS AS POSSIBLY CARCINOGENIC TO HUMANS

Lyon, France, May 31, 2011 -- The WHO/International Agency for Research on Cancer (IARC) has 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.

But let‘s at least look at some of the incriminating clues that health and biology research has revealed to date. And let‘s look at the responses of both industry and the FCC.

The most widely cited evidence implicating wireless phones concerns gliomas, a very serious type of brain tumor. The evidence of elevated risk for such tumors among heavy cell phone users comes from several sources.

Gliomas account for roughly half of all malignant brain tumors, which are relatively rare. The annual incidence of primary malignant brain tumors in the U.S. is only 8.2 per 100,000 people, according to the International Radio Surgery Association.

Still, when projected over the entire U.S. population, the public health impact is potentially very significant.

Assuming roughly four new glioma cases annually in the U.S. per 100,000 people, yields over 13,000 new cases per year over a total U.S. population of 330 million. Even a doubling of that rate would mean 13,000 new gliomas, often deadly, per year. A tripling, as some studies have found, could mean as many as 26,000 more new cases annually. Indeed, the respected online site Medscape in January 2015 reported results of Swedish research under the headline: *Risk for Glioma Triples With Long-Term Cell Phone Use*.[30]

And here‘s some eye-opening quantitative perspective: the wars in Iraq and Afghanistan, waged now for more than a decade each, have together resulted in roughly 7,000 U.S. deaths.

Preliminary—though still inconclusive—research has suggested other potential negative health effects. Swedish, Danish and Israeli scientists have all found elevated risk of salivary gland tumors. One Israeli studied suggested elevated thyroid cancer risk. Some research has found that men who carry their phones in their pockets may suffer sperm count damage. One small study even suggests that young women who carry wireless devices in their bras are unusually vulnerable to breast cancer.

And while industry and government have never accepted that some portion of the population is unusually sensitive to electromagnetic fields, many people continue to complain of a broad range of symptoms that include general weakness, headaches, nausea and dizziness from exposure to wireless.

Some have suggested that the health situation with wireless is analogous to that of tobacco before court decisions finally forced Big Tobacco to admit guilt and pay up. In some ways, the analogy is unfair. Wireless research is not as conclusively incriminating as tobacco research was. And the identified health risks with wireless, significant as they are, still pale compared with those of tobacco.

But let‘s not dismiss the analogy outright. There is actually a very significant sense in which the tobacco-wireless analogy is uncannily valid.

People tend to forget that the tobacco industry—like the wireless industry—also adopted a policy of tone-deaf denial. As recently as 1998, even as evidence of tobacco toxicity grew overwhelming, cigarette maker Phillip Morris was writing newspaper advertorials insisting there was no proof smoking caused cancer.

It seems significant that the responses of wireless and its captured agency—the FCC—feature the same obtuse refusal to examine the evidence. The wireless industry reaction features stonewalling public relations and hyper aggressive legal action. It can also involve undermining the credibility and cutting off the funding for researchers who do not endorse cellular safety. It is these hardball tactics that look a lot like 20th century Big Tobacco tactics. It is these hardball tactics—along with consistently supportive FCC policies—that heighten suspicion the wireless industry does indeed have something to hide.

Begin with some simple facts issuing from meta-analysis of cellular research. Dr. Henry Lai, emeritus professor of bioengineering at the University of Washington, has reviewed hundreds of published scientific papers on the subject. He wanted to see how many studies demonstrated that non-ionizing radiation produces biological effects beyond the heating of tissue. This is critical since the FCC emission standards protect only against heating. The assumption behind these standards is that there are no biological effects beyond heating.

But Dr. Lai found that just over half—actually 56%—of 326 studies identified biological effects. And the results were far more striking when Dr. Lai divided the studies between those that were industry-funded and those that were independently funded. Industry-funded research identified biological effects in just 28% of studies. But fully 67% of non-industry funded studies found biological effects (Insert Slide—Cell Phone Biological Studies).

A study conducted by Swiss and British scientists also looked at how funding sources affected scientific conclusions on the possible health effects of cell phone usage. They found that of studies privately funded, publicly funded and funded with mixed sponsorship, industry-funded studies were ~~l~~least likely to report a statistically significant result."[31] ~~T~~The interpretation of results from studies of health effects of radiofrequency radiation should take sponsorship into account," the scientists concluded.[32]

So how does the FCC handle a scientific split that seems to suggest bias in industry-sponsored research?

In a posting on its Web site that reads like it was written by wireless lobbyists, the FCC chooses strikingly patronizing language to slight and trivialize the many scientists and health and safety experts who've found cause for concern. In a two page Web post titled ~~"W~~Wireless Devices and Health Concerns," the FCC four times refers to either ~~"s~~some health and safety interest groups," ~~"s~~some parties," or ~~"s~~some consumers" before in each case rebutting their presumably groundless concerns about wireless risk.[33] Additionally, the FCC site references the World Health Organization as among those organizations who've found that ~~"t~~the weight of scientific

evidence" has not linked exposure to radiofrequency from mobile devices with ―any known health problems."

Yes, it's true that the World Health organization remains bitterly divided on the subject. But it's also true that a 30 member unit of the WHO called the International Agency for Research on Cancer (IARC) was near unanimous in pronouncing cell phones ―possibly carcinogenic" in 2011. How can the FCC omit any reference to such a pronouncement? Even if it finds reason to side with pro-industry scientists, shouldn't this government agency also mention that cell phones are currently in the same potential carcinogen class as lead paint?

Now let's look a bit more closely at the troublesome but presumably clueless crowd of ―some parties" that the FCC so cavalierly hastens to dismiss? Let's begin with **Lennart Hardell**, professor of Oncology and Cancer Epidemiology at the University Hospital in Oreboro, Sweden.

Until recently it was impossible to gain any real sense of brain tumor risk from wireless since brain tumors often take 20 or more years to develop. But the cohort of long-term users has been growing. In a study published in the International Journal of Oncology in 2013, Dr. Hardell and Dr. Michael Carlberg found that the risk of glioma—the most deadly type of brain cancer—rose with cell phone usage. The risk was highest among heavy cell phone users and those who began to use cell phones before the age of 20.[34]

Indeed, those who used their phones at least 1640 hours (which would be roughly 30 minutes a day for nine years) had nearly three times the glioma incidence. Drs. Hardell and Carlberg also found that gliomas tend to be more deadly among heavy wireless callers.[35]

Perhaps of greatest long-term relevance, glioma risk was found to be four times higher among those who began to use mobile phones as teenagers or earlier. These findings, along with the established fact that it generally takes decades for tumors induced by environmental agents to appear, suggest that the worst consequences of omnipresent wireless devices have yet to be seen.

In a 2013 paper published in *Reviews on Environmental Health*, Drs. Hardell and Carlberg argued that the 2011 finding of the IARC that identified cell phones as a ―possibly carcinogenic" needs to be revised. The conclusion on radiofrequency electromagnetic fields from cell phones should now be ―cell phones are not just a possible carcinogen." They can now be ―regarded as carcinogenic to humans" and the direct cause of gliomas (as well as acoustic neuromas, a less serious type of tumor).[36] Of course, these views are not universally accepted.

The usual spin among industry supporters when presented with research that produces troubling results is along the lines of: ―We might pay attention if the results are duplicated." In fact, the Hardell results were echoed in the French CERENAT study, reported in May of 2014. The CERENAT study also found higher risk among heavy users, defined as those using their phones at least 896 hours (just 30 minutes a day for five years). ―These additional data support

previous findings concerning a possible association between heavy mobile phone use and brain tumors," the study concluded.[37]

Cell phones are not the only wireless suspects. Asked what he would do if he had policy-making authority, Dr. Hardell swiftly replied that he would ~~b~~an wireless use in schools and pre-schools. You don't need Wi-Fi," he noted.[38] This is especially interesting in view of the FCC's sharply hiked spending to promote and extend Wi-Fi usage, as well as its consistent refusal to set more stringent standards for children (more on all this later). But for now let's further fill out the roster of the FCC's unnamed ~~s~~ome parties."

Martin Blank is a Special Lecturer in Physiology and Cellular Biophysics at Columbia University. Unlike Dr. Hardell, who looks at broad epidemiological effects over time, Dr. Blank sees cause for concern in research showing there is biological response at the cellular level to the type of radiation emitted by wireless devices. ~~T~~he biology tells you unequivocally that the cell treats radiation as a potentially damaging influence," Dr. Blank said in a late 2014 interview.[39]

~~T~~he biology tells you it's dangerous at a low level," he added. Though some results have been difficult to replicate, researchers have identified a wide range of cellular responses including genetic damage and penetration of the blood brain barrier. Dr. Blank specifically cited the ~~c~~ellular stress response" in which cells exposed to radiation start to make proteins.

It is still not clear whether biological responses at the cellular level translate into human health effects. But the research seems to invalidate the basic premise of FCC standards that the only biological effect of the type of radiation produced by wireless devices is tissue heating at very high power levels. But the standards-setting agencies ~~i~~gnore the biology," according to Dr. Blank. He describes the FCC as being ~~in~~ industry's pocket."[40]

Sweden's Lund University is annually ranked among the top 100 universities in the world. **Leif Salford** has been chairman of the Department of Neurosurgery at Lund since 1996. He is also a former president of the European Association for Neuro-Oncology. In the spring of 2000, Professor Salford told me that wireless usage constituted ~~t~~he world's largest biological experiment ever."[41]

He has conducted numerous experiments exposing rats to cellular-type radiation. Individual experiments have shown the radiation to penetrate the blood-brain barrier, essential to protecting the brain from bloodstream toxins. Professor Salford also found that rats exposed to radiation suffered loss of brain cells. ~~A~~ rat's brain is very much the same as a human's. They have the same blood-brain barrier and neurons. We have good reason to believe that what happens in rat's brains also happens in humans," he told the BBC in 2003. Dr. Salford has also speculated that mobile radiation could trigger Alzheimer's disease in some cases but emphasized that much more research would be needed to establish any such causal relationship. Does this man deserve to be dismissed as one of a nameless and discredited group of ~~s~~ome parties?"

And what about the **American Academy of Pediatrics (AAP),** which represents 60,000 American doctors who care for children? In a December 12, 2012 letter to former Ohio Congressman Dennis Kucinich, AAP President Dr. Thomas McInerny writes: ―Children are disproportionately affected by environmental exposures, including cell phone radiation. The differences in bone density and the amount of fluid in a child's brain compared to an adult's brain could allow children to absorb greater quantities of RF energy deeper into their brains than adults."[42]

In a subsequent letter to FCC officials dated August 29, 2013, Dr. McInerny points out that ―children, however, are not little adults and are disproportionately impacted by all environmental exposures, including cell phone radiation." Current FCC exposure standards, set back in 1996, ―do not account for the unique vulnerability and use patterns specific to pregnant women and children," he wrote. (Insert slide: A Plea from Pediatricians). Does an organization representing 60,000 practitioners who care for children deserve to be brushed off along with ―some health and safety interest groups?"

So what is the FCC doing in response to what at the very least is a troubling chain of clues to cellular danger? As it has done with wireless infrastructure, the FCC has to this point largely relied on industry ―self-regulation." Though it set standards for device radiation emissions back in 1996, the agency doesn't generally test devices itself. Despite its responsibility for the safety of cell phones, the FCC relies on manufacturers' good-faith efforts to test them. Critics contend that this has allowed manufacturers undue latitude in testing their devices.

Critics further contend that current standards, in place since cell phones were barely in use, are far too lax and do not reflect the heavy usage patterns that have evolved. Worse still, industry is allowed to test its own devices using an imprecise system that makes no special provision for protecting children and pregnant women. One 2012 study noted that the procedure widely used by manufacturers to test their phones ―substantially underestimates" the amount of RF energy absorbed by 97% of the population, ―especially children." A child's head can absorb over two times as much RF energy. Other persons with smaller heads, including women, are also more vulnerable. The authors recommend an alternative computer simulation technique that would provide greater insight into the impact of cellular radiation on children and on to the specific RF absorption rates of different tissues, which vary greatly.[43]

Acting on recommendations of the General Accounting Office, the FCC is now reconsidering its standards for wireless testing and allowed emissions. On the surface, this may seem to represent an effort to tighten standards to promote consumer health and safety. But many believe the FCC's eventual new standard will actually be weaker, intensifying any health risk from industry's self-reported emission levels. ―They're under great pressure from industry to loosen the criteria," notes Joel Moskowitz, director of the Center for Family and Community Health at UC Berkeley's School of Public Health.[44] One fear is that the FCC could measure the allowed radiation absorption level (SAR) over a wider sample of tissue, effectively loosening the

standard allowable energy absorption. One FCC official, who asked that his name not be used, contended that a decision had not yet been made to loosen the standard.

But to this point, there is little evidence the FCC is listening to anyone beyond its familiar friends in the wireless industry. Carl Blackman, a scientist at the Environmental Protection agency until retiring in 2014, notes that the FCC does rely to some degree on an inter-agency governmental group for advice on health matters. The group includes, for example, representatives from the EPA and the FDA.

Blackman served on that advisory group and he says that it has been divided. Though some government advisers to the FCC find evidence of wireless health risks convincing, others remain skeptical, said Blackman. Root of the skepticism: even though numerous researchers have found biological and health effects, the mechanism for action by non-ionizing radiation on the human body has still not been identified. "I don't think there's enough of a consensus within the Radio Frequency Inter-agency Working Group for them to come out with stricter standards," he says.[45]

But political pressures also figure mightily in all this. The EPA, notably, was once a hub of research on RF effects, employing as many as 35 scientists. However, the research program was cut off in the late 80s during the Regan presidency. Blackman says he was personally "forbidden" to study health effects by his "supervisory structure."[46] He termed it "a political decision" but recognized that if he wanted to continue to work at the EPA he would have to do research in another area.

Blackman is cautious in imputing motives to the high government officials who wanted his work at EPA stopped. But he does say that political pressure has been a factor at both the EPA and FCC: "The FCC people were quite responsive to the biological point of view. But there are also pressures on the FCC from industry." The FCC, he suggests, may not just be looking at the scientific evidence "The FCC's position—like the EPA's—is influenced by political considerations as well."[47]

Still, the FCC has ultimate regulatory responsibility and cannot indefinitely pass the buck on an issue of fundamental public health. Remarkably, it has not changed course despite the IARC classification of cell phones as possibly carcinogenic, despite the recent studies showing triple the glioma risk for heavy users, despite the floodtide of research showing biological effects, and despite even the recent defection of core industry booster Alex Lerchl. It is the refusal of both industry and the FCC to even acknowledge this cascade of warning signs that seems most incriminating.

Of course, industry behavior goes well beyond pushing for the FCC's willful ignorance and inaction. Industry behavior also includes self-serving public relations and hyper aggressive legal action. It can also involve undermining the credibility of and cutting off the funding for researchers who do not endorse cellular safety. It is these hardball tactics that recall 20th century Big Tobacco tactics. It is these tactics that heighten suspicion that the wireless industry does

indeed have a dirty secret. And it is those tactics that intensify the spotlight on an FCC that so timidly follows the script of the fabulously wealthy, bullying, billion-dollar beneficiaries of wireless.

Chapter Four: You Don't Need Wires To Tie People Up

So let's look a little more deeply at some of the actions of an industry group that boasts of 500 meetings a year with the FCC. Lobbying is one thing. Intimidation is another. CTIA has shown its skill at—and willingness to use—both.

Outright legal bullying is a favored tactic. The City of San Francisco passed an ordinance in 2010 that required cell phone manufacturers to display more prominently information on the emissions from their devices. This information was already disclosed—but often buried—in operator manuals and on manufacturer websites. The idea was to ensure that consumers saw information already mandated and provided.

Seeing this as a threat to its floodtide of business, the industry sued the City of San Francisco. The City, fearing a prolonged legal fight with an industry that generates hundreds of billions of dollars in annual revenue, backed down.

On May 12, 2015, Berkeley, California's City Council unanimously passed a similar ordinance. Joel Moskowitz, director of the Center for Family and Community Health at the University of California-Berkeley's School of Public Health, has been involved in the effort. Berkeley, he says, didn't want to run into the same legal threats that paralyzed San Francisco. So it tried to draft the most inoffensive and mild language possible. The proposed Cell Phone Right to Know ordinance: "To assure safety, the Federal Government requires that cell phones meet radio frequency (RF) exposure guidelines. If you carry or use your phone in a pants or shirt pocket or tucked into a bra when the phone is ON and connected to a wireless network, you may exceed the federal guidelines for exposure to RF radiation. This potential risk is greater for children. Refer to the instructions in your phone or user manual for information about how to use your phone safely."[48]

Sounds pretty inoffensive, no? Not to the CTIA, which indicated that it was prepared to sue, according to Berkeley City Attorney Zach Cowan.[49] (On June 8th, CTIA did indeed sue the City of Berkeley.)

Well, from the industry point of view, why not throw around your weight? Smash mouth legal tactics have been highly successful thus far as industry has managed to throttle several efforts to implicate manufacturers in cases where heavy users suffered brain tumors.

But one current case has advanced in district court in Washington to the point where the judge allowed plaintiffs to present expert witness testimony. The industry response: file a legal action seeking to invalidate long-held court methods for qualifying expert witnesses.

This is a very rich industry that does not hesitate to outspend and bully challengers into submission. Meanwhile, amidst the legal smoke and medical confusion, the industry has

managed to make the entire world dependent on its products. Even tobacco never had so many hooked users.

Such sustained success in the face of medical doubt has required industry to keep a lid on critics and detractors. Many scientists who've found real or potential risk from the sort of microwave radiation emanating from wireless devices have learned there is a price to be paid for standing up to the industry juggernaut. A few prominent examples:

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In 1994, University of Washington researchers Henry Lai and N.P. Singh found that rats exposed to microwave radiation suffered DNA damage to their brain cells. This was a scary finding since DNA damage can lead to mutations and possibly cancer.

The reaction from industry was swift. Motorola was at that time the U.S. market leader in cell phones. In a memorandum obtained by the journal Microwave News, Motorola PR honcho Norm Sandler outlined how the company could ―downplay the significance of the Lai study." One step: ―We have developed a list of independent experts in this field and are in the process of recruiting individuals willing and able to reassure the public on these matters," Sandler wrote. After outlining such measures, he concluded that Motorola had ―sufficiently war-gamed" the issue. The practices of lining up industry-friendly testimony and ―war-gaming" researchers who come up with unfavorable results have been persistent themes with this industry.

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After Lai's results were published, Motorola decided to sponsor further research on microwaves and DNA damage. Oftentimes, lab results cannot be reproduced by other

researchers, particularly if experiments are tweaked and performed a bit differently. Non-confirming studies raise doubt, of course, on the original work.

Motorola lined up Jerry Phillips, a scientist at the Veteran‘s Administration Medical Center in Loma Linda, California, and Phillips tested the effect of radiation at different frequencies from those tested by Lai and Singh. Nevertheless, Phillips found that at some levels of exposure, DNA damage increased, while at other levels it decreased. Such findings were ―consistent‖ with the sorts of effects produced by chemical agents, Phillips said in an interview.[50] In some cases, the radiation may have activated DNA repair mechanisms, reducing the overall microwave effect. But what was important, Phillips explained, is that there were *any* biological effects at all. The wireless industry has long contended—and the FCC has agreed—that there is no evidence that non-ionizing radiation at the frequencies and power levels used by cell phones is biologically active.

Understanding the potential impact of ―biological effect‖ findings, Motorola again turned to damage control, said Phillips. He recalls receiving a phone call from a Motorola R&D executive. ―I don‘t think you‘ve done enough research,‘‖ Phillips recalls being told. The study wasn‘t ready for publication, according to the Motorola executive. Phillips was offered more money to do further research without publishing the results of what he‘d done.

But Phillips felt he‘d done enough. Despite warnings for his own boss to ―give Motorola what it wants,‖ Phillips went ahead and published his findings in 1998. Since then, Phillips‘ industry funding has dried up. Meanwhile, as many other researchers report, government funding to do independent research on microwave radiation has dried up, leaving the field at least in the U.S. to industry-funded scientists. ―There is no money to do the research,‖ Said Phillips. ―It‘s not going to come from government because government is controlled by industry.‖[51]

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Om P. Gandhi is Professor of Electrical and Computer Engineering at the University of Utah and a leading expert in dosimetry—measurement of non-ionizing radiation absorbed by the human body. Even before cell phones were in wide use, Professor Gandhi had concluded that children absorb more emitted microwave radiation. ―The concentration of absorbed energy is 50 to 80% greater,‖ he explained.[52]

These conclusions were not acceptable to Professor Gandhi‘s industrial sponsors. In 1998, he recalls, an executive from a cell phone manufacturer—which he did not want to identify—told him directly that if he did not discontinue his research on children his funding would be cut off. Professor Gandhi recalled replying: ―I will not stop. I am a tenured professor at the University of Utah and I will not reject my academic freedom.‖ Professor Gandhi also recalled some of his thought process: ―I wasn‘t going to order my students to alter their results so that I can get funding.‖ His industry sponsors cancelled his contract and asked for a return of funds.

Professor Gandhi believes that some cell phone users require extra protection because their heads are smaller and more absorptive. ―Children, as well as women and other individuals with smaller heads absorb more concentrated energy because of the proximity of the radiating antenna to the brain tissue," he said. And yet the FCC has not acted to provide special protection for these groups. Asked why not, Professor Gandhi conceded that he doesn't know. He does note, however, that recent standards-setting has been dominated by industry representatives.[53]

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While the mobile industry refuses to admit to even the possibility that there is danger in RF radiation, giant insurance companies see things differently. Several insurers have in recent years issued reports highlighting product liability risk with cell phones. This is important because it is evidence that where money is on the line professionals outside the industry see the risk of legal liability.

Legal exposure could be one reason—perhaps the central one—the industry continues to stonewall. Should legal liability be established, one key question will be how much wireless executives knew—and at what point in time. Meanwhile, the combination of public relations denials, legal intimidation and the selective application of pressure on research follows a familiar pattern. ―The industry is basically using the tobacco industry playbook," UC Berkeley's Moskowitz said in a recent radio interview.[54]

That playbook has thus far been highly successful in warding off attention, regulation and legal incrimination.

Chapter Five: $270 Billion . . . and Looking for Handouts

The FCC's network of corruption doesn't just shield industry from needed scrutiny and regulation on matters of public health and safety. Sometimes it just puts its hand directly into the public pocket and redistributes that cash to industry supplicants.

Such is arguably the case with the Universal Service Fund. Originally established to extend telephone service to rural and urban areas that industry would find difficult or uneconomical to wire, the USF is now shifting from subsidizing landline phone service to subsidizing the extension of broadband Internet. USF monies also support the Lifeline program, which subsidizes cell phone service to low-income consumers, and the E-Rate program, which subsidizes Internet infrastructure and service to schools and libraries.

Since 1998, more than $110 billion has been allocated to Universal Service programs, notes Charles Davidson, director of the Advanced Communications Law & Policy Institute at New York Law School. The FCC has allocated over $40 billion to the E-Rate program alone.

Who pays the freight for these high-cost programs? You do.

Technically, landline and wireless phone companies are assessed for the Universal Service fund's expenditures. But the FCC also allows those companies to pass on such charges to their subscribers, which they do. Both landline and wireless subscribers pay a monthly Universal Service charge that is tacked on to their phone bills. That charge has been rising and recently amounted to a 16% surcharge on interstate calls.

Consumers who pay for these programs might be interested to learn that both the E-Rate and Lifeline programs have been riddled with fraud. Government watchdogs have repeatedly found the programs to be inefficient and prone to inflated and fraudulent claims. But the programs have been a windfall for tech and telecom industry beneficiaries. Wherever the FCC presides, it seems, these industries reap a windfall.

The General Accounting Office (GAO) has issued several reports citing fraud, waste and mismanagement, along with inadequate FCC oversight of the subsidy program. Bribery, kickbacks and false documentation can perhaps be expected in a handout program mandated by Congress and only indirectly supervised by the FCC.

But the scope of fraud has been impressive. The most striking corruption has marred the E-Rate program, which subsidizes Internet hardware, software and service for schools and libraries, and the Lifeline cell phone subsidies.

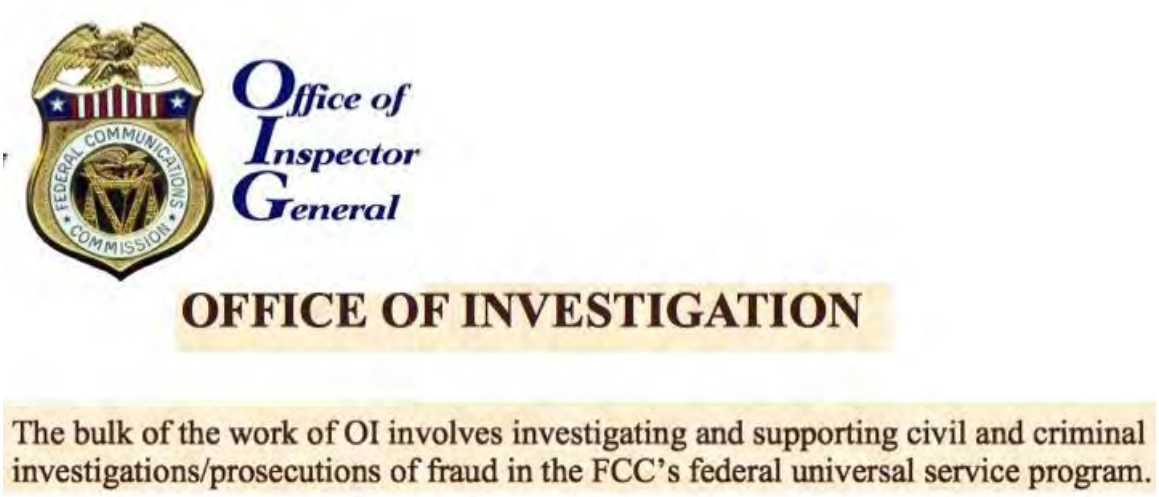
In recent years, several school districts have paid fines to settle fraud cases involving bribery, kickbacks, non-competitive bidding of contracts and false documentation in the E-Rate

program. More eye opening perhaps are the settlements of fraud claims by tech giants like IBM, Hewlett Packard and AT&T. The HP case, for example, involved some colorful bribery allegations, including gifts of yachts and Super Bowl tickets. HP settled for $16 million. An HP official and a Dallas Independent School District official both received jail sentences.

The Lifeline program has also been riddled with fraud. A Wall Street Journal investigation of the five top corporate beneficiaries of Lifeline showed that 41% of more than 6 million subsidy claimants "couldn't demonstrate their eligibility or didn't respond to requests for certification."[55] AT&T, Verizon, and Sprint Nextel were three of the major Lifeline beneficiaries.

The FCC has initiated several efforts to clean up USF programs and seems honestly determined to bring greater accountability and efficiency to its subsidy efforts. Nevertheless, problems with fraud persist, as reported recently by the FCC's own top investigator.

Congress established the FCC's Office of Inspector General in 1989 to "provide objective and independent investigations, audits and reviews of the FCC's programs and operations." Here's what the FCC's internal investigative unit said in a September 30, 2014 report to Congress about its Office of Investigation (OI): "*The bulk of the work of OI involves investigating and supporting civil and criminal investigations/prosecutions of fraud in the FCC's federal universal service program*."[56]



Fraud—as pervasive and troubling as it has been—is just one of the problems with the programs of universal service. It may not even be the fundamental problem. More fundamental issues concern the very aim, logic and efficiency of programs to extend broadband and wireless technology at public expense. Though the aims of extending service to distant impoverished areas seem worthy on the surface, there are many reasons to think the major beneficiaries of these programs are the technology companies that win the contracts.

Lobbyists have long swarmed over the FCC looking to get an ever-growing piece of the USF honeypot. An FCC report on meetings with registered lobbyists details a 2010 meeting with representatives of the International Society for Technology in Education and other education lobbyists. Topics discussed, according to the FCC report, included ~~"~~the need to raise the E-Rate's annual cap."[57]

The CTIA, leaving no stone unturned in its efforts to pump up member revenues, last year responded to a House hearing on the USF by grousing that ~~"~~current USF-supported programs skew heavily toward support of wireline services. . . . The concentration of USF monies to support wireline services is inconsistent with technological neutrality principles and demonstrated consumer preferences," CTIA wrote..[58] An industry that generates hundreds of billions of dollars in equipment and service revenues annually bellies up for a bigger slice of the $8 billion a year USF.

The grousing has paid off. The FCC recently announced that it will raise spending on E-Rate from what had been a cap of $2.4 billion a year to $3.9 billion. A significant portion of new outlays will go to Wi-Fi—yet another wireless industry victory at the FCC. But the CTIA is by no means the only industry group pressing the FCC.

Leading the roster of active lobbyists on E-Rate issues is the Software and Information Industry Association. Beginning in 2006, SIAA led all lobbyists with 54 mentions of E-Rate in its filings, according to the Center for Responsive Politics. SIAA board members include executives from tech heavyweights Google, Oracle and Adobe Systems.

Tech business leaders—many of them direct beneficiaries of FCC programs—made a direct pitch to FCC Chairman Wheeler last year to hike E-Rate funding. ~~"~~The FCC must act boldly to modernize the E-Rate program to provide the capital needed to upgrade our K-12 broadband connectivity and Wi-Fi infrastructure within the next five years," the executives wrote.[59]

There were dozens of corporate executive signees to this letter, including the CEOs of many Fortune 500 giants. But let's just consider the participation of three: top executives of Microsoft, Google and HP all joined the call to expand E-Rate subsidies. Consider the simple fact that these three tech giants alone had revenues of $270 billion—more than a quarter of a trillion dollars—in a recent four-quarter period. Together, they produced nearly $40 billion in net income. And yet their top executives still thought it necessary to dun the FCC—and really, they were surreptitiously hitting up the public—for ramped-up spending on what was then a $2.4 billion a year program.

Is that greed? Arrogance? Or is it simply behavior conditioned by success in repeatedly getting what they want at the public trough? Almost never mentioned in these pleas for higher subsidies is the fact that ordinary American phone subscribers are the ones footing the bill for the E-Rate program—not the FCC or the telecom industry.

Much of the added spending, as noted, will go towards the installation of wireless networks. And yet Wi-Fi does not have a clean bill of health. When Lennart Hardell, professor of Oncology and Cancer Epidemiology at the University Hospital in Orebro, Sweden, was asked what he would do if given policy authority over wireless health issues, he replied swiftly that he would ―ban wireless use in schools and pre-school." Noting that there are wired alternatives, Professor Hardell flatly stated: ―You don't need Wi-Fi."[60] And yet the FCC, prodded by an industry ever on the lookout for incremental growth opportunities, is ignoring the health of youngsters to promote expanded Wi-Fi subsidies in schools across the U.S.

And what about the merit of the program itself? Overlooking the fraud and lobbying and Wi-Fi safety issues for a moment, shouldn't schools and libraries across the country be equipped with the best electronic gear, accessing the Internet at the fastest speeds? Doesn't the government owe that to its younger citizens, especially those disadvantaged by the long-referenced digital divide?

Well, maybe. But answers to these questions hinge on even more fundamental question: Do students actually learn more or better with access to the latest high-speed electronic gadgetry?

It would be foolish to argue that nobody benefits from access to high-speed Internet. But the benefits are nowhere near as broad or rich as corporate beneficiaries claim. Some researchers, for example, have concluded that computers don't seem to have positive educational impact—they may even have negative impact—when introduced into the home or freely distributed to kids from low income backgrounds.

Duke University researchers Jacob Vigdor and Helen Ladd studied the introduction of computers into North Carolina homes. They found that the academic performance of youngsters given computers actually declined. *"The introduction of home computer technology is associated with modest but statistically significant and persistent negative impacts on student math and reading test scores,"* the authors wrote in a National Bureau of Economic Research Working Paper.[61] The impact was actually most negative on the poorer students.

A study in the Journal of International Affairs examined the impact of the global One Laptop Per Child Program (OLPC), which has distributed millions of computers to children around the world. Researchers Mark Warschauer and Morgan Ames conclude: *"The analysis reveals that provision of individual laptops is a utopian vision for the children in the poorest countries, whose educational and social futures could be more effectively improved if the same investments were instead made on more proven and sustainable interventions. Middle- and high-income countries may have a stronger rationale for providing individual laptops to children, but will still want to eschew OLPC's technocratic vision. In summary, OLPC represents the latest in a long line of technologically utopian schemes that have unsuccessfully attempted to solve complex social problems with overly simplistic solutions*."[62]

Access to computers in the home may not work educational magic. But what about computers in the classroom? Don't they have educational value there?

The anecdotal evidence is mixed at best. Consider how students in Los Angeles, newly equipped with flashy iPads at a mind-boggling taxpayer cost of more than $1 billion, went about using the new tools to improve their educational performance. "Instead of solving math problems or doing English homework, as administrators envisioned, more than 300 Los Angeles Unified School District students promptly cracked the security setting and started tweeting, posting to Facebook and playing video games."[63]

But let's cut through the self-serving corporate claims and the troubling anecdotes to hear from someone who actually has had extensive and unique field experience. Kentaro Toyama was co-founder of Microsoft's research lab in India. Over more than five years he oversaw at least a dozen projects that sought to address educational problems with the introduction of computer technology. His conclusion: "The value of technology has been over-hyped and over-sold."

The most important factor in improving schools, says Toyama, now the W.K Kellogg Associate Professor of Community Information at the University of Michigan, is good teachers. Without good, well-trained teachers, adequate budgets and solid school administration, technology does little good. "Technology by itself never has any kind of positive impact," he said.[64]

The only schools in his experience that benefited from increased technology investment were those where "the teachers were very good, the budgets adequate." The richer schools, in essence. But as both Vigdor and Warschauer found, the introduction of technology has by itself little if any positive effect. For a public conditioned to believe in the virtues of new technology, such testimony is a bracing dose of cold reality.

But what about cost? Doesn‘t technology in the schools more efficiently replace alternative investments? Cost reductions are often the most persuasive argument for technology, Toyama agrees. But even these have been overstated. The costs of introducing new technology run far beyond initial hardware and software investments, said Toyama. In reality, the total costs of ownership—including maintenance, training, and repair—typically run to five or ten times the initial cost, according to Toyama. He said of the investment in technology for cost benefits: ―I would say that in the long run—and even in the medium run and the short-run—that‘s probably the worst and most misguided conclusion to come to.”[65]

He adds: ―The inescapable conclusion is that significant investments in computers, mobile phones and other electronic gadgets in education are neither necessary nor warranted for most school systems. In particular, the attempt to use technology to fix underperforming class rooms . . . is futile. And for all but wealthy, well-run schools, one-to-one computer programs cannot be recommended in good conscience.”[66]

But that doesn‘t keep industry lobbyists from recommending them. And it hasn‘t kept the FCC for spending scores of billions subsidizing technology to the very groups least likely to benefit from it.

Unmoved by the arguments of researchers and educators like Vigdor, Warschauer, and Toyama, the FCC keeps moving to increase technology subsidies. Ignoring research that disputes the value of technology in closing the so-called ―digital divide,” the FCC has even pioneered a new slogan: ―the Wi-Fi gap.”

In announcing that it was lifting E-Rate‘s annual budget from $2.4 billion to $3.9 billion and stepping up investment in wireless networking, FCC chairman Wheeler exulted that ―10 million students are going to experience new and better opportunities.”[67] The impact on consumer pocketbooks (and potentially on youngsters‘ health from daily Wi-Fi exposure) were not mentioned.

The two Republican members of the FCC did at least recognize the pocketbook impact. ―It always seems easier for some people to take more money from the American people via higher taxes and fees rather than do the hard work,” said Commissioner Michael O‘Reilly.[68]

The subsidized provision of high-speed Internet service is yet another pet project of the FCC. Julius Genachowski, chairman from 2009 to 2013, championed the transition of the USF from landline phone service to broadband. Universal broadband Internet connections would begin to absorb the monies collected from consumers to extend basic phone service.

As with government subsidies for cell phone service, classroom technology, and Wi-Fi, there are basic questions about the wisdom of subsidizing broadband. Charles Davidson and Michael Santorelli of the New York Law School found that spending billions to extend broadband is a flawed approach since there are many largely ignored reasons people choose not to adopt

broadband. ―Everybody is pushing broadband non-stop," noted Davidson, director of the Law School's Advanced Communications Law and Policy Institute. ―I think the FCC is focused on the wrong set of issues," he said.[69]

Already, he explained, over 98% of Americans have access to wired or wireless broadband. The issue is not one of supply. It's one of demand. Many people—for a variety of reasons—don't really care about broadband, he contends. Price is one issue. Also powerful factors—but given almost no attention—are privacy and security concerns. ―In our view, they should be focused on barriers to meaningful broadband utilization: privacy and security," said Davidson.[70]

But consumer privacy (more on this subject in Chapter Seven) has no well-funded lobby with limitless access to the FCC.

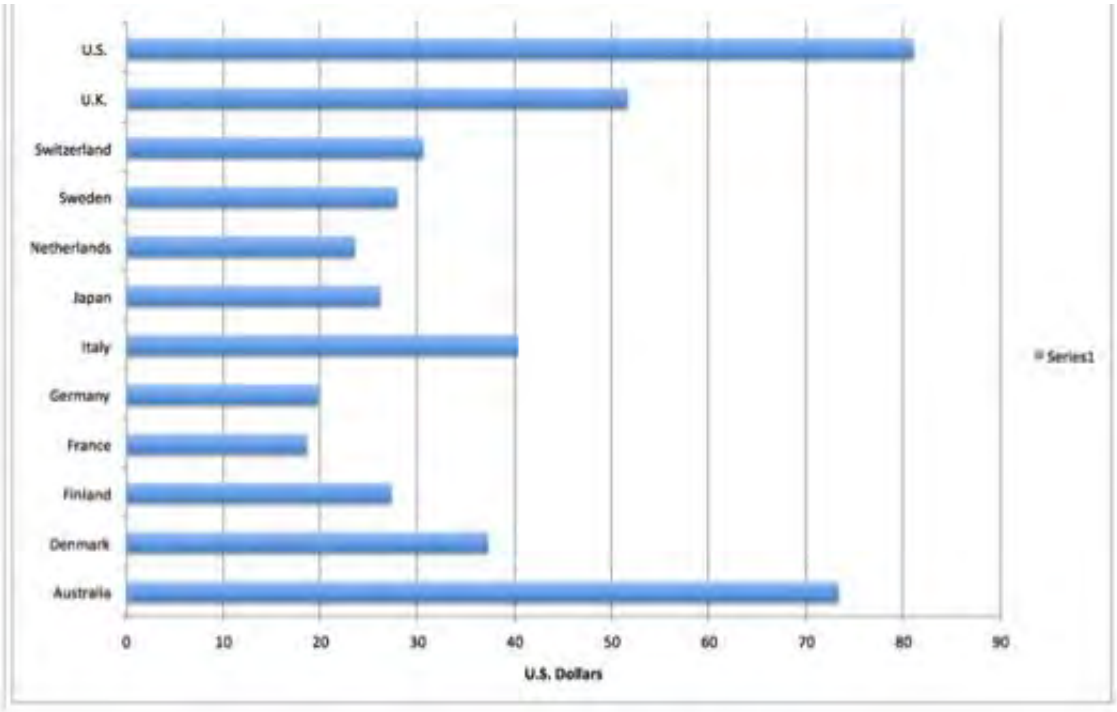
Chapter Six: The Cable Connection

The network has also been active in diluting FCC control of the cable television industry. Over the years, cable has devolved into major de facto local monopolies. Comcast and Time Warner Cable, whose merger proposal was dropped in April, are dominant forces in both cable television and broadband Internet subscriptions. Somehow, though, they have managed to steer clear of one another in specific markets, giving each pricing power where it faces little local competition.

It's interesting that cable companies annually rank in consumer polls among the ~~"m~~most hated" or ~~"m~~most disliked" American corporations. Indeed, Comcast and Time Warner Cable often top the ~~"m~~most hated" list.[71] Why would these companies—providers of the TV programming that has so expanded consumer options in recent decades—be so widely scorned? After all, the U.S. has been a leader in developing both cable technology and diverse television programming.

The problem is that it hasn't been anything close to a leader in bringing down subscriber prices. Industry consultants typically measure pricing by the metric of average revenue per subscriber. Industry trackers at IHS compared the price of U.S. pay television (which includes satellite services) to those in more than 60 other countries. U.S. prices were the highest, with only Australia even coming close. The average revenue per subscriber in the U.S. in 2013 was $81. But in France it was just $18.55. In Germany it was $19.68. In Japan it was just over $26.

Pay TV Monthly Revenue Per Person:



And U.S. cable prices have risen in recent years at rates three or more times the rate of inflation. This has been going on for some time. From 1995 to 2013 cable rates increased at a 6.1% annual clip. The Consumer Price Index, by contrast, rose by just 2.4% annually. Former FCC commissioner Michael Copps says the FCC shares a major part of the blame. "The FCC is as culpable for allowing that as much as the companies for imposing it," he said.[72]

One area where the FCC has contributed to the problem is in its traditional rubber-stamping of merger agreements. The proposed Comcast/Time Warner Cable deal has been shelved, largely because of Justice Department reservations. But a long run of earlier FCC-sanctioned deals allowed Comcast and Time Warner Cable to grow to the market dominance—and attendant pricing power—they currently command.

Lofty monthly cable bills pinch consumers. But it's more than that. Subscribers paying $80 a month are often paying for a lot of channels they don't watch and don't want. The FCC has never required cable operators to charge for what consumers actually want to watch. Kevin Martin, who chaired the FCC from 2005 to 2009, pushed to "unbundle" programming in hopes of lowering bills. But the issue was never resolved. Only recently have viable competitive alternatives to cable's "bundled" packages become available. The satellite service Dish, for example, months ago introduced its Sling offering that enables consumers to opt for smaller and cheaper packages.

In fairness to cable operators, it should be pointed that programmers often require operators to take unwanted or fledgling channels along with their stars. New York cable operator Cablevision Systems filed suit against Viacom in 2013, charging that in order to get popular channels like MTV and Nickelodeon it was also forced to take low-rated channels like Nicktoons and VH1 Soul. But the simple truth is that no matter who is to blame, the cable consumer pays high prices, typically for some programming he doesn't want. As it often does when powerful interests pursue dubious practices, the FCC has for the most part idly stood by.

Still, the FCC isn't entirely to blame. Some factors in the growth of the cable giants cannot be laid at its doorstep. Local municipalities often granted monopoly or duopoly status in granting franchises to cable network builders. With the huge capital investments required to cable metropolitan areas, this once seemed to make sense.

And over the years, the cable giants have used a variety of tactics to weaken what little local competition they may have had. Active lobbyists on the local level, the cable giants have managed to convince a growing number of states to outlaw municipal systems that could threaten private corporate incumbents. The FCC for many years declined to tangle with the states in this matter, partly due to the opposition of Republican commissioners. But the Wheeler-led Commission did vote recently to override state laws that limit the build-out of municipal cable systems.

Still, many years of industry subservience will be difficult to swiftly undo. One linchpin merger shows how FCC decision-making has been thoroughly undermined by the revolving door, lobbying, and carefully targeted campaign contributions. All conspired in Comcast's pivotal 2011 buyout of NBC Universal, a deal which reinforced Comcast's domination of both cable and broadband access. This deal also set the stage for the recent headline-grabbing acrimony over the issue of net neutrality.

In 2011, mighty Comcast proposed to acquire NBC Universal. A series of mergers including the 1986 acquisition of Group W assets and the 2002 acquisition of AT&T's cable assets had already vaulted Comcast into cable market leadership. In bidding for NBC Universal, a huge step towards vertical integration, Comcast was once again raising the stakes. NBC Universal would give Comcast a treasure trove of programming, including valued sports content like NFL football and the Olympics.

Suddenly, the issue was not just cable subscriber base size—where Comcast had already bought its way to dominance. NBC Universal would also allow Comcast to consolidate its growing power as a broadband Internet provider. And with NBC Universal's programming assets, Comcast would gain new leverage when negotiating prices to carry the competing programming content of rivals. This would prompt a new round of debate over net neutrality. Couldn't a programming-rich Comcast slow down rival services—or charge them more to carry their programming?

To short-circuit any potential opposition to the merger, Comcast assembled a superstar cast of lobbyists. As Susan Crawford reports in her 2013 book, "Comcast hired almost eighty former government employees to help lobby for approval of the merger, including several former chiefs of staff for key legislators on congressional antitrust committees, former FCC staffers and Antitrust Division lawyers, and at least four former members of Congress.[73] Such "profligate hiring," Crawford observes, pretty much silenced the opposition to the deal. If Comcast had already retained one member of a lobbying firm, the firm could not under conflict of interest rules object to the deal. And Comcast had locked up key lobbying shops. Money was both weapon and silencer.

Of course, Comcast had always been a big spender on lobbying, with outlays exceeding $12 million every year since 2008. Lobbying costs peaked in 2011 at $19.6 million, according to the Center for Responsive Politics.

For its part, the FCC had a long history of approving most media mergers. So it was hardly a great surprise when the agency, after exacting some relatively minor concessions from Comcast, rubber-stamped the deal. Comcast would thus broaden its footprint as local monopoly distributor of cable. And with its new programming assets, it would enhance its leverage in negotiating deals to carry its rivals' programming. It would also fortify its position of growing strength as broadband Internet gatekeeper.

The most telling footnote to the deal would come just four months later. FCC Commissioner Meredith Atwell Baker, who voted to approve the merger in January 2011, left the FCC to become a top-tier Comcast lobbyist in May. It was the ultimate—and perhaps most telling—glide of the revolving door.

Baker's was a high-profile defection. But it was neither the first nor the last. Comcast had successfully convinced other FCC officials to take their expertise and government contacts to the cable giant. Comcast has long been a master at spinning the revolving door to its own advantage. "Comcast has been very good at hiring everyone who is very smart," said Crawford.[74]

Approval of the NBC Universal deal was another in the long string of FCC merger approvals that made Comcast a nationwide monopolist that could dictate both pricing and viewer programming choice.

But the deal may have had another unintended consequence. It set the stage for Comcast's subsequent battles on net neutrality. "Those mergers gave additional oomph to the issue of net neutrality," noted former commissioner Copps. Speaking specifically of Comcast's buyout of NBC Universal, IHS senior analyst Eric Brannon agreed. "That merger laid the grounds for net neutrality."

In allowing Comcast to acquire major programming assets, the deal would sharpen questions about the power of gatekeepers like Comcast to control the flow of traffic from rival Web services. So in bowing to lobbyist pressure, the FCC would bring on itself a whole new set of pressures by focusing public attention on the issue of net neutrality.

With activists rounding up comments from the public and hip TV personalities like HBO's John Oliver also beating the drums, net neutrality quickly grew into a popular issue that won the support of President Obama, and by proxy, his hand-picked appointee Tom Wheeler. When the FCC ruled in February of 2015 that it would seek Title II authority to regulate the Internet and presumably block any favoritism by broadband gatekeepers, it seemed to finally cast its lot with the public against steamrolling corporate interests

The issue had simmered for years but reached full boil when movie purveyor Netflix, which had argued that its service was slowed down by Comcast, signed a side deal ensuring better download speeds for its wares. This triggered an outburst of public concern that Comcast was now in position to operate "fast" and "slow" lanes, depending on whether a rival programmer could afford to ensure that Comcast provide adequate download speed.

With nearly 4 million comments—many supplied or encouraged by public interest groups—filed to the FCC, net neutrality was a bankable political issue. And there's no question, net neutrality attracted public interest because it gave cable viewers—long furious at the treatment by the monopolists who send them monthly bills—issues of both viewing pleasure and economics.

But it also fed into the longstanding sentimental but increasingly unrealistic view of the Internet as the last bastion of intellectual freedom. Internet romanticists have long seen the Web as a place that somehow deserves special rules for breaking the stranglehold of traditional media and offering exciting new communications, information retrieval and shopping efficiencies.

Yes, the Internet is a modern marvel. This is beyond dispute. But some of the favors it has won from government over the years have had unfortunate unintended consequences.

In the 1990s, for example, net access providers were repeatedly exempted as an ~~"in~~fant industry" from paying access charges to the Baby Bells even though they had to connect users through local phone networks. The long distance companies were then paying as much as $30 billion a year for the privilege. But the Internet was exempted.

As the late 90s approached, the Internet was no longer an infant industry. Still, the exemption from access charges was extended. That exemption essentially allowed AOL in the late 90s to offer unlimited unmetered online time, a key factor in boosting usage and siphoning advertisers from print media. Why buy an ad in print that might get viewed with the transitory flip of a page when you can get round-the-clock attention online?[75] FCC decisions to grant the Internet access-charge exemptions arguably accelerated the decline of print media and much of the quality journalism print advertising could once support.

Meanwhile, retailers on the Internet were making inroads into brick and mortar retail business with the help of a Supreme Court-sanctioned exemption from collecting sales tax.[76] This judicial coddling of the Internet was the death knell for many smaller mom and pop local businesses, already challenged to match online pricing. And that's not all. The special favors continue virtually every year, as Congress proposes and/or passes legislation to extend special tax exemptions to Internet services.

Well, maybe tax breaks aren't such a bad idea for such an innovative and transformational emerging technology. For all its faults, the Internet—gateway to all goods, repository of all things, wizardly guide to all knowledge, enabler of universal self-expression—is undeniably cool.

But let's not deny that the combination of tax advantages and deregulation was toxic. Allow an industry to emerge with advantages over useful existing industries that largely play by the rules—well, maybe that can be rationalized. But then fail to hold the upstart industry to the same rules, allowing it more leeway to trample fundamental rights because it has the technical capacity to do so. Well, then you have a cruel Faustian bargain.

With the see-no-evil deregulatory gospel loosing all constraints, the Web would devolve into a playground for corporate snoops and criminals. For all its wonders, the Internet comes at a cost: the loss of control over personal data, the surrender of personal privacy, sometimes even the confiscation of identity.

Perhaps the most favorable consequence of net neutrality—and one that has gotten surprisingly little attention—is that it could set the stage for privacy reform. (More on this in Chapter Seven). The FCC can now choose to exercise its Title II powers to enforce privacy standards over broadband Internet. Privacy is one area where the FCC has done a pretty good job in the past.

Worth remembering, though, is that the hard-fought public victory over Net Neutrality may be transitory. AT&T and others have threatened to go to court to upend the FCC rules. And there's a fair chance a Republican Congress will legislate against Title II.

Meanwhile, though, one supreme irony has begun to unfold in the marketplace.

Modern-day laissez fair ideologues love to invoke the wisdom of markets as represented by the ~~"m~~ysterious hand" of Adam Smith. Unfortunately, in the absence of effective regulation, the putatively wise ~~"m~~ysterious hand" generally seems to work its magic for those with huge financial resources and the political access it buys.

In the current cable situation, however, the mysterious hand may actually be working in consumer-friendly ways. Years of regulation that favored the cable companies have now backfired as the market reacts to monopolistic pricing and content control.

Whereas cable giants have commanded premium monthly subscriber prices to deliver packages of largely unwatched channels, the market is now beginning to burst with new ~~"d~~ebundled" options that are whittling away at cable's vast subscriber base.

Satellite service Direct TV, as noted, now offers its streaming video Sling TV package of popular networks that includes live sports and news. Amazon, Apple, CBS, HBO, Netflix, Sony, and others offer a variety of streaming video options that allow viewers to cut the cable cord. Suddenly, consumers have the cherry-picking capability that bundled—and expensive—cable packages have never allowed.

In this case, at least, the unintended consequences of the FCC's pro-industry policies may be producing an unexpected pro-consumer twist.

Chapter Seven: What about Privacy?

Has any issue gotten as much lip service—and as little meaningful action?

For all the various congressional bills, corporate self-regulatory schemes and presidential Privacy Bill of Rights proposals, the simple truth remains that no personal information is safe on the Internet. Data brokers have built a multi-billion dollar business exchanging information used to build profiles of Net users. Your shopping and surfing habits, your health history, your banking data, your network of social ties, perhaps even your tax filings are all potentially exposed online. Both legal and criminal enterprises amass this information. And it doesn't go away.

At any given moment people you don't know somehow know where you are. They may very well know when you made your last bank deposit, when you had your last asthma attack or menstrual period. Corporations encourage and pay for every bit of information they can use or sell. Creepy? Perhaps, but as Jeff Chester, president of the Center for Digital Democracy points out: "The basic business model that drives online is advertising."[77]

The FCC largely escapes blame on this one. It is the Federal Trade Commission that has had primary responsibility for protecting Internet privacy. The FCC does have some limited authority, which, some critics say, could have been exercised more vigorously. But for the most part the FCC is not to blame for the rampant online abuse of personal privacy and identity.

The FCC does however have privacy authority over the phone, cable and satellite industries. Until recently, at least, the FCC has kept privacy issues at bay among the companies in these industries. "The FCC has generally taken privacy very seriously," noted Harold Feld, a senior vice president at the non-profit Public Knowledge.[78]

But dynamics now in place suggest that privacy may be the next great testing ground for the FCC. A new chance, perhaps, to champion public interest. Even before the opportunity for privacy enforcement under Title II regulatory powers, the FCC faces new challenges from phone companies, now itching to monetize their vast consumer data stashes the way Net companies have. The commonly used term is "Google envy."

"Until now, ISPs (Internet Service Providers) have mostly not gotten into hot water on privacy—but that's changing," observed Jonathan Mayer, a fellow at the Center for Internet and Society.[79] Verizon and AT&T, major providers of mobile Internet access, have each introduced "super cookies" that track consumer behavior even if they try to delete older, less powerful, forms of cookies. AT&T is actually charging its customers an extra $30 a month *not* to be tracked.

Showdowns loom.

In adopting Title II to enforce net neutrality, the FCC has made broadband Internet access a telecom service subject to regulation as a ―common carrier." This reclassification means that the FCC could choose to invoke privacy authority under Title II's Section 222. That section, previously applied to phone and cable companies, mandates the protection of consumer information. Such information—called CPNI for Customer Proprietary Network Information—has kept phone companies from selling data on whom you call, from where you call and how long you spend on the phone. Consumers may have taken such protection for granted on their phone calls. But they have no such protection on their Internet activity—which, as noted, has been a multi-billion dollar safe house hideaway for corporate and criminal abusers of personal privacy.

Now, though, the FCC could put broadband Internet communications under Section 222 protection. To Scott Cleland, a telecom industry consultant who has often been ahead of the analytic pack, this would be a momentous decision.

When the smoke clears—and it hasn't yet—the FCC could make consumer identifiers like IP addresses the equivalent of phone numbers. Suddenly, the Internet companies that have trafficked in all that personal data would be subject to the same controls as the phone and cable companies.

Cleland argues that the risk for privacy abuses extends beyond broadband access providers like Comcast and Verizon to Internet giants like Google and Facebook that have until now flourished with all that personal data. ―They are at risk and they are going to live under the uncertainty their business model could be ruled illegal by the FCC," Cleland said.[80]

Much has been written about the legal challenges broadband access providers intend to mount against the FCC's new rules. But Cleland argues that a very different type of legal action could engulf companies that have benefited from the use and sale of private data. Trial lawyers, he argues, will see opportunity in rounding up massive class action suits of Internet users whose privacy has been violated. What sorts of privacy abusers face legal action? Anyone who has ―collected CPNI via some type of cookie," according to Cleland.

―Right now, edge providers like Google, Facebook and Twitter are at risk of being sued by trial lawyers," he said.[81]

Sounds great for consumers who care about privacy on the Internet and how it has been abused. But the FCC, Cleland was reminded, has never been a consumer advocate. ―Bingo," replied Cleland. That's what makes the FCC's potential move into privacy protection so important and so surprising, he suggests.

There are other signs that the FCC under Tom Wheeler might actually become more consumer-friendly on the issue of data privacy. While Wheeler has brought some former associates from lobbying groups to the FCC, he has also peppered his staff with respected

privacy advocates. Indeed, he named Gigi Sohn, longtime president of the non-profit Public Knowledge, as Counsellor to the Chairman in April.

Another appointee with a privacy background is Travis LeBlanc, head of the FCC‘s Enforcement Bureau. In previous employment in California‘s Office of the Attorney General, LeBlanc was active in enforcing online privacy. LeBlanc has stated an interest in privacy and has already taken action against two firms that exposed personal information—including social security numbers—on unprotected Internet servers.

But many aspects of LeBlanc‘s approach to regulating Internet privacy under Title II remain unclear. Unfortunately, the FCC declined repeated requests to make LeBlanc available for an interview. (It also declined to answer written questions on its enforcement intentions in both privacy and cell tower infrastructure emissions.)

It remains to be seen if LeBlanc and his superiors at the FCC are really willing to take on privacy enforcement. Such a stance would require great courage as the entire Internet infrastructure is built around privacy abuse. It is also questionable whether the FCC would have the courage to challenge Google—a rare corporate ally in the battles over Net Neutrality.

Chapter Eight: Dependencies Power the Network of Corruption

As a captured agency, the FCC is a prime example of institutional corruption. Officials in such institutions do not need to receive envelopes bulging with cash. But even their most well-intentioned efforts are often overwhelmed by a system that favors powerful private influences, typically at the expense of public interest.

Where there is institutional corruption, there are often underlying dependencies that undermine the autonomy and integrity of that institution. Such is the case with the FCC and its broader network of institutional corruption.

As noted earlier, the FCC is a single node on a corrupt network that embraces Congress, congressional oversight committees and Washington social life. The network ties the public sector to the private through a frictionless revolving door—really no door at all.

Temptation is everywhere in Washington, where moneyed lobbyists and industry representatives throw the best parties and dinners. Money also allows industry to control other important factors, like the research agenda. All of this works together to industry‘s advantage because—as with other instances of institutional corruption—there are compromising dependencies. Policy makers, political candidates and legislators, as well as scientific researchers are all compromised by their dependence on industry money.

Dependency #1 – So much of the trouble here comes back to the core issue of campaign finance. Cable, cellular and educational tech interests know where to target their funds for maximum policy impact. And the contributions work, seemingly buying the silence of key committee congressmen—even those with past records as progressives. Key recipients of industry dollars include Massachusetts Senator Ed Markey and, until he retired, California Democrat Henry Waxman. Though they have intermittently raised their voices on such issues as data privacy and cellular health and safety, neither has shown any great inclination to follow through and take up what would have to be a long and tough fight on these issues.

Dependency #2 – Democrats might be expected to challenge industry now and then. They traditionally have done so, after all. But this is the post-*Citizens United* era where the Supreme Court has turned government into a giant auction house.

Bid the highest price and you walk home with the prize—your personal congressman, legislative loophole, even an entire political party.

Such is the case with technology industries and the Democrats. The communications/electronics industry is the third largest industry group in both lobbying and campaign contributions, according to the Center for Responsive Politics. In just 2013 and 2014, this industry sector spent well over $750 million on lobbying.[82]

Only the finance/insurance/real estate and health industries outspend the tech sector on lobbying. But those industry groups lean Republican. Over 62% of the finance/insurance/real estate campaign contributions go to the GOP. Health contributions lean Republican 57% to 43%. But the technology group leans sharply to Democrats, who got 60% of contributions in the 2013-2014 election cycle.[83] The two next largest industry groups—energy/natural resources and agribusiness—also lean heavily Republican. So of the top five industry groups whose money fuels and often tilts elections four are strongly Republican. The Democrats need the tech industry—and they show that dependence with consistent support, rarely raising such public interest issues as wireless health and safety and Internet privacy.

Dependency #3 – Spectrum auctions give the wireless industry a money-making aura. In recent Congressional testimony, an FCC official reminded legislators that the FCC has over the years been a budget-balancing revenue-making force.[84] Indeed, the auctions of electromagnetic spectrum, used by all wireless communications companies to send their signals, have yielded nearly $100 billion in recent years. The most recent auction to wireless providers produced the unexpectedly high total of $43 billion. No matter that the sale of spectrum is contributing to a pea soup of electromagnetic ~~–s~~mog" whose health consequences are largely unknown. The government needs money and Congress shows its appreciation with consistently pro-wireless policies.

Dependency #4 – Science is often the catalyst for meaningful regulation. But what happens when scientists are dependent on industry for research funding? Under pressure from budget cutters and deregulators, government funding for research on RF health effects has dried up. The EPA, which once had 35 investigators in the area, has long since abandoned its efforts.[85] Numerous scientists have told me there's simply no independent research funding in the U.S. They are left with a simple choice: work on industry-sponsored research or abandon the field.

Chapter Nine: A Modest Agenda for the FCC

Nobody is proposing that cell phones be banned. Nor does anyone propose the elimination of the Universal Service program or other radical reforms. But there are some steps—and most are modest—that the FCC can take now to right some of the wrongs that result from long years of inordinate industry access and influence:

1. Acknowledge that there may be health risks in wireless communications. Take down the dismissive language. Maturely and independently discuss the research and ongoing debate on the safety of this technology.

2. In recognition of this scientific uncertainty, adopt a precautionary view on use of wireless technology. Require prominent point-of-sale notices suggesting that users who want to reduce health risks can adopt a variety of measures, including headphones, more limited usage and storage away from at-risk body parts.

3. Back off the promotion of Wi-Fi. As Professor Lennart Hardell has noted, there are wired alternatives that do not expose children to wireless risk.

4. Petition Congress for the budgetary additions needed to expand testing of emissions on antenna sites. It was Congress after all that gave industry carte blanche for tower expansion so long as they comply with FCC standards. But there is evidence of vast non-compliance and Congress needs to ensure that tower infrastructure is operating within the law.

5. Acknowledge that children and pregnant women may be more vulnerable to the effects of RF emissions and require special protection.

6. Promote cable debundling as a way to lighten consumer cable bills, especially for those customers who don‘t care about high-cost sports programming.

7. Apply more rigorous analysis to properly assess the value of technology in education. Evidence continues to pile up that technology in education is not as valuable as tech companies claim. Pay less attention to tech CEOs—pay more attention to the researchers who‘ve actually studied the impact of trendy technology fixes on learning

8. Take over enforcement of personal privacy rights on the Internet. Of all the basic suggestions here, this would require the most courage as it would involve challenging many of the entrenched powers of the Internet.

Chapter Ten: Stray Thoughts

Some concluding thoughts:

Why do so many of the most dubious FCC policies involve technology?

In large part, of course, because the FCC has authority over communications and that is a sector that has been radically transformed—along with so many others—by technology.

Let's be clear, though. The problem is not technology, which unarguably brings countless benefits to modern life. The problem is with the over-extension of claims for technology's usefulness and the worshipful adulation of technology even where it has fearful consequences. Most fundamentally, the problem is the willingness in Washington—for reasons of both venality and naïveté—to give technology a free pass.

Personally, I don't believe that just because something can be done it should heedlessly be allowed. Murder, rape and Ponzi schemes are all doable—but subject to prohibition and regulation. Government regulators have the responsibility to examine the consequences of new technologies and act to at least contain some of the worst. Beyond legislators and regulators, public outrage and the courts can also play a role—but these can be muffled indefinitely by misinformation and bullying.

There are precedents for industries (belatedly perhaps) acting to offset the most onerous consequences of their products. In responding to a mix of litigation, public demand and regulatory requirement, the auto industry, for example, has in the last 50 years substantially improved the safety and environmental footprint of its products.

Padded instrument panels, seat belts, air bags, and crumple zones have all addressed safety issues. Environmental concerns have been addressed with tightened emissions and fuel consumption standards. The response to new safety challenges is ongoing. Before side air bags were widely deployed, sedan drivers side-swiped by much larger SUVs were at vastly disproportionate risk of death and dismemberment.[86] But the deployment of side air bags has ~~"s~~substantially" reduced the risk of collision deaths.[87] Overall, auto fatality rates per 100,000 persons have dropped by nearly 60% in the U.S. since 1966.[88] Today, automakers continue to work on advanced safety features like collision avoidance.

It can be argued that most of these safety improvements came decades after autos were in wide usage and only in response to outrage at Ralph Nader's 1965 revelations on the auto industry.[89] No matter the catalysts. The simple truth remains that the auto industry—and its regulators—have for the last half-century been addressing safety and environmental issues.

But with the overwhelming application of money and influence, information and communications technologies have almost totally escaped political scrutiny, regulatory control, and legal discipline.

Should the Internet have been allowed to develop into an ultra-efficient tool for lifting personal information that includes financial records, health histories and social security numbers? Should wireless communications be blindly promoted even as new clues keep suggesting there may be toxic effects? Should local zoning authorities and American citizens be stripped of the right to protect their own health? Should education be digitized and imposed just because technology companies want to develop a new market and lock in a younger customer base?

All these questions can perhaps be rolled up in one: do we all just play dead for the corporate lobbyists and spinners who promote the unexamined and unregulated application of their products?

Finally, a word about the structure of the FCC. With five commissioners—no more than three from the same party—the structure seems to make some kind of sense.

But in practice, it works out poorly. The identification of commissioners by party tends to bring out the worst in both Republicans and Democrats. Instead of examining issues with clear-sighted independence, the commissioners seem to retreat into the worst caricatures of their parties. The Republicans spout free market and deregulatory ideology that is most often a transparent cover for support of business interests. The Democrats seems satisfied if they can implement their pet spending programs—extension of broadband wireless to depressed urban and rural schools, cell phone subsidies for low income clients. The result is a Commission that fulminates about ideology and spends heavily to subsidize powerful interests.

Perhaps one solution would be to expand the Commission to seven by adding two public interest Commissioners. The public interest only rarely prevails at the FCC. So it would represent vast improvement if both Republican and Democrat commissioners had to vie for support of public interest representatives in order to forge a majority. The public interest, in other words, would sometimes carry the swing votes.

It‘s very hard to believe, though, that Congress would ever approve such a plan. It simply represents too much of a threat to the entrenched political power of the two parties. Why would they ever agree to a plan that dilutes that power?

It‘s also worth noting that the public interest is not always easy to define. Sometimes there are arguably conflicting definitions. Still, an FCC with public interest commissioners is an idea worth consideration. It would at least require party apologists to defend how they so consistently champion the moneyed interests that have purchased disproportionate access and power in Washington.

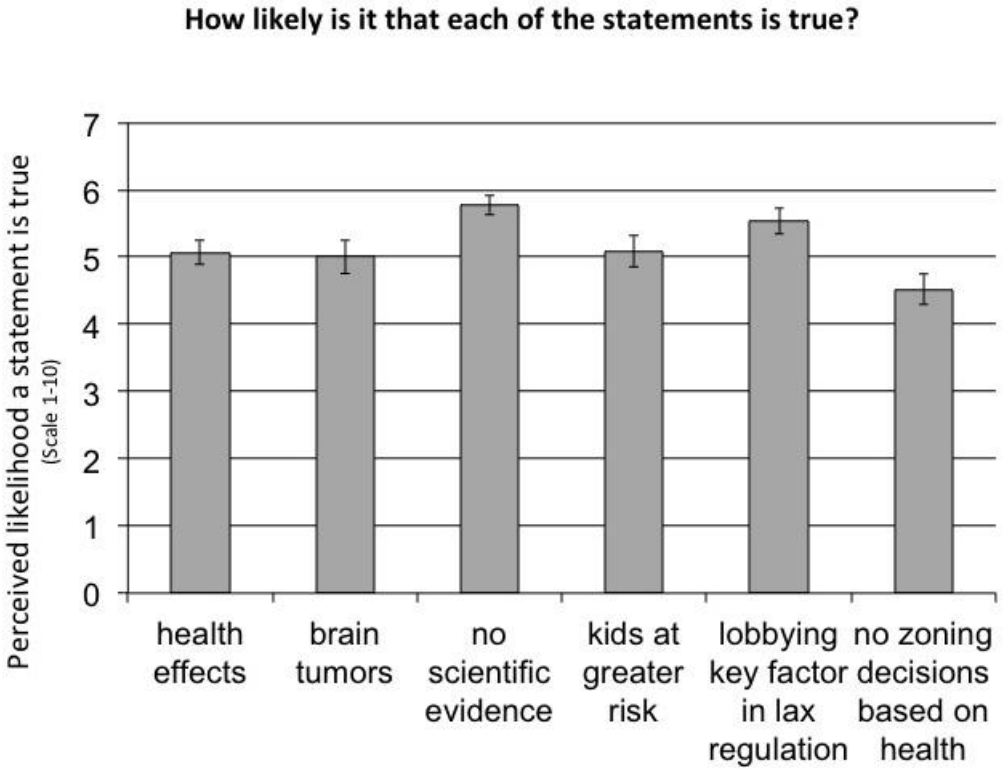
Appendix—Survey of Consumer Attitudes

What does the public believe about the science and politics of wireless health research? Under what conditions would people change wireless usage patterns? Is the FCC currently trusted to protect public health? How would confirmation of health risks affect trust in the FCC?

These are some of the questions Ann-Christin Posten[90] and Norm Alster[91] hoped to answer with an April 2015 online survey of 202 respondents. Participants were recruited through Amazon's Mechanical Turk online platform. All were U.S. residents and had achieved qualifying approval rates in prior Mechanical Turk surveys.

Participants were asked how likely they believed the following statements to be true:

> Statement 1. Prolonged and heavy cell phone use can have a variety of damaging effects on health.
>
> Statement 2. Prolonged and heavy cell phone use triples the risk of brain tumors.
>
> Statement 3. There is no scientific evidence that proves that wireless phone usage can lead to cancer or a variety of other problems.
>
> Statement 4. Children and pregnant women are especially vulnerable to radiation from wireless phones, cell towers and Wi-Fi
>
> Statement 5. Lobbying and campaign contributions have been key factors in keeping the government from acknowledging wireless hazards and adopting more stringent regulation.
>
> Statement 6. The U.S. Congress forbids local communities from considering health concerns when deciding whether to issue zoning permits for wireless antennae.

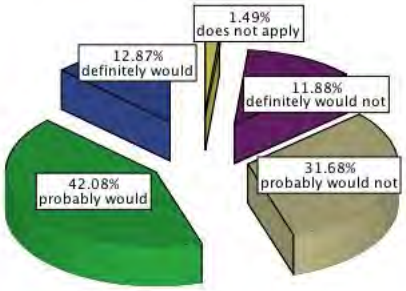


Two findings seem especially interesting:

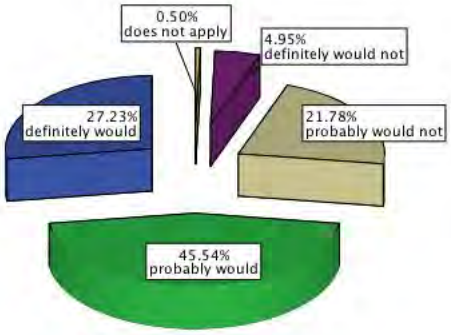
1. Statement 3 received a higher credibility rating than Statements 1 and 2. The different credibility levels are statistically significant. Respondents are more likely to trust in wireless safety than to believe there are general or specific health risks.

2. The only statement that is a matter of uncontested fact is Statement 6 on the outlawing of opposition to antenna sites on health grounds. (All other statements have been both proclaimed and denied.) And yet Statement 6 was least likely to be believed. Just 1.5% of respondents recognized this as an "absolutely true" statement. Over 14% thought this statement was "not true at all." Answers to this question would seem to reflect public ignorance on the political background to wireless health issues.

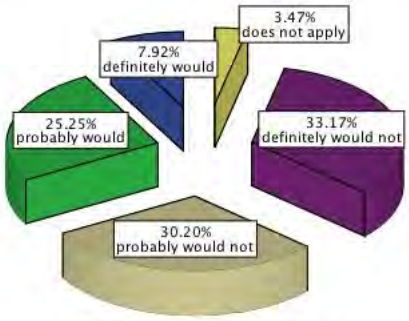
Participants were also asked how they would change behavior if claims of wireless health risks were established as true:



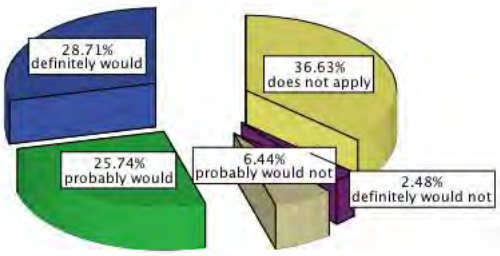
**If statement 1 was true,
I would start using headphones.**



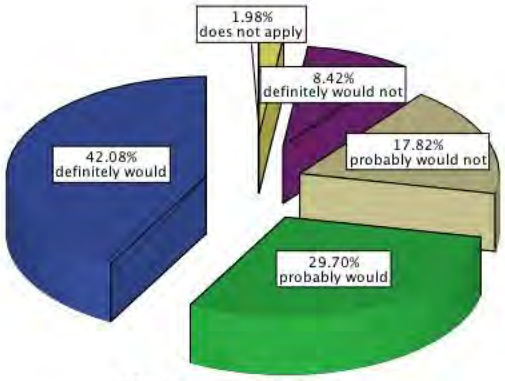
**If statement 1 was true,
I would restrict the amount of time
I spend on the phone.**



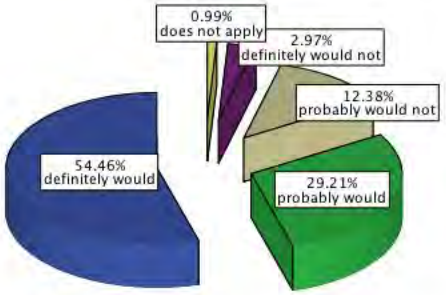
**If statement 1 was true,
I would start up a new land line
account for home use.**



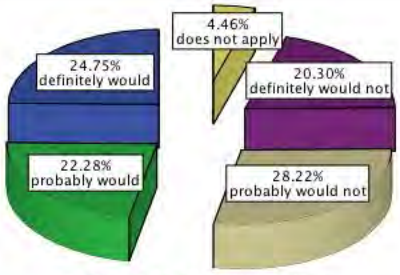
**If statement 1 was true,
I would restrict my children's cell phone use.**



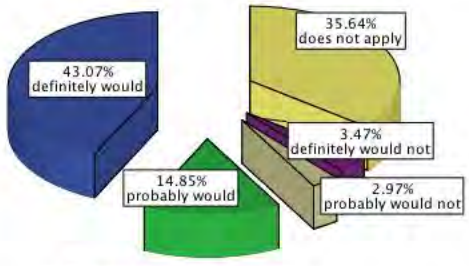
**If statement 2 was true,
I would start using headphones.**



**If statement 2 was true,
I would restrict the amount of time
I spend on the phone.**



**If statement 2 was true,
I would start up a new land line
account for home use.**



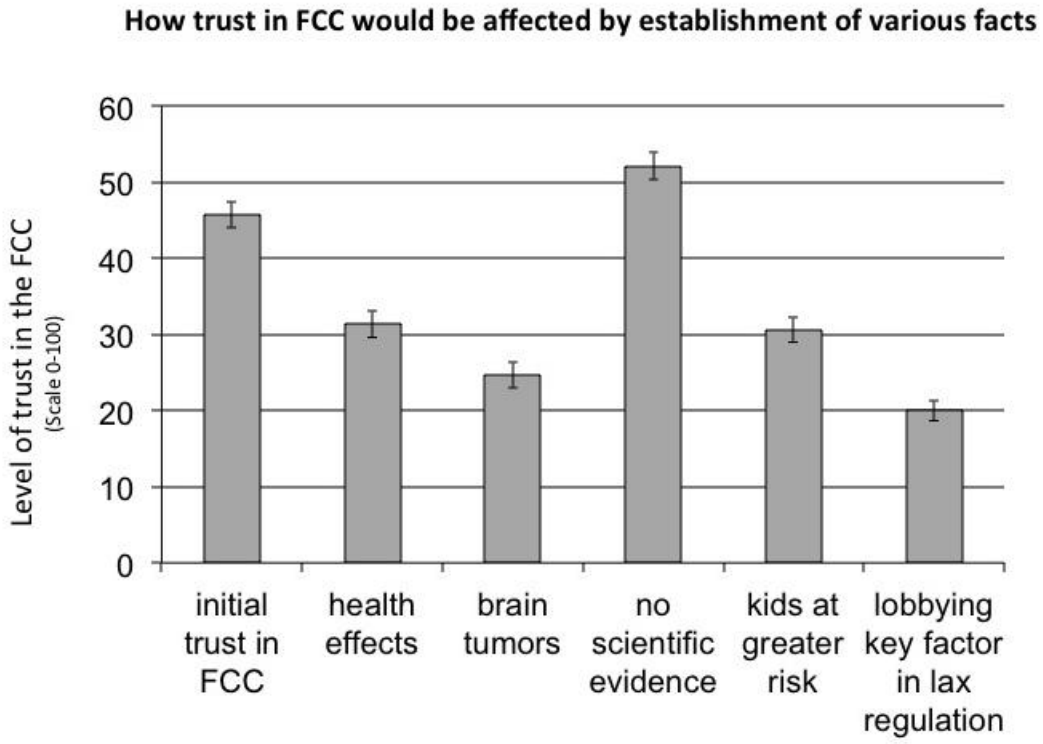
**If statement 2 was true,
I would restrict my children's cell phone use.**

The greatest impact on behavior came when respondents were asked to assume it is true that prolonged and heavy cell phone use triples the risk of brain tumors. More than half said they would ~~"d~~efinitely" restrict the amount of time spent on the phone. Just over 43% would ~~"d~~efinitely" restrict their children's phone use. Perhaps most surprisingly, close to 25% would ~~"d~~efinitely" start up a new landline phone account. (This last response suggests it may be foolishly premature for the phone giants to exit the landline business just yet.)

The inclination of consumers to change behavior should negative health effects be confirmed suggests the stakes are enormous for all companies that derive revenue from wireless usage.

This survey points to—but cannot answer—some critical questions: Do wireless companies better protect themselves legally by continuing to deny the validity of all troublesome research? Or should they instead be positioning themselves to maintain consumer trust? Perhaps there is greater financial wisdom in listening to the lawyers right now and denying all chance of harm. If so, however, why would anyone seriously concerned about health listen to the industry—or to its captured agency? That's a question the FCC will eventually need to answer.

Trust could eventually become a central issue. Respondents were initially asked to describe their level of trust in the wireless industry and in the FCC as its regulator. Not surprisingly, establishment of any of the presumed health risks—or confirmation of inordinate industry pressure—resulted in statistically significant diminution of trust in both the industry and the FCC.



On a scale of 1 to 100, the FCC had a mean baseline trust level of 45.66. But if the tripling of brain tumor risk is established as definitely true, that number falls all the way to 24.68. If ~~l~~obbying and campaign contributions" have been ~~k~~ey factors" in keeping the government from acknowledging wireless hazards, the trust level in the FCC plummets to 20.02. All results were statistically significant.

It's clear that at this point confirmation of health dangers—or even of behind-the-scenes political pressures—from wireless will substantially diminish public trust in the FCC. Skeptics might argue that this gives the FCC motive to continue to downplay and dismiss further evidence of biological and human health effects. Those of a more optimistic bent might see in these findings reason to encourage an FCC concerned about public trust to shake itself loose from special interests.

Endnotes

[1] Former CTIA vice president John Walls in Kevin Kunze's documentary film *Mobilize*, introduced in 2014 at the California Independent Film Festival.

[2] November 2014 interview with Renee Sharp.

[3] December 2014 interview with Twaun Samuel.

[4] Dr. George Carlo and Martin Schram, *Cell Phones, Invisible Hazards In The Wireless Age* (Carroll & Graf, 2001), 18.

[5] Center for Responsive Politics.

[6] Id.

[7] November 2014 interview with Michael Copps.

[8] January 2015 interview with Newton Minow.

[9] Daniel Lathrop, "From Government Service to Private Practice: Writers of Telecom Law Move to K Street," Center for Public Integrity, October 28, 2004, http://www.publicintegrity.org/2004/10/28/6597/government-service-private-practice.

[10] B. Blake Levitt and Henry Lai, "Biological Effects from Exposure to Electromagnetic Radiation Emitted By Cell Tower Base Stations and Other Antenna Arrays," NRC Research Press Web site, November 5, 2010.

[11] Id., 381.

[12] Id.

[13] S. Sivani and D. Sudarsanam, "Impacts of Radio-Frequency Electromagnetic Field (RF_EMF) from Cell Phone Towers and Wireless Devices on Biosystem and Ecosystem – A Review," *Biology and Medicine* 4.4 (2013): 202.

[14] Id., 206-208.

[15] January 2015 interview with Robert Weller.

[16] Letter from Michelle C. Farquhar, Chief of the FCC's Wireless Telecommunications Bureau, to Thomas Wheeler, President and CEO of the Cellular Telecommunications Industry Association, January 13, 1997.

[17] Id.

[18] Letter from FCC Chairman Thomas Wheeler to former FCC Commissioner Jonathan Adelstein, President and CEO, PCIA-The Wireless Infrastructure Association, March 14, 2014.

[19] December 2014 interview with James R. Hobson.

[20] January 2015 interview with Marvin Wessel.

[21] Id.

[22] January 2015 interview with Janet Newton.

[23] Robert Weller interview.

[24] Best's Briefing, "Emerging Technologies Pose Significant Risks with Possible Long-Tail Losses," February 11, 2013, http://www.ambest.com/directories/bestconnect/EmergingRisks.pd.

[25] Online survey conducted in April 2015 on Amazon's Mechanical Turk platform.

[26] CTIA, "Policy & Initiatives: Innovation," http://www.ctia.org/policy-initiatives/policy-topics/innovation.

[27] February 2015 interview with Dennis Kucinich.

[28] Alexander Lerchl, Melanie Klose, and Karen Grote et al., "Tumor Promotion by Exposure to Radiofrequency Electromagnetic Fields below Exposure Limits for Humans," *Biochemical and Biophysical Research Communications* 459.4 (2015): 585-590.

[29] WHO/International Agency for Research on Cancer (IARC), "IARC Classifies Radiofrequency Electromagnetic Fields As Possibly Carcinogenic To Humans," Press Release No. 208, May 31, 2011.

[30] Medscape, "Brain Cancer CME Learning Center," http://www.medscape.org/resource/brain-cancer/cme.

[31] Anke Huss, Matthias Egger, Kerstin Hug, Karin Huwiler-Muntener, and Martin Roosli, "Source of Funding and Results of Studies of Health Effects of Mobile Phone Use: Systemic Review of Experimental Studies," *Environmental Health Perspectives* 115.1 (2007): 1-4, 1.

[32] Id.

[33] Federal Communications Commission, "Wireless Devices and Health Concerns," http://www.fcc.gov/guides/wireless-devices-and-health-concerns.

[34] Lennart Hardell, Michael Carlberg, Fredrik Soderqvist, and Kjell Hansson Mild, "Case-Control Study of the Association between Malignant Brain Tumours Diagnosed between 2007 and 2009 and Mobile and Cordless Phone Use," *International Journal of Oncology* 43.6 (2013): 1833-1845.

[35] Lennart Hardell and Michael Carlberg, "Use of Mobile and Cordless Phones and Survival of Patients with Glioma," *Neuroepidemiology* 40.2 (2012): 101-108.

[36] Lennart Hardell and Michael Carlberg, "Using the Hill Viewpoints from 1965 for Evaluating Strengths of Evidence of the Risk for Brain Tumors Associated with Use of Mobile and Cordless Phones," *Reviews on Environmental Health* 28.2-3 (2013): 97-106.

[37] Gaelle Coureau, Ghislaine Bouvier, and Pierre Lebailly, et al., "Mobile Phone Use and Brain Tumors in the CERENAT Case-Control Study," *Occupational and Environmental Medicine* 71.7 (2014): 514-522, doi:10.1136/oemed-2013-101754.

[38] October 2014 interview with Lennart Hardell.

[39] December 2014 interview with Martin Blank.

[40] Id.

[41] Norm Alster, "Cell Phones: We Need More Testing," *BusinessWeek,* August 14, 2000, 39.

[42] Quoted in American Academy of Pediatrics, "American Academy of Pediatrics Endorses Cell Phone Safety Bill," Press Release, December 20, 2012, http://www.ewg.org/release/american-academy-pediatrics-endorses-cell-phone-safety-bil.

[43] Om P. Gandhi, L. Lloyd Morgan, Alvaro Augusto de Salles, Yueh-Ying Han, Ronald B. Herberman, and Devra Lee Davis, "Exposure Limits: The Underestimation of Absorbed Cell Phone Radiation, Especially in Children," *Electromagnetic Biology and Medicine* 31.1 (2012): 34-51.

[44] November 2014 interview with Joel Moskowitz.

[45] February 2015 interview with Carl Blackman.

[46] Id.

[47] Id.

[48] Lawrence Lessig, Roy L. Furman Professor of Law and Leadership at Harvard Law School, helped to draft the Right to Know ordinance and has offered pro bono legal representation to the city of Berkeley. Professor Lessig was director of the Lab at Harvard's Safra Center for Ethics, from which the Project on Public Narrative was spun off in November of 2014.

[49] May 2015 interview with Berkeley City Attorney Zach Cowan

[50] December 2014 interview with Jerry Phillips.

[51] Id.

[52] February 2015 interview with Om P. Gandhi.

[53] Id.

[54] Radio interview on WBAI-FM, "Wireless Radiation: What Scientists Know and You Don't, With Dr. Joel Moskowitz," March 10, 2015.

[55] Spencer Ante, "Millions Improperly Claimed U.S. Phone Subsidies," *Wall Street Journal*, February 11, 2013, http://allthingsd.com/201330212/millions-improperly-claimed-u-s-phone-subsidies/.

[56] Federal Communications Commission Office of Inspector General, "Semiannual Report to Congress for the Period April 1, 2014 - September 30, 2014," 20, http://transition.fcc.gov/oig/FCC_OIG_SAR_09302014a.pdf.

[57] Federal Communications Commission, "Reports on Meetings and Telephone Calls with Registered Lobbyists Regarding General Recovery Act Policy Issues," March 2, 2010.

[58] CTIA - The Wireless Association, "Response to White House Paper on Universal Service Policy," September 19, 2014, http://www.ctia.org/docs/default-source/Legislative-Activity/ctia-usf-response-to-house-white-paper-091914.pdf?sfvrsn=0.

[59] Open Letter from Executives of 50 Leading Companies to Tom Wheeler, Chairman of the FCC, January 30, 2014, http://erate2.educationsuperhighway.org/#ceos-letter. See also David Nagel, "50 Top Execs Urge E-Rate Modernization To Propel Broadband in Schools," *The Journal*, January 30, 2014.

[60] October 2014 interview with Lennart Hardell.

[61] Jacob L. Vigdor and Helen F. Ladd, "Scaling the Digital Divide: Home Computer Technology and Student Achievement," Calder Urban Institute Working Paper, No. 48, June 2010.

[62] Mark Warschauer and Morgan Ames, "Can One Laptop Per Child Save the World's Poor?" *Journal of International Affairs* 64.1 (2010): 33-51.

[63] John Rogers, "L.A. Students Get iPads, Crack Firewall, Play Games," *Associated Press,* October 5, 2013, http://bigstory.ap.org/article/la-students-get-ipads-start-playing-video-games.

[64] April 2015 interview with Kentaro Toyama.

[65] Id.

[66] Id.

[67] FCC Chairman Tom Wheeler, quoted in Grant Gross, "FCC Approves Plan to Spend $1B a Year on School Wi-Fi," IDG News Service, July 11, 2014.

[68] Michael O'Rielly, "Dissenting Statement by Commissioner Michael O'Rielly," 2, http://e-ratecentral.com/files/fcc/DOC-328172A7.pdf, after FCC in July of 2014 voted to increase Wi-Fi spending.

[69] February 2015 interview with Charles Davidson and Michael Santorelli.

[70] Id.

[71] The University of Michigan's American Customer Satisfaction Index, http://www.theacsi.org/the-american-customer-satisfaction-index.

[72] September 2014 interview with Michael Copps.

[73] Susan Crawford, *Captive Audience: The Telecom Industry and Monopoly Power in the New Gilded Age* (Yale University Press, 2013), 212.

[74] October 2014 interview with Susan Crawford.

[75] Norm Alster, "A Little Help from the Feds," *BusinessWeek,* January 24, 2000, 42.

[76] 1992 Supreme Court decision in *Quill Corp. v. North Dakota*, 504 U.S. 298 (1992).

[77] February 2015 conversation with Jeff Chester.

[78] April 2015 interview with Harold Feld.

[79] March 2015 interview with Jonathan Mayer.

[80] April 2015 interview with Scott Cleland.

[81] Id.

[82] Center for Responsive Politics.

[83] Id.

[84] "Testimony of Jon Wilkins, Managing Director, Federal Communications Commission," Before the Committee on Energy and Commerce, Subcommittee on Communications and Technology, U.S. House of Representatives, March 4, 2015.

[85] Alster, "Cell Phones: We Need More Testing," 39.

[86] Danny Hakim and Norm Alster, "Lawsuits: This Year's Model," *New York Times,* May 30, 2004, http://www.nytimes.com/2004/05/30/business/lawsuits-this-year-s-model.html.

[87] A.T. McCartt and S.Y. Kyrychenko, "Efficacy of Side Airbags in Reducing Driver Deaths in Driver-Side Car and SUV Collisions," *Traffic Injury Prevention* 8.2 (2007): 162-170.

[88] National Highway Traffic Safety Administration, "Traffic Safety Facts 2012," 18, http://www-nrd.nhtsa.dot.gov/Pubs/812032.pdf.

[89] Ralph Nader, *Unsafe At Any Speed: The Designed-In Dangers of the American Automobile* (Grossman Publishers, 1965).

[90] Lab Fellow, Edmond J. Safra Center for Ethics, Harvard University.

[91] Investigative Journalism Fellow, Project on Public Narrative at Harvard Law School.