ENVIRONMENTAL HEALTH TRUST

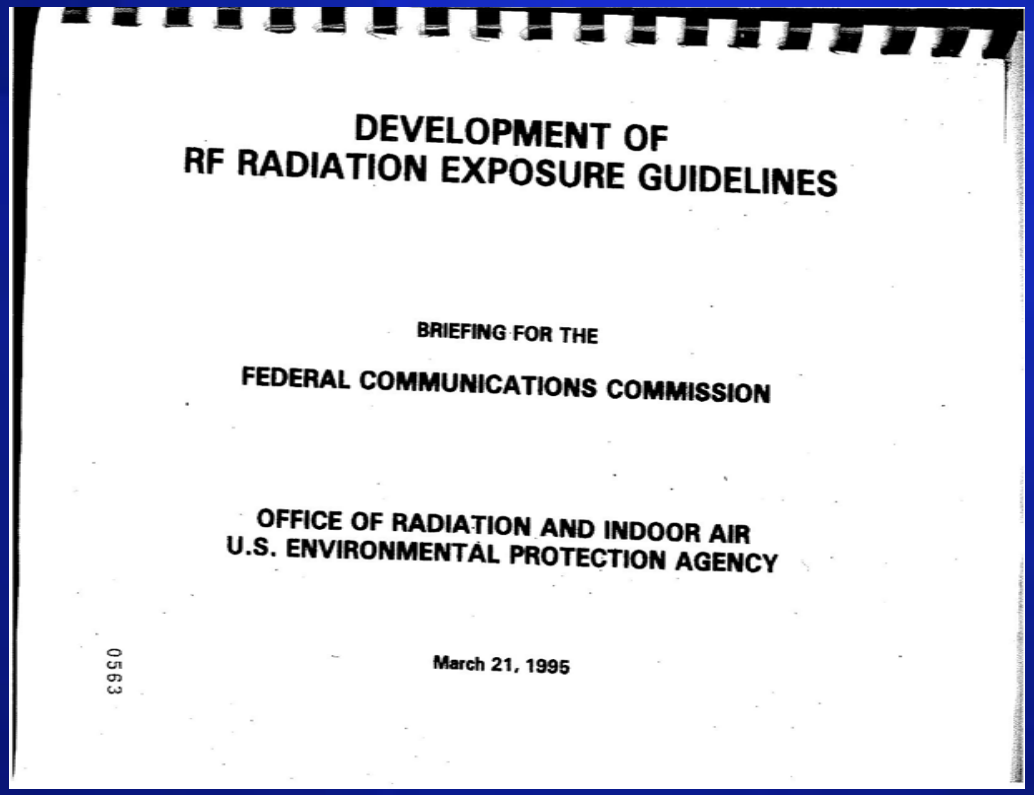
U.S. Policy and Regulatory Needs Cell Tower Radiation

Theodora Scarato MSW

Executive Director Environmental Health Trust

Before 1996: EPA was in Development of RF Exposure Guidelines

“Completion of the guidelines in a timely manner remains a priority of this office.”
-Romano Trovato, Director EPA Office of Radiation and Air, June 19, 1995



DEVELOPMENT OF
RF RADIATION EXPOSURE GUIDELINES

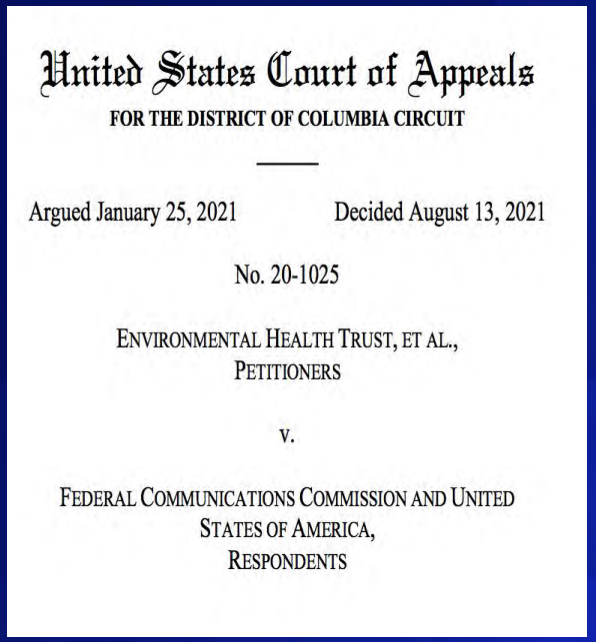
BRIEFING FOR THE

FEDERAL COMMUNICATIONS COMMISSION

OFFICE OF RADIATION AND INDOOR AIR
U.S. ENVIRONMENTAL PROTECTION AGENCY

March 21, 1995

0563



United States Court of Appeals
FOR THE DISTRICT OF COLUMBIA CIRCUIT

Argued January 25, 2021 Decided August 13, 2021

No. 20-1025

ENVIRONMENTAL HEALTH TRUST, ET AL.,
PETITIONERS

v.

FEDERAL COMMUNICATIONS COMMISSION AND UNITED STATES OF AMERICA,
RESPONDENTS

Environmental Health Trust et al. v. the FCC

2021: United States Court of Appeals for the D.C. Circuit : **FCC did not provide evidence of examining the record.**

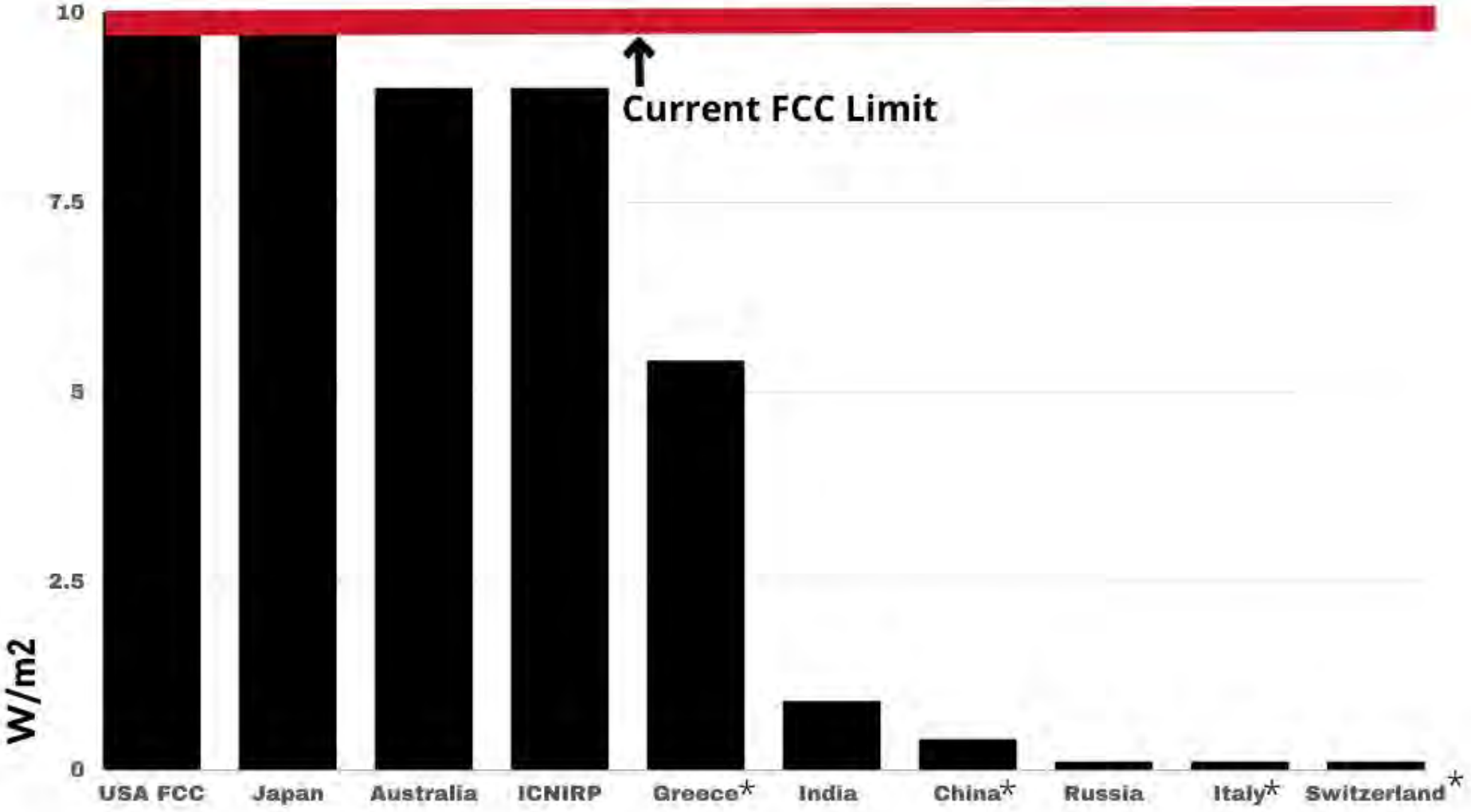
The Court mandated the FCC address :

- long-term exposure
- children's vulnerability
- Impacts to the developing brain and reproductive system
- environmental effects
- technological developments since 1996

No response so far.

ENVIRONMENTAL HEALTH TRUST

Radio Frequency Radiation Exposure Limits for the General Public
Cell Towers & Wireless Networks in Homes and/or Sensitive Areas
■ Limit for 1800 MHz W/m2 equivalent plane wave density



*Switzerland and Italy: Precautionary exposure limitations, at places of sensitive use such as apartment buildings, schools, hospitals, permanent workplaces and children's playgrounds and where people stay for hours.
China: The standard cites the precautionary principal and encourages facility and equipment owners to take measures to reduce public exposures. Greece: 300 meter radius around schools, kindergartens and hospitals.

@Environmental Health Trust

EPA
United States Environmental Protection Agency

CDC
Centers for Disease Control and Prevention

NIH National Cancer Institute

FDA
U.S Food and Drug Administration

Department of Labor
United States of America

Wireless Radiation Regulatory Gaps

There is no review of all of the relevant evidence on bioeffects by any U.S. regulatory agency.

EHTRUST.ORG
ENVIRONMENTAL HEALTH TRUST

No agency with activity regarding the **health and environmental effects of cell tower** and **4G/5G "small" cell** antennas.

Government Accountability Office 2012, 2020

ENVIRONMENTAL HEALTH TRUST

Communities with large setbacks for wireless antennas.

1500 feet

- Shelburne, MA
- Copake, NY
- Sallisaw, OK
- Bar Harbor ME:

1000 feet

- Stockbridge, MA
- San Diego County CA

500 feet

- Scarsdale New York

250 feet

- Ithaca NY

16 New York Community Boards passed moratoriums or letters of disapprovals

ENVIRONMENTAL HEALTH TRUST

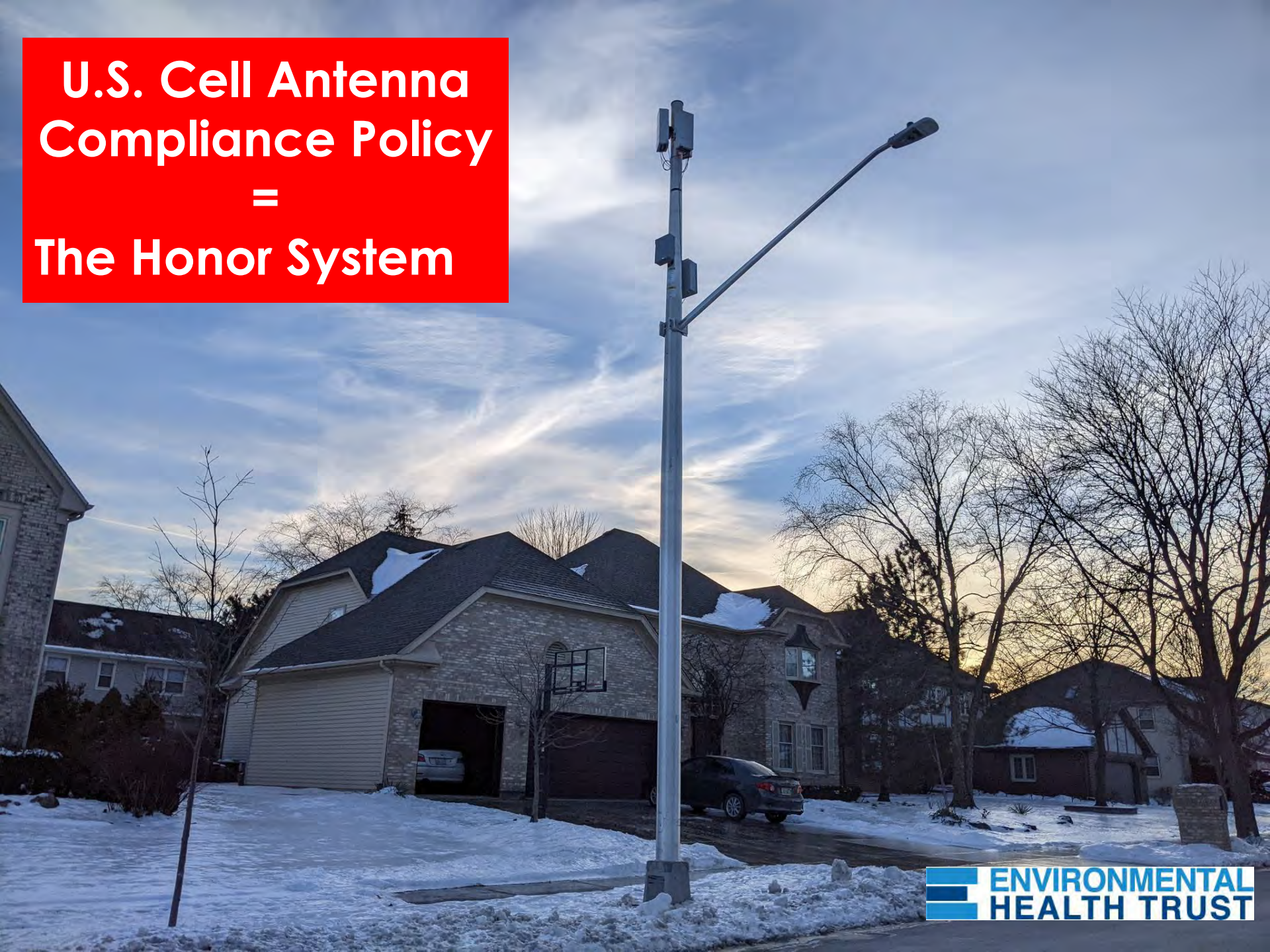

San Francisco 2019

Regulatory Gap

No **compliance and enforcement** program for **cell towers** or **5G/4G** "small" cells.

ENVIRONMENTAL HEALTH TRUST

U.S. Cell Antenna Compliance Policy = The Honor System



View of “Small” Cell Being Installed Window of Pittsburgh Home

No FCC Review of RF Reports

- No **standardization for RF compliance report formats**
- No **follow up** on recommendations
- **Lack of transparency** in documentation.

ENVIRONMENTAL HEALTH TRUST


Louisiana

USA Regulatory Gaps

No **measuring** **monitoring** or **mapping** for environmental RF levels.

ENVIRONMENTAL HEALTH TRUST

Governments That Measure Environmental Cell Tower Radiation

France, Greece, Turkey, Switzerland, India, Israel, United Kingdom, Australia, French Polynesia, Senegal, Guinea, Monaco, Bhutan, Austria, Gibraltar, Brussels Belgium, Bulgaria, Tunisia, Bahrain, Norway, Brazil, Malta, Thailand, Croatia, Lithuania, Serbia, Spain

ENVIRONMENTAL HEALTH TRUST

NATIONAL OBSERVATORY
OF ELECTROMAGNETIC FIELDS

USA Regulatory Gaps

No **federal registry** of all wireless facility sites.

ENVIRONMENTAL HEALTH TRUST


Upper East Side, New York City Apartment

Pending Federal Legislation Preempts Local and State Control

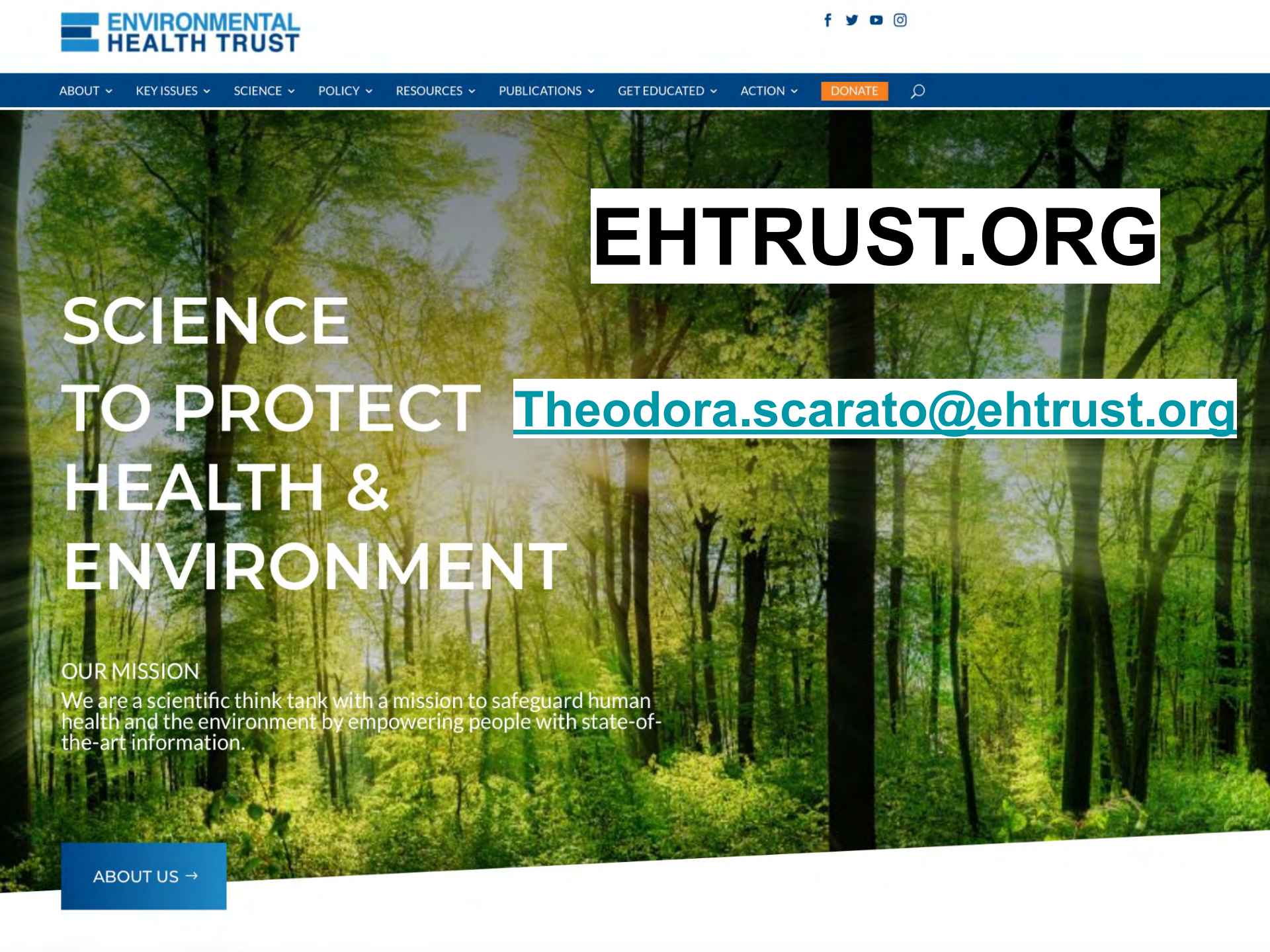
HR 3557:

- Virtually eliminates states' rights and local authority overplacement
- Exempts most wireless deployments from the National Environmental Policy Act (NEPA) and National Historic Preservation Act (NHPA).

How can governments rely on FCC to protect public and the environment with such regulatory gaps ?

- No Enforcement Program
- No Standardized Data Backed Compliance Procedures
- No Measuring and Monitoring
- No Federal Registry
- No Health and Environmental Surveillance
- No Ongoing Research Review
- No Regular Evaluation of FCC Limits.

ENVIRONMENTAL HEALTH TRUST


ENVIRONMENTAL HEALTH TRUST
ABOUT
KEY ISSUES
SCIENCE
POLICY
RESOURCES
PUBLICATIONS
GET EDUCATED
ACTION
DONATE
EHTRUST.ORG
SCIENCE TO PROTECT HEALTH & ENVIRONMENT
Theodora.scarato@ehtrust.org
OUR MISSION
We are a scientific think tank with a mission to safeguard human health and the environment by empowering people with state-of-the-art information.
ABOUT US →

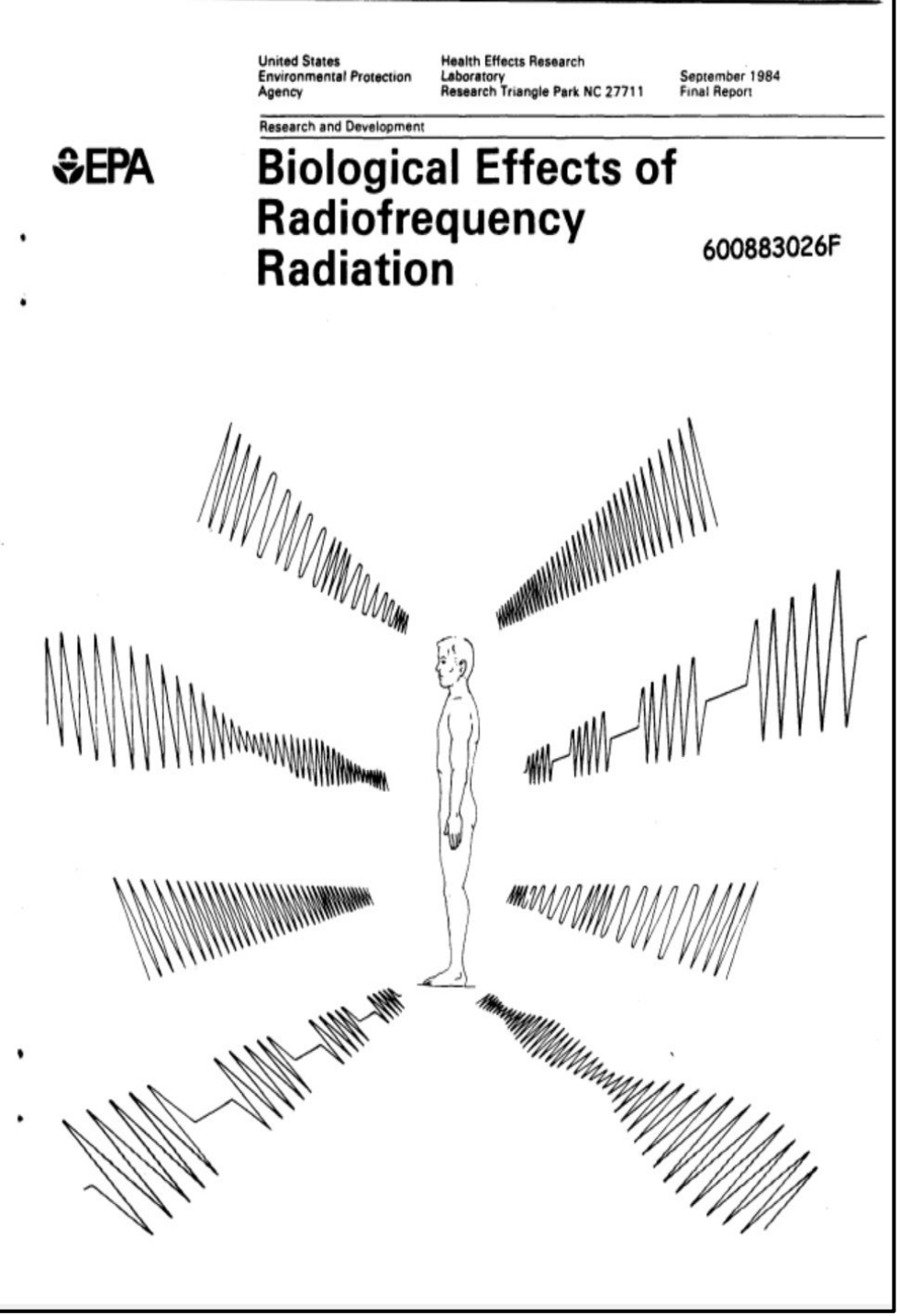
FDA U.S. FOOD & DRUG ADMINISTRATION

"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 of the FDA Office of Policy Center for Devices and Radiological Health January 11, 2022

View from third floor of home in Pennsylvania with "small" cell going up

EHTRUST.ORG
ENVIRONMENTAL HEALTH TRUST



"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
to Scarato July 8, 2020 and 2023

ENVIRONMENTAL HEALTH TRUST

NIH NATIONAL CANCER INSTITUTE

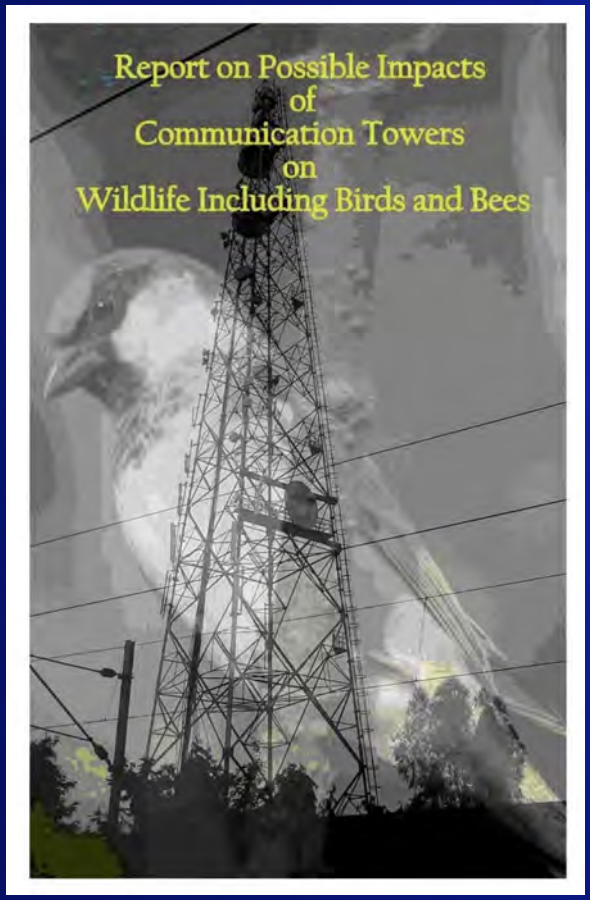
“The NCI is not involved in the regulation of radiofrequency telecommunications infrastructure and devices, nor do we make recommendations.”

“Neither the literature reviews, nor the fact sheets, make safety determinations.”

-National Cancer Institute

7/30/2020 and 4/2018

EHTRUST.ORG
ENVIRONMENTAL HEALTH TRUST



Why India Lowered RF Limits to 10% of ICNIRP

2012 Inter-Ministerial report reviewed the research (Ministry of Environment and Forest) on birds, bees, plants, humans, and other wildlife.

Conclusions:
While there were significant research gaps,
"the vast majority of published literature indicate deleterious effects of EMFs in various species."
(Sivani and Sudarsanam 2012).

Recommendations:

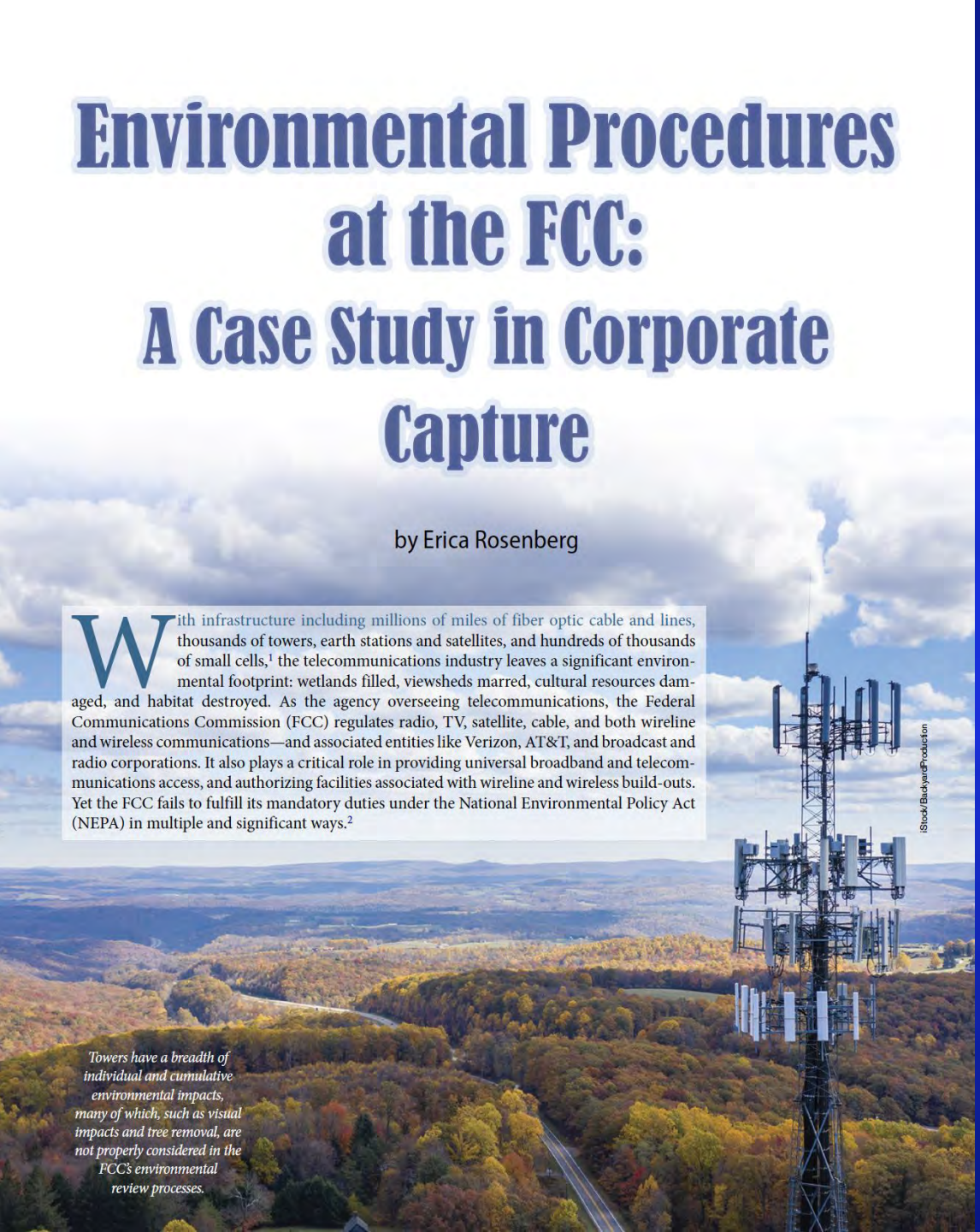
- More stringent RF limits
- EMFs be "recognized as a pollutant" with regular auditing of EMF levels near schools, hospitals, and ecologically sensitive areas..
- More protections for flora and fauna in urban areas

ENVIRONMENTAL HEALTH TRUST

Environmental Procedures at the FCC: A Case Study in Corporate Capture

by Erica Rosenberg

With infrastructure including millions of miles of fiber optic cable and lines, thousands of towers, earth stations and satellites, and hundreds of thousands of small cells,[1] the telecommunications industry leaves a significant environmental footprint: wetlands filled, viewsheds marred, cultural resources damaged, and habitat destroyed. As the agency overseeing telecommunications, the Federal Communications Commission (FCC) regulates radio, TV, satellite, cable, and both wireline and wireless communications—and associated entities like Verizon, AT&T, and broadcast and radio corporations. It also plays a critical role in providing universal broadband and telecommunications access, and authorizing facilities associated with wireline and wireless build-outs. Yet the FCC fails to fulfill its mandatory duties under the National Environmental Policy Act (NEPA) in multiple and significant ways.[2]



iStock/BackyardProduction

Towers have a breadth of individual and cumulative environmental impacts, many of which, such as visual impacts and tree removal, are not properly considered in the FCC's environmental review processes.

How the FCC Fails to Follow Environmental Laws and Fails the Public

"The result of the FCC's lack of accountability is cumulative and incalculable environmental damage: views of protected landscapes and historic sites ruined, wetlands filled, endangered species habitat cleared, sacred sites desecrated, burial mounds and archaeological sites disturbed, and fragile underwater environments degraded."

'Attorney Erica Rosenberg
Former Assistant Chief, Competition and Infrastructure Policy Division at the Federal Communications Commission
Wireless Telecommunications Bureau
Harvard University, BA and Boston College Law School, JD.

ehtrust.org

ENVIRONMENTAL HEALTH TRUST

Base Station Antennas Increasing Environmental Levels

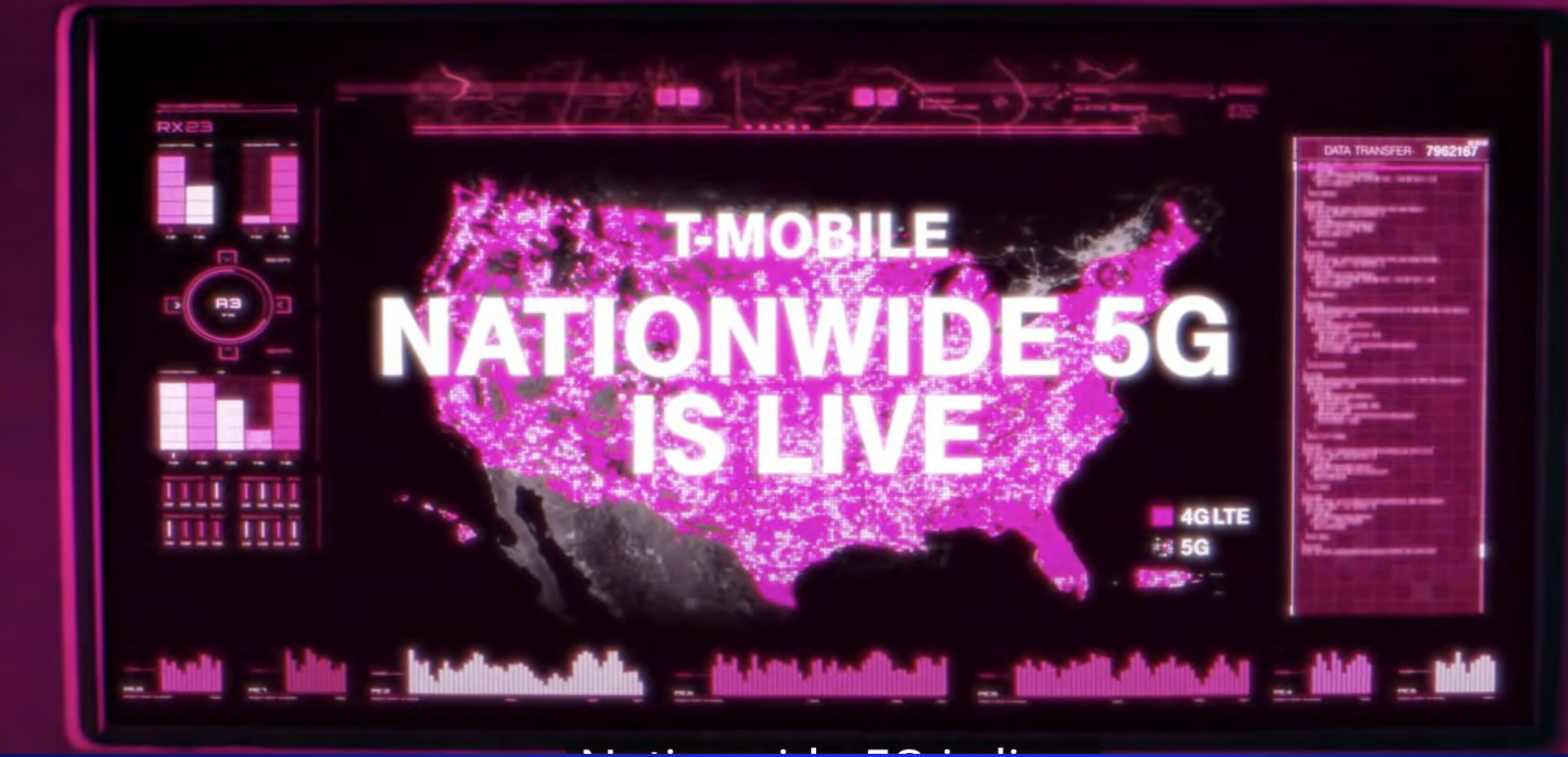
- A 2018 multi-country study (Sagar et al. 2018) found RF measurements in Los Angeles, California now 70 times higher than levels measured in City in the late ‘70s, as part of a twelve-city study (Tell and Mantiply 1982; Hankin 1986).
- In the 1982 report, TV and FM radio broadcast antennas were the dominant contributors to the RF exposures.
- The 2018 study found that RF emissions from mobile phone base stations was now generally the dominant contributor to exposures in most outdoor areas.

Warns Shareholders of Risk But Not Consumers Nor Neighbors

"If **radio frequency emissions from wireless handsets or equipment** on our communications infrastructure are **demonstrated to cause negative health effects**, potential future claims could adversely affect our operations, costs or revenues….**We currently do not maintain any significant insurance** with respect to these matters."

-Crown Castle 10-K

ENVIRONMENTAL HEALTH TRUST



T-Mobile

In addition, **the FCC has from time to time gathered data regarding wireless device emissions, and its assessment of the risks associated with using wireless devices may evolve based on its findings.** Any of these allegations or changes in risk assessments could result in customers purchasing fewer devices and wireless services, could result in significant legal and regulatory liability, and could have a material adverse effect on our business, reputation, financial condition, cash flows and operating results."
(T- Mobile 10-K Report page 21)

ENVIRONMENTAL HEALTH TRUST

Verizon Total Mobile Protection Insurance Defines Non-ionizing Radiation as "Pollution"

LIBERTY INSURANCE UNDERWRITERS INC., or one of its insurance company affiliates.

WIRELESS COMMUNICATIONS EQUIPMENT COVERAGE INSURANCE POLICY

B. EXCLUSIONS

This insurance does not apply to loss or damage identified in any of the following or directly or indirectly caused by or resulting from any of the following:

16. Pollution

The discharge, dispersal, seepage, migration or escape of pollutants. Pollutants means 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 non-ionizing radiation and/or waste. Waste includes materials to be recycled, reconditioned or reclaimed.

ENVIRONMENTAL HEALTH TRUST

New Hampshire Commission on 5G Health and the Environment
2020 REPORT

One year of investigation with testimony by expert scientists. 15 recommendations to protect the public and environment.

- State should measure RFR and post maps with RF measurements..
- RFR signal strength measurements for cell sites should be done by independent contractors.
- NH professional licensure to offer RF measurement education for home inspectors.

ENVIRONMENTAL HEALTH TRUST

Sheffield and Great Barrington Massachusetts

Residents voted in favor of a citizen's petition

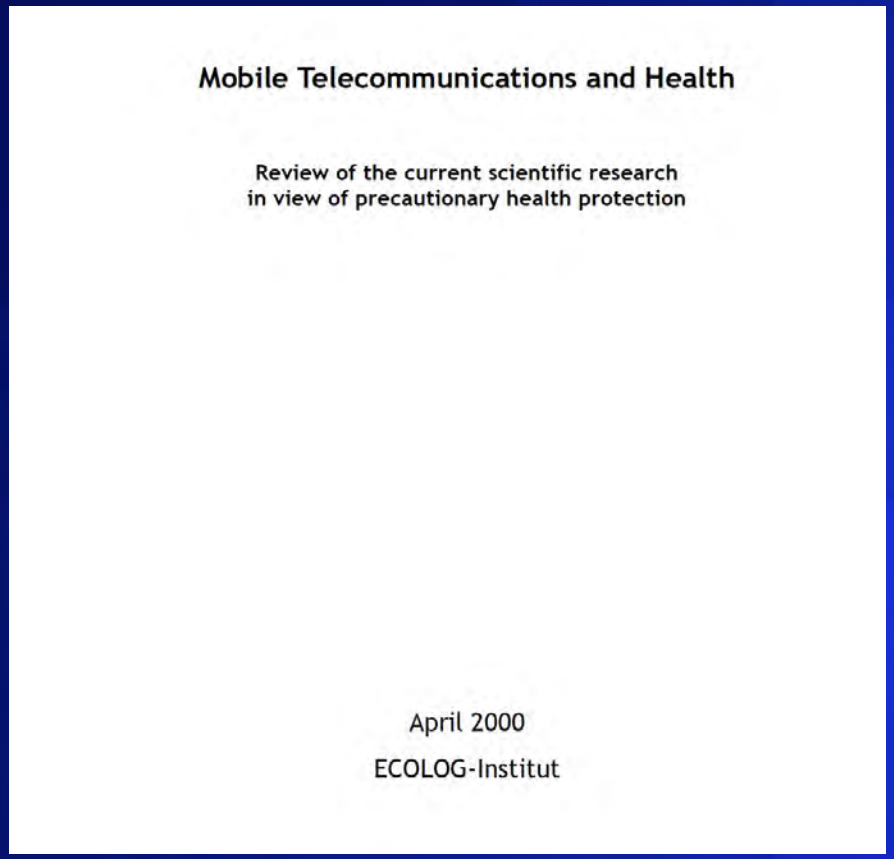
- applications for 5G installations incomplete until FCC completes environmental review and updates its limits.

Fountain Hill, Arizona

Moratorium on 5G until full review of issue/policies by town.

- EHT et al v FCC lawsuit and research linking exposure to health effects highlighted.

ENVIRONMENTAL HEALTH TRUST



Ecolog Institute Report (2000) commissioned by T-Mobile **recommended an exposure limit 1000 times lower** than the FCC's current power density limit.

https://ehtrust.org/wp-content/uploads/T-mobile-RF-Radiation-Ecolog-2000-Report-.pdf

Los Angeles California School District Office of Health and Safety developed a **"cautionary level" for radiofrequency radiation 10,000 times lower than FCC regulations** because: "it is believed that a more conservative level is necessary to protect children, who represent a potentially vulnerable and sensitive population."

2022 South Carolina RF Measurement Study

RF hotspots and elevated RF exposures to people
when antennas were mounted close to ground on utility poles (Koppel and Hardell)

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.

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

TARMO KOPPEL[1,3] and LENNART HARDELL WORLD ACADEMY OF SCIENCES JOURNAL 4: 23, 2022

EHTRUST.ORG
ENVIRONMENTAL HEALTH TRUST

Environmental Pollution 242 (2018) 643–658

Contents lists available at ScienceDirect

Environmental Pollution

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

Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective☆

Dominique Belpomme [a, b, 1], Lennart Hardell [a, c, 1, 2], Igor Belyaev [a, d, e, 1], Ernesto Burgio [a, f], David O. Carpenter [a, g, h, *, 1]

[a] European Cancer Environment Research Institute, Brussels, Belgium
[b] Paris V University Hospital, Paris, France
[c] Department of Oncology, Orebro University Hospital, Faculty of Medicine, Orebro, Sweden
[d] Department of Radiobiology, Cancer Research Institute, Biomedical Research Center, Slovak Academy of Science, Bratislava, Slovak Republic
[e] Laboratory of Radiobiology, Institute of General Physics, Russian Academy of Science, Moscow, Russian Federation
[f] Instituto Scientifico Biomedico Euro Mediterraneo, Mesagne, Italy
[g] Institute for Health and the Environment, University at Albany, Albany, NY, USA
[h] Child Health Research Centre, The University of Queensland, Faculty of Medicine, Brisbane, Australia

ARTICLE INFO

Article history:
Received 6 April 2018
Received in revised form
31 May 2018
Accepted 4 July 2018
Available online 6 July 2018

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

Contents lists available at ScienceDirect

Toxicology Letters

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

Adverse health effects of 5G mobile networking technology under real-life conditions

Ronald N. Kostoff[a,*], Paul Heroux[b], Michael Aschner[c], Aristides Tsatsakis[d,e]

[a] Research Affiliate, School of Public Policy, Georgia Institute of Technology, Georgia, United States
[b] Toxicology and Health Effects of Electromagnetism, McGill University, Canada
[c] Molecular Pharmacology, Einstein Center of Toxicology, Albert Einstein College of Medicine, United States
[d] Laboratory of Toxicology, Medical School, University of Crete, Voutes, 71409 Heraklion, Crete, Greece
[e] Department of Analytical, Toxicology, Pharmaceutical Chemistry and Pharmacognosy, Sechenov University, 119991 Moscow, Russia

GRAPHICAL ABSTRACT

Adverse Health Effects of Wireless Radiation on Humans				
Metabolic Disturbance	Reactive Oxygen Species Generation	Genotoxicity and Carcinogenicity	Immunotoxicity and Inflammation	Apoptosis and Necrosis
Discomfort Symptoms	Sensory Disorders	Sleep Disorders	Congenital Abnormalities	Precancerous Conditions
CANCER	**NEURODEGENERATION**	**INFERTILITY**	**NEUROBEHAVIORAL**	**CARDIOVASCULAR**

Contents lists available at ScienceDirect

Environmental Research

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

Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102)☆

Anthony B. Miller[a,*], L. Lloyd Morgan[b], Iris Udasin[c], Devra Lee Davis[d,e]

[a] Dalla Lana School of Public Health, University of Toronto, Canada
[b] Environmental Health Trust, Berkeley, CA, United States
[c] Rutgers University School of Public Health, United States
[d] Environmental Health Trust, Teton Village, WY, United States
[e] Hebrew University of Jerusalem, Israel

ARTICLE INFO

Keywords:
Brain cancer
Vestibular schwannoma
Salivary gland tumor
Electric hypersensitivity
Glioma
Meningioma
Radio frequency fields
Cell phones
Mobile phones

ABSTRACT

Epidemiology studies (case-control, cohort, time trend and case studies) published since the International Agency for Research on Cancer (IARC) 2011 categorization of radiofrequency radiation (RFR) from mobile phones and other wireless devices as a possible human carcinogen (Group 2B) are reviewed and summarized. Glioma is an important human cancer found to be associated with RFR in 9 case-control studies conducted in Sweden and France, as well as in some other countries. Increasing glioma incidence trends have been reported in the UK and other countries. Non-malignant endpoints linked include acoustic neuroma (vestibular Schwannoma) and meningioma. Because they allow more detailed consideration of exposure, case-control studies can be superior to cohort studies or other methods in evaluating potential risks for brain cancer. When considered with recent animal experimental evidence, the recent epidemiological studies strengthen and support the conclusion that RFR should be categorized as carcinogenic to humans (IARC Group 1). Opportunistic epidemiological studies are proposed that can be carried out through cross-sectional analyses of high, medium, and low mobile phone users with respect to hearing, vision, memory, reaction time, and other indicators that can easily be assessed through standardized computer-based tests. As exposure data are not uniformly available, billing records should be used whenever available to corroborate reported exposures.

International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF)
Environmental Health (2022) 21:92
https://doi.org/10.1186/s12940-022-00900-9

Environmental Health

COMMENT Open Access

Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: implications for 5G

International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF)*

Abstract

In the late-1990s, the FCC and ICNIRP adopted radiofrequency radiation (RFR) exposure limits to protect the public and workers from adverse effects of RFR. These limits were based on results from behavioral studies conducted in the 1980s involving 40–60-minute exposures in 5 monkeys and 8 rats, and then applying arbitrary safety factors to an apparent threshold specific absorption rate (SAR) of 4 W/kg. The limits were also based on two major assumptions: any biological effects were due to excessive tissue heating and no effects would occur below the putative threshold SAR, as well as twelve assumptions that were not specified by either the FCC or ICNIRP. In this paper, we show how the past 25 years of extensive research on RFR demonstrates that the assumptions underlying the FCC's and ICNIRP's exposure limits are invalid and continue to present a public health harm. Adverse effects observed at exposures below the assumed threshold SAR include non-thermal induction of reactive oxygen species, DNA damage, cardiomyopathy, carcinogenicity, sperm damage, and neurological effects, including electromagnetic hypersensitivity. Also, multiple human studies have found statistically significant associations between RFR exposure and increased brain and thyroid cancer risk. Yet, in 2020, and in light of the body of evidence reviewed in this article, the FCC and ICNIRP reaffirmed the same limits that were established in the 1990s. Consequently, these exposure limits, which are based on false suppositions, do not adequately protect workers, children, hypersensitive individuals, and the general population from short-term or long-term RFR exposures. Thus, urgently needed are health protective exposure limits for humans and the environment. These limits must be based on scientific evidence rather than on erroneous assumptions, especially given the increasing worldwide exposures of people and the environment to RFR, including novel forms of radiation from 5G telecommunications for which there are no adequate health effects studies.

Keywords: Federal Communications Commission (FCC), International commission on non-ionizing radiation protection (ICNIRP), Radiofrequency radiation (RFR), Exposure limits, Exposure assessment, Radiation health effects, Reactive oxygen species (ROS), DNA damage, 5G, Scientific integrity, Cell phone*, Mobile phone*

"Based on lessons that should have been learned from studies on RFR at frequencies below 6 GHz, we should no longer rely on the untested assumption that current or future wireless technology, including 5G, is safe without adequate testing. To do otherwise is not in the best interest of either public or environmental health."

Radiation Analysis in a Gradual 5G Network Deployment Strategy

Ahmad M. El-Hajj
Electrical & Computer Eng. Department
Beirut Arab University
Beirut, Lebanon
a.elhajj@bau.edu.lb

Tarek Naous
Electrical & Computer Eng. Department
Beirut Arab University
Beirut, Lebanon
tareknaous@ieee.org

***Abstract*—In a world where many overlapping 2G, 3G, and 4G electromagnetic radiation sources already exist, concerns regarding the potential increase in these radiation levels following the roll-out of 5G networks are growing. The deployment of 5G is expected to increase power density levels drastically, given the limitations of mmWave communications that impose a notably higher number of base stations to cover a given area of interest. In this paper, we propose a gradual deployment strategy of a 5G network for a small area in downtown Austin, Texas, using the already existing 4G LTE sites of the area. The radiated power density of the proposed 5G network is then analyzed according to several electromagnetic field (EMF) exposure limits and compared to the radiation levels of the same area where only the LTE network is present. Simulation results for the selected area demonstrate the significant increase in radiation levels resulting from the addition of 5G cell towers.**

***Index Terms*—5G, Network Planning, Radiation Analysis**

commissions and organizations that many governments will rely on when future 5G networks are deployed. However, these regulations have contradicting limits, many of which have remained the same before the year 2000. Therefore, designing a 5G network with radiation levels that complies with all the safety limits is a difficult task given the current regulations.

Despite the ongoing standardization of 5G technology, several works in the literature have presented 5G network deployment studies. The cost and coverage implications of deploying a 5G network in Britain has been presented in [3] where it was shown that full coverage had exponentially rising costs due to network densification. Additional 5G network designs for different cities were presented in [4]–[6] without any consideration for the constraints of electromagnetic radiations

Articles

Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations

Zothansiama, Mary Zosangzuali, Miriam Lalramdinpuii & **Ganesh Chandra Jagetia**

Pages 295-305 | Received 27 Apr 2017, Accepted 30 Jun 2017, Published online: 04 Aug 2017

Download citation https://doi.org/10.1080/15368378.2017.1350584 Check for updates

ABSTRACT

Radiofrequency radiations (RFRs) emitted by mobile phone base stations have raised concerns on its adverse impact on humans residing in the vicinity of mobile phone base stations. Therefore, the present study was envisaged to evaluate the effect of RFR on the DNA damage and antioxidant status in cultured human peripheral blood lymphocytes (HPBLs) of individuals residing in the vicinity of mobile phone base stations and comparing it with healthy controls. The study groups matched for various demographic data including age, gender, dietary pattern, smoking habit, alcohol consumption, duration of mobile phone use and average daily mobile phone use. The RF power density of the exposed individuals was significantly higher ($p < 0.0001$) when compared to the control group. The HPBLs were cultured and the DNA damage was assessed by cytokinesis blocked micronucleus (MN) assay in the binucleate lymphocytes. The analyses of data from the exposed group ($n = 40$), residing within a perimeter of 80 m of mobile base stations, showed significantly ($p < 0.0001$) higher frequency of micronuclei when compared to the control group, residing 300 m away from the mobile base station/s. The analysis of various antioxidants in the plasma of exposed individuals revealed a significant attrition in glutathione (GSH) concentration ($p < 0.01$), activities of catalase (CAT) ($p < 0.001$) and superoxide dismutase (SOD) ($p < 0.001$) and rise in lipid peroxidation (LOO) when compared to controls. Multiple linear regression analyses revealed a significant association among reduced GSH concentration ($p < 0.05$), CAT ($p < 0.001$) and SOD ($p < 0.001$) activities and elevated MN frequency ($p < 0.001$) and LOO ($p < 0.001$) with increasing RF power density.

KEYWORDS: Antioxidants genotoxicity humans micronucleus power density

Contents lists available at ScienceDirect

Environmental Research

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

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

L. Falcioni, L. Bua, E. Tibaldi, M. Lauriola, L. De Angelis, F. Gnudi, D. Mandrioli, M. Manservigi, F. Manservisi, I. Manzoli, I. Menghetti, R. Montella, S. Panzacchi, D. Sgargi, V. Strollo, A. Vornoli, F. Belpoggi*

Cesare Maltoni Cancer Research Center, Ramazzini Institute, Castello di Bentivoglio, via Saliceto 3, Bentivoglio, 40010 Bologna, Italy

ARTICLE INFO

Keywords:
RF
Sprague-Dawley rats
Life-span bioassay
Mobile phone
Carcinogenicity

ABSTRACT

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.

5G: Low , Mid and High Band- Submillimeter and Millimeter Waves

Netherland Health Council recommends against 26 GHz for 5G due to lack of safety data.

“The International Association of Fire Fighters’ position on locating cell towers commercial wireless infrastructure on fire department facilities, as adopted by its membership in August 2004 (1), is that the IAFF oppose the use of fire stations as base stations for towers and/or antennas for the conduction of cell phone transmissions until a study with the highest scientific merit and integrity on health effects of exposure to low-intensity RF/MW radiation is conducted and it is proven that such sitings are not hazardous to the health of our members.”

California Firefighter Unions carved themselves out of State proposed bills that would streamline small facilities in right of way.

8 Community Boards in New York City disapprovals and moratoriums on 5G poles.

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

Contents lists available at ScienceDirect

Environmental Research

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

Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102)☆

Anthony B. Miller[a,*], L. Lloyd Morgan[b], Iris Udasin[c], Devra Lee Davis[d,e]

[a] Dalla Lana School of Public Health, University of Toronto, Canada
[b] Environmental Health Trust, Berkeley, CA, United States
[c] Rutgers University School of Public Health, United States
[d] Environmental Health Trust, Teton Village, WY, United States
[e] Hebrew University of Jerusalem, Israel

ARTICLE INFO

Keywords:
Brain cancer
Vestibular schwannoma
Salivary gland tumor
Electric hypersensitivity
Glioma
Meningioma
Radio frequency fields
Cell phones
Mobile phones

ABSTRACT

Epidemiology studies (case-control, cohort, time trend and case studies) published since the International Agency for Research on Cancer (IARC) 2011 categorization of radiofrequency radiation (RFR) from mobile phones and other wireless devices as a possible human carcinogen (Group 2B) are reviewed and summarized. Glioma is an important human cancer found to be associated with RFR in 9 case-control studies conducted in Sweden and France, as well as in some other countries. Increasing glioma incidence trends have been reported in the UK and other countries. Non-malignant endpoints linked include acoustic neuroma (vestibular Schwannoma) and meningioma. Because they allow more detailed consideration of exposure, case-control studies can be superior to cohort studies or other methods in evaluating potential risks for brain cancer. When considered with recent animal experimental evidence, the recent epidemiological studies strengthen and support the conclusion that RFR should be categorized as carcinogenic to humans (IARC Group 1). Opportunistic epidemiological studies are proposed that can be carried out through cross-sectional analyses of high, medium, and low mobile

Environmental Pollution 242 (2018) 643–658

Contents lists available at ScienceDirect

Environmental Pollution

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

Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective☆

Dominique Belpomme [a, b, 1], Lennart Hardell [a, c, 1, 2], Igor Belyaev [a, d, e, 1], Ernesto Burgio [a, f], David O. Carpenter [a, g, h, *, 1]

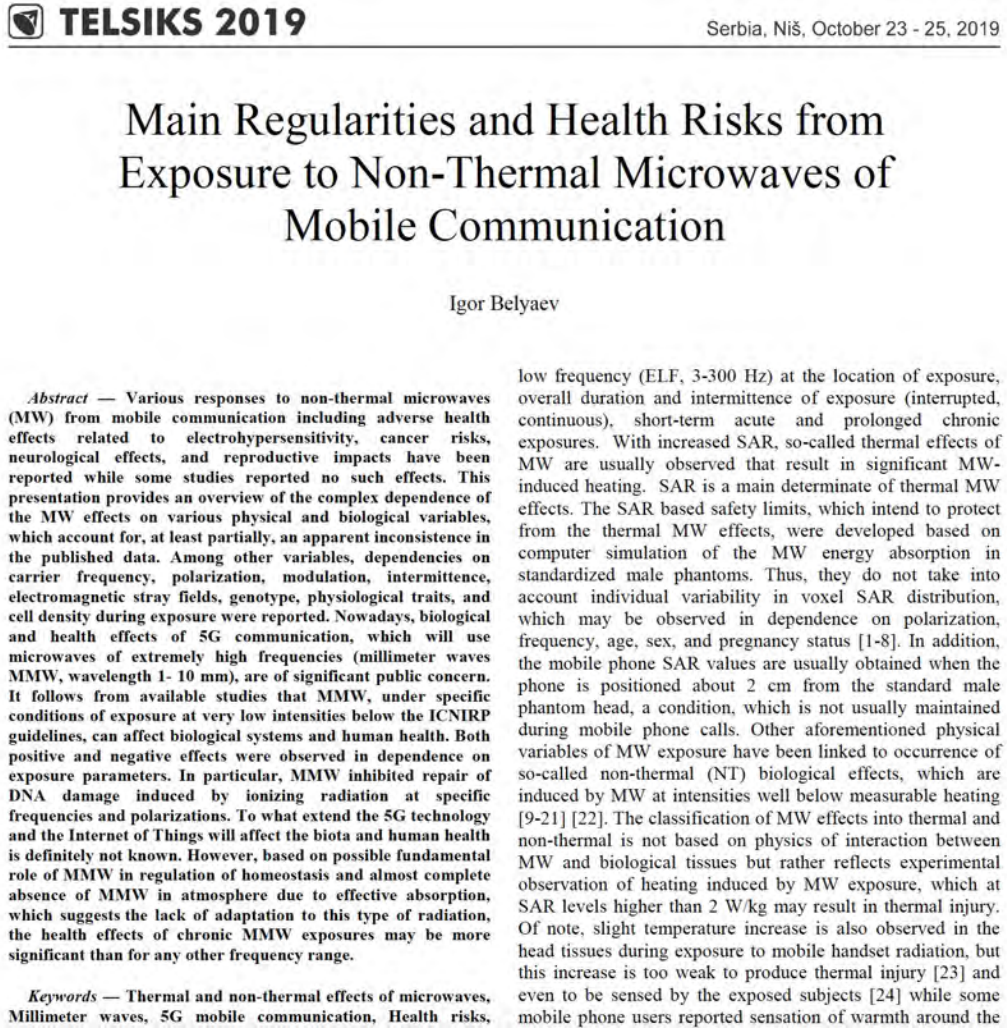
[a] European Cancer Environment Research Institute, Brussels, Belgium
[b] Paris V University Hospital, Paris, France
[c] Department of Oncology, Orebro University Hospital, Faculty of Medicine, Orebro, Sweden
[d] Department of Radiobiology, Cancer Research Institute, Biomedical Research Center, Slovak Academy of Science, Bratislava, Slovak Republic
[e] Laboratory of Radiobiology, Institute of General Physics, Russian Academy of Science, Moscow, Russian Federation
[f] Instituto Scientifico Biomedico Euro Mediterraneo, Mesagne, Italy
[g] Institute for Health and the Environment, University at Albany, Albany, NY, USA
[h] Child Health Research Centre, The University of Queensland, Faculty of Medicine, Brisbane, Australia

ARTICLE INFO

Article history:
Received 6 April 2018
Received in revised form
31 May 2018
Accepted 4 July 2018
Available online 6 July 2018

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.



TELSIKS 2019 Serbia, Niš, October 23 - 25, 2019

Main Regularities and Health Risks from Exposure to Non-Thermal Microwaves of Mobile Communication

Igor Belyaev

Abstract — **Various responses to non-thermal microwaves (MW) from mobile communication including adverse health effects related to electrohypersensitivity, cancer risks, neurological effects, and reproductive impacts have been reported while some studies reported no such effects. This presentation provides an overview of the complex dependence of the MW effects on various physical and biological variables, which account for, at least partially, an apparent inconsistence in the published data. Among other variables, dependencies on carrier frequency, polarization, modulation, intermittence, electromagnetic stray fields, genotype, physiological traits, and cell density during exposure were reported. Nowadays, biological and health effects of 5G communication, which will use microwaves of extremely high frequencies (millimeter waves MMW, wavelength 1- 10 mm), are of significant public concern. It follows from available studies that MMW, under specific conditions of exposure at very low intensities below the ICNIRP guidelines, can affect biological systems and human health. Both positive and negative effects were observed in dependence on exposure parameters. In particular, MMW inhibited repair of DNA damage induced by ionizing radiation at specific frequencies and polarizations. To what extend the 5G technology and the Internet of Things will affect the biota and human health is definitely not known. However, based on possible fundamental role of MMW in regulation of homeostasis and almost complete absence of MMW in atmosphere due to effective absorption, which suggests the lack of adaptation to this type of radiation, the health effects of chronic MMW exposures may be more significant than for any other frequency range.**

Keywords — **Thermal and non-thermal effects of microwaves, Millimeter waves, 5G mobile communication, Health risks,**

low frequency (ELF, 3-300 Hz) at the location of exposure, overall duration and intermittence of exposure (interrupted, continuous), short-term acute and prolonged chronic exposures. With increased SAR, so-called thermal effects of MW are usually observed that result in significant MW-induced heating. SAR is a main determinate of thermal MW effects. The SAR based safety limits, which intend to protect from the thermal MW effects, were developed based on computer simulation of the MW energy absorption in standardized male phantoms. Thus, they do not take into account individual variability in voxel SAR distribution, which may be observed in dependence on polarization, frequency, age, sex, and pregnancy status [1-8]. In addition, the mobile phone SAR values are usually obtained when the phone is positioned about 2 cm from the standard male phantom head, a condition, which is not usually maintained during mobile phone calls. Other aforementioned physical variables of MW exposure have been linked to occurrence of so-called non-thermal (NT) biological effects, which are induced by MW at intensities well below measurable heating [9-21] [22]. The classification of MW effects into thermal and non-thermal is not based on physics of interaction between MW and biological tissues but rather reflects experimental observation of heating induced by MW exposure, which at SAR levels higher than 2 W/kg may result in thermal injury. Of note, slight temperature increase is also observed in the head tissues during exposure to mobile handset radiation, but this increase is too weak to produce thermal injury [23] and even to be sensed by the exposed subjects [24] while some mobile phone users reported sensation of warmth around the

According to Belyaev 2019, "the health effects of chronic MMW exposures may be more significant than for any other frequency range."
Nowadays, biological and health effects of 5G communication, which will use microwaves of extremely high frequencies (millimeter waves MMW, wavelength 1- 10 mm), are of significant public concern. It follows from available studies that MMW, under specific conditions of exposure at very low intensities below the ICNIRP guidelines, can affect biological systems and human health. Both positive and negative effects were observed in dependence on exposure parameters. In particular, MMW inhibited repair of DNA damage induced by ionizing radiation at specific frequencies and polarizations. To what extend the 5G technology and the Internet of Things will affect the biota and human health is definitely not known. However, based on possible fundamental role of MMW in regulation of homeostasis and almost complete absence of MMW in atmosphere due to effective absorption, which suggests the lack of adaptation to this type of radiation, the health effects of chronic MMW exposures may be more significant than for any other frequency range."

ELECTROMAGNETIC BIOLOGY AND MEDICINE
2022, VOL. 41, NO. 2, 230–255
https://doi.org/10.1080/15368378.2022.2065683

Taylor & Francis
Taylor & Francis Group

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]

[a]Department of Bioengineering, University of Washington, Seattle, WA, USA; [b]New Preston, CT, USA

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.

ARTICLE HISTORY
Received 15 February 2022
Accepted 1 April 2022

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

Environmental Research xxx (xxxx) xxx

Contents lists available at ScienceDirect

Environmental Research

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

Problems in evaluating the health impacts of radio frequency radiation

Paul Ben Ishai [a,*], Devra Davis [b,c], Hugh Taylor [d], Linda Birnbaum [e,1]

[a] Department of Physics, Ariel University, Ariel, 4070000, Israel
[b] Environmental Health Trust, Washington, DC, 20002, USA
[c] School of Medicine,Ondokuz-Mayis University, Samsun, Turkey
[d] Yale School of Medicine, New Haven, CT, 05620, USA
[e] National Institute of Environmental Health Sciences and National Toxicology Program, Durham, NC, 27709, USA

ARTICLE INFO

Keywords:
Mobile communications
Electromagnetic radiation exposure
Precautionary principle
NTP
EHS
Non-thermal effects
FCC
ICNIRP

ABSTRACT

In an effort to clarify the nature of causal evidence regarding the potential impacts of RFR on biological systems, this paper relies on a well-established framework for considering causation expanded from that of Bradford Hill, that combines experimental and epidemiological evidence on carcinogenesis of RFR. The Precautionary Principle, while not perfect, has been the effective lodestone for establishing public policy to guard the safety of the general public from potentially harmful materials, practices or technologies. Yet, when considering the exposure of the public to anthropogenic electromagnetic fields, especially those arising from mobile communications and their infrastructure, it seems to be ignored. The current exposure standards recommended by the Federal Communications Commission (FCC) and International Commission on Non-Ionizing Radiation Protection (ICNIRP) consider only thermal effects (tissue heating) as potentially harmful. However, there is mounting evidence of non-thermal effects of exposure to electromagnetic radiation in biological systems and human populations. We review the latest literature on *in vitro* and *in vivo* studies, on clinical studies on electromagnetic hypersensitivity, as well as the epidemiological evidence for cancer due to the action of mobile based radiation exposure. We question whether the current regulatory atmosphere truly serves the public good when considered in terms of the Precautionary Principle and the principles for deducing causation established by Bradford Hill. We conclude that there is substantial scientific evidence that RFR causes cancer, endocrinological, neurological and other adverse health effects. In light of this evidence the primary mission of public bodies, such as the FCC to

ELECTROMAGNETIC BIOLOGY AND MEDICINE
2022, VOL. 41, NO. 2, 230–255
https://doi.org/10.1080/15368378.2022.2065683

Taylor & Francis
Taylor & Francis Group

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]

[a]Department of Bioengineering, University of Washington, Seattle, WA, USA; [b]New Preston, CT, USA

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.

ARTICLE HISTORY
Received 15 February 2022
Accepted 1 April 2022

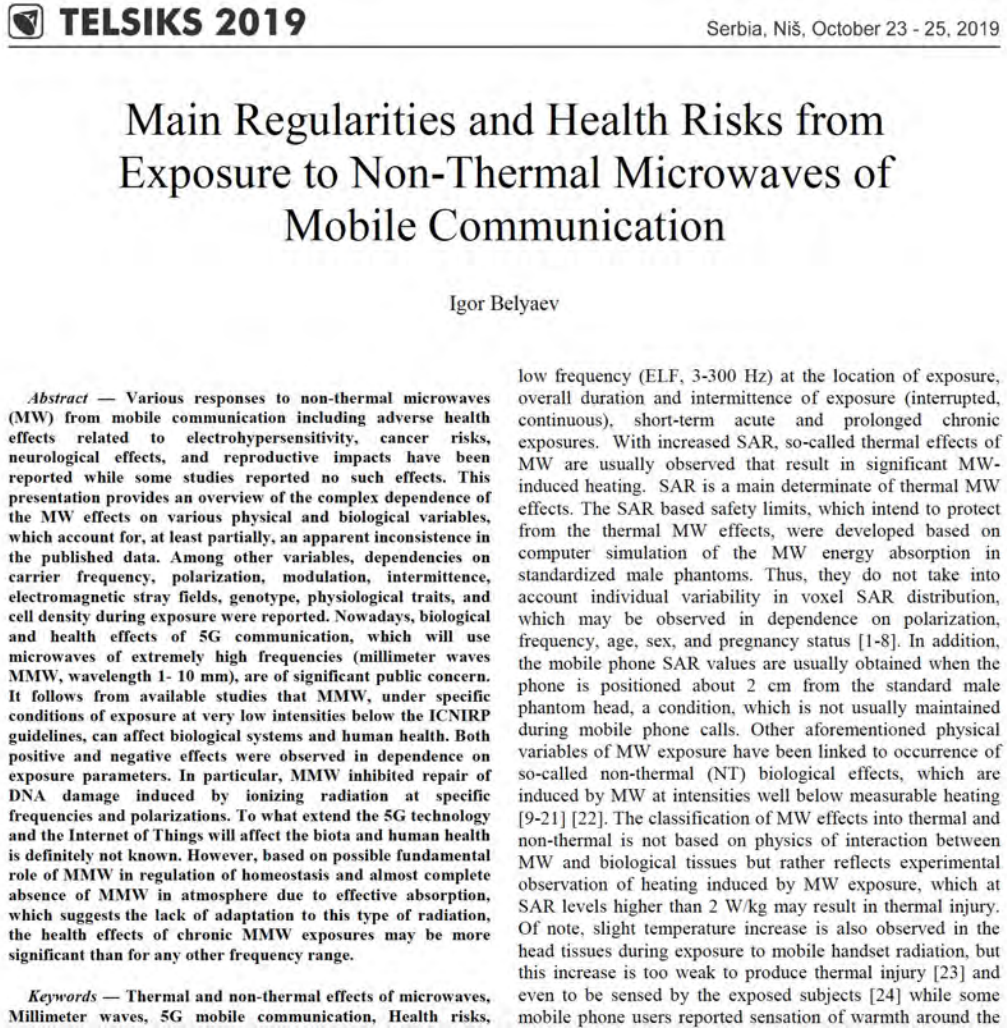
KEYWORDS
Radiofrequency radiation (RFR); intensity; duration of exposure; modulation; specific absorption rate (SAR); biological effects

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.



TELSIKS 2019 Serbia, Niš, October 23 - 25, 2019

Main Regularities and Health Risks from Exposure to Non-Thermal Microwaves of Mobile Communication

Igor Belyaev

Abstract — **Various responses to non-thermal microwaves (MW) from mobile communication including adverse health effects related to electrohypersensitivity, cancer risks, neurological effects, and reproductive impacts have been reported while some studies reported no such effects. This presentation provides an overview of the complex dependence of the MW effects on various physical and biological variables, which account for, at least partially, an apparent inconsistence in the published data. Among other variables, dependencies on carrier frequency, polarization, modulation, intermittence, electromagnetic stray fields, genotype, physiological traits, and cell density during exposure were reported. Nowadays, biological and health effects of 5G communication, which will use microwaves of extremely high frequencies (millimeter waves MMW, wavelength 1- 10 mm), are of significant public concern. It follows from available studies that MMW, under specific conditions of exposure at very low intensities below the ICNIRP guidelines, can affect biological systems and human health. Both positive and negative effects were observed in dependence on exposure parameters. In particular, MMW inhibited repair of DNA damage induced by ionizing radiation at specific frequencies and polarizations. To what extend the 5G technology and the Internet of Things will affect the biota and human health is definitely not known. However, based on possible fundamental role of MMW in regulation of homeostasis and almost complete absence of MMW in atmosphere due to effective absorption, which suggests the lack of adaptation to this type of radiation, the health effects of chronic MMW exposures may be more significant than for any other frequency range.**

Keywords — **Thermal and non-thermal effects of microwaves, Millimeter waves, 5G mobile communication, Health risks,**

low frequency (ELF, 3-300 Hz) at the location of exposure, overall duration and intermittence of exposure (interrupted, continuous), short-term acute and prolonged chronic exposures. With increased SAR, so-called thermal effects of MW are usually observed that result in significant MW-induced heating. SAR is a main determinate of thermal MW effects. The SAR based safety limits, which intend to protect from the thermal MW effects, were developed based on computer simulation of the MW energy absorption in standardized male phantoms. Thus, they do not take into account individual variability in voxel SAR distribution, which may be observed in dependence on polarization, frequency, age, sex, and pregnancy status [1-8]. In addition, the mobile phone SAR values are usually obtained when the phone is positioned about 2 cm from the standard male phantom head, a condition, which is not usually maintained during mobile phone calls. Other aforementioned physical variables of MW exposure have been linked to occurrence of so-called non-thermal (NT) biological effects, which are induced by MW at intensities well below measurable heating [9-21] [22]. The classification of MW effects into thermal and non-thermal is not based on physics of interaction between MW and biological tissues but rather reflects experimental observation of heating induced by MW exposure, which at SAR levels higher than 2 W/kg may result in thermal injury. Of note, slight temperature increase is also observed in the head tissues during exposure to mobile handset radiation, but this increase is too weak to produce thermal injury [23] and even to be sensed by the exposed subjects [24] while some mobile phone users reported sensation of warmth around the

According to Belyaev 2019, "the health effects of chronic MMW exposures may be more significant than for any other frequency range."
Nowadays, biological and health effects of 5G communication, which will use microwaves of extremely high frequencies (millimeter waves MMW, wavelength 1- 10 mm), are of significant public concern. It follows from available studies that MMW, under specific conditions of exposure at very low intensities below the ICNIRP guidelines, can affect biological systems and human health. Both positive and negative effects were observed in dependence on exposure parameters. In particular, MMW inhibited repair of DNA damage induced by ionizing radiation at specific frequencies and polarizations. To what extend the 5G technology and the Internet of Things will affect the biota and human health is definitely not known. However, based on possible fundamental role of MMW in regulation of homeostasis and almost complete absence of MMW in atmosphere due to effective absorption, which suggests the lack of adaptation to this type of radiation, the health effects of chronic MMW exposures may be more significant than for any other frequency range."

University of Pittsburgh
Law Review

The FCC Keeps Letting Me Be: Why Radiofrequency Radiation Standards Have Failed to Keep Up With Technology

"The FCC and FDA have failed in their obligation to prescribe safe RFR guidelines produced from wireless communication devices to protect the public health and safety."

Insurance Companies Rank RF Risk as "High" Industry Standard to Exclude Coverage

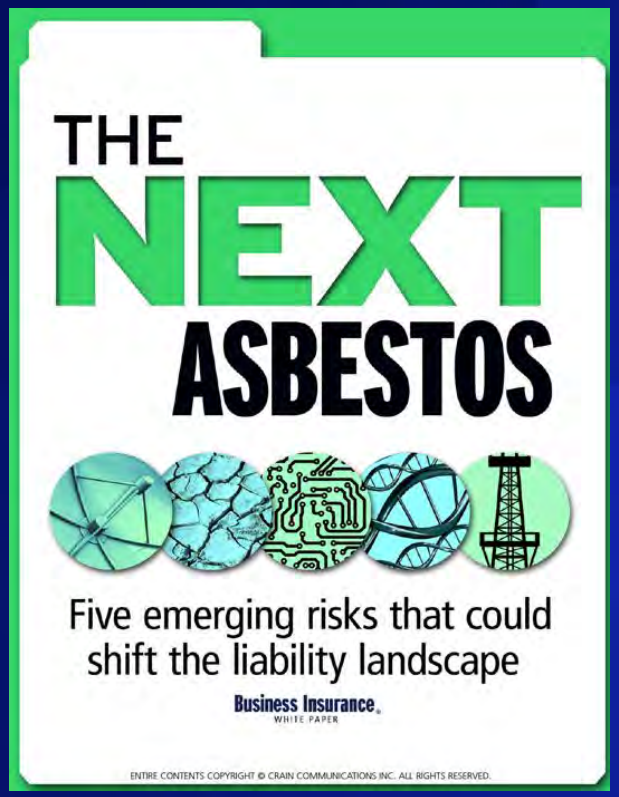


Image: 2011 *Business Insurance White Paper*

"The danger with EMF is that, like asbestos, the exposure insurers face is underestimated and could grow exponentially and be with us for many years."

-Lloyds of London 2010 Report

- Swiss Re Report 2019 5G rated as a "high off the leash" emerging risk
- Swiss Re Reports *2013, 2014* ranks the "unforeseen consequences of EMF" to the insurance industry as "High"
- No insurance coverage for cell phone companies for EMF damages since 1997.
- Insurance companies exclude EMFs as an industry standard in general policies.

ENVIRONMENTAL HEALTH TRUST

Environmental Research 214 (2022) 113851

Contents lists available at ScienceDirect

Environmental Research

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

Evidence for a health risk by RF on humans living around mobile phone base stations: From radiofrequency sickness to cancer

A. Balmori [1]

C/ Rigoberto Cortejoso, 14 47014, Valladolid, Spain

ARTICLE INFO

Keywords:
Base station
Cell tower
Health
Mast
RF radiation
Microwave syndrome
Radar
Radio antennas

ABSTRACT

The objective of this work was to perform a complete review of the existing scientific literature to update the knowledge on the effects of base station antennas on humans. Studies performed in real urban conditions, with mobile phone base stations situated close to apartments, were selected. Overall results of this review show three types of effects by base station antennas on the health of people: radiofrequency sickness (RS), cancer (C) and changes in biochemical parameters (CBP). Considering all the studies reviewed globally (n = 38), 73.6% (28/38) showed effects: 73.9% (17/23) for radiofrequency sickness, 76.9% (10/13) for cancer and 75.0% (6/8) for changes in biochemical parameters. Furthermore, studies that did not meet the strict conditions to be included in this review provided important supplementary evidence. The existence of similar effects from studies by different sources (but with RF of similar characteristics), such as radar, radio and television antennas, wireless smart meters and laboratory studies, reinforce the conclusions of this review. Of special importance are the studies performed on animals or trees near base station antennas that cannot be aware of their proximity and to which psychosomatic effects can never be attributed.

1. Introduction

During the last few decades, hundreds of thousands of mobile phone base stations and other types of wireless communications antennas have been installed around the world, in cities and in nature, including protected natural areas, in addition to pre-existing antennas (television, radio broadcasting, radar, etc.). Only the aesthetic aspects or urban regulations have been generally considered in this deployment, while the biological, environmental and health impacts of the associated non-ionizing electromagnetic radiation emissions have not been assessed so far. Therefore, the effects on humans living around these anthropogenic electromagnetic field sources (antennas) have not been considered.

In France, there is a significant contribution of mobile phone base stations in the exposure to radiofrequency electromagnetic fields (RF-EMF) of urban citizens living nearby (De Giudici et al., 2021). Some studies from India indicate that more than 15% of people have levels of EMF strength above 12 V/m due to their proximity to antennas (Premlal and Eldhose, 2017). Exposure estimates have shown that RF-EMF from mobile telephone systems is stronger in urban than in rural areas. For instance, in Sweden the levels of RF radiation have increased considerably in recent years, both outdoor and indoor, due to new telecommunication technologies, and the median power density measured for RF fields between 30 MHz and 3 GHz was 16 $\mu W/m^2$ in rural areas, 270 $\mu W/m^2$ in urban areas and 2400 $\mu W/m^2$ in city areas (Hardell et al., 2018). Total exposure varies not only between urban and rural areas but also, depending on residential characteristics, between different floors of a building, with a tendency for building exposure to increase at higher floors (Breckenkamp et al., 2012).

Over the past five decades, and more intensively since the beginning of this century, many studies and several reviews have been published on the effects of anthropogenic electromagnetic radiation on humans living around the antennas. The first studies were carried out with radio and television antennas, investigating increases in cancer and leukaemia (Milham, 1988; Maskarinec et al., 1994; Hocking et al., 1996; Dolk et al., 1997a, 1997b; Michelozzi et al., 1998; Altpeter et al., 2000), as well as around radars (Kolodynski and Kolodynska, 1996; Goldsmith, 1997).

Regarding base station antennas, there are scientific discrepancies in their effects: some studies concluded that there are no health-related effects (e.g. Augner and Hacker, 2009; Blettner et al., 2009; Röösli et al., 2010; Baliatsas et al., 2016) whereas others found increases in cancer and other health problems in humans living around antennas (e.g. Santini et al., 2002; Navarro et al., 2003; Bortkiewicz et al., 2004;

E-mail address: abalmorimartinez@gmail.com.
[1] Independent researcher

https://doi.org/10.1016/j.envres.2022.113851
Received 15 April 2022; Received in revised form 26 June 2022; Accepted 5 July 2022
Available online 14 July 2022

Eger et al., 2004; Wolf and Wolf, 2004; Abdel-Rassoul et al., 2007; Khurana et al., 2010; Dode et al., 2011; Shinjyo and Shinjyo, 2014; Gandhi et al., 2015; López et al., 2021; Rodrigues et al., 2021). There is a specific symptomatology linked to radar and RF exposure at low levels, characterized by functional disturbances of the central nervous system (headache, sleep disturbance, discomfort, irritability, depression, memory loss, dizziness, fatigue, nausea, appetite loss, difficulty in concentration, dizziness, etc.), that has been termed 'RF sickness' (Lilienfeld et al., 1978; Johnson Lyakouris, 1998; Navarro et al., 2003).

The objective of this study was to perform a complete review of the existing scientific literature to update the knowledge on the effects of base stations on humans living around the antennas.

2. Methods

A search was performed in the EMF portal, Google Scholar and PubMed databases with the words: "mobile phone base station and health" or "cell tower and health".

Only studies performed in real urban conditions, with mobile phone base stations situated close to apartments, were selected. Studies conducted in larger regions with numerous antennas, based on surveys and geographic data, were also included.

On the contrary, studies were excluded that considered different sources of electromagnetic radiation, such as mobile phone base stations together with broadcast transmitters (TV and radio), radar, mobile phones, cordless phones, Wi-Fi or wireless smart meters. Also excluded were those that included antennas and powerlines jointly. Studies that only performed measurements or modelling of radiation levels in the environment of the antennas or in the body, but did not deal with health effects, were excluded, as were surveys on risk perception and the nocebo effect, modelled radiofrequency electromagnetic field exposure from mobile-phone base stations or perceived exposure. All experimental laboratory studies, experiments in an exposure chamber or adapted room were also excluded. Finally, the comments or criticism of previously published studies were also excluded. However, due to their importance the conclusions of some of the excluded studies will be discussed in the corresponding section.

3. Results

The studies that met the selected criteria are presented in chronological order in Table 1, catalogued as Y/N depending on whether or not they found effects. The selected studies cover three types of effects: radiofrequency sickness (RS) (according to Lilienfeld et al., 1978; Johnson Lyakouris, 1998), cancer (C) and changes in biochemical parameters (CBP). Table 1 also includes the authors, year and country, antenna type, study design, diseases and symptoms found/not found and the main conclusions of each study.

Considering all the selected studies (n = 38), 73.6% (28/38) showed effects: 73.9% (17/23) for radiofrequency sickness, 76.9% (10/13) for cancer and 75.0% (6/8) for changes in biochemical parameters (Fig. 1). Therefore, most of the studies carried by research groups from twenty different countries reach the same conclusions.

For the reasons previously explained, the following studies (n = 85) were not considered in this review, even though the conclusions of some of these studies will be discussed later due to their importance regarding the similarities of the electromagnetic radiation types involved and the health effects found in many cases. Several studies only performed measurements or modelling of radiation levels in the environment of the antennas or in the body, but did not deal with the effects on health (e.g. Aniołczyk, 1999; Henderson and Bangay, 2006; Keow and Radiman, 2006; Neitzke et al., 2007; Bürgi et al., 2008; Augner et al., 2009; Chen and Chuang, 2009; Schmiedel et al., 2009; Viel et al., 2009; Hansson et al., 2011; Alhekail et al., 2012; Breckenkamp et al., 2012; Beekhuizen et al., 2013; Bürgi et al., 2014; Lyare et al., 2019; Urbinello et al., 2014; Lemaire et al., 2016; Admawi, 2021; De Giudici et al., 2021; Kazaure et al., 2021; Yetiş and Kayili, 2021). Some were surveys on risk perception and the nocebo effect, modelled RF-EMF exposure from mobile-phone base stations or perceived exposure (Wiedemann et al., 2006; Dohle et al., 2012; Kowall et al., 2012; Freudenstein et al., 2015; Dieudonné, 2016; Klaps et al., 2016; Martens et al., 2017; Koh et al., 2020). Others jointly considered various sources of electromagnetic fields such as telephone antennas, mobile phones, cordless phones, Wi-Fi, powerlines or wireless smart meters (Seitz et al., 2005; Baliatsas et al., 2011; Atzmon et al., 2012; Eskander et al., 2012; Frei et al., 2012; Lamech, 2014; Singh and Pati, 2016; Boehmert et al., 2020; Akkam et al., 2020). Some studied the effects of radio or television antennas (Milham, 1988; Maskarinec et al., 1994; Hocking et al., 1996; Dolk et al., 1997a, 1997b; McKenzie et al., 1998; Michelozzi et al., 1998; Altpeter et al., 2000; Hocking and Gordon, 2000; Boscolo et al., 2001; Cooper et al., 2001; Michelozzi et al., 2002; Hallberg and Johansson, 2002; Elwood, 2003; Ha et al., 2003; Park et al., 2004; Abelin et al., 2005; Altpeter et al., 2006; Ha et al., 2007; Satta et al., 2018). Others were radar studies (Kolodynski and Kolodynska, 1996; Goldsmith, 1997; Szmigielski et al., 2001; Yakymenko et al., 2011; Schoeni et al., 2016; Martens et al., 2018). Some studies performed experiments in a laboratory, exposure chamber or adapted room, with simulated or real electromagnetic radiation from base station antennas (e.g. Zwamborn et al., 2003; Hinrichs et al., 2005; Regel et al., 2006, 2007; Eltiti et al., 2007; Leitgeb et al., 2008; Riddervold et al., 2008; Augner et al., 2009; Augner et al., 2010; Wallace et al., 2010; Danker-Hopfe et al., 2010; Falcioni et al., 2018; Azimzadeh and Jelodar, 2019; Smith-Roe et al., 2020). Some reports were comments or criticisms of previously published studies (e.g. Coggon, 2006; Röösli and Huss, 2008; Bithell, 2010; Dode and Leão, 2012; Foster and Trottier, 2012; Mortazavi, 2014, 2017).

4. Discussion

The results of this review show three types of effects by base station antennas on the health of humans: radiofrequency sickness, cancer and changes in biochemical parameters (Fig. 1). From among all these studies, most of them found effects (73.6%). Thus, despite some limitations and differences in study design, statistical measures, risk estimates and exposure categories (Khurana et al., 2010), together they provide a consistent view of the effects on the health of people living in the vicinity of base station antennas.

Studies conducted in large regions with numerous antennas, based on surveys and geographic data (e.g. Augner and Hacker, 2009; Dode et al., 2011; Baliatsas et al., 2016; Martens et al., 2017; Dode et al. al., 2021), have the limitation that there may be many factors other than the base station antennas affecting the health of the population (environmental and occupational determinants of diseases and symptoms, individual characteristics such as food and life habits, activity level, smoking, self-medication, individual pathologies or genetic factors) that can act as confounding factors. It is important to mention here that the meters used for power density measurements in research papers should have more high quality equipment and better measurement methods.

On the other hand, some studies did not meet the strict conditions to be considered in this review, but due to their importance regarding the similarities of the electromagnetic radiation types involved and the effects found in many cases, they provide important supplementary evidence, as we will see in the next paragraphs.

For example, mobile phone users had an increased risk of headache (one of the typical symptoms for RF sickness near base station antennas) compared with non-users, and the risk of headache was also increased in those who had a longer daily call duration and higher daily call frequency (Wang et al., 2017). The same was also seen with cancer (Hardell et al., 2007). On the other hand, the symptoms caused by wireless smart meters were similar to those reported by people exposed to RF fields emitted by mobile phones (Lamech, 2014).

Table 1
Studies that met the selected criteria.

N°	Reference and country	Antenna type	Study design	Diseases and symptoms found/not found	Main conclusions
1 Y RS	Santini et al. (2002), 2003a and 2003b France	Base station antennas GSM 900 and 1800 MHz	Questionnaire survey in 530 people	Effects found on: -tiredness -headache -sleep disturbance -discomfort -irritability -depression -memory loss -dizziness -libido decrease -visual perturbations	Effects occur up to a distance of 300 m from the antenna. Older subjects are more sensitive. Also, hat the facing location is the worst position for some symptoms s tudied, especially for distances till 100 m from base stations. The frequency of reported complaints is significantly higher for women in comparison with men
2 Y RS	Gómez-Perretta et al., 2013 Spain	Base station antennas GSM 900 and 1800 MHz	Questionnaire survey in 101 people and electric field measurements	Effects found on: -fatigue -irritability -headache -nausea -appetite loss -discomfort -sleep disturbance -depression -difficulty in concentration -dizziness	Significant correlation between the declared severity of the symptoms and the measured power density. The separation of respondents into two different exposure groups also showed an increase of the declared severity in the group with the higher exposure. The incidence of most of the symptoms was related to exposure levels, independently of the demographic variables and some possible risk factors. Health changes related with GSM exposure seem to occur in a manner unrelated with those fears
3 Y RS	Bortkiewicz et al. (2004) Poland	Base station antennas	Review of previous publications	Effects found on: -circulatory system -sleep disturbances -irritability depression -blurred vision -concentration -difficulties nausea -lack of appetite -headache -vertigo	Relationship between the incidence of individual symptoms, the level of exposure, and the distance. This association was observed in both groups of persons, those who linked their complaints with the presence of the base station and those who did not notice such a relation.
4 Y C	Eger et al. (2004) Germany	2 Base station antennas	Number of cancer cases in the selected population (1045 resident) in Naila to compare results an inner area (within a distance of 400 m from the base station antennas) and outer area (beyond 400 m).	The number of newly developed cancer cases in the inner area is more than the expected number taken from the cáncer register, which represents the total population being irradiated. The group who had lived during the past five years within a distance of 400 m from the Base station antennas have a two times higher risk of developing cancer than that of the average population. The relative risk of getting cancer in the inner área compared with the Saarland cancer register is 1.7.	The risk of newly developing cancer was three times higher among those patients who had lived during past ten years (1994–2004), within a distance of 400 m From the cellular transmitter, in comparison to those who had lived further away.
5 Y C	Wolf and Wolf (2004) Israel	1 Base station antenna	A cancer incidence study to investigate the incidence of cancer cases of individuals (the cohort included 622 people) exposed to a Base station antenna, in comparison to those of a nearby clinic out of that area, to the national incidence rates of the whole country and to the incidence rates in the whole town of Netanya	There were 4.15 times more cases of cáncer in area A (breast carcinoma, ovary carcinoma, lung carcinoma, Hodgkin's disease, osteoid osteoma, and hypernephroma) than in the entire population.	The study indicates an association between an increased incidence of cancer and living in proximity to a Base station antenna.
6 Y RS	Hutter et al. (2006) Austria	10 Base station antennas in the 900 MHz band	Questionnaire survey in 365 subjects and exposure measurements	Effects found on: -headache -difficulties to concéntrate -Cold hands or feet No effects found on: -vertigo -palpitations -tremor -hot flushes -sweating -loss of apetite -loss of energy, -exhaustion -tiredness	Self-reported symptoms like headache and difficulties in concentrating show an association with microwave exposure from base stations, not attributable to subjects' fear of health effects from these sources. Other symptoms, like sleeping problems, seem to be more due to fear of adverse health effects than actual exposure.

(*continued on next page*)

Table 1 (*continued*)

N°	Reference and country	Antenna type	Study design	Diseases and symptoms found/not found	Main conclusions
				-feeling strained -sleep	
7 Y RS	Abdel-Rassoul et al. (2007) Egypt	Base station antennas (GSM)	Questionnaire survey on 85 exposed persons and 80 controls	Effects found on: -headache -memory changes -dizziness -tremors -depressive symptoms -sleep disturbance No effects found on: -Blurred visión -Irritability -Lack of concentration	The prevalence of neuropsychiatric complaints were significantly higher among exposed inhabitants than controls. Inhabitants living nearby mobile phone base stations are at risk for developing neuropsychiatric problems and some changes in the performance of neurobehavioral functions either by facilitation or inhibition.
8 N CBP	Augner and Hacker (2009) Austria	Base station antennas	Questionnaire survey on fifty-seven participants and saliva samples	Self-declared base station neighbors (≤100 m) had significantly higher concentrations of alpha-amylase in their saliva, higher rates in symptoms, somatization, obsessive-compulsive, anxiety, phobic anxiety. There were no differences in EMF-related health concern scales.	Self-declared base station neighbors are more strained than others. EMF-related health concerns cannot explain these findings.
9 N RS	Blettner et al. (2009) Berg-Beckhoff et al. (2009) Germany	Base station antennas (GMS 900 and 1800 and UMTS 2170)	Questionnaire survey on 30,047 participants and geo-coding information on the residence distance (less or more than 500 m) to the nearest mobile phone base station. In a second phase RF measurements were conducted for a sub-sample in the households of 1500 persons	The mailed questionnaire included a list of 38 symptoms that have been reported in previous studies to be possibly associated with RF-EMF exposure	Participants who were concerned about or attributed adverse health effects to mobile phone base stations and those living in the vicinity of a mobile phone base station (500 m), reported slightly more health complaints tan others. The observed slightly higher prevalence of health complaints near base stations cannot be explained by attributions or concerns alone. The worries and health complaints of people living close to mobile phone base stations need to be taken seriously. Measured RF-EMFs emitted from mobile phone base stations were not associated with health disturbances. However, the study shows that sleep disturbances and health complaints are related to the attribution of adverse health effects to mobile phone base stations.
10 Y RS C	Kundi and Hutter (2009) Austria	Base station antennas	Review of previous publications	Effects found on: Adverse neurobehavioral symptoms or cancer	There are indications from epidemiology that such exposures affect wellbeing and health weakly supported by human provocation studies and an inconclusive body of evidence from animal and in vitro studies. Cross-sectional investigations of subjective health as a function of distance or measured field strength, despite differences in methods and robustness of study design, found indications for an effect of exposure that is likely independent of concerns and attributions. Two ecological studies of cancer in the vicinity of base stations report both a strong increase of incidence within a radius of 350 and 400 m respectively. Due to the limitations inherent in this design no firm conclusions can be drawn, but the results underline the urgent need for a comprehensive investigation of this issue
11 Y C	Eger and Jahn (2010) Germany	Base station antennas	Questionnaire survey on 255 persons	Effects found on: -sleep problems -depression -headaches -cerebral affections -concentration difficulties -joint problems -infections -skin problems	A significant relationship between mean exposure levels of the study participants and reported health symptoms. Within the 400-m radius around the transmitter, a higher symptom rate could be documented for 14 out of 19 symptom groups in the highest exposure groups compared to groups

(*continued on next page*)

Table 1 (*continued*)

N°	Reference and country	Antenna type	Study design	Diseases and symptoms found/not found	Main conclusions
				-dizziness -cardiovascular problems -disturbance of equilibrium -visual problems -nosebleed -gastrointestinal problems No effects found on: -toothaches -hormonal imbalances -weight gain -weight loss	further away from the transmitter and the difference is statistically significant. Decreasing symptom scores in relation to decreasing mean exposure levels caused by cell phone transmitter emissions
12 N C	Elliott et al. (2010) Great Britain	Base station antennas	Data on all registered cases of cancer in children aged 0–4 in Great Britain and data on mobile phone base stations to investigate the risk of early childhood cancer associated with the mother's exposure to radiofrequency from and proximity to mobile phone base stations during pregnancy.	Of the 1397 cases, there were 251 brain and central nervous system cancers and 527 cases of leukaemia and non-Hodgkin's lymphoma. The study found no association between mobile phone base stations and risk of cáncer.	In this systematic national investigation the authors found no association between risk of cancer in young children and estimated exposures to radiofrequency from mobile phone base stations during pregnancy. However there is a research paper limitation on page 5: "our models did not include information on other sources of radiofrequency exposure, such as from microcells or picocells" and the city centers (especially) are full of these kind of antennas.
13 Y RS C	Khurana et al. (2010) international	Base station antennas	Review of previous publications	Effects found on: Adverse neurobehavioral symptoms or cancer	The authors identified a total of 10 epidemiological studies that assessed for putative health effects of mobile pone base stations. Seven of these studies explored the association between base station proximity and neurobehavioral effects and three investigated cancer. The authors found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances <500 m from base stations.
14 N RS	Röösli et al. (2010) Switzerland	Base station antennas (GMS 900 and 1800 and UMTS 2170)	Systematic review	There are no adverse effects	Not indication of an association between any health outcome and RF-EMF exposure from mobile phone base stations at levels typically found in our everyday environment. There is also no evidence that EHS individuals are more susceptible to base station radiation than the rest of the population. The evidence for the absence of long-term effects is limited.
15 N CBP C	Yildirim et al. (2010) Turkey	Base station antennas	Blood samples to analise the micronucleus (MN) frequency and chromosomal aberrations on blood in people living around mobile phone base stations and healthy controls.	There was not a significant difference of MN frequency and chromosomal aberrations between the two study groups.	Mobile phones and their base stations do not produce important carcinogenic changes.
16 Y RS	Alazawi, 2011 Iran	8 Base station antennas	Questionnaire survey on 375 subjects. Not measurements	Effects found on: -headaches -sleep disturbances -irritability -depressive -tendencies -feeling of discomfort, -difficulties in concentration -memory loss -lowering of libido	This study shows that inhabitants living nearby mobile phone base stations are at risk for developing non specific health symptoms, the facing position appears to be the worst one for distances from cellular phone base stations <100 m. It is advisable that cellular phone base stations should not be sited closer than 300 m to populations, as a precautionary measure, sitting of base stations should be such as to minimize exposure of neighbors.
17 Y C	Dode et al. (2011) Brazil	Base station antennas	This research was conducted in a broad environmental context, aiming to verify if there is a spatial correlation between the Base station antennas and the cases of death by neoplasia during the period between 1996 and 2006 in Belo Horizonte municipality (Brazil).	The mortality rates and the relative risk were higher for the residents inside a radius of 500 m from the Base station antennas, compared to the average mortality rate of the entire city, and a decreased dose– response gradient was observed for residents who lived farther away from these base stations.	The research showed the existence of a spatial correlation between cases of death by neoplasia and the locations of the Base station antennas, in the Belo Horizonte municipality from 1996 to 2006.

(*continued on next page*)

Table 1 (*continued*)

N°	Reference and country	Antenna type	Study design	Diseases and symptoms found/not found	Main conclusions
18 Y C	Li et al. (2012) Taiwan	Base station antennas	Population-based case–control study in Taiwan considerering incident cases aged 15 years or less and admitted in 2003–2007 for all neoplasm (n = 3481 children). Exposure of each study subject to radio frequency (RF) was indicated by the averaged annual power density within 5 years prior to the neoplasm diagnosis. Controls were randomly selected.	Taiwanese children with higher-than median exposure of RF potentially emitted from Base station antennas were at significantly increased risk of all neoplasms combined. Although there were also positive associations between RF power density and risks of brain neoplasm and leukaemia in children, such associations did not reach statistical significance.	This study noted a significantly increased risk of all neoplasms in children with higher-than-median RF exposure to Base station antennas. The slightly elevated risk was seen for leukaemia and brain neoplasm, but was not statistically significant.
19 N C	Stewart et al. (2012) Great Britain	1 Base station antennas (GMS 1800)	Data on cancer incidence and mortality accessing the medical information of near residents	The study cannot conclude that the base station is responsible for the incidence of cancer in the local residents	Although the age range for local residents with cancer in the suspected cluster was younger than might be generally expected, there was no evidence that their cancer incidence is associated with the mobile phone base station. 10 cancers were registered after installation of the base station. However, the collection of cancers does not fulfil the criteria for a cancer cluster; the cases are a mixed variety of relatively common cancers. No single type of cancer was dominant, all but one were common types of cancer and none were seen in a group not usually affected by that cancer. Data from primary and secondary care also provide evidence that lifestyle and family history factors could have contributed to some individual cases.
20 N RS	Islam and Mohammed (2014) Bangladesh	Base station antennas	Questionnaire survey on 220 adults living near a Base station antenna for at least one year in two selected areas	Half of the respondents experienced problems in sleeping patterns, recent episodes of headache or dizziness and mood change, anxiety, or depression. 11 respondents experienced some generalized burning sensation and 4 reported episodes of shaking or fits. 48 respondents mentioned one or more other health effects, such as mood changes/problem, buzzing in the head, hopelessness, palpitation, tachycardia, heaviness of chest, anorexia, diarrhoea, and skin diseases.	From the results of the study cannot conclude that the health effects are direct results of the base station antennas. However, the complaints were similar to those of other studies, which shows the importance of conducting further research to determine the effects of electromagnetic radiarion from base station antennas on human health and should be considered as a public health concern.
21 Y RS	Pachuau and Pachuau (2014) India	Base station antennas (GSM 900)	Questionnaire survey conducted on 64 adults (31 female, 33 male) and electric field measurements. Health symptoms of RF exposure faced by the inhabitants within 50 m and outside 50 m from the tower were analysed and compared.	Effects found on: -Muscle pain -Fatigue -Sleep disorder -Nausea -Skin problema -Dizziness -Feeling of discomfort -Difficulty in concentration -Memory loss -Visual disruption	Inhabitants living within 50 m had more health complaints than those living outside 50 m. It was also found that females had more complaints than males
22 Y RS	Shinjyo and Shinjyo (2014) Japan	2 base station antennas (CDMA 800 MHz and 2 GHz)	Medical examinations and health questionnaires comparing the health of 107 residents during the base station's operation and after its removal. Measurement of the power density	Effects found on: -fatigue -eye problems -sleep disturbances -dizziness -headache -tinnitus -nasal bleeding No effects found on: -tachycardia -tumours -skin problems -rhinitis -angina pectoris -hearing loss	A total of 34 residents suffered from health problems after installation of the 800 MHz antennas. Three months after their removal this number decreased to 13. There were 41 residents who had health problems after installation of the 2 GHz antennas, and this number decreased to 15 after removal of the 2 GHz antennas. In total 49 residents suffered from health problems during operation of both the 800 MHz and the 2 GHz antennas. However, this number decreased to 25 after removal of both sets of antennas.The residents had no prior knowledge about possible adverse health effects of RF-EMFs. Health problems of the residents were associated with the operation of the

(*continued on next page*)

Table 1 (*continued*)

N°	Reference and country	Antenna type	Study design	Diseases and symptoms found/not found	Main conclusions
					mobile phone base station and these problems improved after its removal.
23 Y CBP	Gandhi et al. (2015) India	Base station antennas	Questionnaire survey and blood simples from 91 individuals, with 70% (63) residing in a populated area with a mobile phone base station (the sample group) and 30% (28) in a sparsely-populated zone without any nearby base stations (the control group). Radiofrequency field measurements	Effects found on: Genetic damage parameters of DNA migration length, damage frequency (DF) and damage index	Genetic damage was significantly increased in the sample group compared to that in the controls. The 2.5–4.5-fold increase in DNA damage in peripheral blood lymphocytes of persons staying near a mobile phone base station is of acute concern given that all neoplasia initiate via unrepaired DNA damage. In the light of the above observations and the statistically significant genetic damage observed in those residing within 300 m of a mobile phone base station in this study, it implies that the effects of radiations from mobile phone base stations cannot be overlooked, as unrepaired DNA damage can lead to cancer, precocious ageing and age-related effects.
24 Y CBP	Meo et al. (2015) Saudi Arabia	2 Base station antennas (925 MHz) near two schools	RF-EMF measurements and blood sample collection	Effects found on: -chronic hyperglycemia -increased HbA1c -diabetes mellitus	Students who were exposed to high EMFR generated by MPBS had significantly higher HbA1c and prevalence of pre diabetes mellitus compared to the students who exposed to low EMFR. EMFR appears to be another risk factor contributing to high levels of HbA1c and risk of type 2 diabetes mellitus.
25 Y RS	Pachuau et al. (2015) India	Base station antennas (GSM 900)	Questionnaire survey from 50 exposed and 50 control individuals. Power density measurements	Effects found on: -fatigue -sleep disruption -headache -dizziness -muscle pain -cramp No effects found on: -nausea -discomfort -difficulty in concentration -memory los -skin problems -visual disruption -hearing problem	Inhabitants living near mobile tower are having more health complaints than those inhabitants living in the area where there is no mobile tower
26 Y CBP	Al-Quzwini et al. (2016) Iraq	Base station antennas	Questionnaire survey. Two hundred couples (one hundred subfertile couples as a study group, and one hundred fertile couples as a control group. Semen analysis	Twenty-nine percentage of subfertile couples had exposure to environmental hazards (communication's tower beside their house-within 50 m), and 71% non-hazard. The duration of the exposure to the environmental factor ranged from 2 to 7 years.	The exposure to environmental hazards shows significant difference between the subfertile and the fertile men; as higher percentage of exposure to mobile phone tower among subfertile group, 29% versus 12% for the fertile group,
27 N RS	Baliatsas et al. (2016) The Netherlands	Base station antennas (GSM and UMTS)	Health records from 1069 adult participants, All participants were living within 500 m from the nearest bases station. A propagation model combined with a questionnaire was used to assess indoor exposure to RF-EMF from MPBS at T1. Estimation of exposure at T0 was based on number of antennas at T0 relative to T1.	Compared to the baseline period, there was a higher prevalence of symptoms theoretically relevant to EMF at T1. A significant increase was observed in the prevalence of ear symptoms and a two-fold (but not significant) increase in the prevalence of skin symptoms. Overall, the total prevalence was slightly lower at T1. A consistent association between UMTS exposure and different clusters of GP-registered symptoms, for the self-declared mobile phone base stations-sensitive group.	This before-after study found no evidence that RF-EMF exposure from mobile phone base stations is associated with the development of non-specific symptoms in the general population, corroborating recent observational studies. Subgroup analyses among people with self-reported sensitivity to base stations showed a higher prevalence for most symptoms at T1 compared to baseline and there was some indication for a higher risk of non-specific symptoms for the mobile phone base stations-sensitive group, in relation to exposure.
28 N RS	Klaps et al. (2016) Austria	Base station antennas	Meta-analysis based on the results of 17 studies	The effects of mobile phone base stations seem to be rather unlikely. However, nocebo effects occur.	It is unclear whether electromagnetic fields emitted by mobile phone base stations affect well-being in adults. The existing studies on this topic are highly inconsistent.
29 Y	Singh et al. (2016) India	4 Base station antennas		Effects found: -sleep disturbances	A majority of the subjects who were residing near the mobile base station

(*continued on next page*)

Table 1 (*continued*)

N°	Reference and country	Antenna type	Study design	Diseases and symptoms found/not found	Main conclusions
RS CBP			Questionnaire survey and salivary analysis in 20 individuals (case group) and 20 (control group)	-headache -dizziness -irritability -concentration difficulties -hypertension	had various complaints. A majority of the study subjects had significantly lesser stimulated salivary secretion as compared to the control subjects. The effects of prolonged exposure to EMRs from mobile phone base stations on the health and well-being of the general population cannot be ruled out.
30 Y RS	Premlal and Eldhose, 2017 India	14 Base station antennas	Questionnaire survey (229 persons) and power density measurements	Joint pain, sleep disorders, migraine related headaches and digestive problems	For 32 different diseases, only 4 were found to have obvious relation to the cell tower radiation. Females are more prone to the bad effects of cell tower radiation. The current Indian standard for cell tower exposure is inadequate for the safe living.
31 Y CBP	Taheri et al. (2017) Iran	Base station antennas	45 healthy individuals with their home near BTS antenna (exposed group) and 45 healthy subjects who were away from the antenna	In the exposed group, the whole number of white blood cells, the level of hematocrit, percent of monocytes, eosinophils and basophils were significantly lower than the control group. The number of red blood cells, their average volume and the mean concentration of hemoglobin were notably higher than the controls. There was not observed a significant difference between the two groups in hemoglobin, its mean concentration, platelet count, percent of lymphocytes and neutrophils as well as serum levels of cytokines IL-4, IL-10 and interferon γ.	The radiation of base station antennas influenced the blood and immune systems.
32 Y RS C	Vijay and Choudhary (2017) India	40 Base station antennas (900–1800 MHz)	Questionnaire survey	Effects found: - headache - depression - sleep disturbance - nausea - fatigue - asthma - cancer - Alzheimer's disease - multiple sclerosis - brain tumor.	The questionnaires show that people have some kind of physical or mental illness after the installation of mobile towers.
33 Y CBP	Zothansiama et al. (2017) India	6 Base station antennas (900–1800 MHz)	Questionnaire survey. Blood sample collection and lymphocyte culture. Power density measurement. Exposed group (n = 40) Control group (n = 40) The study was envisaged to evaluate the effect of RFR on the DNA damage and antioxidant status in cultured human peripheral blood lymphocytes of individuals residing in the vicinity of mobile phone base stations and comparing it with healthy controls.	Effects found: -higher frequency of micronuclei -decreased antioxidants	The analyses of data from the exposed group residing within a perimeter of 80 m of mobile base stations, showed significantly higher frequency of micronuclei when compared to the control group, residing 300 m away from themobile base station. The analysis of various antioxidants in the plasma of exposed individuals revealed a significant attrition in glutathione concentration, activities of catalase and superoxide dismutase and rise in lipid peroxidation when compared to controls. Multiple linear regression analyses revealed a significant association among decreased antioxidants and elevated miconuclei frequency with increasing RF power density. The persistence of DNA unrepaired damage leads to genomic instability which may lead to several health disorders including the induction of cancer.
34 Y RS	Meo et al. (2019) Saudi Arabia	Two different schools both situated nearby base station antennas (925 MHz)	Cognitive function, motor screening task and spatial working memory were tested, and also RF measurements were made.	There was a statistically significant impairment in the motor screening task and spatial working memory among students who were exposed to high RF generated by base station antennas (School 2: 10.021 μW/cm^2) compared to students who were exposed to lower levels of RF (School 1: 2.010 μW/cm^2).	High exposure to RF-EMF produced by base station antennas is associated with a decrease in fine and gross motor skills and spatial working memory and attention in school adolescents compared to students who had been exposed to low RF-EMF.

(*continued on next page*)

Table 1 (*continued*)

N°	Reference and country	Antenna type	Study design	Diseases and symptoms found/not found	Main conclusions
35 Y RS	Ali et al. (2021) Iraq	Base station antennas (900–1800 MHz)	Questionnaire survey comparing two groups. The first group (n = 79) was located in a town with three cell phone towers with less than a hundred meters apart. The second study group (n = 79) was limited to the area almost empty from cell phone towers. Electric field measurements were made.	There was a significant association between health problems (skin problem, hair loss issues, sleeping difficulties, and fertility issues) and distance to towers (less distance, more problems: P-value < 0.05). In regards to health problems (abnormalities, blood pressure issues, tumours cases, and memory and concentration difficulties), the obtained results were not statistically significant.	The results showed an increase in both short- and long-term health problems near base stations antennas in general.
36 Y RS C	López et al., 2021 Spain	9 Base station antennas	Questionnaire survey on 268 persons, 174 in exposed área and 94 in control área, and EMF measurements	Effects found on -headache -dizziness -instability -tachycardias -nightmares No effects found on: -fainting	People who are exposed to higher radiation values present more severe headaches, dizziness and nightmares. 5.6% cancer cases in the study population, a percentage 10 times higher tan that of the total Spanish population.
37 N RS	Martin et al. (2021) France	Base station antennas	Questionnaire survey in 354 residents from buildings located at a distance of 250 m or less from the base station antennas in the main transmit beam of the antennas and home exposure measurements	No significant association between RF-EMF exposure and the overall symptoms score, nor between RF-EMF exposure from MPBSs and insomnia-like symptoms. There was a significant association between RF-EMF exposure and insomnia-like symptoms only for participants who attributed their symptoms to radiofrequencies.	The findings of the study do not support the hypothesis of an association between RF-EMF exposure and health outcomes, such as self-reported non-specific or insomnia-like symptoms in the general population. However, they may suggest a possible association between such exposure and insomnia-like symptoms among people reporting environmental concerns.
38 Y C	Rodrigues et al. (2021) Brazil	Base station antennas	This is an ecological study using capitals as the unit of analysis. The authors 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 and investigated all cancer types and some specific types (breast, cervix, lung, and esophagus cancers).	For all cancers and for the specific types investigated (breast, cervix, lung, and esophagus cancers), the higher the exposure to RBS radiofrequency, the higher the median of mortality rate.	The results indicates that the exposure to radiofrequency electromagnetic fields from an RBS increases the rate of mortality by all cancers and specifically by breast, cervix, lung, and esophageal cancers. These conclusions are based on the fact that the findings of the study indicate that, the higher the RBS radiofrequency exposure, the higher the cancer mortality rate, especially for cervix cancer. The spatial analysis showed that the highest radiofrequency exposure was observed in a city located in the southern region of Brazil, which also showed the highest mortality rate for all types of cancer and specifically for lung and breast cancers.

4.1. Investigations with radar and radio/television antennas

In studies carried out in the last century, occupational exposure of people to microwave radiation (RF) related to military, industrial and radio uses, as well as radio waves, showed several types of effects: an increase in spontaneous abortions, changes in red and white blood cell counts and an increase in childhood, testicular and other cancers. These findings suggest that RF exposures are potentially carcinogenic and have other health effects; the author recommends precautionary measures to avoid unnecessary exposure (Goldsmith, 1997). An analysis of particular locations of diagnosed neoplasms indicates significantly higher morbidity rates in the military exposed to RF for alimentary tract cancers, skin tumours, neoplasms and cerebral and haematological/lymphatic malignancies. For haematological/lymphatic malignancies, the difference in morbidity between exposed and unexposed military was the largest. This may suggest that spontaneous neoplasms develop faster in the exposed group, with a shorter latency period than in those not exposed. In fact, in exposed subjects, the disease occurs 5–10 years earlier (Szmigielski et al., 2001). On the other hand, children exposed to radar electromagnetic radiation had less developed memory and attention, their reaction time was slower and their neuromuscular apparatus endurance was decreased (Kolodynski and Kolodynska, 1996).

In several studies performed around radio and television antennas, there was a significant decrease in the risk of cancer and leukaemia with increasing distance to the antennas (Maskarinec et al., 1994; Dolk et al., 1997a, 1997b; Hocking and Gordon, 2000; Michelozzi et al., 2002; Park et al., 2004). People exposed to a radio antenna shortwave broadcasting station in Schwarzenburg (Switzerland) had sleep disturbances, which were more frequent in exposed than in unexposed subjects (Altpeter et al., 2000).

Thus, the coincidences of similar effects from studies with different sources of electromagnetic radiation (but with similar pulsed, polarized and modulated radiation), such as radar or radio/television antennas, reinforce the conclusions of this review. Non-ionizing EMF are among the fastest growing forms of environmental pollution, its increase around the world in recent years has been exponential (Bandara and Carpenter, 2018) and symptoms reported today may be classic microwave/RF sickness (Levitt and Lai, 2010).

4.2. RF exposure incidents among diplomats (Havanna syndrome)

From late 2016 through August 2017, US government personnel on a diplomatic mission in Havana, Cuba, reported neurological symptoms, including cognitive, balance, visual and hearing disturbances, sleep

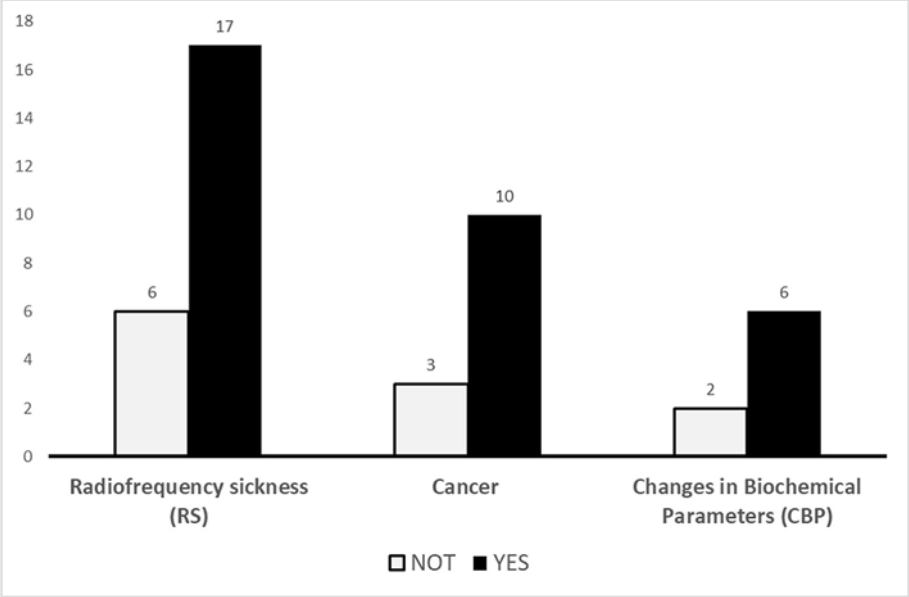


Fig. 1. Results on effects according to the study type considered.

disturbances and headaches. These individuals appeared to have sustained injuries to generalized brain networks with no associated history of head trauma (Swanson et al., 2018). They complained of cognitive decline, fatigue and headache, especially after cognitive exertion, and in some cases tinnitus, nausea and balance problems (Dyer, 2018). This mysterious disease that affected US and Canadian diplomats in Cuba (and later also in China) has confused the FBI, the State Department and US intelligence agencies.

The reported facts seem consistent with pulsed RF/microwave as the source of injuries to the affected diplomats (Golomb, 2018). The same conclusion was later reached by the National Academy of National Academies of Sciences (2020), who reported that many of the chronic or non-specific symptoms were consistent with known effects of RF, such as dizziness, headache, fatigue, nausea, anxiety, cognitive deficits and memory loss. In general, directed pulsed RF energy appears to be the most plausible mechanism to explain these cases. Such symptoms had already been described much earlier at the Moscow embassy (Lilienfeld et al., 1978; Johnson Lyakouris, 1998).

There are objective pathophysiological changes and health effects induced by EMF exposure that can biologically damage the organism and are noxious agents in healthy people (Belpomme and Irigaray, 2022).

4.3. Important laboratory studies

The United States National Toxicology Program (NTP) tested the two main modulation types used for mobile phones worldwide for GSM (2G) and UMTS (3G/4G), in a two-year rodent cancer bioassay under near-field exposure conditions; the experiments included additional assays for genotoxicity endpoints (Smith-Roe et al., 2020). They found clear evidence of carcinogenic activity, and more specifically malignant schwannomas of the heart, malignant gliomas of the brain and benign, malignant or complex pheochromocytomas (combined) of the adrenal medulla. They also found increased DNA damage (measured by the comet assay) in the frontal cortex of male mice, in the leukocytes of female mice and in the hippocampus of male rats, indicating that mobile phone EMF could cause DNA damage and consequent carcinogenesis. In a similar large carcinogenicity study by the Ramazzini Institute, Falcioni et al. (2018) examined far-field exposure to GSM 1800 MHz EMF and reported very similar results to the NTP study. Specifically, they also found increased incidence of tumours of the brain and heart in the mobile phone EMF-exposed Sprague-Dawley rats. Furthermore, these tumours are of the same histotype as those observed in some epidemiological studies on mobile phone users (Hardell et al., 2007).

Kostoff et al. (2020) emphasizes that most of the laboratory experiments conducted to date were not designed to identify the more severe adverse effects reflective of the real-life operating environment in which wireless radiation systems operate, as many experiments do not include pulsing and modulation of the carrier signal and the majority do not account for synergistic adverse effects of other toxic stimuli.

4.4. Importance of studies with biological parameters and those performed on animals and plants

Despite the scientific evidence shown in the studies carried out in many countries by different teams of researchers that we have reviewed, several studies conclude that no effects are found and blame it on risk perception and the nocebo effect (Wiedemann et al., 2006; Kowall et al., 2012; Freudenstein et al., 2015; Dieudonné, 2016; Klaps et al., 2016; Koh et al., 2020). However, the nocebo effect is not supported by objective data (Belpomme and Irigaray, 2022), by the results of cancer studies (Eger et al., 2004; Wolf and Wolf, 2004; Dode et al., 2011; Li et al., 2012; Rodrigues et al., 2021), by studies on changes in haematological parameters (Gandhi et al., 2015; Meo et al., 2015; Taheri et al., 2017; Zothansiama et al., 2017), by hormonal changes after long-term exposure (Eskander et al., 2012), by salivary secretion (Singh et al., 2016) and by effects on fertility (Al-Quzwini et al., 2016). Many reviews on the health effects of mobile phones have reached the same conclusions regarding their effects on male infertility (El-Hamd and Aboeldahab, 2018). Unfortunately, the studies that allude to the nocebo effect seem to be the ones taken into account by the World Health Organization (World Health Organization, 2015).

On the other hand, studies performed on animals or trees near base station antennas are especially important, because animals and plants cannot be aware of their proximity and therefore nocebo or psychosomatic effects cannot be attributed (Balmori, 2005, 2010; Balmori and Hallberg, 2007; Hässig et al., 2012; Lázaro et al., 2016; Waldmann-Selsam et al., 2016; Levitt et al., 2021). In fact, a similar result of this study for humans was found in a review on the significant ecological effects of RF EMF in 65% of the studies on vertebrates, birds and plants (Cucurachi et al., 2013).

Moreover, for these effects, perfectly plausible mechanisms of action

have already been proposed. Plasma membrane calcium channels and other voltage-gated ion channels are irregularly activated/inactivated by man-made EMF in both animals and plants, increasing intracellular [Ca^{2+}] and altering intracellular ion concentrations (Panagopoulos et al., 2002, 2021; Pall, 2016).

Under the influence of non-thermal intensities of microwave radiation, often there are important signals of some hazardous changes in cell metabolism. A significant increase of reactive oxygen species and nitrogen oxide generation in cells under non-thermal intensities has been detected both in vivo and in vitro (Yakymenko et al., 2011; Belpomme and Irigaray, 2022). Thus, the different findings clearly argue for a causal role of EMF in inducing free radical species, including overproduction of reactive oxygen and nitrogen species or suppression of antioxidant defence in cells (Belpomme and Irigaray, 2022). Furthermore, this exposure can result in DNA damage through oxidative stress with reactive oxygen species/free radical overproduction (Yakymenko et al., 2011; Kıvrak et al., 2017; Panagopoulos et al., 2021).

5. The Precautionary Principle

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is a private organization that issues exposure guidelines that are then adopted by governments, but it has been accused of having conflicts of interest (Hardell and Carlberg, 2020; Hardell et al., 2021). The ICNIRP (2010, 2020) limits are thousands of times above the levels where effects are recorded for both extremely low frequency and RF man-made EMF and account only for thermal effects, whereas the vast majority of recorded effects are non-thermal. These existing guidelines for public health protection only consider the effects of acute intense (thermal) exposures and do not protect from lower level long-term exposures (Israel et al., 2011; Yakymenko et al., 2011; Blank et al., 2015; Starkey, 2016; Belpomme and Irigaray, 2022). The exposure duration is crucial to assess the induced effects.

The Precautionary Principle is one of the fundamental principles of the European Union, governing policies related to the environment, health and food safety (Harremoes et al., 2013). This principle enables decision-makers to adopt precautionary measures when the scientific evidence regarding an environmental or human health factor is not certain regarding its safety. Therefore, despite the existing ample and rapidly increasing scientific evidence, no significant progress has been made over all these years, at least at the level of guidelines issued by the responsible authorities and official regulatory bodies. Some authors have pointed out that the source of funding correlates with study findings, and many systematic reviews and meta-analyses in this field have failed to correct for this source of funding bias, which has likely underestimated the evidence for causation (Carpenter, 2019). A growing number of scientists have been calling internationally on governments to raise their safety standards for RF-EMF (Blank et al., 2015; Hardell and Nyberg, 2020; Frank, 2021). Thus, there is an urgent need to adopt the Precautionary Principle and impose more restrictive levels (Zinelis, 2010; Yakymenko et al., 2011; Blank et al., 2015; Starkey, 2016).

6. Conclusion

In the current circumstances, it seems that the scientific experts in the field are very clear about the serious problems we are facing and have expressed this through important appeals (Blank et al., 2015; Hardell and Nyberg, 2020). However, the media, the responsible organizations (World Health Organization, 2015) and the governments are not transmitting this crucial information to the population, who remain uninformed. For these reasons, the current situation will probably end in a crisis not only for health but also for this technology itself, as it is unsustainable and harmful to the environment and the people.

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

Abelin, T., Altpeter, E., Röösli, M., 2005. Sleep disturbances in the vicinity of the short-wave broadcast transmitter Schwarzenburg. Somnologie-Schlafforschung und Schlafmedizin 9 (4), 203–209.
Akkam, Y., A Al-Taani, A., Ayasreh, S., Almutairi, A., Akkam, N., 2020. Correlation of blood oxidative stress parameters to indoor radiofrequency radiation: a cross sectional study in Jordan. Int. J. Environ. Res. Publ. Health 17 (13), 4673.
Alazawi, S.A., 2011. Mobile phone base stations health effects. Diyala J. Med. 1 (1), 44–52.
Alhekail, Z.O., Hadi, M.A., Alkanhal, M.A., 2012. Public safety assessment of electromagnetic radiation exposure from mobile base stations. J. Radiol. Prot. 32 (3), 325.
Altpeter, E., Battaglia, M., Bader, A., Pfluger, D., Minder, C.E., Abelin, T., 2000, June. Ten years experience with epidemiological research in the vicinity of the short-wave broadcasting area Schwarzenburg: what does the story tell us. In: Proceedings of the International Conference on Cell Tower Siting. Salzburg, Austria, pp. 7–8.
Altpeter, E.S., Röösli, M., Battaglia, M., Pfluger, D., Minder, C.E., Abelin, T., 2006. Effect of short-wave (6–22 MHz) magnetic fields on sleep quality and melatonin cycle in humans: the Schwarzenburg shut-down study. Bioelectromagnetics 27 (2), 142–150.
Abdel-Rassoul, G., Abou El-Fateh, O., Abou Salem, M., Michael, A., Farahat, F., El-Batanouny, M., Salem, E., 2007. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology 28 (2), 434–440.
Admawi, H.K., 2021. Assessment of electromagnetic pollution in some hospitals and schools in Al-najaf city. J. Eng. 27 (3), 1–14.
Ali, M.T., Muhsen, Y.R., Chisab, R.F., Abed, S.N., 2021. Evaluation study of radio frequency radiation effects from cell phone towers on human health. Radioelectron. Commun. Syst. 64 (3), 155–164.
Al-Quzwini, O.F., Al-Taee, H.A., Al-Shaikh, S.F., 2016. Male fertility and its association with occupational and mobile phone towers hazards: an analytic study. Middle East Fertil. Soc. J. 21 (4), 236–240.
Altpeter, E., Battaglia, M., Bader, A., Pfluger, D., Minder, C.E., Abelin, T., 2000. Ten years experience with epidemiological research in the vicinity of the short-wave broadcasting area Schwarzenburg: what does the story tell us. In: Proceedings of the International Conference on Cell Tower Siting, vol. 78. Salzburg, Austria, pp. 127–132.
Aniołczyk, H., 1999. Electromagnetic field pattern in the environment of GSM base stations. Int. J. Occup. Med. Environ. Health 12 (1), 47–58.
Atzmon, I., Linn, S., Richter, E., Portnov, B.A., 2012. Cancer risks in the druze isifya village: reasons and RF/MW antennas. Pathophysiology 19 (1), 21–28.
Augner, C., Hacker, G.W., 2009. Are people living next to mobile phone base stations more strained? Relationship of health concerns, self-estimated distance to base station, and psychological parameters. Indian J. Occup. Environ. Med. 13 (3), 141.
Augner, C., Florian, M., Pauser, G., Oberfeld, G., Hacker, G.W., 2009. GSM base stations: short-term effects on well-being. Bioelectromagnetics 30 (1), 73–80.
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 (3), 199–207.
Azimzadeh, M., Jelodar, G., 2019. Alteration of testicular regulatory and functional molecules following long-time exposure to 900 MHz RFW emitted from BTS. Andrologia 51 (9), e13372.
Baliatsas, C., van Kamp, I., Kelfkens, G., Schipper, M., Bolte, J., Yzermans, J., Lebret, E., 2011. Non-specific physical symptoms in relation to actual and perceived proximity to mobile phone base stations and powerlines. BMC Publ. Health 11 (1), 1–12.
Baliatsas, C., van Kamp, I., Bolte, J., Kelfkens, G., van Dijk, C., Spreeuwenberg, P., et al., 2016. Clinically defined non-specific symptoms in the vicinity of mobile phone base stations: a retrospective before-after study. Sci. Total Environ. 565, 714–720.
Balmori, A., 2005. Possible effects of electromagnetic fields from phone masts on a population of white stork (Ciconia ciconia). Electromagn. Biol. Med. 24 (2), 109–119.
Balmori, A., Hallberg, Ö., 2007. The urban decline of the house sparrow (Passer domesticus): a possible link with electromagnetic radiation. Electromagn. Biol. Med. 26 (2), 141–151.
Balmori, A., 2010. Mobile phone mast effects on common frog (Rana temporaria) tadpoles: the city turned into a laboratory. Electromagn. Biol. Med. 29 (1–12), 31–35.
Bandara, P., Carpenter, D.O., 2018. Planetary electromagnetic pollution: it is time to assess its impact. Lancet Planet. Health 2 (12), e512–e514.
Beekhuizen, J., Vermeulen, R., Kromhout, H., Bürgi, A., Huss, A., 2013. Geospatial modelling of electromagnetic fields from mobile phone base stations. Sci. Total Environ. 445, 202–209.
Belpomme, D., Irigaray, P., 2022. Why Electrohypersensitivity and Related Symptoms Are Caused by Non-ionizing Man-Made Electromagnetic Fields: an Overview and Medical Assessment. Environmental Research, 113374.
Berg-Beckhoff, G., Blettner, M., Kowall, B., Breckenkamp, J., Schlehofer, B., Schmiedel, S., et al., 2009. Mobile phone base stations and adverse health effects:

phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. Occup. Environ. Med. 66 (2), 124–130.
Bithell, J.F., 2010. Childhood cancer and proximity to mobile phone masts. Bmj 340.
Blank, M., Havas, M., Kelley, E., Lai, H., Moskowitz, J., 2015. International Appeal: scientists call for protection from non-ionizing electromagnetic field exposure. Eur. J. Oncol. 20 (3/4), 180–182.
Blettner, M., Schlehofer, B., Breckenkamp, J., Kowall, B., Schmiedel, S., Reis, U., et al., 2009. Mobile phone base stations and adverse health effects: phase 1 of a population-based, cross-sectional study in Germany. Occup. Environ. Med. 66 (2), 118–123.
Boehmert, C., Freudenstein, F., Wiedemann, P., 2020. A systematic review of health risk communication about EMFs from wireless technologies. J. Risk Res. 23 (5), 571–597.
Bortkiewicz, A., Zmyślony, M., Szyjkowska, A., Gadzicka, E., 2004. Subjective symptoms reported by people living in the vicinity of cellular phone base stations: review. Med. Pr. 55 (4), 345–351.
Boscolo, P., Di Sciascio, M.B., D'ostilio, S., Del Signore, A., Reale, M., Conti, P., et al., 2001. Effects of electromagnetic fields produced by radiotelevision broadcasting stations on the immune system of women. Sci. Total Environ. 273 (1–3), 1–10.
Breckenkamp, J., Blettner, M., Schüz, J., Bornkessel, C., Schmiedel, S., Schlehofer, B., Berg-Beckhoff, G., 2012. Residential characteristics and radiofrequency electromagnetic field exposures from bedroom measurements in Germany. Radiat. Environ. Biophys. 51 (1), 85–92.
Bürgi, A., Theis, G., Siegenthaler, A., Röösli, M., 2008. Exposure modeling of high-frequency electromagnetic fields. J. Expo. Sci. Environ. Epidemiol. 18 (2), 183–191.
Bürgi, A., Scanferla, D., Lehmann, H., 2014. Time averaged transmitter power and exposure to electromagnetic fields from mobile phone base stations. Int. J. Environ. Res. Publ. Health 11 (8), 8025–8037.
Carpenter, D.O., 2019. Extremely low frequency electromagnetic fields and cancer: how source of funding affects results. Environ. Res. 178, 108688.
Chen, H.Y., Chuang, C.Y., 2009. Currents induced in human bodies during radiofrequency exposure near a cellular phone base station. Electromagnetics 29 (1), 13–23.
Coggon, D., 2006. Health risks from mobile phone base stations. Occup. Environ. Med. 63 (5), 298–299.
Cooper, D., Hemmings, K., Saunders, P., 2001. Re: "Cancer incidence near radio and televisión transmitters in Great Britain. I. Sutton Coldfield transmitter"; II. All high power transmitters. Am. J. Epidemiol. 153, 202–204.
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.
Danker-Hopfe, H., Dorn, H., Bornkessel, C., Sauter, C., 2010. Do mobile phone base stations affect sleep of residents? Results from an experimental double-blind sham-controlled field study. Am. J. Hum. Biol. 22 (5), 613–618.
De Giudici, P., Genier, J.C., Martin, S., Doré, J.F., Ducimetiere, P., Evrard, A.S., et al., 2021. Radiofrequency exposure of people living near mobile-phone base stations in France. Environ. Res. 194, 110500.
Dieudonné, M., 2016. Does electromagnetic hypersensitivity originate from nocebo responses? Indications from a qualitative study. Bioelectromagnetics 37 (1), 14–24.
Dode, A.C., Leao, M.M., Tjo Fde, A., Gomes, A.C., Dode, D.C., Dode, M.C., 2011. moreira CW, condessa VA, albinatti C, and caiaffa WT. Mortality by neoplasia and cellular telephone base stations in the belo horizonte municipality, minas gerais state, Brazil. Sci. Total Environ. 409, 3649–3665.
Dode, A.C., Leão, M.M., 2012. Comments on" Foster KR, Trottier L, comments on" mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state,. Sci. Total Environ. 442, 553–556 (2012. The Science of the total environment.
Dohle, S., Keller, C., Siegrist, M., 2012. Mobile communication in the public mind: insights from free associations related to mobile phone base stations. Hum. Ecol. Risk Assess. 18 (3), 649–668.
Dolk, H., Shaddick, G., Walls, P., Grundy, C., Thakrar, B., Kleinschmidt, I., Elliott, P., 1997a. Cancer incidence near radio and television transmitters in Great Britain I. Sutton Coldfield transmitter. Am. J. Epidemiol. 145 (1), 1–9.
Dolk, H., Elliot, G., Shaddick, G., Walls, P., Thakrar, B., 1997b. Cancer incidence near radio and television transmitters in great britain, Part 2. All high tower transmitters. Am. J. Epidemiol. 145, 10–17.
Dyer, O., 2018. Microwave weapon caused syndrome in diplomats in Cuba, US medical team believes. BMJ Br. Med. J. (Clin. Res. Ed.) 362.
Eger, H., Hagen, K.U., Lucas, B., Vogel, P., Voit, H., 2004. Einfluss der räumlichen Nähe von Mobilfunksendeanlagen auf die Krebsinzidenz. Umwelt-Medizin-Gesellschaft 17 (4), 326–335.
Eger, H., Jahn, M., 2010. Specific health symptoms and cell phone radiation in Selbitz (Bavaria, Germany)—evidence of a dose-response relationship. umwelt-medizin-gesellschaft 23, 130–139.
El-Hamd, M.A., Aboeldahab, S., 2018. Cell phone and male infertility: an update. J. Integrat. Nephrol. Androl. 5 (1), 1.
Elliott, P., Toledano, M.B., Bennett, J., Beale, L., De Hoogh, K., Best, N., Briggs, D.J., 2010. Mobile phone base stations and early childhood cancers: case-control study. Bmj 340.
Eltiti, S., Wallace, D., Ridgewell, A., Zougkou, K., Russo, R., Sepulveda, F., et al., 2007. Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double-blind randomized provocation study. Environ. Health Perspect. 115 (11), 1603–1608.
Elwood, J.M., 2003. Epidemiological studies of radio frequency exposures and human cancer. Bioelectromagnetics 24 (S6), S63–S73.
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 (1–2), 157–161.
Falcioni, L., Bua, L., Tibaldi, E., Lauriola, M., De Angelis, L., Gnudi, F., Belpoggi, F., 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.
Foster, K.R., Trottier, L., 2012. Comments on" Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil" by AC Dode et al, 2011. In: Science of the Total Environment, vol. 409, pp. 3649–3665. The Science of the total environment, 450, 366-368.
Frank, J.W., 2021. Electromagnetic fields, 5G and health: what about the precautionary principle? J. Epidemiol. Community Health 75 (6), 562–566.
Frei, P., Mohler, E., Braun-Fahrländer, C., Fröhlich, J., Neubauer, G., Röösli, M., 2012. Cohort study on the effects of everyday life radio frequency electromagnetic field exposure on non-specific symptoms and tinnitus. Environ. Int. 38 (1), 29–36.
Freudenstein, F., Wiedemann, P.M., Brown, T.W., 2015. Exposure perception as a key indicator of risk perception and acceptance of sources of radio frequency electromagnetic fields. J. Environ. Public Health 2015, 9. https://doi.org/10.1155/2015/198272.
Gandhi, G., Kaur, G., Nisar, U., 2015. A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. Electromagn. Biol. Med. 34 (4), 344–354.
Goldsmith, J.R., 1997. Epidemiologic evidence relevant to radar (microwave) effects. Environ. Health Perspect. 105 (Suppl. 6), 1579–1587.
Golomb, B.A., 2018. Diplomats' mystery illness and pulsed radiofrequency/microwave radiation. Neural Comput. 30 (11), 2882–2985.
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.
Ha, M., Lim, H.J., Cho, S.H., Choi, H.D., Cho, K.Y., 2003. Incidence of cancer in the vicinity of Korean AM radio transmitters. ArchivE Environ. Health 58 (12), 756–762.
Ha, M., Im, H., Lee, M., Kim, H.J., 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. 166 (3), 270–279.
Hansson, B., Thors, B., Törnevik, C., 2011. Analysis of the effect of mobile phone base station antenna loading on localized SAR and its consequences for measurements. Bioelectromagnetics 32 (8), 664–672.
Hallberg, Ö., Johansson, O., 2002. Melanoma incidence and frequency modulation (FM) broadcasting. ArchivE Environ. Health 57 (1), 32–40.
Hardell, L., Carlberg, M., Söderqvist, F., Mild, K.H., Morgan, L.L., 2007. Long-term use of cellular phones and brain tumours: increased risk associated with use for > or =10 years. Occup. Environ. Med. 64 (9), 626–632 submitted for publication.
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 (5), 7871–7883.
Hardell, L., Carlberg, M., 2020. [Comment] Health risks from radiofrequency radiation, including 5G, should be assessed by experts with no conflicts of interest. Oncol. Lett. 20 (4), 1, 1.
Hardell, L., Nyberg, R., 2020. [Comment] Appeals that matter or not on a moratorium on the deployment of the fifth generation, 5G, for microwave radiation. Mole. Clinic. Oncol. 12 (3), 247–257.
Hardell, L., Nilsson, M., Koppel, T., Carlberg, M., 2021. Aspects on the international commission on non-ionizing radiation protection (ICNIRP) 2020 guidelines on radiofrequency radiation. J. Cancer Sci. Clinic. Therapeutics 5 (2), 250–285.
Harremoes, P., Gee, D., MacGarvin, M., Stirling, A., Keys, J., Wynne, B., Vaz, S.G. (Eds.), 2013. The Precautionary Principle in the 20th Century: Late Lessons from Early Warnings. Routledge, London.
Hässig, M., Jud, F., Spiess, B., 2012. Increased occurrence of nuclear cataract in the calf after erection of a mobile phone base station. Schweizer Archiv Fur Tierheilkunde 154 (2), 82–86.
Henderson, S.I., Bangay, M.J., 2006. Survey of RF exposure levels from mobile telephone base stations in Australia. Bioelectromagnetics: J. Bioelectromag. Soc., Soc. Phys. Regul. Biol. Med., European Bioelectromag. Assoc. 27 (1), 73–76.
Hinrichs, H., Heinze, H.J., Rotte, M., 2005. Human sleep under the influence of a GSM 1800 electromagnetic far field. Somnologie-Schlafforschung und Schlafmedizin 9 (4), 185–191.
Hocking, B., Gordon, I.R., Grain, H.L., Hatfield, G.E., 1996. Cancer incidence and mortality and proximity to TV towers. Med. J. Aust. 165 (11–12), 601–605.
Hocking, B., Gordon, I., 2000. Decreased survival for childhood leukemia in proximity to TV towers. In: Poster Presented at the Annual Scientific Meeting of the Royal Australian College of Physicians in Adelaide. SA, Australia.
Hutter, H.P., Moshammer, H., Wallner, P., Kundi, M., 2006. Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup. Environ. Med. 63 (5), 307–313.
ICNIRP, 2010. Guidelines for limiting exposure to time-varying electric and magnetic fields (1Hz to 100 kHz). Health Phys. 99 (6), 818–836.
ICNIRP, 2020. Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz). Health Phys. 118 (5), 483–524.
Islam, S., Mohammed, S., 2014. Awareness and self-reported health hazards of electromagnetic waves from mobile phone towers in Dhaka, Bangladesh: a pilot study. Adv. Pub. Health 2014, 7. https://doi.org/10.1155/2014/952832, 952832.
Johnson Lyakouris, A.G., 1998. Radiofrequency (RF) sickness in the Lilienfeld study: an effect of modulated microwaves? ArchivE Environ. Health 53, 3, 1998.

Kazaure, J.S., Matthew, U.O., Okafor, N.U., Okey, O.D., 2021. Telecommunication network performances and evaluation of radio frequency electromagnetic radiation: health effects of the RF-EMR GSM base stations. Int. J. Inf. Commun. Technol. Hum. Dev. 13 (3), 16–37.
Keow, M.A., Radiman, S., 2006. Assessment of radiofrequency/microwave radiation emitted by the antennas of rooftop-mounted mobile phone base stations. Radiat. Protect. Dosim. 121 (2), 122–127.
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 (3), 263–267.
Kıvrak, E.G., Yurt, K.K., Kaplan, A.A., Alkan, I., Altun, G., 2017. Effects of electromagnetic fields exposure on the antioxidant defense system. J. Micros. Ultrastruct. 5 (4), 167–176.
Klaps, A., Ponocny, I., Winker, R., Kundi, M., Auersperg, F., Barth, A., 2016. Mobile phone base stations and well-being—a meta-analysis. Sci. Total Environ. 544, 24–30.
Koh, T.H., Choi, J.W., Seo, M., Choi, H.D., Kim, K., 2020. Factors affecting risk perception of electromagnetic waves from 5G network base stations. Bioelectromagnetics 41 (7), 491–499.
Kolodynski, A.A., Kolodynska, V.V., 1996. Motor and psychological functions of school children living in the area of the Skrunda Radio Location Station in Latvia. Sci. Total Environ. 180 (1), 87–93.
Kostoff, R.N., Heroux, P., Aschner, M., Tsatsakis, A., 2020. Adverse health effects of 5G mobile networking technology under real-life conditions. Toxicol. Lett. 323, 35–40.
Kundi, M., Hutter, H.P., 2009. Mobile phone base stations—effects on wellbeing and health. Pathophysiology 16 (2–3), 123–135.
Kowall, B., Breckenkamp, J., Blettner, M., Schlehofer, B., Schüz, J., Berg-Beckhoff, G., 2012. Determinants and stability over time of perception of health risks related to mobile phone base stations. Int. J. Publ. Health 57 (4), 735–743.
Lamech, F., 2014. Self-reporting of symptom development from exposure to radiofrequency fields of wireless smart meters in Victoria, Australia: a case series. Alternative Ther. Health Med. 20 (6), 28.
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. 20 (2), 315–324.
Lemaire, T., Wiart, J., De Doncker, P., 2016. Variographic analysis of public exposure to electromagnetic radiation due to cellular base stations. Bioelectromagnetics 37 (8), 557–562.
Leitgeb, N., Schröttner, J., Cech, R., Kerbl, R., 2008. EMF-protection sleep study near mobile phone base stations. Somnologie-Schlafforschung und Schlafmedizin 12 (3), 234–243.
Levitt, B.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.
Levitt, B.B., Lai, H.C., Manville, A.M., 2021. Effects of Non-ionizing Electromagnetic Fields on Flora and Fauna, Part 2 Impacts: How Species Interact with Natural and Man-Made EMF. Reviews on Environmental Health.
Li, C.Y., Liu, C.C., Chang, Y.H., Chou, L.P., Ko, M.C., 2012. A population-based case–control study of radiofrequency exposure in relation to childhood neoplasm. Sci. Total Environ. 435, 472–478.
Lilienfeld, A.M., Tonascia, J., Tonascia, S., et al., 1978. Foreign Service Health Status Study. Department of State, Washington, DC. Final report contract no. 6025-619037 (NTS publication PB-288163).
López, I., Félix, N., Rivera, M., Alonso, A., Maestú, C., 2021. What is the radiation before 5G? A correlation study between measurements in situ and in real time and epidemiological indicators in Vallecas, Madrid. Environ. Res. 194, 110734.
Lyare, R.N., Volskiy, V., Vandenbosch, G.A., 2019. Study of the correlation between outdoor and indoor electromagnetic exposure near cellular base stations in Leuven, Belgium. Environ. Res. 168, 428–438.
Martens, A.L., Slottje, P., Smid, T., Kromhout, H., Vermeulen, R.C., Timmermans, D.R., 2018. Longitudinal associations between risk appraisal of base stations for mobile phones, radio or television and non-specific symptoms. J. Psychosom. Res. 112, 81–89.
Martens, A.L., Slottje, P., Timmermans, D.R., Kromhout, H., Reedijk, M., Vermeulen, R. C., Smid, T., 2017. Modeled and perceived exposure to radiofrequency electromagnetic fields from mobile-phone base stations and the development of symptoms over time in a general population cohort. Am. J. Epidemiol. 186 (2), 210–219.
Martin, S., De Giudici, P., Genier, J.C., Cassagne, E., Doré, J.F., Ducimetière, P., et al., 2021. Health disturbances and exposure to radiofrequency electromagnetic fields from mobile-phone base stations in French urban areas. Environ. Res. 193, 110583.
Maskarinec, G., Cooper, J., Swygert, L., 1994. Investigation of increased incidence in childhood leukemia near radio towers in Hawaii: preliminary observations. J. Environ. Pathol. Toxicol. Oncol. 13 (1), 33–37.
McKenzie, D.R., Yin, Y., Morrell, S., 1998. Childhood incidence of acute lymphoblastic leukemia and exposure to broadcast radiation in Sydney—a second look. Aust. N. Z. J. Publ. Health 22 (3 Suppl. l), 360–367.
Meo, S.A., Alsubaie, Y., Almubarak, Z., Almutawa, H., AlQasem, Y., Hasanato, R.M., 2015. Association of exposure to radio-frequency electromagnetic field radiation (RF-EMFR) generated by mobile phone base stations with glycated hemoglobin (HbA1c) and risk of type 2 diabetes mellitus. Int. J. Environ. Res. Publ. Health 12 (11), 14519–14528.
Meo, S.A., Almahmoud, M., Alsultan, Q., Alotaibi, N., Alnajashi, I., Hajjar, W.M., 2019. Mobile phone base station tower settings adjacent to school buildings: impact on students' cognitive health. Am. J. Men's Health 13 (1), 1557988318816914.
Michelozzi, P., Ancona, C., Fusco, D., Forastiere, F., Perucci, C.A., 1998. Risk of leukemia and residence near a radio transmitter in Italy. Epidemiology 9 (4), S111.
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, Italy. Am. J. Epidemiol. 155 (12), 1096–1103.
Milham Jr., S., 1988. Increased mortality in amateur radio operators due to lymphatic and hematopoietic malignancies. Am. J. Epidemiol. 127 (1), 50–54.
Mortazavi, S.M.J., 2014. Subjective symptoms related to GSM radiation from mobile phone base stations: a cross-sectional study. J. Biomed. Phys. Eng. 4 (1).
Mortazavi, S.M.J., 2017. RE:"Modeled and perceived exposure to radiofrequency electromagnetic fields from mobile-phone base stations and the development of symptoms over time in a general population cohort". Am. J. Epidemiol. 186 (10), 1217, 1217.
National Academies of Sciences, 2020. Engineering, and medicine. An assessment of illness in US government employees and their families at overseas embassies. https://doi.org/10.17226/25889.
Navarro, E.A., Segura, J., Portolés, M., Gómez-Perretta de Mateo, C., 2003. The microwave syndrome: a preliminary study in Spain. Electromagn. Biol. Med. 22 (2–3), 161–169.
Neitzke, H.P., Osterhoff, J., Peklo, K., Voigt, H., 2007. Determination of exposure due to mobile phone base stations in an epidemiological study. Radiat. Protect. Dosim. 124 (1), 35–39.
Pachuau, L., Pachuau, Z., 2014. Study of cell tower radiation and its health hazards on human body. IOSR J. Appl. Phys. (IOSR-JAP) 2278–4861.
Pachuau, L., Pachuau, Z., Zothansiama, 2015. Comparisons of non specific health symptoms faced by inhabitants exposed to high and low power density from mobile phone tower radiation. Int. J. Recent Innov. Trends Comput. Commun. 3 (2), 94–98.
Pall, M., 2016. Electromagnetic fields act similarly in plants as in animals: probable activation of calcium channels via their voltage sensor. Curr. Chem. Biol. 10 (1), 74–82.
Panagopoulos, D.J., Karabarbounis, A., Margaritis, L.H., 2002. Mechanism for action of electromagnetic fields on cells. Biochem. Biophys. Res. Commun. 298, 95–102.
Panagopoulos, D.J., Karabarbounis, A., Yakymenko, I., Chrousos, G.P., 2021. Human-made electromagnetic fields: ion forced-oscillation and voltage-gated ion channel dysfunction, oxidative stress and DNA damage. Int. J. Oncol. 59 (5), 1–16.
Park, S.K., Ha, M., Im, H.J., 2004. Ecological study on residences in the vicinity of AM radio broadcasting towers and cancer death: preliminary observations in Korea. Int. Arch. Occup. Environ. Health 77 (6), 387–394.
Premlal, P.D., Eldhose, N.V., 2017. Mobile tower radiation-an assessment of radiation level and its health implications in the residential areas of western ghats in idukki, Kerala. Int. J. Appl. Eng. Res. 12 (20), 9548–9554.
Regel, S.J., Negovetic, S., Röösli, M., Berdiñas, V., Schuderer, J., Huss, A., et al., 2006. UMTS base station-like exposure, well-being, and cognitive performance. Environ. Health Perspect. 114 (8), 1270–1275.
Regel, S.J., Tinguely, G., Schuderer, J., Adam, M., Kuster, N., Landolt, H.P., Achermann, P., 2007. Pulsed radio-frequency electromagnetic fields: dose-dependent effects on sleep, the sleep EEG and cognitive performance. J. Sleep Res. 16 (3), 253–258.
Riddervold, I.S., Pedersen, G.F., Andersen, N.T., Pedersen, A.D., Andersen, J.B., Zachariae, R., et al., 2008. Cognitive function and symptoms in adults and adolescents in relation to rf radiation from UMTS base stations. Bioelectromagnetics: J. Bioelectromag. Soc., Soc. Phys. Regul. Biol. Med., European Bioelectromag. Assoc. 29 (4), 257–267.
Rodrigues, N.C.P., Dode, A.C., Andrade, M.K.D.N., O'Dwyer, G., Monteiro, D.L.M., Reis, I.N.C., et al., 2021. The effect of continuous low-intensity exposure to electromagnetic fields from radio base stations to cancer mortality in Brazil. Int. J. Environ. Res. Publ. Health 18 (3), 1229.
Röösli, M., Huss, A., 2008. Mobile phone base station exposure and symptoms. Environ. Health Perspect. 116 (2), A62–A63.
Röösli, M., Frei, P., Mohler, E., Hug, K., 2010. Systematic review on the health effects of exposure to radiofrequency electromagnetic fields from mobile phone base stations. Bull. World Health Organ. 88, 887–896.
Santini, R., Santini, P., Danze, J.M., Le Ruz, P., Seigne, M., 2002. Enquête sur la santé de riverains de stations relais de téléphonie mobile: I/Incidences de la distance et du sexe. Pathol. Biol. 50 (6), 369–373.
Santini, R., Santini, P., Le Ruz, P., Danze, J.M., Seigne, M., 2003a. Survey study of people living in the vicinity of cellular phone base stations. Electromagn. Biol. Med. 22 (1), 41–49.
Santini, R., Santini, P., Danze, J.M., Le Ruz, P., Seigne, M., 2003b. Symptoms experienced by people in vicinity of base stations: II/Incidences of age, duration of exposure, location of subjects in relation to the antennas and other electromagnetic factors. Pathol. Biol. 51 (7), 412–415.
Satta, G., Mascia, N., Serra, T., Salis, A., Saba, L., Sanna, S., et al., 2018. Estimates of environmental exposure to radiofrequency electromagnetic fields and risk of lymphoma subtypes. Radiat. Res. 189 (5), 541–547.
Schmiedel, S., Brüggemeyer, H., Philipp, J., Wendler, J., Merzenich, H., Schüz, J., 2009. An evaluation of exposure metrics in an epidemiologic study on radio and television broadcast transmitters and the risk of childhood leukemia. Bioelectromagnetics 30 (2), 81–91.
Shinjyo, T., Shinjyo, A., 2014. Significant decrease of clinical symptoms after mobile phone base station removal–an intervention study. Umwelt medizin gesellschaft (Environ. Med. Company) 27, 294–301.
Schoeni, A., Roser, K., Bürgi, A., Röösli, M., 2016. Symptoms in Swiss adolescents in relation to exposure from fixed site transmitters: a prospective cohort study. Environ. Health 15 (1), 1–8.
Seitz, H., Stinner, D., Eikmann, T., Herr, C., Röösli, M., 2005. Electromagnetic hypersensitivity (EHS) and subjective health complaints associated with

electromagnetic fields of mobile phone communication—a literature review published between 2000 and 2004. Sci. Total Environ. 349 (1–3), 45–55.
Singh, M.M., Pati, A.K., 2016. Effects of radiation emanating from base transceiver station and mobile phone on sleep, circadian rhythm and cognition in humans–a review. Biol. Rhythm. Res. 47 (3), 353–388.
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 (1), 54.
Smith-Roe, S.L., Wyde, M.E., Stout, M.D., Winters, J.W., Hobbs, C.A., Shepard, K.G., Witt, K.L., 2020. Evaluation of the genotoxicity of cell phone radiofrequency radiation in male and female rats and mice following subchronic exposure. Environ. Mol. Mutagen. 61 (2), 276–290.
Starkey, S.J., 2016. Inaccurate official assessment of radiofrequency safety by the advisory group on non-ionising radiation. Rev. Environ. Health 31 (4), 493–503.
Stewart, A., Rao, J.N., Middleton, J.D., Pearmain, P., Evans, T., 2012. Mobile telecommunications and health: report of an investigation into an alleged cancer cluster in Sandwell, West Midlands. Perspect. Public Health 132 (6), 299–304.
Swanson, R.L., Hampton, S., Green-McKenzie, J., Diaz-Arrastia, R., Grady, M.S., Verma, R., et al., 2018. Neurological manifestations among US government personnel reporting directional audible and sensory phenomena in Havana, Cuba. JAMA 319 (11), 1125–1133.
Szmigielski, S., Sobiczewska, E., Kubacki, R., 2001. Carcinogenic potency of microwave radiation: overview of the problem and results of epidemiological studies on Polish military personnel. Eur. J. Oncol. 6, 193–200.
Taheri, M., Roshanaei, G., Ghaffari, J., Rahimnejad, S., Khosroshahi, B.N., Aliabadi, M., Eftekharian, M.M., 2017. The effect of Base Transceiver Station waves on some immunological and hematological factors in exposed persons. Hum. Antibodies 25 (1–2), 31–37.
Urbinello, D., Joseph, W., Huss, A., Verloock, L., Beekhuizen, J., Vermeulen, R., et al., 2014. Radio-frequency electromagnetic field (RF-EMF) exposure levels in different European outdoor urban environments in comparison with regulatory limits. Environ. Int. 68, 49–54.
Viel, J.F., Clerc, S., Barrera, C., Rymzhanova, R., Moissonnier, M., Hours, M., Cardis, E., 2009. Residential exposure to radiofrequency fields from mobile phone base stations, and broadcast transmitters: a population-based survey with personal meter. Occup. Environ. Med. 66 (8), 550–556.
Vijay, S., Choudhary, M.P., 2017. Study on health effects of mobile tower radiation on human beings. Int. Res. J. Eng. Technol 4 (11), 1548–1552.
Waldmann-Selsam, C., Balmori-de la Puente, A., Breunig, H., Balmori, A., 2016. Radiofrequency radiation injures trees around mobile phone base stations. Sci. Total Environ. 572, 554–569.
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 (1), 1–7.
Wallace, D., Eltiti, S., Ridgewell, A., Garner, K., Russo, R., Sepulveda, F., et al., 2010. Do TETRA (Airwave) base station signals have a short-term impact on health and well-being? A randomized double-blind provocation study. Environ. Health Perspect. 118 (6), 735–741.
World Health Organization (WHO), 2015. International EMF Project – Progress Report. https://cdn.who.int/media/docs/default-source/radiation-international-emf-project-reports/emf-iac-2016-progress-report.pdf?sfvrsn=7b2836c0_2.
Wiedemann, P.M., Thalmann, A.T., Grutsch, M.A., Schütz, H., 2006. The impacts of precautionary measures and the disclosure of scientific uncertainty on EMF risk perception and trust. J. Risk Res. 9 (4), 361–372.
Wolf, R., Wolf, D., 2004. Increased incidence of cancer near a cell-phone transmitter station. Int. J. Cancer Prev. 1 (2), 123–128.
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.
Yetiş, C., Kayili, M.T., 2021. Determination of EMF pollution in the context of urban health: the case of safranbolu. Comput. Res. Prog. Appl. Sci. Eng.: Transact. Civil Environ. Eng. 7, 1–10, 2021 Article ID: 2418.
Yildirim, M.S., Yildirim, A., Zamani, A.G., Okudan, N., 2010. Effect of mobile phone station on micronucleus frequency and chromosomal aberrations in human blood cells. Genet. Counsel. 21 (2), 243.
Zinelis, S.A., 2010. The precautionary principle: radiofrequency exposures from mobile telephones and base stations. Environ. Health Perspect. 118 (1), A16. A16.
Zothansiama, 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 (3), 295–305.
Zwamborn, A.P.M., Vossen, S.H.J.A., van Leersum, B.J.A.M., Ouwens, M.A., Mäkel, W. N., 2003. Effects of Global Communication System Radio-Frequency Fields on Well Being and Cognitive Functions of Human Subjects with and without Subjective Complaints.

Toxicology Letters 323 (2020) 35–40

Contents lists available at ScienceDirect

Toxicology Letters

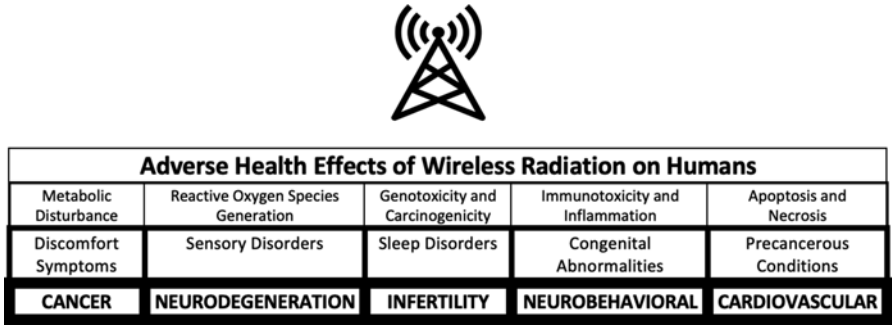
journal homepage: www.elsevier.com/locate/toxlet

Adverse health effects of 5G mobile networking technology under real-life conditions

Ronald N. Kostoff[a,*], Paul Heroux[b], Michael Aschner[c], Aristides Tsatsakis[d,e]

[a] Research Affiliate, School of Public Policy, Georgia Institute of Technology, Georgia, United States
[b] Toxicology and Health Effects of Electromagnetism, McGill University, Canada
[c] Molecular Pharmacology, Einstein Center of Toxicology, Albert Einstein College of Medicine, United States
[d] Laboratory of Toxicology, Medical School, University of Crete, Voutes, 71409 Heraklion, Crete, Greece
[e] Department of Analytical, Toxicology, Pharmaceutical Chemistry and Pharmacognosy, Sechenov University, 119991 Moscow, Russia

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Electromagnetic fields
Wireless radiation
Non-ionizing radiation
Mobile networking technology
5G
Adverse health effects
Toxicology
Toxic stimuli combinations
Synergistic effects
Combined effects
Systemic effects
Real-life simulation

ABSTRACT

This article identifies adverse effects of non-ionizing non-visible radiation (hereafter called wireless radiation) reported in the premier biomedical literature. It emphasizes that most of the laboratory experiments conducted to date are not designed to identify the more severe adverse effects reflective of the real-life operating environment in which wireless radiation systems operate. Many experiments do not include pulsing and modulation of the carrier signal. The vast majority do not account for synergistic adverse effects of other toxic stimuli (such as chemical and biological) acting in concert with the wireless radiation. This article also presents evidence that the nascent 5G mobile networking technology will affect not only the skin and eyes, as commonly believed, but will have adverse systemic effects as well.

1. Introduction

Wireless communications have been expanding globally at an exponential rate. The latest imbedded version of mobile networking technology is called 4G (fourth generation), and the next version (called 5G- fifth generation) is in the early implementation stage. Neither 4G

* Corresponding author.
E-mail addresses: rkostoff@gmail.com (R.N. Kostoff), toxlab.uoc@gmail.com (A. Tsatsakis).

https://doi.org/10.1016/j.toxlet.2020.01.020
Received 12 December 2019; Received in revised form 16 January 2020; Accepted 23 January 2020
Available online 25 January 2020
0378-4274/

Main Regularities and Health Risks from Exposure to Non-Thermal Microwaves of Mobile Communication

Igor Belyaev

Abstract — **Various responses to non-thermal microwaves (MW) from mobile communication including adverse health effects related to electrohypersensitivity, cancer risks, neurological effects, and reproductive impacts have been reported while some studies reported no such effects. This presentation provides an overview of the complex dependence of the MW effects on various physical and biological variables, which account for, at least partially, an apparent inconsistence in the published data. Among other variables, dependencies on carrier frequency, polarization, modulation, intermittence, electromagnetic stray fields, genotype, physiological traits, and cell density during exposure were reported. Nowadays, biological and health effects of 5G communication, which will use microwaves of extremely high frequencies (millimeter waves MMW, wavelength 1- 10 mm), are of significant public concern. It follows from available studies that MMW, under specific conditions of exposure at very low intensities below the ICNIRP guidelines, can affect biological systems and human health. Both positive and negative effects were observed in dependence on exposure parameters. In particular, MMW inhibited repair of DNA damage induced by ionizing radiation at specific frequencies and polarizations. To what extend the 5G technology and the Internet of Things will affect the biota and human health is definitely not known. However, based on possible fundamental role of MMW in regulation of homeostasis and almost complete absence of MMW in atmosphere due to effective absorption, which suggests the lack of adaptation to this type of radiation, the health effects of chronic MMW exposures may be more significant than for any other frequency range.**

Keywords — **Thermal and non-thermal effects of microwaves, Millimeter waves, 5G mobile communication, Health risks, Cancer, Physical mechanisms.**

I. Thermal versus Non-Thermal Microwave Effects, Their Main Regularities

Exposures to microwaves (MW, 300 MHz-300 GHz) vary in many parameters: incident power density (PD), specific absorption rate (SAR), frequency/wavelength, polarization (linear, ellipsoidal, circular, unpolarized), continuous wave (CW) and pulsed fields, modulation (amplitude, frequency, phase, complex), far field/near field, static magnetic field (SMF) and stray electromagnetic fields (EMF) of extremely low frequency (ELF, 3-300 Hz) at the location of exposure, overall duration and intermittence of exposure (interrupted, continuous), short-term acute and prolonged chronic exposures. With increased SAR, so-called thermal effects of MW are usually observed that result in significant MW-induced heating. SAR is a main determinate of thermal MW effects. The SAR based safety limits, which intend to protect from the thermal MW effects, were developed based on computer simulation of the MW energy absorption in standardized male phantoms. Thus, they do not take into account individual variability in voxel SAR distribution, which may be observed in dependence on polarization, frequency, age, sex, and pregnancy status [1-8]. In addition, the mobile phone SAR values are usually obtained when the phone is positioned about 2 cm from the standard male phantom head, a condition, which is not usually maintained during mobile phone calls. Other aforementioned physical variables of MW exposure have been linked to occurrence of so-called non-thermal (NT) biological effects, which are induced by MW at intensities well below measurable heating [9-21] [22]. The classification of MW effects into thermal and non-thermal is not based on physics of interaction between MW and biological tissues but rather reflects experimental observation of heating induced by MW exposure, which at SAR levels higher than 2 W/kg may result in thermal injury. Of note, slight temperature increase is also observed in the head tissues during exposure to mobile handset radiation, but this increase is too weak to produce thermal injury [23] and even to be sensed by the exposed subjects [24] while some mobile phone users reported sensation of warmth around the ear [25].

Vilenskaya and co-authors [26] and Devyatkov [27] have reported pioneering data on the NT effects of millimeter waves (MMW, 30-300 GHz, wavelength 1-10 mm in vacuum, to be used in 5G mobile communication) upon exposure of various biological objects. Webb was the first to establish the highly resonant effects of ultra-weak MMW on the induction of λ-phage in lysogenic bacterial E. coli cells [28]. These findings were subsequently corroborated by independent research groups [29, 30]. In these and subsequent studies the observed spectra of MMW action were found to have the following regularities: (1) strong dependence on frequency (frequency windows of resonance type), (2) there was a specific PD threshold below which no effect was observed, and above which the effects of exposure depended only weakly on power over several orders of magnitude (so-called

Igor Belyaev is with the Cancer Research Institute, Biomedical Research Center, University Science Park for Biomedicine, Slovak Academy of Sciences, Dubravska cesta 9, 845 05 Bratislava, Slovak Republic (e-mail: Igor.Beliaev@savba.sk).

978-1-7281-0878-0/19/$31.00 ©2019 IEEE

Environmental Research 214 (2022) 113851

Contents lists available at ScienceDirect

Environmental Research

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

Evidence for a health risk by RF on humans living around mobile phone base stations: From radiofrequency sickness to cancer

A. Balmori [1]

C/ Rigoberto Cortejoso, 14 47014, Valladolid, Spain

ARTICLE INFO

Keywords:
Base station
Cell tower
Health
Mast
RF radiation
Microwave syndrome
Radar
Radio antennas

ABSTRACT

The objective of this work was to perform a complete review of the existing scientific literature to update the knowledge on the effects of base station antennas on humans. Studies performed in real urban conditions, with mobile phone base stations situated close to apartments, were selected. Overall results of this review show three types of effects by base station antennas on the health of people: radiofrequency sickness (RS), cancer (C) and changes in biochemical parameters (CBP). Considering all the studies reviewed globally (n = 38), 73.6% (28/38) showed effects: 73.9% (17/23) for radiofrequency sickness, 76.9% (10/13) for cancer and 75.0% (6/8) for changes in biochemical parameters. Furthermore, studies that did not meet the strict conditions to be included in this review provided important supplementary evidence. The existence of similar effects from studies by different sources (but with RF of similar characteristics), such as radar, radio and television antennas, wireless smart meters and laboratory studies, reinforce the conclusions of this review. Of special importance are the studies performed on animals or trees near base station antennas that cannot be aware of their proximity and to which psychosomatic effects can never be attributed.

1. Introduction

During the last few decades, hundreds of thousands of mobile phone base stations and other types of wireless communications antennas have been installed around the world, in cities and in nature, including protected natural areas, in addition to pre-existing antennas (television, radio broadcasting, radar, etc.). Only the aesthetic aspects or urban regulations have been generally considered in this deployment, while the biological, environmental and health impacts of the associated non-ionizing electromagnetic radiation emissions have not been assessed so far. Therefore, the effects on humans living around these anthropogenic electromagnetic field sources (antennas) have not been considered.

In France, there is a significant contribution of mobile phone base stations in the exposure to radiofrequency electromagnetic fields (RF-EMF) of urban citizens living nearby (De Giudici et al., 2021). Some studies from India indicate that more than 15% of people have levels of EMF strength above 12 V/m due to their proximity to antennas (Premlal and Eldhose, 2017). Exposure estimates have shown that RF-EMF from mobile telephone systems is stronger in urban than in rural areas. For instance, in Sweden the levels of RF radiation have increased considerably in recent years, both outdoor and indoor, due to new telecommunication technologies, and the median power density measured for RF fields between 30 MHz and 3 GHz was 16 $\mu W/m^2$ in rural areas, 270 $\mu W/m^2$ in urban areas and 2400 $\mu W/m^2$ in city areas (Hardell et al., 2018). Total exposure varies not only between urban and rural areas but also, depending on residential characteristics, between different floors of a building, with a tendency for building exposure to increase at higher floors (Breckenkamp et al., 2012).

Over the past five decades, and more intensively since the beginning of this century, many studies and several reviews have been published on the effects of anthropogenic electromagnetic radiation on humans living around the antennas. The first studies were carried out with radio and television antennas, investigating increases in cancer and leukaemia (Milham, 1988; Maskarinec et al., 1994; Hocking et al., 1996; Dolk et al., 1997a, 1997b; Michelozzi et al., 1998; Altpeter et al., 2000), as well as around radars (Kolodynski and Kolodynska, 1996; Goldsmith, 1997).

Regarding base station antennas, there are scientific discrepancies in their effects: some studies concluded that there are no health-related effects (e.g. Augner and Hacker, 2009; Blettner et al., 2009; Röösli et al., 2010; Baliatsas et al., 2016) whereas others found increases in cancer and other health problems in humans living around antennas (e.g. Santini et al., 2002; Navarro et al., 2003; Bortkiewicz et al., 2004;

E-mail address: abalmorimartinez@gmail.com.
[1] Independent researcher

https://doi.org/10.1016/j.envres.2022.113851
Received 15 April 2022; Received in revised form 26 June 2022; Accepted 5 July 2022
Available online 14 July 2022

International Journal of
Environmental Research and Public Health

MDPI

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]

1 Sérgio Arouca National School of Public Health, Oswaldo Cruz Foundation, Rio de Janeiro 21041-210, Brazil; monicakra@gmail.com (M.K.d.N.A.); odwyer@ensp.fiocruz.br (G.O.); inesreis@ensp.fiocruz.br (I.N.C.R.); verafrossard@gmail.com (V.C.F.); valeriaslino@gmail.com (V.T.S.L.)
2 Institute of Social Medicine, Rio de Janeiro State University, Rio de Janeiro 20550-900, Brazil
3 Instituto Metodista Izabela Hendrix, Belo Horizonte, Minas Gerais 30160-012, Brazil; mreengenharia@mreengenharia.com.br
4 Medical Sciences College, Rio de Janeiro State University, Rio de Janeiro 20550-170, Brazil; denimonteiro2@yahoo.com.br
5 Federal Center for Technological Education Celso Suckow da Fonseca, Rio de Janeiro 20271-110, Brazil; roberto.88rpr@gmail.com
6 Petrobras, Rio de Janeiro 20031-912, Brazil
* Correspondence: nadiacristinapr@gmail.com

check for updates

Citation: Rodrigues, N.C.P.; Dode, A.C.; de Noronha Andrade, M.K.; O'Dwyer, G.; Monteiro, D.L.M.; Reis, I.N.C.; Rodrigues, R.P.; Frossard, V.C.; Lino, V.T.S. The Effect of Continuous Low-Intensity Exposure to Electromagnetic Fields from Radio Base Stations to Cancer Mortality in Brazil. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1229. https://doi.org/10.3390/ijerph18031229

Received: 10 December 2020
Accepted: 23 January 2021
Published: 29 January 2021

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.

Keywords: cancer; mortality; electromagnetic fields; breast neoplasms; lung neoplasms; esophageal neoplasms; uterine cervical neoplasms

1. Background

Mobile phones have become extremely common in modern times. Wireless technology has a large number of Radio Base Stations (RBSs), which transmit information through radiofrequency signals. In 2006, there were already more than 1.4 million RBSs in the world [1]. In the Brazilian capitals, RBSs were implemented in 1992 in Brasília (the capital of Brazil), and in 2017, there were 27,145 RBSs indexed in the capitals [2].

The effect of electromagnetic fields emanating from RBS on health is not very well known. The World Health Organization (WHO) reported, in 2006, that scientific knowledge indicates that RBS radiofrequency exposure is within the international standards and, therefore, does not pose a risk to human health [1]. However, in 2014, the WHO recognized the need to promote research to investigate the effect of the radiofrequency field on human

Environmental Science & Technology Letters

pubs.acs.org/journal/estlcu

Letter

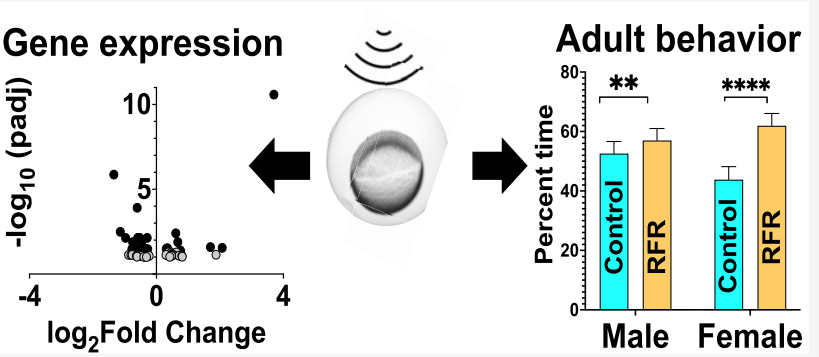
Transcriptomic and Long-Term Behavioral Deficits Associated with Developmental 3.5 GHz Radiofrequency Radiation Exposures in Zebrafish

Subham Dasgupta, Connor Leong, Michael T. Simonich, Lisa Truong, Huaping Liu, and Robyn L. Tanguay*

Cite This: *Environ. Sci. Technol. Lett.* 2022, 9, 327−332

Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information



ABSTRACT: The rapid deployment of the fifth-generation (5G) spectrum by the telecommunication industry is intended to promote better connectivity and data integration among various industries. However, concerns among the public about the safety and health effects of radiofrequency radiations (RFRs) emitted from the newer-generation cell phone frequencies remain, partly due to the lack of robust scientific data. Previously, we used developmental zebrafish to model the bioactivity of 3.5 GHz RFR, a frequency used by 5G-enabled cell phones, in a novel RFR exposure chamber. With RFR exposures from 6 h post-fertilization (hpf) to 48 hpf, we observed that, despite no teratogenic effects, embryos showed subtle hypoactivity in a startle response behavior assay, suggesting abnormal sensorimotor behavior. This study builds upon the previous one by investigating the transcriptomic basis of RFR-associated behavior effects and their persistence into adulthood. Using mRNA sequencing, we found a modest transcriptomic disruption at 48 hpf, with 28 differentially expressed genes. KEGG pathway analysis showed that biochemical pathways related to metabolism were significantly perturbed. Embryos were grown to adulthood, and then a battery of behavioral assays suggested subtle but significant abnormal responses in RFR-exposed fish across the different assays evaluated that suggest potential long-term behavioral effects. Overall, our study suggests the impacts of RFRs on the developing brain, behavior, and the metabolome should be further explored.

INTRODUCTION

The gradual rollout of fifth-generation (5G) frequencies has spurred increased scrutiny of their potential health effects over the past several years. Radiofrequency radiations (RFRs) emitted from these signals are non-ionizing, but skepticism about their safety remains, partly due to the lack of robust scientific data. This knowledge gap has contributed to valid public concerns about fully understanding 5G cell signal safety but has also been misappropriated to fuel baseless and dangerous conspiracy theories; e.g., a fabricated causal link between 5G and COVID-19 occurrence has led to violence against telecommunication engineers in Britain.[1,2] Our hope is that robust studies of the health effects of 5G RFRs will provide scientific facts to dampen the unscientific noise.

Several studies, including a recent one conducted by the National Institute of Health National Toxicology Program, have addressed specific health effects of pre-5G RFR frequencies and have shown that exposure to these frequencies can lead to oxidative stress, neurological outcomes, and, in rare cases, carcinogenesis.[3−6] 5G frequencies penetrate less through the skin and, therefore, should be less capable of impacting biology than lower-frequency (pre-5G) RFR. Because higher-

Received: January 13, 2022
Revised: February 10, 2022
Accepted: February 11, 2022
Published: March 3, 2022

https://doi.org/10.1021/acs.estlett.2c00037
Environ. Sci. Technol. Lett. 2022, 9, 327−332

Ecotoxicology and Environmental Safety 243 (2022) 113983

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

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

Changes in rat spatial learning and memory as well as serum exosome proteins after simultaneous exposure to 1.5 GHz and 4.3 GHz microwaves

Hui Wang [a,1], Yu Liu [a,b,1], Yunbo Sun [a,1], Li Zhao [a], Ji Dong [a], Xinping Xu [a], Haoyu Wang [a], Jing Zhang [a], Binwei Yao [a], Xuelong Zhao [a], Shuchen Liu [a,*], Ke Zhang [b,*], Ruiyun Peng [a,*]

[a] Beijing Institute of Radiation Medicine, Beijing 100850, China
[b] College of Education, Hebei University, No. 180 of Wusi East Road, Baoding, China

ARTICLE INFO

Edited by: Mohamed Abdel-Daim

Keywords:
Microwave
Spatial learning and memory
Hippocampus
Exosomes
Proteomics

ABSTRACT

This study aimed to elucidate the effects and biological targets sensitive to simultaneous 1.5 and 4.3 GHz microwave exposure in rats. A total of 120 male Wistar rats were divided randomly into four groups: the sham (S group), 1.5 GHz microwave exposure (L group), 4.3 GHz microwave exposure (C group) and simultaneous 1.5 and 4.3 GHz microwave exposure (LC group) groups. Spatial learning and memory, cortical electrical activity, and hippocampal ultrastructure were assessed by the Morris Water Maze, electroencephalography, and transmission electron microscopy, respectively. Additionally, serum exosomes were isolated by ultracentrifugation and assessed by Western blotting, nanoparticle tracking and transmission electron microscopy. The serum exosome protein content was assessed by label-free quantitative proteomics. Impaired spatial learning and memory decreased cortical excitability, and damage to the hippocampal ultrastructure were observed in groups exposed to microwaves, especially the L and LC groups. A total of 54, 145 and 296 exosomal proteins were differentially expressed between the S group and the L, C and LC groups, respectively. These differentially expressed proteins were involved in the synaptic vesicle cycle and SNARE interactions during vesicular transport. Additionally, VAMP8, Syn7 and VMAT are potential serum markers of simultaneous microwave exposure. Thus, exposure to 1.5 and 4.3 GHz microwaves induced impairments in spatial learning and memory, and simultaneous microwave exposure had the most severe effects.

1. Introduction

With the rapid development of communication networks, scientists have begun to examine the health hazards of increasing use of microwave communication equipment (Hardell and Nyberg, 2020; Liu et al., 2021). According to the literature, the central nervous system (CNS) is one of the most vulnerable systems to microwave exposure (Chauhan et al., 2017; Kesari et al., 2013; Maaroufi et al., 2014; Narayanan et al., 2018; Suhhova et al., 2013). In addition, studies have examined the effects of single-frequency microwave exposure, indicating that the degree of harm was largely related to microwave frequency (Fragopoulou et al., 2018; Zhang et al., 2017). However, although multiple microwave frequencies are used in daily life, few studies have evaluated the effects of simultaneous exposure to multiple frequencies of microwaves.

Learning and memory, two of the most important brain functions, as well as their associated brain region (the hippocampus) (Zola-Morgan and Squire, 1993) are of particular interest and have attracted substantial attention in studies of the effects of microwave exposure. Chauhan's team found damaged cortical and hippocampal pyramidal neurons in the brains of rats exposed to 2.45 GHz microwave radiation for 2 h/d at 0.2 mW/cm^2 over 35 d (Chauhan et al., 2017). Li et al. (2015) reported impaired performance on the Morris Water Maze (MWM) in rats exposed to 2.856 GHz microwave radiation for 6 weeks at different intensities administered three times a week for 6 min each (Li et al., 2015). Nayaranan et al. found that rats exposed to 900 MHz microwave radiation for 1 h/day over 28 d showed impaired performance in the MWM as well as structural damage to hippocampal neurons (Narayanan et al., 2015).

However, previous studies have mainly focused on changes in neurons, synaptic plasticity, and related receptors (Wang et al., 2017a; Zhao et al., 2012). Recent studies have shown that interneuronal communication (consisting of neurons and other cells in the brain, especially glial

* Corresponding authors.
E-mail addresses: liusc118@163.com (S. Liu), zhangkecompany_1@sina.com (K. Zhang), ruiyunpeng18@126.com (R. Peng).
[1] Hui Wang, Yu Liu and Yunbo Sun contributed equally to this work and are co-first authors

https://doi.org/10.1016/j.ecoenv.2022.113983
Received 26 March 2022; Received in revised form 22 June 2022; Accepted 14 August 2022
Available online 17 August 2022

International Journal of
Molecular Sciences

MDPI

Article

Immune Responses to Multi-Frequencies of 1.5 GHz and 4.3 GHz Microwave Exposure in Rats: Transcriptomic and Proteomic Analysis

Li Zhao †, Chuanfu Yao †, Hui Wang, Ji Dong, Jing Zhang, Xinping Xu, Haoyu Wang, Binwei Yao, Ke Ren, Liu Sun and Ruiyun Peng *

Beijing Institute of Radiation Medicine, Beijing 100850, China; lillyliz@163.com (L.Z.); yaomax2010@126.com (C.Y.); wanghui597bj@163.com (H.W.); djtjwj@163.com (J.D.); zhang115614@163.com (J.Z.); xxpbjhd@163.com (X.X.); smart106@126.com (H.W.); ybwcsq@163.com (B.Y.); okayke1@163.com (K.R.); 13103249606@163.com (L.S.)

* Correspondence: ruiyunpeng18@126.com

† These authors contributed equally to this work.

Abstract: With the rapidly increasing application of microwave technologies, the anxiety and speculation about microwave induced potential health hazards has been attracting more and more attention. In our daily life, people are exposed to complex environments with multi-frequency microwaves, especially L band and C band microwaves, which are commonly used in communications. In this study, we exposed rats to 1.5 GHz (L10), 4.3 GHz (C10) or multi-frequency (LC10) microwaves at an average power density of 10 mW/cm^2. Both single and multi-frequency microwaves induced slight pathological changes in the thymus and spleen. Additionally, the white blood cells (WBCs) and lymphocytes in peripheral blood were decreased at 6 h and 7 d after exposure, suggesting immune suppressive responses were induced. Among lymphocytes, the B lymphocytes were increased while the T lymphocytes were decreased at 7 d after exposure in the C10 and LC10 groups, but not in the L10 group. Moreover, multi-frequency microwaves regulated the B and T lymphocytes more strongly than the C band microwave. The results of transcriptomics and proteomics showed that both single and multi-frequency microwaves regulated numerous genes associated with immune regulation and cellular metabolism in peripheral blood and in the spleen. However, multi-frequency microwaves altered the expression of many more genes and proteins. Moreover, multi-frequency microwaves down-regulated T lymphocytes' development, differentiation and activation-associated genes, while they up-regulated B lymphocytes' activation-related genes. In conclusion, multi-frequency microwaves of 1.5 GHz and 4.3 GHz produced immune suppressive responses via regulating immune regulation and cellular metabolism-associated genes. Our findings provide meaningful information for exploring potential mechanisms underlying multi-frequency induced immune suppression.

Keywords: microwave; radiation; immune response; transcriptomic; proteomic

Citation: Zhao, L.; Yao, C.; Wang, H.; Dong, J.; Zhang, J.; Xu, X.; Wang, H.; Yao, B.; Ren, K.; Sun, L.; et al. Immune Responses to Multi-Frequencies of 1.5 GHz and 4.3 GHz Microwave Exposure in Rats: Transcriptomic and Proteomic Analysis. *Int. J. Mol. Sci.* **2022**, *23*, 6949. https://doi.org/10.3390/ijms23136949

Academic Editor: Michel Salzet

Received: 25 May 2022
Accepted: 20 June 2022
Published: 22 June 2022

1. Introduction

Microwave technology, non-ionizing electromagnetic radiation ranging from 300 MHz to 300 GHz, has been widely used in various fields, such as mobile communication, medicine, industrial synthesis and so on [1–4]. In addition, the anxiety and speculation about the potential health hazards caused by microwaves have been growing in recent years [5,6]. In the past decades, most of the researchers aimed to uncover the biological effects caused by microwaves with a single frequency at indicated power density [7,8]. Our group has previously reported that S band microwaves, ranging from 2 GHz to 4 GHz, could cause significant injuries on several organs and tissues, including the nervous system, cardiovascular system, reproductive system and immune system [9–12]. Moreover, the potential underlying mechanisms were explored [7,13,14]. However, people are always

Environmental Research xxx (xxxx) xxx

Contents lists available at ScienceDirect

Environmental Research

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

Problems in evaluating the health impacts of radio frequency radiation

Paul Ben Ishai [a,*], Devra Davis [b,c], Hugh Taylor [d], Linda Birnbaum [e,1]

[a] Department of Physics, Ariel University, Ariel, 4070000, Israel
[b] Environmental Health Trust, Washington, DC, 20002, USA
[c] School of Medicine,Ondokuz-Mayis University, Samsun, Turkey
[d] Yale School of Medicine, New Haven, CT, 05620, USA
[e] National Institute of Environmental Health Sciences and National Toxicology Program, Durham, NC, 27709, USA

ARTICLE INFO

Keywords:
Mobile communications
Electromagnetic radiation exposure
Precautionary principle
NTP
EHS
Non-thermal effects
FCC
ICNIRP

ABSTRACT

In an effort to clarify the nature of causal evidence regarding the potential impacts of RFR on biological systems, this paper relies on a well-established framework for considering causation expanded from that of Bradford Hill, that combines experimental and epidemiological evidence on carcinogenesis of RFR. The Precautionary Principle, while not perfect, has been the effective lodestone for establishing public policy to guard the safety of the general public from potentially harmful materials, practices or technologies. Yet, when considering the exposure of the public to anthropogenic electromagnetic fields, especially those arising from mobile communications and their infrastructure, it seems to be ignored. The current exposure standards recommended by the Federal Communications Commission (FCC) and International Commission on Non-Ionizing Radiation Protection (ICNIRP) consider only thermal effects (tissue heating) as potentially harmful. However, there is mounting evidence of non-thermal effects of exposure to electromagnetic radiation in biological systems and human populations. We review the latest literature on *in vitro* and *in vivo* studies, on clinical studies on electromagnetic hypersensitivity, as well as the epidemiological evidence for cancer due to the action of mobile based radiation exposure. We question whether the current regulatory atmosphere truly serves the public good when considered in terms of the Precautionary Principle and the principles for deducing causation established by Bradford Hill. We conclude that there is substantial scientific evidence that RFR causes cancer, endocrinological, neurological and other adverse health effects. In light of this evidence the primary mission of public bodies, such as the FCC to protect public health has not been fulfilled. Rather, we find that industry convenience is being prioritized and thereby subjecting the public to avoidable risks.

1. Introduction

The perennial question of the biological impacts of Radio Frequency Radiation (RFR) constitutes an especially challenging matter that has come to the fore recently, in part driven by public concerns over the introduction of 5G mobile communications. 5G Small Cell base stations are permitted to be sited as close as 3 m from the ground in proximity to homes, schools and offices in many locales in the US. In the U.S. alone, the industry estimates that up to one million new antennas will be required. 5G ranges broadly from 800 MHz to 100 GHz (Document). As Lin (2022a) has noted, for the higher mm-wave bands, wider spectrum is only accessible over short distances and will depend on the construction of numerous new cells in the dense urban environment. Despite Industry claims (*5G,* EMF Exposure and Safety, 2020), an increase in the number of transmitters is expected to lead to much higher levels of exposure for the general public (Blackman and Forge, 2019). This has provoked public concerns regarding the potential health impacts of RFR.

For nearly a century, well-established controlled bioassay protocols have traditionally formed the foundation for predicting and setting limits for public health exposures to pharmaceuticals, pesticides, radiation, and other agents. Yet as regarding the potential impacts of RFR, positive adverse experimental findings on RFR-induced carcinogenicity that have historically provided guidance for preventive policies, have been subjected to extraordinary and unprecedented attacks. The same can be said for studies of individuals exposed to RFR that solely confirm whether or not past harm has taken place. Research and training in this

* Corresponding author.
E-mail address: paulbi@ariel.ac.il (P. Ben Ishai).
[1] Scientist Emeritus and former Director.

https://doi.org/10.1016/j.envres.2022.115038
Received 30 September 2022; Received in revised form 6 December 2022; Accepted 8 December 2022

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. Nonionizing 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.

Key words: radiofrequency radiation (RFR), antenna arrays, cellular phone base stations, microwave sickness, nonionizing electromagnetic fields, environmental pollution.

Résumé : La localisation des stations de base pour téléphones cellulaires et autres infrastructures cellulaires, comme les installations d'antennes sur les toitures, surtout dans les quartiers résidentiels, constitue un sujet litigieux d'utilisation du territoire. La résistance locale de la part des résidents et propriétaires fonciers limitrophes repose souvent sur les craintes d'effets adverses pour la santé, en dépit des réassurances venant des fournisseurs de services de télécommunication, à l'effet qu'ils appliquent les standards internationaux d'exposition. En plus de rapports anecdotiques, certaines études épidémiologiques font état de maux de tête, d'éruption cutanée, de perturbation du sommeil, de dépression, de diminution de libido, d'augmentations du taux de suicide, de problèmes de concentration, de vertiges, d'altération de la mémoire, d'augmentation du risque de cancers, de trémulations et autres effets neurophysiologiques, dans les populations vivant au voisinage des stations de base. Les auteurs révisent ici les études existantes portant sur les gens, vivant ou travaillant près d'infrastructures cellulaires ou autres études pertinentes qui pourraient s'appliquer aux expositions à long terme à la radiation de radiofréquence de faible intensité « RFR ». Bien que la recherche épidémiologique spécifique dans ce domaine soit rare et contradictoire, et que de telles expositions soient difficiles à quantifier compte tenu des degrés croissants du bruit de fond des RFR provenant de produits de myriades de consommateurs personnels, il existe certaines recherches qui justifient la prudence dans l'installation des infrastructures. Les futures études épidémiologiques sont nécessaires afin de prendre en compte la totalité des expositions à la RFR ambiante. Les symptômes rapportés jusqu'ici pourraient correspondre à la maladie classique des micro-ondes, décrite pour la première fois en 1978. Les champs électromagnétiques non-ionisants constituent les formes de pollution environnementale croissant le plus rapidement. On peut effectuer certaines extrapolations à partir de recherches autres qu'épidémiologiques concernant les effets biologiques d'expositions à des degrés bien au-dessous des directives internationales.

Mots-clés : radiofréquence de faible intensité « RFR », les installations d'antennes, des stations de base pour téléphones cellulaires, la maladie classique des micro-ondes, les champs électromagnétiques non-ionisants, pollution environnementale.

[Traduit par la Rédaction]

Received 30 April 2010. Accepted 6 August 2010. Published on the NRC Research Press Web site at er.nrc.ca on 5 November 2010.

B.B. Levitt.[1] P.O. Box 2014, New Preston, CT 06777, USA.
H. Lai. Department of Bioengineering, Box 355061, University of Washington, Seattle, WA 98195, USA.

[1]Corresponding author (e-mail: blakelevit@cs.com; bbl353355@gmail.com).

frontiers | Frontiers in Public Health

TYPE Opinion
PUBLISHED 26 January 2023
DOI 10.3389/fpubh.2023.1058454

OPEN ACCESS

EDITED BY
Dariusz Leszczynski,
University of Helsinki, Finland

REVIEWED BY
Yael Stein,
Hadassah Medical Center, Israel
Wolfgang Kainz,
HPC for MRI Safety, United States

*CORRESPONDENCE
Victor Leach
✉ victor.leach@orsaa.org

SPECIALTY SECTION
This article was submitted to Radiation and Health, a section of the journal Frontiers in Public Health

RECEIVED 30 September 2022
ACCEPTED 03 January 2023
PUBLISHED 26 January 2023

CITATION
McCredden JE, Weller S and Leach V (2023) The assumption of safety is being used to justify the rollout of 5G technologies.
Front. Public Health 11:1058454.
doi: 10.3389/fpubh.2023.1058454

The assumption of safety is being used to justify the rollout of 5G technologies

Julie E. McCredden[1], Steven Weller[1,2] and Victor Leach[1]*

[1]Oceania Radiofrequency Scientific Advisory Association Inc. (ORSAA), Scarborough, QLD, Australia, [2]Centre for Environmental and Population Health, School of Medicine and Dentistry, Griffith University, Brisbane, QLD, Australia

KEYWORDS

5G, EMR, wireless radiation, EMF database, environmental health, conflicts of interest, science communication

Introduction

The advent of fifth-generation (5G) wireless communication introduces new technology utilizing near-millimeter radiofrequency waves [i.e., with a frequency of 30–300 GHz (mmWaves)]. The long-term effects of these signals on humans and the environment are unknown. Scientific literature reviews investigating biological harm from mmWave usage have concluded … *no in-depth conclusions can be drawn*… [(1), p. 16] and *no confirmed evidence* [(2), p. 601]. Unfortunately, these statements of scientific uncertainty have been used by industry and government advisory bodies to reassure the public of the safety of the 5G rollout. However, the assumption that 5G technologies are safe is not an evidence-based conclusion (3). Why this is so cannot be easily understood from existing summaries or reviews (4). Therefore, this article takes one step back from reviews to the original papers, so as to provide a visible overview of the existing mmWave evidence base. It then examines how the science is being conducted and communicated, finding errors in reasoning that cloud judgements and the subsequent conclusions drawn from the existing research.

Mapping out the mmWave research landscape

Public policy regarding the safety of electromagnetic fields (EMF) is often formulated from reviews rather than from individual papers, e.g., the recent SCHEER opinion (5). Literature reviews give readers a narrow view of past research, with many papers ignored or removed at the beginning of the review process. It is also possible that quality papers are being omitted in this process (4). Thus, all relevant mmWave research literature is not yet fully transparent to the readership in this field. To help the research community to formulate an initial overview opinion, we have mapped out the broader landscape by making visible the range of biological and health effect topics contained within the mmWave literature (see below). Then, within the main topics investigated, we have made evident the number of studies showing effects vs. the number of studies showing no effects "regardless of the study design, merit, flaws, experimental quality, shortcomings, limitations, or methodological weaknesses" [(6), p. 2]. As such, this opinion piece is not to be considered as a systematic review. However, the papers presented here [listed in Supplementary Table 1 (all >6GHz experimental papers) and (epidemiological papers)] could be used as the basis for future exploration utilizing a more formal systematic review approach.

Database search for studies on mmWaves and health

Literature reviews investigating EMF typically use several existing information sources, such as PubMed, EMF-portal, and the Institute of Electrical and Electronics Engineers (IEEE). However, these databases cover a much broader range of topics than the bioeffects of electromagnetic radiation, such as medical procedures and accidents, computational models and non-experimental theoretical discussions. To address the need for a focused knowledge collection, the Oceania Radiofrequency Scientific Advisory Association (ORSAA) (7) has developed the ORSAA Database of EMF Bioeffects (ODEB) (8) containing peer-reviewed studies investigating the biological and health effects of electromagnetic fields on humans, animals and the environment.

ODEB[1] was first established using the entire research database of the Australian Radiation Protection & Nuclear Safety Agency (ARPANSA) and then expanded to incorporate all relevant papers from PubMed and the EMF-portal. ODEB also includes military studies from the 70's, biophysics research from the 80's onwards, and all experimental and epidemiological research from both industry and independent scientists since 2012. ODEB currently comprises over 4,000 peer-reviewed publications and is being continually updated. It is searchable in many different categories including biological effect end-points, exposure parameters, study type etc. When papers are added to the ODEB database, they are screened for relevance. This description of the ODEB collection and its sources has been provided to demonstrate that the database is an adequate resource for the mmWave literature overview described below.

Investigation limited to below-threshold, mmWave papers

The experimental papers delivering mmWave exposures at or below the ICNIRP limits test whether the current ICNIRP exposure thresholds are adequate to guarantee safety for the public. A literature search was thus performed by requesting from ODEB all papers that used radiofrequencies > 6 GHz and exposure intensities below the International Commission on Non-Ionizing Radiation Protection (ICNIRP); i.e., the 4 W/kg whole-body Specific Absorption Rate (SAR) limit and the 200 W m^{-2} local tissue incident power density limit; [(9), p. 6–8]. The result was a set of 295 papers containing all of the papers in the recent Karipidis et al. mmWave review (10), plus an additional 79 more experimental papers (nine non-English) and 19 more epidemiology papers (five non-English). Given that this paper aims to map out the entire landscape, inclusion of the 14 non-English papers is appropriate.

Including all of these sources, the ODEB search produced a current literature base for mmWave research comprising 238 experimental papers and 57 epidemiology papers [see Supplementary Table 1 (all >6GHz experimental papers) and (epidem papers)]. This is a relatively small knowledge base, given the many combinations of experimental parameters requiring examination, such as frequency, modulation pattern, intensity, exposure duration, and the numerous types of tissues, cells, and biological functions. In comparison with the broader radiofrequency literature, mmWave research constitutes <10% of the knowledge base.

Main themes

As there are so few experimental studies on the bioeffects of mmWaves, rigorous literature reviews at this point in time are most likely destined to find no strong evidence. Instead, it is instructive to map out the main biological and health categories that have been investigated within the entire collection of studies, for the reasons given above and to help identify focus areas for future research.

Experimental papers emerging from the ODEB literature search (previously described) were automatically classified into their main biological and health categories. Within these, the number of studies showing significant effects and the number of studies showing no significant effects were tabled. Four papers with uncertain effects [i.e., where outcomes were not reported, or conclusions were qualified (8)] were excluded. The results for the experimental studies are summarized in Figure 1 below.

Figure 1 shows that the mmWave experimental studies cover a wide range of bioeffects. Furthermore, for most of the categories in Figure 1, from *biochemical* to *behavior*, a preliminary weight of evidence is visible. Overall, this picture suggests that mmWaves may affect many biological and health categories that warrant further investigation. Several of these categories have potential implications for public health, e.g., cellular oxidative stress, changes in immune function, genotoxicity, brain/neuronal changes, and cell membrane permeability. In particular, effects have been found in all studies that have investigated oxidative stress [cellular stress due to the over-production of reactive oxygen species and the reduction of oxidative defenses (11)]. Oxidative stress underlies many auto-immune and chronic conditions, such as diabetes, cardiovascular disease, Alzheimer's disease and depression, some of which are becoming an increasing social and economic threat worldwide (12).

The existing epidemiology papers [listed in Supplementary Table 1 (epidem papers)] mainly focus on the effects of occupational exposures, e.g., the occurrence of lymphoma or the reduction of sperm count in radar workers. Of these papers, the majority show effects from mmWave exposures.

Countries involved in mmWave research

In order to understand where the mmWave research has been performed, the country of origin was extracted from ODEB

1 ODEB is a free research tool Available at: https://a037613.fmphost.com/fmi/webd/Research_Review_V4.

10.3389/fpubh.2023.1058454

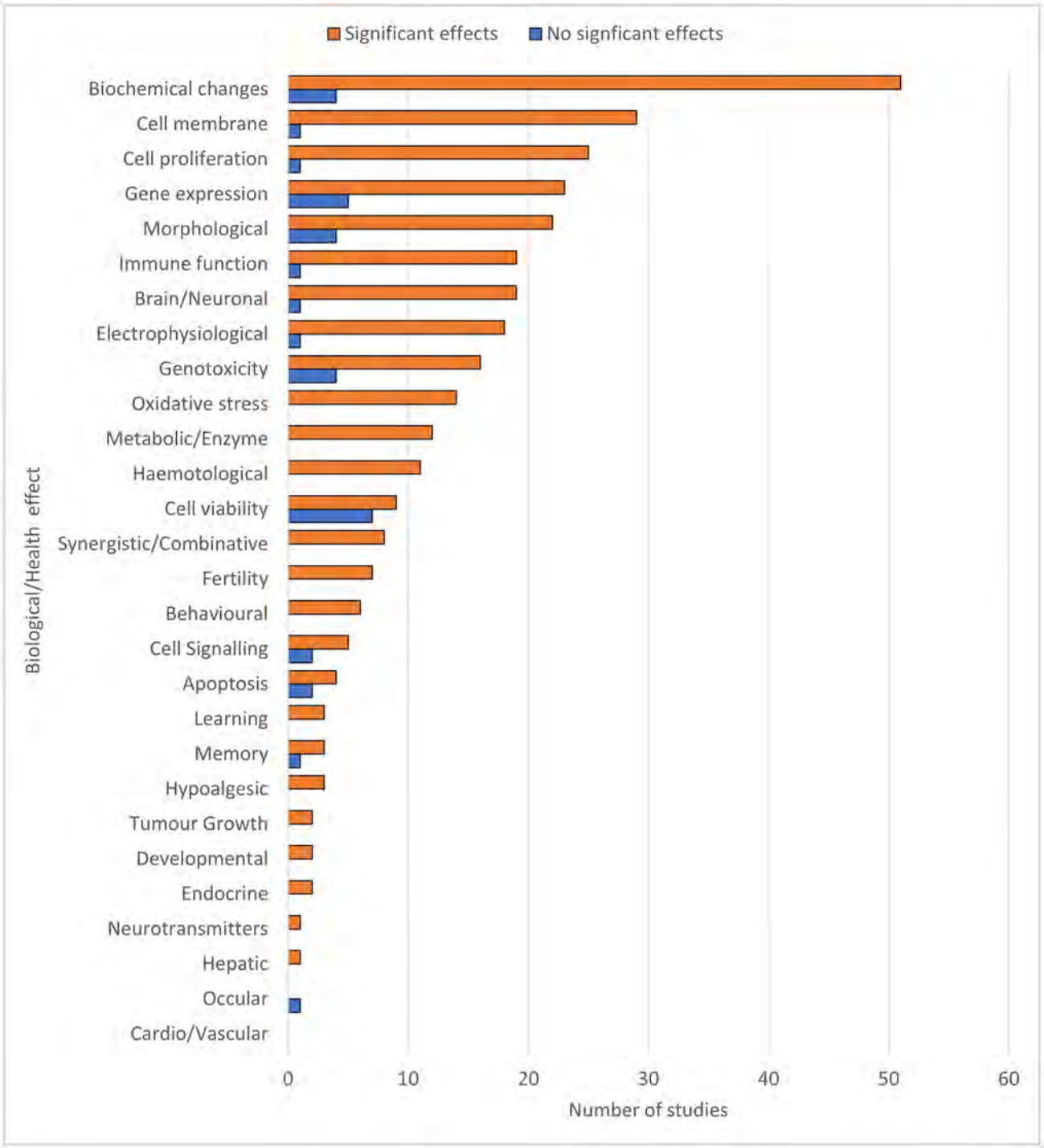


FIGURE 1
The main biological and health categories present in the mmWave experimental (i.e., *in vitro* and *in vivo*) literature base, and within each category, the number of papers producing effects vs. the number of papers resulting in no significant effects. The total number of studies is greater than the total number of papers because any given paper may have conducted more than one study and investigated more than one biological effect.

for all the papers included in this overview. Results showed that a large proportion of the research has been carried out in Russia (23%) and in the US (21%). Some countries have conducted several studies, and these make up a further third of the research: Italy (10%), France (6%), India (5%), Armenia (5%), Japan (4%), and China (3%). Countries that have each conducted only a few studies make up the remaining 23% of the research base.

Discussion

An overall trend despite the limited number of studies

Figure 1 shows that the relevant experimental research is minimal, as has been acknowledged in reviews (1, 2, 13). It is thus far too early for scientists to establish any definite theories because the experimental work using mmWaves is limited, there are a large number of end-points and processes to be considered, and for some biological end-points, the evidence appears contradictory. However, Figure 1 also reveals that the overall picture emerging from the existing knowledge base suggests a range of biological effects, some with strong evidence (>90% of studies), that may have potential health implications.

From the existing research, we can draw two conclusions:

1. For scientists, *the understanding of how mmWaves affect biological systems is still in its early stages*, thus there is an urgent need for further focused research to be conducted;
2. For policy makers, *there is enough smoke to suggest the risk of fire*, and therefore there is an urgent need for protective policy.

As Gee has pointed out (14), these two statements are not contradictory. The amount of evidence available in any area of science lies on a continuum from very weak (1–10%) to very strong (90–100%). Scientists require *strong* evidence of causality before laying down a new theory. In the case of the existing evidence for harm from 5G, scientists rightfully maintain that there are *no well-understood causal* links. However, government authorities tasked with protecting the health of humans, animals or plants need only *moderate* evidence as reasonable grounds for concern to enact the Precautionary Principle [e.g., (15)]. With so few experimental studies, but with an overall trend for biological effects, Figure 1 suggests that the current situation is one of *plausible risk*.

While the field of mmWave research has a limited knowledge base, there are early signs of evidence for bioeffects (as described above) that have implications for health. It is interesting to compare the interpretations of this state of affairs made by scientists compared to global policy makers. The science regarding skin is still *insufficient* to *devise science-based exposure limits*, says the scientist Leszczynski and so *precautionary measures should be considered for the deployment of the 5G* (13). In contrast, the industry-linked ICNIRP and the European Union (16) have determined that insuÿcient evidence provides reassurance of safety. No *evidence of harm* has been misconstrued as *evidence of no harm* [(17), p. 690], allowing the 5G rollout to proceed unfettered.

Standards compromised

When setting exposure limits, ICNIRP has not addressed the early evidence of biological effects with the potential to cause harm (18), as would be required by a risk management approach. ICNIRP radiation protection philosophy is thus deficient and not in alignment with that of the International Commission on Radiation Protection (ICRP) (19). The ICRP has a clear philosophy of radiation protection based on Justification, Optimization and Limitation.

Under the ICRP global radiation protection code of ethics, where mass exposures of populations are occurring without permission, even mild evidence of harm would be enough to advise governments to give pause to the technology, to consider the potential risks, to commit funds to further research and to enact strict precautions.

These precautions are not being implemented because the early message of plausible risk is unfortunately not being heard, partly due to poor reasoning and partly due to poor communication, as described below.

Logical fallacies in the communication of science

Along with assessing data quality, researchers can use the tools of reason to assess the quality of statements made in papers. Logical fallacies occur when various methods of argument are used to distort the reasoning, either intentionally or not (20). The art of integrating logical fallacies into communications has been used in the past by selected scientists working for industry, in order to convince the public and policy makers that their products do no harm, e.g., the smoking lobby used such techniques for decades (21). We have found that faulty reasoning has also been used to discuss mmWaves both in the public domain and in the research literature (4). To bring these issues to light and to invite discussion, some of the more frequently used logical fallacies are named in the sections below. These fallacies may not be intentional; e.g., they may be a result of simplifying the message so that the public can digest it. However, it is the responsibility of protection agencies, industry and researchers to ensure that their communications are clear and that fallacies are not inadvertently created when information is delivered to policy makers and to the public.

Fallacies used in describing millimeter waves

When government agencies or researchers introduce 5G technology as being based on mmWaves which are already in use in airport security screening [e.g., (2, 22)], this can create a "Faulty Analogy". This type of fallacy occurs when **two** things are alike in one or more ways, but then the incorrect assumption is made that they are necessarily alike in other ways (23). In this case, airport scanners and 5G technologies are similar in one way, in that they both use mmWaves; however, this similarity can lead people to believe that 5G technologies are also just as harmless as they believe airport scanners to be. In reality, the two types of technology are dissimilar in several important ways that are not mentioned in communications: (i) airport body scanners expose people for a few seconds and very infrequently, whereas exposures to 5G technologies occur many times a day throughout a person's lifetime, and (ii) the waveforms used by airport scanners are much simpler and not easily comparable with complex 5G waveforms. Using a Faulty Analogy to introduce mmWaves to the public could prevent consumers from considering any risks or from taking active precautions.

Millimeter waves are also introduced as if they are harmless for the human body. For mmWaves, the critically exposed organs are the skin and sclera of the eyes, and when 5G exposures are being discussed, it is often stated that mmWaves do not penetrate more

than a few millimeters into the skin. This creates a "Red Herring" fallacy (23), because it diverts attention toward the less important issue of skin surface tissue, and away from the more important issues of the mechanisms and biological functions of the skin. The facts that are ignored are: (i) In skin research, *penetrates* is a technical term, meaning that two-thirds of the original signal's energy is absorbed. There is still one-third that travels further, into deeper skin layers, nerves and blood. (ii) Skin is rich in nerves that are connected to the central and autonomic nervous systems. (iii) Skin is the body's first line of defense, rich in protective bacteria and part of the immune, waste management, and endocrine systems (13, 24).

There is very limited research into the bioeffects of mmWaves on the skin (13). The endocrine neurotransmitter and cardio systems to which the skin is connected and the critical sclera of the eyes have had a cursory investigation, as shown in Figure 1. However, it is predicted from theoretical models that the skin's sweat gland ducts (SGD) act as helical antennas, which can potentially carry mmWaves much deeper into the body (25, 26). Such deeper penetration has been confirmed, albeit at higher frequencies (94 GHz) (27). There are also predictions that transients from short pulses due to high data rates may create secondary waves called *Brillouin Precursors* that penetrate even deeper into the body, leading to the unwinding of large molecules, cell membrane damage and blood-brain leakage (28). Furthermore, Brillouin precursors do not decay as expected, which can lead to hot spots deep within the body (29). There are further concerns that the rapid pulse trains contained within 5G signals will cause intense hot spots on the skin, resulting in permanent tissue damage (30), and that the current ICNIRP guidelines do not protect against these hot-spots (31).

Altogether, these facts paint a very different picture of plausible risk than does the "Red Herring" statement given in public 5G communications that mmWaves only penetrate a few millimeters into the skin. Fifth and sixth-generation technologies should not be advancing without investigating the above issues, which are currently being ignored.

Fallacies used in reviews

When mmWave reviews are conducted, several principles are repeatedly used for critiquing experiential design and for dismissing or excluding various papers. However, we have found that several fallacies are present in these arguments, as described below.

Exposure principles confuse necessary and sufficient conditions

Quality studies need to report the dosimetry of the exposure signals clearly (i.e., what frequencies were used and what power densities or SARs were measured). Good dosimetry is a *necessary* condition of good reporting. However, it is not *sufficient* to guarantee that the exposures used in the experiment are adequate for testing the hypothesis, for the following reasons.

Real-world 5G signals are complex and variable. First, there are the variable low-frequency pulses (control, pilot, synchronization signals) and modulations being carried on the high-frequency 5G carrier waves. In addition, to send multiple signals simultaneously, many 4G/5G technologies use Orthogonal Frequency-Division Multiplexing (OFDM), which requires extremely high peak amplitudes. These methods of signal transfer create complexities in the waveforms that cannot be fully replicated using simulated signals created by frequency generators. Complex real-world signals are more bioactive (32) and are thus more likely to show bioeffects. Not surprisingly then, experiments that use signal generators are less likely to produce effects, while those that use real-world devices (e.g., mobile phones with, 50, 200, 500, or 217 Hz pulses embedded within the signals) are more likely to produce effects (32). That is, experiments that use real-world signals have a higher power (probability of finding an effect if there is one) than experiments that use simulated signals.

The type of exposure (to real-world devices/signals or to signal generators) thus needs to be a principle for judging the quality of a paper. However, this important principle is often ignored. Instead, a "Confusion of Necessary with Suÿcient Condition" fallacy occurs, where a study is acknowledged for reporting the *necessary* dosimetry, but the review does not ensure the inclusion of the more important *sufficient* conditions of the exposure, required to test the hypothesis. This means that studies with lower power are included in reviews and treated as if they are of high quality just because they reported the dosimetry. At the same time, studies with a higher power, that used real-world signals can be dismissed in the review because they do not clearly report the dosimetry [e.g., (33)].

As noted in (32) some reports have claimed that experiments that use a simulated signal from generators are superior because this allows the signal to be controlled in the laboratory experiment. However, this can be a "Red Herring" issue. While highly controlled experiments are to be aimed for, they are not the highest priority if they prevent the experimenter from being able to test the stimulus that is creating the response (which thereby reduces the power of the test).

Weakest points rather than strengths highlighted

Reviews also use other "quality of the study" issues to exclude papers or to downplay their results [e.g., (2)]. However, some of these issues are actually examples of the "Straw Person" fallacy, which occurs when the weakest points of an argument are attacked while stronger points are ignored. This fallacy can create a misrepresentation of an opponent's position in order to make one's own argument appear superior. Examples of the "Straw Person" fallacy occur in reviews that use less important issues as grounds to dismiss otherwise relevant and scientifically sound papers. Some examples of "Straw Person" dismissals are given below.

No replication or inconsistent results used to downplay results

Due to the low number of mmWave studies, the complexity of available parameter combinations, and given that all the studies are forging new ground, a lack of replication and inconsistencies between studies is to be expected. Moreover, it is well-known that funding bodies and universities do not fund replication studies. Therefore, lack of replication is a "Straw Person" in this emerging field, and to downplay the results of a sound experiment on that basis is fallacious; e.g., Two *studies by a Russian research group have also reported indicators of DNA damage in bacteria; however, these results have not been verified by other investigators* [(2), p. 599].

Collective "Straw Person" dismissal also occurs. For example, Figure 1 shows a range of bioeffects, leading to the suggestion of considerable "smoke" that warrants further investigation of a possible "fire". In contrast, the range of bioeffects is watered down in (2) by framing them as not yet replicated; e.g., *Although many bioeffects have been reported in many of the experimental studies, the results were generally not independently reproduced* [(2), p. 600].

"Poor methodology" has several meanings

Most experiments can be critiqued for containing some flaw or another; however, flaws occur on a continuum from minor to serious. To accuse a study of a *serious* methodological flaw requires a precise description of that flaw, e.g., the identification of a confounding variable. In contrast, if an experiment includes a noise factor, this is not a serious methodological flaw. The noise factor may weaken the result, by adding more randomness to the measurements, and therefore making it less likely that an effect will be found (i.e., by reducing the power of the test); however, the noise does not fully compromise the study.

Thus, when the term "methodological flaw" is used throughout a review, a logical fallacy of "Equivocation" may occur, because the meaning of this key term has one meaning in one portion of the discussion and then another meaning in another portion of the discussion (23). A concluding summary statement, e.g., that "many of the mmWave papers have methodological flaws", may then give the impression that all these studies have *major* flaws. In reality, many of the papers could contain non-major issues, such as noise factors and incorrect error bars. Without full explanations, it is impossible to tell if the flaws that papers are being accused of are fatal or non-fatal. We suggest that future reviews avoid a possible equivocation fallacy, by classifying methodological flaws into levels of seriousness, such as high, medium, and low and by giving clear justifications for why each paper is classified as such.

Non-linear dose-response misunderstood

Sometimes papers are rejected because they do not show a linear relationship between dose (exposure intensity × exposure duration) and effect. This is an incorrect rejection built on the "Red Herring" assumption that there is a linear relationship between dose and effect for radiofrequencies. This assumption has been countered by research that shows that (i) there are windows of power and frequency that cause harm (34), and (ii) that the human perceptual system has a non-linear response to electromagnetic frequencies (35–37). While linear dose-response models may be appropriate for telecommunications signaling, they are not appropriate for modeling biological responses where feedback mechanisms and adaptive responses occur.

The above examples of inappropriate dismissal of papers in reviews suggest that the credible evidence base for mmWave effects is likely to be larger than stated. To quote Barnes and Greenbaum (38), also cited by Lai (39).

> *The evidence that weak radiofrequency (RF) and low-frequency fields can modify human health is still less strong, but the experiments supporting both conclusions are too numerous to be uniformly written off as a group due to poor technique, poor dosimetry, or lack of blinding in some cases, or other good laboratory practices* [(38), p. 2].

Conclusions from reviews can be misinterpreted

After dismissing much of the evidence showing effects, as well as reporting the contradictory results, reviews have concluded that there is *no conclusive evidence* of harm. However, an "Appeal to Ignorance" fallacy can occur when the reviewers, the industry, and ICNIRP then give the impression that the statement *there is no harm* must be true because no counter evidence to that conclusion has been found; i.e., *because we have not found conclusive evidence of harm*. This fallacy has the effect of wrongfully shifting the burden of proof away from the one making the claim of no harm (23). In reality, the onus of proof is on industry and government to continue funding research that can enable a better understanding of the effects of mmWaves on humans and the environment.

The above logical fallacies embedded within the analysis and communication of the mmWave science may have resulted in significant omissions of critical studies or incorrect judgements about papers within reviews, making their conclusions unreliable; [e.g., see (4)].

Reviews that contain these fallacies are not a suitable basis on which to build public policy or safety standards.

Fallacies used in setting standards

Several fallacies are also embedded within the ICNIRP guidelines, for mmWaves as well as other radiofrequencies.

Only heating matters

The main fallacy that has been pointed out by many researchers is the "Thermal Only" fallacy, whereby ICNIRP and industry have adopted the position that *only heating can produce important biological or health effects*. This "Red Herring" takes the focus away from research that investigates non-thermal biological and health effects. For example, in the main mmWave literature review of skin effects presented within the current ICNIRP guidelines, a decision has been made to focus on heating effects only [(9), p. 6–8].

Averaging is an adequate measure of harm

When ICNIRP assumes that averaging over time and space are effective measures for measuring the, this is the fallacy of "Slanting" because not all of the evidence available is being used to inform the case (20).

The ICNIRP premise that averaging over time and space is suÿcient to calculate harm from exposure is deficient in realism in several ways. First, the statistical use of an average assumes an underlying normal distribution, which is not the case for complex telecommunications signaling. Moreover, averages hide potential biophysical effects resulting in a conclusion of no harm overall, even though extreme harm may have occurred for a small portion of tissue [see (18, 30)].

10.3389/fpubh.2023.1058454

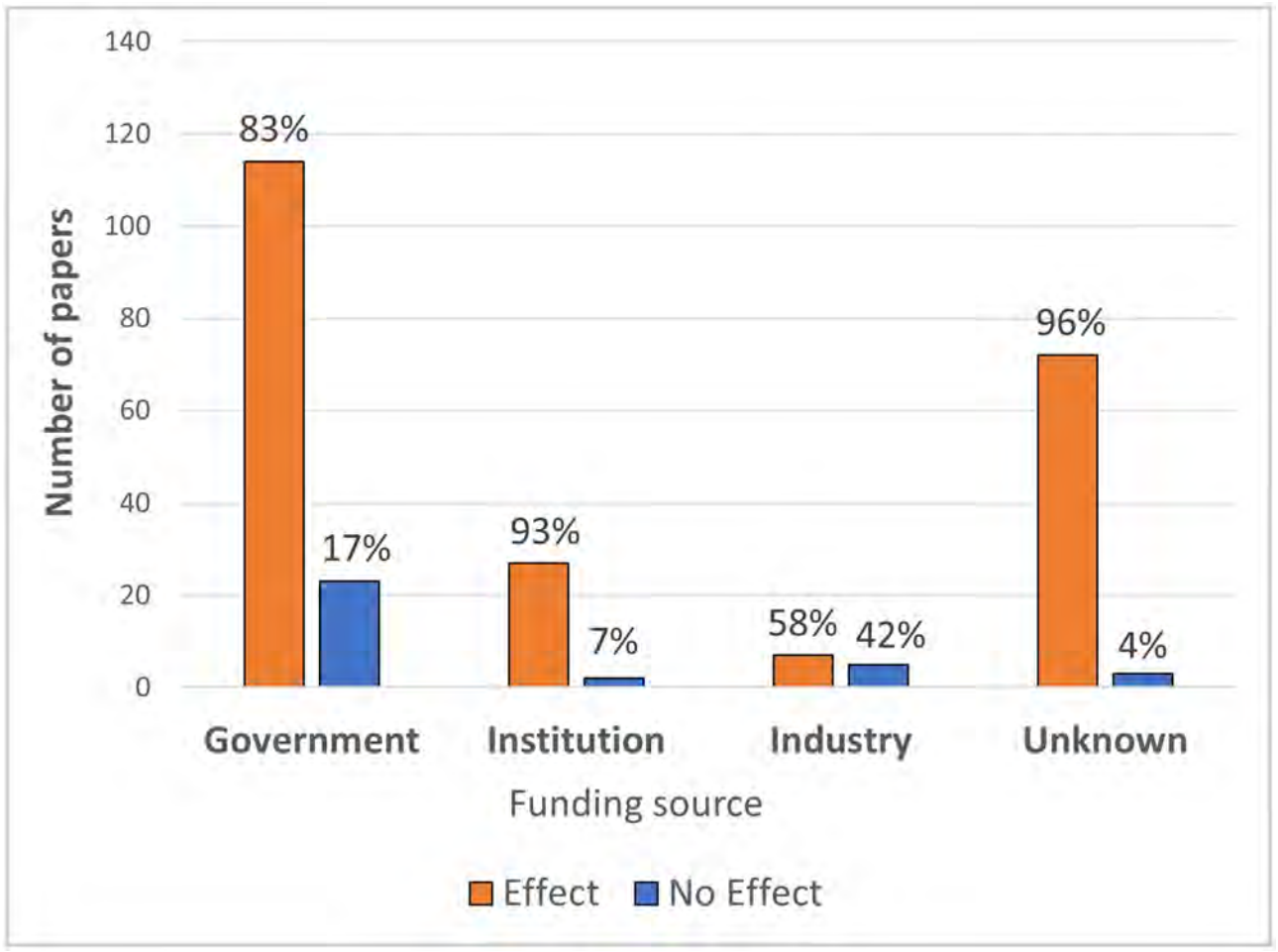


FIGURE 2
The relative proportion of "Effects" and "No Effects" outcomes from studies according to the funding source.

Authority uncertain

The fallacy of "Appeal to Authority" occurs when claims are believed because they are made by alleged authorities, but not all of the following are true: (i) they are making claims within their field of expertise, (ii) they are presenting facts about which there is some agreement, and (iii) they can be trusted (23). While bodies like ICNIRP and the WHO International EMF Project are given formal authority, other researchers have criticized them for being a small-self referencing group (40) with no dissenting voices (41). These bodies present one consistent message: that there is no evidence of harm from radiofrequencies, including mmWaves. In contrast, hundreds of scientists around the world with concerns for safety have appealed to the European Union for a moratorium on the 5G rollout (42, 43). Because there is no clear agreement on the facts, to assume an ultimate voice of authority on this topic is fallacious.

Furthermore, some expert scientists researching in this field have links with industry; therefore, conclusions from their papers need to be treated with caution. This is because industry can influence the science (44). For example, industry-funded research for UHF studies (including when partnered with government or military, public trusts, private foundations and institutions) was found to typically use short-term, single one-off exposures created by signal generators, to predominantly expose cell lines (*in vitro*) rather than live animals (*in vivo*) and to avoid epidemiological studies (45). These design decisions have resulted in studies that do not provide insights into potential health effects associated with multiple long-term, real-world exposure scenarios.

Similar to Huss et al. (46), an analysis of mmWave studies demonstrates how industry funding influences outcomes. Industry funded mmWave studies have produced a lower overall proportion of "Effect" outcomes, compared to government-funded and institution-based studies (see Figure 2).

Conclusions

The potential long-term health risks from global EMF continue to rise as exposures in the built environment increase in time and density. Mankind has chosen to base the justification for this rollout on shaky foundations, where there is minimal understanding of the impact of new radiofrequencies being introduced into the environment on long-term human and planetary health.

The evidence presented above suggests that there are credible risks of biological interference effects for frequencies planned for 5G, occurring well-below ICNIRP reference limits. Given the ubiquitous and often non-consensual nature of man-made wireless radiation exposures, the presence of even a small number of significant bioeffects requires follow up with more focused research.

The communication of existing investigations has not been fully clear or transparent. It is the responsibility of government review panels, regulatory bodies, scientists, public advocates, industry and policy makers to clearly communicate the research and its implications, so as to ensure that no fallacious conclusions can be drawn. If these are allowed to continue, both those delivering the message and the unsuspecting billions using their new 5G devices may be led in a direction that places global public and environmental health at risk.

The mmWave evidence base that has been made visible in this article suggests that plausible health effects cannot be ruled out, and that urgent action is needed on two fronts:

1. Further sound scientific research, *done carefully, using the best laboratory practices and sufficiently large samples to produce significant results*, funded and overseen by trusted bodies with appropriate expertise (38).
2. Precautionary actions to be taken by policy makers *via* use of *risk aversion* strategies such as the actions recommended in an EU commissioned report [(47), p. 152–153]. Risk aversion constitutes good leadership.

The limitations of scientific knowledge imply moral courage in taking precautionary action in time to avert harm [(17), p. 687].

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Funding

The Oceania Radiofrequency Scientific Advisory Association Inc., (ORSAA) is funded by membership subscriptions and donations, with no funding from industry or government institutions. All funding for the production of this manuscript was provided by ORSAA, with thanks to the late Bruce Rowe for his bequest.

Acknowledgments

We thank the Oceania Radiofrequency Scientific Advisory Association (ORSAA) and its members for their support. Special thanks to the Bruce Rowe Foundation for his generous donation that has made this publication possible.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1058454/full#supplementary-material

References

1. Simkó M, Mattsson M-O. 5G wireless communication and health effects—A pragmatic review based on available studies regarding 6 to 100 GHz. *Int J Environ Res Public Health.* (2019) 16:3406. doi: 10.3390/ijerph16183406

2. Karipidis K, Mate R, Urban D, Tinker R, Wood A. 5G mobile networks and health—A state-of-the-science review of the research into low-level RF fields above 6 GHz. *J Expos Sci Environ Epidemiol.* (2021) 31:585–605. doi: 10.1038/s41370-021-00297-6

3. Jureidini J, McHenry LB. The illusion of evidence based medicine. *BMJ.* (2022) 376:e702 doi: 10.1136/bmj.o702

4. Weller S, May M, McCredden J, Leach V, Phung D, Belyaev I. Comment on "5G mobile networks and health-a state-of-the- science review of the research into low-level RF fields above 6 GHz" by Karipidis et al. *J Expo Sci Environ Epidemiol.* (2022) 1–4. doi: 10.1038/s41370-022-00497-8

5. SCHEER. *Preliminary Opinion on the Need of a Revision of the Annexes in Council Recommendation 1999/519/EC and Directive 2013/35/EU, in View of the Latest Scientific evidence Available wiTh Regard to Radiofrequency (100kHz - 300GHz).* Brussels: European Commission; Scientific Committee on Health Environmental and Emerging Risks (2000).

6. Lin JC. Carcinogenesis from chronic exposure to radio-frequency radiation. *Front Public Health.* (2022) 4167:1042478. doi: 10.3389/fpubh.2022.1042478

7. *Oceania Radiofrequency Scientific Advisory Association*. (2015). Available online at: Available from: https://www.orsaa.org/ (accessed March 28, 2022).

8. Leach V, Weller S, Redmayne M. A novel database of bio-effects from non-ionizing radiation. *Rev Environ Health.* (2018) 33:273–80. doi: 10.1515/reveh-2018-0017

9. International Commission on Non-Ionizing Radiation Protection. Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz). *Health Phys.* (2020) 118:483–524. doi: 10.1097/HP.0000000000001210

10. Wood A, Mate R, Karipidis K. Meta-analysis of *in vitro* and *in vivo* studies of the biological effects of low-level millimetre waves. *J Expo Sci Environ Epidemiol.* (2021) 31:606–13. doi: 10.1038/s41370-021-00307-7

11. Mortazavi SMJ, Mortazavi SAR. Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. *Electromagn Biol Med.* (2016) 35:186–202. doi: 10.3109/15368378.2015.1043557

12. Klimova B, Kuca K, Maresova P. Global view on Alzheimer's disease and diabetes mellitus: threats, risks and treatment Alzheimer's disease and diabetes mellitus. *Curr Alzheimer Res.* (2018) 15:1277–82. doi: 10.2174/1567205015666180925110222

13. Leszczynski D. Physiological effects of millimeter-waves on skin and skin cells: an overview of the to-date published studies. *Rev Environ Health.* (2020) 35:493–515. doi: 10.1515/reveh-2020-0056

14. Gee D. Late Lessons from Early Warnings: towards realism and precaution with EMF? *Pathophysiology.* (2009) 16:217–31. doi: 10.1016/j.pathophys.2009.01.004

15. European Commission. *Commission adopts Communication on Precautionary Principle*. Brussels (2000).

16. European Commission. *5G and Electromagnetic Fields*. Brussels (2021).

17. Gee D. More or less precaution? In: Gee D, Grandjean P, Hansen SF, van den Hove S, MacGarvin M, Martin J, Nielsen G, Quist, D, Stanners D, editors. *Late Lessons From Early Warnings: Science, Precaution, Innovation. EEA Report Vol. 2013 No. 1*. Copenhagen: European Environment Agency (2013). p. 675–701. Available online at: https://www.semanticscholar.org/paper/Implications-for-Science-and-Governance-%7C-More-or-Gee/9eace2d8bdb6600191c66057d383648a0a245ff

18. International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF). Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: implications for 5G. *Environ Health.* (2022) 21:92–116. doi: 10.1186/s12940-022-00900-9

19. Touzet R, González AJ. Protection against ionizing radiation vis-á-vis protection against non-ionizing radiation: Different approaches. In: *Paper presented at the 15th International Congress of the International Radiation Protection Association*. Seoul (2021). p. 85–94. Available online at: https://www.argentina.gob.ar/sites/default/files/mt_arn_2021.pdf#page=87 (accessed January 12, 2023).

20. Dowden BE. *Fallacies*. The Internet Encyclopedia of Philosophy (2006). Available online at: https://iep.utm.edu/fallacy/

21. Bero LA. Tobacco industry manipulation of research. *Public Health Rep.* (2005) 120:200–8. doi: 10.1177/003335490512000215

22. Australian Government Department of Infrastructure Transport Regional Development Communications and the Arts. *Millimetre Waves, EME and 5G - What You Need to Know*. (2021). Available online at: https://www.infrastructure.gov.au/department/media/news/millimetre-waves-eme-and-5g-what-you-need-know (accessed January 12, 2023).

23. Department of Philosophy. *Informal Fallacies*. San Marcos, TX: Texas State University (2022). Available online at: https://www.txst.edu/philosophy/resources/fallacy-definitions.html (accessed January 12, 2023).

24. Grigoriev YG, Samoylov AS. *5G Cellular Standards: Total Radiobiological Assessment of the Danger of Planetary Electromagnetic Radiation Exposure to the Population*. Moscow: Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency (2020). Available online at: https://ouzs.ru/upload/iblock/ceb/ceb17aa082111ea2c7e0514386bcc490.pdf; English translation available at: https://www.orsaa.org/orsaa-research-papers---part-2.html (accessed January 12, 2022).

25. Feldman Y, Puzenko A, Ishai PB, Caduff A, Davidovich I, Sakran F, et al. The electromagnetic response of human skin in the millimetre and submillimetre wave range. *Phys Med Biol.* (2009) 54:3341. doi: 10.1088/0031-9155/54/11/005

26. Betzalel N, Ishai PB, Feldman Y. The human skin as a sub-THz receiver–Does 5G pose a danger to it or not? *Environ Res.* (2018) 163:208–16. doi: 10.1016/j.envres.2018.01.032

27. Shafirstein G, Moros EG. Modelling millimetre wave propagation and absorption in a high resolution skin model: the effect of sweat glands. *Phys Med Biol.* (2011) 56:1329–39. doi: 10.1088/0031-9155/56/5/007

28. Albanese R, Blaschak J, Medina R, Penn J. Ultrashort electromagnetic signals: Biophysical questions, safety issues and medical opportunities. Armstrong lab brooks air force base tx occupational and environmental health directorate (1994). *Aviat Space Environ Med.* (1994) 65:A116–20. Available online at: https://apps.dtic.mil/dtic/tr/fulltext/u2/a282990.pdf (accessed January 12, 2023).

29. Oughstun KE. Noninstantaneous, finite rise-time effects on the precursor field formation in linear dispersive pulse propagation. *JOSA A.* (1995) 12:1715–29. doi: 10.1364/JOSAA.12.001715

30. Neufeld E, Kuster N. Systematic derivation of safety limits for time-varying 5G radiofrequency exposure based on analytical models and thermal dose. *Health Phys.* (2018) 115:705–11. doi: 10.1097/HP.0000000000000930

31. Neufeld E, Samaras T, Kuster N. Discussion on spatial and time averaging restrictions within the electromagnetic exposure safety framework in the frequency range above 6 GHz for pulsed and localized exposures. *Bioelectromagnetics.* (2020) 41:164–8. doi: 10.1002/bem.22244

32. Panagopoulos DJ, Johansson O, Carlo GL. Real versus simulated mobile phone exposures in experimental studies. *Bio Med Res Int.* (2015) 2015:1–8. doi: 10.1155/2015/607053

33. Prihoda TJ. Comprehensive review of quality of publications and meta-analysis of genetic damage in mammalian cells exposed to non-ionizing radiofrequency fields. *Radiat Res.* (2019) 191:20–30. doi: 10.1667/RR15117.1

34. Salford LG, Brun AE, Eberhardt JL, Malmgren L, Persson BRR. Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. *Environ Health Perspect.* (2003) 111:881–3. doi: 10.1289/ehp.6039

35. Marino AA, Carrubba S, McCarty DE. Response to letter to the editor concerning "Electromagnetic hypersensitivity: evidence for a novel neurological syndrome". (2012) 122:402–3. doi: 10.3109/00207454.2011.648764

36. McCarty DE, Carrubba S, Chesson AL, Frilot C, Gonzalez-Toledo E, Marino AA. Electromagnetic hypersensitivity: evidence for a novel neurological syndrome. *Int J Neurosci.* (2011) 121:670–6. doi: 10.3109/00207454.2011.608139

37. Belyaev I. *Dependence of Non-thermal Biological Effects of Microwaves on Physical and Biological Variables: Implications for Reproducibility and Safety Standards. Non-thermal Effects and Mechanisms of Interaction Between Electromagnetic Fields and Living Matter*. Bologna, IT: Ramazzini Institute (2010). p. 187–218.

38. Barnes F, Greenebaum B. Setting guidelines for electromagnetic exposures and research needs. *Bioelectromagnetics.* (2020) 41:392–7. doi: 10.1002/bem.22267

39. Lai H. Genetic effects of non-ionizing electromagnetic fields. *Electromagn Biol Med.* (2021) 40:264–73. doi: 10.1080/15368378.2021.1881866

40. Nordhagen EK, Flydal E. Self-referencing authorships behind the ICNIRP 2020 radiation protection guidelines. *Rev Environ Health.* (2022). doi: 10.1515/reveh-2022-0037. [Epub ahead of print].

41. Hardell L. World Health Organization, radiofrequency radiation and health-a hard nut to crack. *Int J Oncol.* (2017) 51:405–13. doi: 10.3892/ijo.2017.4046

42. Hardell L, Nyberg R. [Comment] Appeals that matter or not on a moratorium on the deployment of the fifth generation, 5G, for microwave radiation. *Mol Clin Oncol.* (2020) 12:247–57. doi: 10.3892/mco.2020.1984

43. Nyberg NR, McCredden JE, Weller SG, Hardell L. The European Union prioritises economics over health in the rollout of radiofrequency technologies. *Rev Environ Health.* (2022). doi: 10.1515/reveh-2022-0106. [Epub ahead of print].

44. Slesin L. *Motorola, Microwaves and DNA Breaks: "War-Gaming" the Lai-Singh Experiments*. Microwave News (1997). p. 13. Available online at: https://microwavenews.com/news/backissues/j-f97issue.pdf (accessed January 11, 2023).

45. Weller S, Leach VA, May M. *Genotoxic Potential of Radiofrequency Exposures*. Radiation protection in Australia (ARPS45) (2022). p. 39. Available online at: https://www.orsaa.org/uploads/6/7/7/9/67791943/genotoxicity_arps_conference_2021_march_2022.pdf

46. Huss A, Egger M, Hug K, Huwiler-Müntener K, Röösli M. Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. *Environ Health Perspect.* (2007) 115:1–4. doi: 10.1289/ehp.9149

47. Belpoggi F. *Health impact of 5G, Study for the Panel for the Future of Science and Technology, Panel for the Future of Science and Technology*. Brussells: European Parliamentary Research Service, Scientific Foresight Unit (2021).

Electromagnetic fields, 5G and health: what about the precautionary principle?

John William Frank

Usher Institute, University of Edinburgh, Edinburgh, UK

Correspondence to
Professor John William Frank; john.frank@ed.ac.uk

Received 2 December 2019
Revised 13 October 2020
Accepted 16 October 2020

ABSTRACT

New fifth generation (5G) telecommunications systems, now being rolled out globally, have become the subject of a fierce controversy. Some health protection agencies and their scientific advisory committees have concluded that there is no conclusive scientific evidence of harm. Several recent reviews by independent scientists, however, suggest that there is significant uncertainty on this question, with rapidly emerging evidence of potentially harmful biological effects from radio frequency electromagnetic field (RF-EMF) exposures, at the levels 5G roll-out will entail. This essay identifies four relevant sources of scientific uncertainty and concern: (1) lack of clarity about precisely what technology is included in 5G; (2) a rapidly accumulating body of laboratory studies documenting disruptive in vitro and in vivo effects of RF-EMFs—but one with many gaps in it; (3) an almost total lack (as yet) of high-quality epidemiological studies of adverse human health effects from 5G EMF exposure specifically, but rapidly emerging epidemiological evidence of such effects from past generations of RF-EMF exposure; (4) persistent allegations that some national telecommunications regulatory authorities do not base their RF-EMF safety policies on the latest science, related to unmanaged conflicts of interest. The author, an experienced epidemiologist, concludes that one cannot dismiss the growing health concerns about RF-EMFs, especially in an era when higher population levels of exposure are occurring widely, due to the spatially dense transmitters which 5G systems require. Based on the precautionary principle, the author echoes the calls of others for a moratorium on the further roll-out of 5G systems globally, pending more conclusive research on their safety.

BACKGROUND

Fifth generation (5G) technology is being widely promoted by politicians, government officials, and private sector interests.[1–3] They contend that its advent will bring clear economic and lifestyle benefits, through massive increases in wireless and mobile connectivity at home, work, school and in the community. Examples of these 5G benefits include driverless vehicles and 'The Internet of Things'—automated and continuous communication between the machines in our daily lives.[4 5] On the other hand, the public health response to this wave of communications innovation has become a sense of deep concern, related to widespread scientific uncertainties, as well as a lack of use of existing evidence, in the current international safety guidelines for 5G and related radio frequency electromagnetic field (RF-EMF) exposures.[5–8] This commentary sets out the reasons for such concern.

WHAT IS 5G AND WHY IS IT DIFFERENT FROM PAST EMF EXPOSURES?

Developed over just the last decade, radio frequency (wireless) transmission systems in the 5G category are being rolled out throughout the world. These systems will massively increase the volume, speed and spatial reach of digital data transfer.[4–6] The four successive previous generations (1G, 2G, 3G and 4G) of wireless transmission systems were deployed initially for wireless and mobile phones (1980s and 1990s), followed by WiFi (2000s), and then smart metres and the Internet of Things (2010s). Each successive generation of transmission systems has used higher frequencies of electromagnetic waves to carry ever-larger volumes of data, faster, in more ubiquitous locations. 5G is widely acknowledged to be a step change in this sequence, since it additionally uses much higher frequency (3 to 300 GHz) radio waves than in the past. 5G will also make use of very new—and thus relatively unevaluated, in terms of safety—supportive technology (including pulsing, beaming, phased arrays and massive input/massive output (MIMO)—see below) to enable this higher data transmission capacity.[4–6]

However—unlike prior generations of wireless transmission systems—5G ultrahigh-frequency waves are easily interrupted by vegetation foliage (and building walls, often requiring additional signal boosting within each building). This inherent fragility of 5G high-frequency waves means that transmission boosting 'cell' antennae are generally required every 100–300 m or less—far more spatially dense than the miles-apart transmission masts required for older 2G, 3G and 4G technology using lower frequency waves.[4–6]

This dense transmission network is also required in order to achieve the 'everywhere/anytime' connectivity promised by 5G developers, and necessitated by new technology such as driverless cars, which must never be out of internet contact, for safety reasons. Critics of 5G agree[6–8]—but its supporters do not[9 10]—that the overall population levels of exposure to RF-EMFs will be greatly increased by the 5G roll-out. One compelling argument for that view is the 'inverse square law' of EMF exposure: intensity varies as the inverse of the square of the distance from the emitting source.[11] With plans afoot internationally to put a 5G booster antenna on 'every second or third lamp-post', it is difficult to believe that overall population exposures will not increase substantially. Existing 4G

To cite: Frank JW. *J Epidemiol Community Health* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/jech-2019-213595

Annals of Case Reports
Hardell L and Nilsson M. Ann Case Rep: 8: 1112
www.doi.org/10.29011/2574-7754.101112
www.gavinpublishers.com

Case Report

Case Report: The Microwave Syndrome after Installation of 5G Emphasizes the Need for Protection from Radiofrequency Radiation

Lennart Hardell[1*], Mona Nilsson[2]

[1]Department of Oncology, Orebro University Hospital, Sweden (retired), The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17, Örebro, Sweden

[2]Swedish Radiation Protection Foundation, Gredby 14, SE-178 92 Adelsö, Sweden

[*]**Corresponding author:** Lennart Hardell, Department of Oncology, Orebro University Hospital, Sweden (retired), The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17, Örebro, Sweden

Citation: Hardell L and Nilsson M (2023) Case Report: The Microwave Syndrome after Installation of 5G Emphasizes the Need for Protection from Radiofrequency Radiation. Ann Case Report. 8: 1112. DOI: 10.29011/2574-7754.101112

Received Date: 28 December 2022; **Accepted Date**: 02 January 2023; **Published Date**: 10 January 2023

Abstract

In this case, report two previously healthy persons, a man aged 63 years and a woman aged 62 years, developed symptoms of the microwave syndrome after installation of a 5G base station for wireless communication on the roof above their apartment. A base station for previous telecommunication generation technology (3G/4G) was present at the same spot since several years. Very high radiofrequency (RF) radiation with maximum (highest measured peak value) levels of 354 000, 1 690 000, and >2 500 000 μW/m^2 were measured at three occasions in the bedroom located only 5 meters below the new 5G base station, compared to maximum (peak) 9 000 μW/m^2 prior to the 5G deployment. The rapidly emerging symptoms after the 5G deployment were typical for the microwave syndrome with e.g., neurological symptoms, tinnitus, fatigue, insomnia, emotional distress, skin disorders, and blood pressure variability. The symptoms were more pronounced in the woman. Due to the severity of symptoms, the couple left their dwelling and moved to a small office room with maximum (peak) RF radiation 3 500 μW/m^2. Within a couple of days, most of their symptoms alleviated or disappeared completely. This medical history can be regarded as a classic provocation test. The RF radiation levels in the apartment were well below the limit proposed to be "safe" below which no health effects would occur, recommended by the International Commission on Non-Ionizing Radiation (ICNIRP). These now presented symptoms of the microwave syndrome were caused by non-thermal effects from RF radiation and highlight that the ICNIRP guidelines used in most countries including Sweden do not protect human health. Guidelines based on all biological negative effects from RF radiation are urgently needed, as well as monitoring human health, not the least due to rapidly increasing levels of exposure.

Keywords: Base station; 5G; Radiofrequency radiation; Electromagnetic hypersensitivity; Microwave syndrome; Health

Introduction

In recent years, human exposure to pulse-modulated microwave radiation [also called radiofrequency (RF) radiation] from wireless technology has increased exponentially. Microwaves are frequencies in the range of 300 MHz to 300 GHz within the radiofrequency (RF) spectrum [1]. The increase is mainly a result of the expansion of 4G+ and 5G as well as an increased amount of consumer products based on technologies that emit microwave radiation.

In parallel with this exploding RF radiation exposure, regulations and so-called safety limits applicable to the permitted RF radiation in most countries are based on a severely outdated approach from the 1950s. These 'safety" limits (or guidelines) only protect people against harmful effects that occur as a result of acute heating, also called thermal effects. These occur when

Annals of Clinical Case Reports

Case Report
Published: 04 Feb, 2023

Development of the Microwave Syndrome in Two Men Shortly after Installation of 5G on the Roof above their Office

*Nilsson M[1] and Hardell L[2]**

[1]Swedish Radiation Protection Foundation, Sweden

[2]The Environment and Cancer Research Foundation, Sweden

Abstract

The 5th generation, 5G, for wireless communication is rolled out without previous studies on potential effects on human health and the environment. In this case study we describe two men, case 1 and case 2, working in three offic rooms close to base stations. After the deployment of 5G, both men developed symptoms typical for the microwave syndrome, e.g., headache, tinnitus, dizziness, balance disorder, concentration and attention deficiency, and fatigue. Radiofrequency Radiation (RFR) after the 5G deployment was measured in the three offices In offic one maximum (peak) RFR during one minute varied from 463 to 1,180,000 μW/m^2, in offic two from 6,230 to 501,000 and in offic three from 13,700 to 613,000 μW/m^2. The symptoms disappeared in both men within a couple of weeks (case 1) or immediately (case 2) after leaving the offic for other office with much lower maximum peak RFR emissions, maximum for case 1 =16 and for case 2 =2,920 μW/m^2. This case report may be regarded as a provocation study on health from 5G RFR. The clinical picture in both men was clearly related to the exposure, although the exposures were well below the guidelines recommended by ICNIRP that are claimed to protect against all health effects. We conclude that the guidelines for RFR exposure based only on tissue heating by ICNIRP are inadequate to protect human health and that 5G appears to provoke symptoms of microwave syndrome in previously healthy people.

Keywords: Base station; 5G; Radiofrequency radiation; Electromagnetic hypersensitivity microwave syndrome; Health

OPEN ACCESS

Correspondence:
Lennart Hardell, The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17, Örebro, Sweden,
E-mail: lennart.hardell@environmentandcancer.com

Received Date: *24 Jan 2023*
Accepted Date: *30 Jan 2023*
Published Date: *04 Feb 2023*

Citation:
Nilsson M, Hardell L. Development of the Microwave Syndrome in Two Men Shortly after Installation of 5G on the Roof above their Office. Ann Clin Case Rep. 2023; 8: 2378.
ISSN: 2474-1655.

Introduction

Guidelines for exposure to Radiofrequency Radiation (RFR), also called microwaves, from ICNIRP [1] and the FCC [2] are based on outdated assumptions that ignore current scientific evidence on health effects. Tissue heating within very short exposure time is the only accepted basis for these guidelines. Thereby these guidelines do not protect against numerous non-thermal health effects observed for RFR exposure at non-thermal levels [3]. Microwaves are frequencies in the range of 300 MHz to 300 GHz and it is within this range of frequencies that modern wireless technologies for instance 3G, 4G, 5G and Wi-Fi operate. People may react to RFR with e.g., insomnia, heart palpitations, tinnitus, skin disorders, headache, and neurological symptoms at exposure levels clearly below the guidelines suggested by ICNIRP and FCC. The terms microwave syndrome, microwave illness, radiofrequency sickness or Electromagnetic Hypersensitivity (EHS) have been attributed to these health effects. The symptoms develop at levels of RFR exposure well below the guidelines from ICNIRP, and are alleviated by elimination of or reduced exposure, but may in some cases persist to some degree. Individuals suffering from EHS react with health symptoms already at very low non-thermal exposure levels to RF-radiation [4]. The symptoms of microwave syndrome or illness were described already in the 1960's by researchers in East European Countries [5] as a consequence of long-term occupational exposure to microwaves/RFR. These non-thermal effects depend primarily on the modulation and/or pulsation of the signal and also on the peak and average intensity of the RFR. The symptoms decline and may disappear completely after exposure has ceased and may after a few days to several weeks have disappeared completely [6]. Recently we published a case report on two persons, who developed the microwave syndrome after installation of base station for 5G on the roof just above their apartment [7]. Due to the severity of the symptoms caused by the sharp increase in non-thermal levels of microwaves from the 5G base station, the couple had to move to

Original Article

DOI: 10.7860/JCDR/2019/39681.12630

Anatomy Section

Effect of 1800-2100 MHz Electromagnetic Radiation on Learning-Memory and Hippocampal Morphology in Swiss Albino Mice

G KRISHNA KISHORE[1], KV VENKATESHU[2], NS SRIDEVI[3]

ABSTRACT

Introduction: With advancing technology the mobile phone with multiple features is used as a multipurpose device and attract people of all age groups. Increased usage of mobile phone raises the question of possible adverse effects on health.

Aim: To assess the 1800-2100 MHz radiation effect on learning-memory and microscopic anatomy of hippocampal Cornu Ammonis (CA3) neurons in mice.

Materials and Methods: A total of 18 albino mice were divided into 3 groups (6 Mice per group). Group-I: Control Group, Group-II: Exposed to Radio frequency-Electromagnetic radiation (RF-EMR) for 30 minutes/day for 3 months, Group-III: Exposed to RF-EMR for 60 minutes/day for 3 months. Followed by the exposure, learning memory was assessed by using Hebb-Williams maze in all the groups. The mice were then sacrificed, brains were dissected out and sections were taken at the level of hippocampus and then stained with Haematoxylin and Eosin for microscopy.

The results were expressed in Mean±SD and analysed by using one-way (analysis of variance) ANOVA followed by LSD (Least Square Difference) test for paired wise data. The p-value<0.05 was considered as statistically significant.

Results: The time taken by the animal to reach the target chamber was significantly increased in Group-III (exposed 60 minutes/day for 3 months), whereas group-II (exposed 30 minutes/day for 3 months) showed no significant changes when compared to Group-I (control group). Microscopic anatomy of hippocampal CA3 neurons in exposed group shows less number of pyramidal cells with darkened nuclei, cytoplasm was vacuolated and cells were scattered.

Conclusion: Exposure to 1800-2100 MHz radiation leads to damage and decrease of neurons in hippocampal region, which alters the learning and memory.

Keywords: Cornu ammonis, Hebb-Williams maze, Radio frequency

INTRODUCTION

The extensive use of Global System for Mobile communication (GSM) mobile phones throughout the world raises the possible adverse effects on human health especially on the Central Nervous System (CNS), the brain. In many countries more than half of the population relies/depend on mobiles for wireless communication and internet data [1]. In 2015, more than 7 billion people were using mobiles in the world, estimating to 62.9% of the world's population. Rapid increase of mobile users in general and specifically upto 80% of youngsters owning a mobile has made communication and technology easier [2].

In this concern, there is a growing interest in scientific community for the potential deleterious effects of Radio Frequency Electro Magnetic Radiation (RF EMR) on the public health, especially much focus on the effects of RF EMR on structural and functional integrity of the brain because the radiation exposure is directly to the head region [3]. In 2006 and 2010, World Health Organisation (WHO) issued a research agenda for high priority research on effects of RF exposure on ageing and neurodegenerative diseases in animals and effects of pre and post-natal RF exposure on development and behaviour in animals [4,5]. The mobile phone releases non-ionising radiation which has low frequency and considered to be safe, but recent studies evidenced that it has an impact on the living tissues especially on the brain which can cause headache, memory loss, heat over the ear, decreased concentration and other cognitive effects [6].

The hippocampus is a part of brain which belongs to the limbic system and is involved in cognitive functions like spatial learning and working memory. It plays a crucial role in the formation of new memories and it is considered as a sensitive region and is affected by mobile phone radiation. The hippocampus is a "S"-shaped folded structure located on the floor of the lateral ventricle on both the cerebral hemispheres. Hippocampal formation consists of hippocampus proper, dentate gyrus and subiculum. Hippocampus proper is also known as Cornu Ammonis (CA), which consists of CA1, CA2, CA3 and CA4 sub-regions [7].

Studies have found that damage to the hippocampal neurons may lead to impairment of memory and learning, behavioural disturbances and impact on Hypothalamo-Pituitary-Adrenal (HPA) axis [3,8,9]. The present study was undertaken to evaluate the long term exposure effect of mobile phone radiofrequency electromagnetic radiation-4G (1800-2100 MHz) on cognitive functions like spatial learning, working memory and hippocampal morphology in adult swiss albino mice.

MATERIALS AND METHODS

The Experimental study was carried out after the approval of Institutional Animal Ethical Committee (IAEC/PHARMA/SDUMC/2017-18/04). The study was conducted at central animal house Sri Devaraj Urs Medical College, Kolar from November 2017-January 2018, the duration of the study was 3 months.

Animals

Six weeks old healthy male Swiss-Albino Mice were used in this study, the animals were procured from Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA) registered brooders-Invivo Biosciences, Bengaluru.

Bioelectromagnetics 40:498–511 (2019)

Early-Life Exposure to Pulsed LTE Radiofrequency Fields Causes Persistent Changes in Activity and Behavior in C57BL/6 J Mice

Kerry A. Broom,[1]* **Richard Findlay**,[2] **Darren S. Addison**,[1] **Cristian Goiceanu**,[3] **and Zenon Sienkiewicz**[1]

[1]*Centre for Radiation, Chemical and Environmental Hazards, Public Health England, Chilton, Oxfordshire, UK*
[2]*Physics Group, EMFcomp Limited, Harwell Campus, Harwell, Oxfordshire, UK*
[3]*Department of Environmental Health, National Institute of Public Health, Regional Center Iasi, Iasi, Romania*

Despite much research, gaps remain in knowledge about the potential health effects of exposure to radiofrequency (RF) fields. This study investigated the effects of early-life exposure to pulsed long term evolution (LTE) 1,846 MHz downlink signals on innate mouse behavior. Animals were exposed for 30 min/day, 5 days/week at a whole-body average specific energy absorption rate (SAR) of 0.5 or 1 W/kg from late pregnancy (gestation day 13.5) to weaning (postnatal day 21). A behavioral tracking system measured locomotor, drinking, and feeding behavior in the home cage from 12 to 28 weeks of age. The exposure caused significant effects on both appetitive behaviors and activity of offspring that depended on the SAR. Compared with sham-exposed controls, exposure at 0.5 W/kg significantly decreased drinking frequency ($P \leq 0.000$) and significantly decreased distance moved ($P \leq 0.001$). In contrast, exposure at 1 W/kg significantly increased drinking frequency ($P \leq 0.001$) and significantly increased moving duration ($P \leq 0.005$). In the absence of other plausible explanations, it is concluded that repeated exposure to low-level RF fields in early life may have a persistent and long-term effect on adult behavior. Bioelectromagnetics. 2019;40:498–511. © 2019 The Authors. Bioelectromagnetics Published by Wiley Periodicals, Inc.

Keywords: **electromagnetic fields; locomotion; activity; brain; rodent**

INTRODUCTION

People are increasingly exposed to a broad spectrum of radiofrequency (RF) fields from an array of sources operating from a few hundred MHz to a few GHz. Sources include mobile and cordless phones, Bluetooth devices, and Wi-Fi [Sienkiewicz et al., 2017]. Despite much research, there are still gaps in knowledge about the potential of low-level RF fields to cause biological effects, and there are concerns that these exposures may have long-term effects on human health [SCENIHR, 2015]. In addition, the ubiquitous nature of our exposure to these RF fields means that, even if the risk to individuals is low, a substantial number of people among the population could experience health effects [Kheifets et al., 2001; WHO, 2010].

Since the development of mobile cellular telephony, adults and children have been exposed to prolonged low-level RF fields from base stations and to acute, localized exposures when the phone handsets are used. Children have been assumed to be more sensitive than adults to these exposures, due to the

Grant sponsor: Department of Health and Social Care Policy Research Programme (Early Life Exposure to RadioFrequency Fields [ELERaFF]); grant number: 091/0211.

Conflict of interest: RF works for an independent EMF safety organization and declares no competing interests. ZS is a member of the main Commission of ICNIRP and declares no competing interests.

*Correspondence to: Kerry A. Broom, Public Health England, Centre for Radiation, Chemical and Environmental Hazards, Chilton, UK. E-mail: Kerry.Broom@phe.gov.uk

Received for review 8 January 2019; Accepted 22 August 2019

DOI:10.1002/bem.22217
Published online 15 September 2019 in Wiley Online Library(wileyonlinelibrary.com).

Planetary electromagnetic pollution: it is time to assess its impact

As the Planetary Health Alliance moves forward after a productive second annual meeting, a discussion on the rapid global proliferation of artificial electromagnetic fields would now be apt. The most notable is the blanket of radiofrequency electromagnetic radiation, largely microwave radiation generated for wireless communication and surveillance technologies, as mounting scientific evidence suggests that prolonged exposure to radiofrequency electromagnetic radiation has serious biological and health effects. However, public exposure regulations in most countries continue to be based on the guidelines of the International Commission on Non-Ionizing Radiation Protection[1] and Institute of Electrical and Electronics Engineers,[2] which were established in the 1990s on the belief that only acute thermal effects are hazardous. Prevention of tissue heating by radiofrequency electromagnetic radiation is now proven to be ineffective in preventing biochemical and physiological interference. For example, acute non-thermal exposure has been shown to alter human brain metabolism by NIH scientists,[3] electrical activity in the brain,[4] and systemic immune responses.[5] Chronic exposure has been associated with increased oxidative stress and DNA damage[6,7] and cancer risk.[8] Laboratory studies, including large rodent studies by the US National Toxicology Program[9] and Ramazzini Institute of Italy,[10] confirm these biological and health effects in vivo. As we address the threats to human health from the changing environmental conditions due to human activity,[11] the increasing exposure to artificial electromagnetic radiation needs to be included in this discussion.

Due to the exponential increase in the use of wireless personal communication devices (eg, mobile or cordless phones and WiFi or Bluetooth-enabled devices) and the infrastructure facilitating them, levels of exposure to radiofrequency electromagnetic radiation around the 1 GHz frequency band, which is mostly used for modern wireless communications, have increased from extremely low natural levels by about 10^{18} times (figure). Radiofrequency electromagnetic radiation is also used for radar, security scanners, smart meters, and medical equipment (MRI, diathermy, and radiofrequency ablation). It is plausibly the most rapidly increasing anthropogenic environmental exposure since the mid-20th century, and levels will surge considerably again, as technologies like the Internet of Things and 5G add millions more radiofrequency transmitters around us.

Unprecedented human exposure to radiofrequency electromagnetic radiation from conception until death has been occurring in the past two decades. Evidence of its effects on the CNS, including altered neurodevelopment[14] and increased risk of some neurodegenerative diseases,[15] is a major concern considering the steady increase in their incidence. Evidence exists for an association between neurodevelopmental or

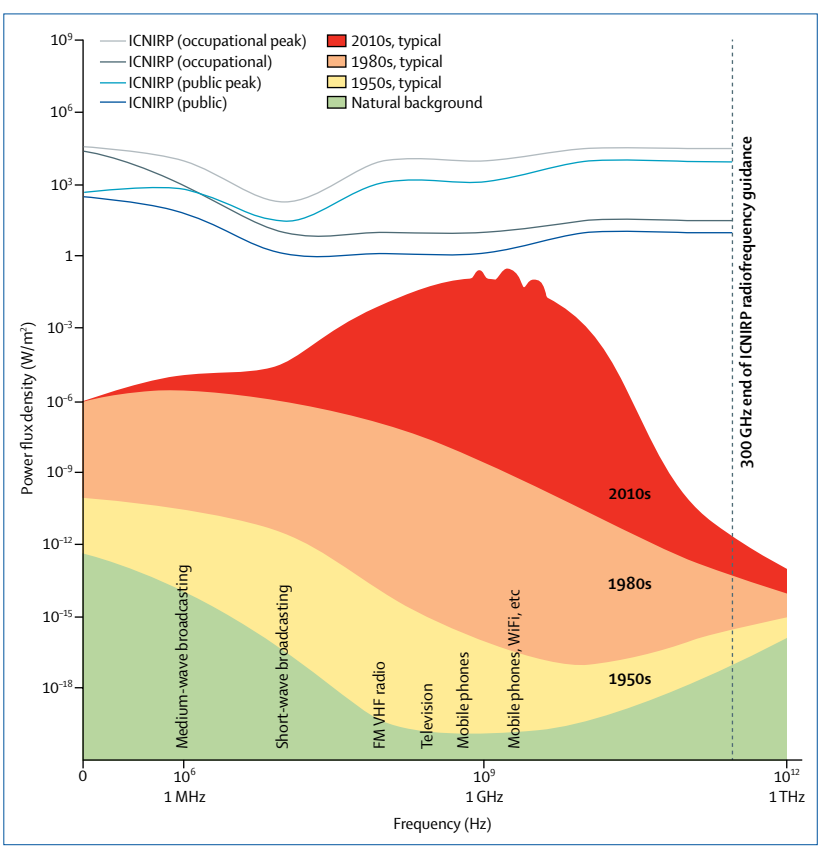


Figure: **Typical maximum daily exposure to radiofrequency electromagnetic radiation from man-made and natural power flux densities in comparison with International Commission on Non-Ionizing Radiation Protection safety guidelines[1]**

Anthropogenic radiofrequency electromagnetic radiation levels are illustrated for different periods in the evolution of wireless communication technologies. These exposure levels are frequently experienced daily by people using various wireless devices. The levels are instantaneous and not time-averaged over 6 minutes as specified by International Commission on Non-Ionizing Radiation Protection for thermal reasons. Figure modified from Philips and Lamburn[12] with permission. Natural levels of radiofrequency electromagnetic radiation were based on the NASA review report CR-166661.[13]

behavioural disorders in children and exposure to wireless devices,[14] and experimental evidence, such as the Yale finding, shows that prenatal exposure could cause structural and functional changes in the brain associated with ADHD-like behaviour.[16] These findings deserve urgent attention.

For the **Oceania Radiofrequency Scientific Advisory Association** see www.orsaa.org

At the Oceania Radiofrequency Scientific Advisory Association, an independent scientific organisation, volunteering scientists have constructed the world's largest categorised online database of peer-reviewed studies on radiofrequency electromagnetic radiation and other man-made electromagnetic fields of lower frequencies. A recent evaluation of 2266 studies (including in-vitro and in-vivo studies in human, animal, and plant experimental systems and population studies) found that most studies (n=1546, 68·2%) have demonstrated significant biological or health effects associated with exposure to anthropogenic electromagnetic fields. We have published our preliminary data on radiofrequency electromagnetic radiation, which shows that 89% (216 of 242) of experimental studies that investigated oxidative stress endpoints showed significant effects.[7] This weight of scientific evidence refutes the prominent claim that the deployment of wireless technologies poses no health risks at the currently permitted non-thermal radiofrequency exposure levels. Instead, the evidence supports the International EMF Scientist Appeal by 244 scientists from 41 countries who have published on the subject in peer-reviewed literature and collectively petitioned the WHO and the UN for immediate measures to reduce public exposure to artificial electromagnetic fields and radiation.

For the **International EMF Scientist Appeal** see www.emfscientist.org

Evidence also exists of the effects of radiofrequency electromagnetic radiation on flora and fauna. For example, the reported global reduction in bees and other insects is plausibly linked to the increased radiofrequency electromagnetic radiation in the environment.[17] Honeybees are among the species that use magnetoreception, which is sensitive to anthropogenic electromagnetic fields, for navigation.

Man-made electromagnetic fields range from extremely low frequency (associated with electricity supplies and electrical appliances) to low, medium, high, and extremely high frequency (mostly associated with wireless communication). The potential effects of these anthropogenic electromagnetic fields on natural electromagnetic fields, such as the Schumann Resonance that controls the weather and climate, have not been properly studied. Similarly, we do not adequately understand the effects of anthropogenic radiofrequency electromagnetic radiation on other natural and man-made atmospheric components or the ionosphere. It has been widely claimed that radiofrequency electromagnetic radiation, being non-ionising radiation, does not possess enough photon energy to cause DNA damage. This has now been proven wrong experimentally.[18,19] Radiofrequency electromagnetic radiation causes DNA damage apparently through oxidative stress,[7] similar to near-UV radiation, which was also long thought to be harmless.

At a time when environmental health scientists tackle serious global issues such as climate change and chemical toxicants in public health, there is an urgent need to address so-called electrosmog. A genuine evidence-based approach to the risk assessment and regulation of anthropogenic electromagnetic fields will help the health of us all, as well as that of our planetary home. Some government health authorities have recently taken steps to reduce public exposure to radiofrequency electromagnetic radiation by regulating use of wireless devices by children and recommending preferential use of wired communication devices in general, but this ought to be a coordinated international effort.

Priyanka Bandara, David O Carpenter
Oceania Radiofrequency Scientific Advisory Association, Scarborough, QLD 4020, Australia (PB); and Institute for Health and the Environment, University at Albany, Rensselaer, NY, USA (DOC)
pri.bandara@orsaa.org

We declare no competing interests. We thank Alasdair Philips for assistance with the figure and Victor Leach and Steve Weller for assistance with the ORSAA Database, which has enabled our overview of the scientific evidence in this area of research.

1 International Commission on Non-Ionizing Radiation Protection. ICNIRP guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). *Health Phys* 1998; **74:** 494–522.
2 Institute of Electrical and Electronics Engineers. IEEE C95.7-2014—IEEE recommended practice for radio frequency safety programs, 3 kHz to 300 GHz. IEEE Standards Association, 2014. https://standards.ieee.org/standard/C95_7-2014.html (accessed Nov 6, 2018).
3 Volkow ND, Tomasi D, Wang GJ, et al. Effects of cell phone radiofrequency signal exposure on brain glucose metabolism. *JAMA* 2011; **305:** 808–13.
4 Schmid MR, Loughran SP, Regel SJ, et al. Sleep EEG alterations: effects of different pulse-modulated radio frequency electromagnetic fields. *J Sleep Res* 2012; **21:** 50–58.

5 Kimata H. Microwave radiation from cellular phones increases allergen-specific IgE production. *Allergy* 2005; **60:** 838–39.

6 Zothansiama, Zosangzuali M, Lalramdinpuii M, Jagetia GC. 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* 2017;**36:** 295–305.

7 Bandara P, Weller S. Biological effects of low-intensity radiofrequency electromagnetic radiation—time for a paradigm shift in regulation of public exposure. *Radiat Protect Australas* 2017; **34:** 2–6.

8 Carlberg M, 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; **2017:** 9218486.

9 Cell phone radio frequency radiation. National Toxicology Program, US Department of Health and Human Services, 2018. https://ntp.niehs.nih.gov/results/areas/cellphones/index.html (accessed Nov 8, 2018).

10 Falcioni L, Bua L, Tibaldi E, 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 1.8GHz GSM base station environmental emission. *Environ Res* 2018; **165:** 496–503.

11 Myers SS. Planetary health: protecting human health on a rapidly changing planet. *Lancet* 2018; **390:** 2860–68.

12 Philips A, Lamburn G. Natural and human-activity-generated electromagnetic fields on Earth. Childhood Cancer 2012; London; April 24–26, 2012.

13 Raines JK. NASA-CR-166661. Electromagnetic field interactions with the human body: observed effects and theories. NASA Technical Reports Server, 1981. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19810017132.pdf (accessed Oct 10, 2018).

14 Divan HA, Kheifets L, Obel C, Olsen J. Prenatal and postnatal exposure to cell phone use and behavioral problems in children. *Epidemiology* 2008; **19:** 523–29.

15 Zhang X, Huang WJ, Chen WW. Microwaves and Alzheimer's disease. *Exp Ther Med* 2016; **12:** 1969–72.

16 Aldad TS, Gan G, Gao XB, Taylor HS. Fetal radiofrequency radiation exposure from 800–1900 mhz-rated cellular telephones affects neurodevelopment and behavior in mice. *Sci Rep* 2012; **2:** 312.

17 Taye RR, Deka MK, Rahman A, Bathari M. Effect of electromagnetic radiation of cell phone tower on foraging behaviour of Asiatic honey bee, *Apis cerana* F. (Hymenoptera: Apidae). *J Entomol Zool Stud* 2017; **5:** 1527–29.

18 Smith-Roe SL, Wyde ME, Stout MD, 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 Conference; Raleigh, NC, USA; Sept 9–13, 2017.

19 Ruediger HW. Genotoxic effects of radiofrequency electromagnetic fields. *Pathophysiology* 2009; **16:** 89–102.

ELECTROMAGNETIC BIOLOGY AND MEDICINE
2022, VOL. 41, NO. 3, 315–324
https://doi.org/10.1080/15368378.2022.2079673

Taylor & Francis
Taylor & Francis Group

Effects of pre and postnatal 2450 MHz continuous wave (CW) radiofrequency radiation on thymus: Four generation exposure

Fazile Cantürk Tan [a], Betül Yalçin [b], Arzu Hanım Yay [b], Burak Tan [c], Korkut Yeğin [d], and Süleyman Daşdağ [e]

[a]Department of Biophysics, Erciyes University, Kayseri, Turkey; [b]Department of Histology and Embryology, Erciyes University, Kayseri, Turkey; [c]Department of Physiology, Erciyes University, Kayseri, Turkey; [d]Department of Electrical and Electronics Engineering, Ege University, İzmir, Turkey; [e]Department of Biophysics, İstanbul Medeniyet University, İstanbul, Turkey

ABSTRACT

This study aims to investigate the effects of pre- and postnatal 2450 MHz continuous wave (CW) radiofrequency radiation (RFR) on the thymus of rats spanning four generations. Four groups; sham, irradiated female, irradiated male, irradiated male and female, each consisting of four rats (one male and three females), were created. During the experiment, rats in the exposure groups were whole-body exposed to 2450 MHz CW-RFR for 12 h/day. Irradiation started one month before the fertilization in the experimental group. When the offspring were two months old, four rats, one male and three female, were allocated for the second-generation study. The remaining offspring were sacrificed under general anesthesia, and their thymuses were removed. The same procedure was applied to the next generation. Two months after the second generation gave birth, third-generation rats were decapitated, and their thymuses were removed. In all groups, cortex, medulla and resident cells could be clearly distinguished in the second and third generations. No differences were observed between the control and two experimental groups, defined as irradiated female and irradiated male. In contrast, vascularization was observed in the thymus of the fourth-generation offspring of the group where both males and females were irradiated. The number of offspring and mass of all rats decreased in the third-generation group. Pre-and postnatal 2450 MHz continuous wave radiofrequency radiation exposure may potentially affect the thymus of future generations.

ARTICLE HISTORY
Received 7 February 2022
Accepted 8 May 2022

KEYWORDS
2450 MHz RF; pre-and postnatal exposure; continuous wave; thymus; four generations

Introduction

The classification of radio frequencies (RF) as 2B agents by the International Agency for Research on Cancer (IARC) and the common use of wireless communication (Wi-Fi) devices in data transmission have raised health fears associated with electromagnetic fields (EMF) exposure. Developing tissues and organs are susceptible to harmful agents. The World Health Organization (WHO) has led research on the effect of early-life exposure to microwave (MW) as high precedence for 2006 and 2010 research on EMF because of the possible vulnerability of children (Laudisi et al. 2012).

Long-term pre- and postnatal RF radiation (RFR) exposure and the delayed effects are not known sufficiently. As the effects of RFR are still uncertain, the Council of Europe recommends that restrictions be placed on internet access and usage of mobile phones in all schools to preserve juveniles from the potential harm of radiation (Watson 2011). There are many reports about the effect of mobile phone exposure on health, but research on the effect of Wi-Fi 2.4 GHz RFR is considerably less than mobile phones (Dasdag et al. 1999, 2000, 2009; Dasdag et al. 2015a). However, Dasdag et al. investigated the effect of pulsed 2.4 GHz RFR on the brain and found it can cause adverse effects (Dasdag et al. 2015b). Although many organs, especially the brain, have been the focus of these studies, the thymus is often overlooked and has not been considered as being affected by RFR.

The thymus is a central organ of the immune system and the lymphatic system, which differentiate into antigen-recognizing cells and lymphocytes produced by the bone marrow in mammalian cells (Dominguez-Gerpe and Rey-Menéndez 2003; Miller 2020; Rezzani et al. 2014). During early embryogenesis, with the onset of hematopoiesis begins development of the immune system and then throughout prenatal life continues with successive hematopoietic cell production, cell migration, and differentiation (Laudisi et al. 2012). The thymus is vulnerable to physiological alters such as pregnancy,

CONTACT Süleyman Daşdağ suleyman.dasdag@medeniyet.edu.tr İstanbul Medeniyet University, Faculty of Medicine, Department of Biophysics, İstanbul 34700, Turkey

Grant information: The financial support from Erciyes University—The Scientific Research Projects of Turkey (ERUBAP); Project number: TYL-2017-7110.

Environmental Research 208 (2022) 112627

Contents lists available at ScienceDirect

Environmental Research

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

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

Tarmo Koppel [a], Mikko Ahonen [b], Michael Carlberg [c], Lennart Hardell [c,*]

[a] Tallinn University of Technology, SOC353 Ehitajate tee 5, 19086, Tallinn, Estonia
[b] Päivölä Institute, Päivölantie 52, Tarttila, 37770, Finland
[c] The Environment and Cancer Research Foundation, Studievägen 35, SE 702 17, Örebro, Sweden

ARTICLE INFO

Keywords:
Radiofrequency radiation
Measurement
Base stations
Health
Cancer
Stockholm

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

* Corresponding author. Studievägen 35, SE-702 17, Örebro, Sweden.
E-mail address: lennart.hardell@environmentandcancer.com (L. Hardell).

https://doi.org/10.1016/j.envres.2021.112627
Received 3 November 2021; Received in revised form 22 December 2021; Accepted 23 December 2021
Available online 4 January 2022

COMMENT

Health risks from radiofrequency radiation, including 5G, should be assessed by experts with no conflicts of interest

LENNART HARDELL and MICHAEL CARLBERG

The Environment and Cancer Research Foundation, SE-702 17 Örebro, Sweden

Received April 8, 2020; Accepted June 19, 2020

DOI: 10.3892/ol.2020.11876

Abstract. The fifth generation, 5G, of radiofrequency (RF) radiation is about to be implemented globally without investigating the risks to human health and the environment. This has created debate among concerned individuals in numerous countries. In an appeal to the European Union (EU) in September 2017, currently endorsed by >390 scientists and medical doctors, a moratorium on 5G deployment was requested until proper scientific evaluation of potential negative consequences has been conducted. This request has not been acknowledged by the EU. The evaluation of RF radiation health risks from 5G technology is ignored in a report by a government expert group in Switzerland and a recent publication from The International Commission on Non-Ionizing Radiation Protection. Conflicts of interest and ties to the industry seem to have contributed to the biased reports. The lack of proper unbiased risk evaluation of the 5G technology places populations at risk. Furthermore, there seems to be a cartel of individuals monopolizing evaluation committees, thus reinforcing the no-risk paradigm. We believe that this activity should qualify as scientific misconduct.

Introduction

Most politicians and other decision-makers using guidelines for exposure to radiofrequency (RF) radiation seem to ignore the risks to human health and the environment. The fact that the International Agency for Research on Cancer (IARC) at the World Health Organization (WHO) in May 2011 classified RF radiation in the frequency range of 30 kHz to 300 GHz to be a 'possible' human carcinogen, Group 2B (1,2), is being ignored. This has been recently exemplified in a hearing at the Tallinn Parliament in Estonia (3).

An important factor may be the influence on politicians by individuals and organizations with inborn conflicts of interests (COIs) and their own agenda in supporting the no-risk paradigm (4,5). The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has repeatedly ignored scientific evidence on adverse effects of RF radiation to humans and the environment. Their guidelines for exposure are based solely on the thermal (heating) paradigm and were first published in ICNIRP 1998 (6), updated in ICNIRP 2009 (7) and have now been newly published in ICNIRP 2020 (8), with no change of concept, only relying on thermal effects from RF radiation on humans. The large amount of peer-reviewed science on non-thermal effects has been ignored in all ICNIRP evaluations (9,10). Additionally, ICNIRP has successfully maintained their obsolete guidelines worldwide.

COIs can be detrimental, and it is necessary to be as unbiased as possible when assessing health risks. There are three points that should be emphasized. Firstly, the evidence regarding health risks from environmental factors may not be unambiguous, and therefore informed judgements must be made. Furthermore, there are gaps in knowledge that call for experienced evaluations, and no conclusion can be reached without value judgements. Secondly, paradigms are defended against the evidence and against external assessments by social networks in the scientific community. Thirdly, the stronger the impact of decisions about health risks on economic, military and political interests, the stronger will stakeholders try to influence these decision processes.

Since the IARC evaluation in 2011 (1,2), the evidence on human cancer risks from RF radiation has been strengthened based on human cancer epidemiology reports (9-11), animal carcinogenicity studies (12-14) and experimental findings on oxidative mechanisms (15) and genotoxicity (16). Therefore, the IARC Category should be upgraded from Group 2B to Group 1, a human carcinogen (17).

The deployment of the fifth generation, 5G, of RF radiation is a major concern in numerous countries, with groups of citizens trying to implement a moratorium until thorough research

Correspondence to: Dr Lennart Hardell, The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17 Örebro, Sweden
E-mail: lennart.hardell@environmentandcancer.com

Key words: Switzerland, European Union, World Health Organization, International Commission on Non-Ionizing Radiation Protection, Scientific Committee on Emerging and Newly Identified Health Risks, Swedish Radiation Safety Authority, 5G, electromagnetic field, appeals, moratorium, microwave radiation, radiofrequency electromagnetic field, health risks, non-ionizing radiation guidelines, conflicts of interest

Review Article

Lennart Hardell* and Tarmo Koppel

Electromagnetic hypersensitivity close to mobile phone base stations – a case study in Stockholm, Sweden

https://doi.org/10.1515/reveh-2021-0169
Received December 9, 2021; accepted February 13, 2022;
published online March 2, 2022

Abstract: A previously healthy worker developed symptoms assigned to electromagnetic hypersensitivity (EHS) after moving to an office with exposure to high levels of anthropogenic electromagnetic fields (EMFs). These symptoms consisted of e.g. headache, arthralgia, tinnitus, dizziness, memory loss, fatique, insomnia, transitory cardiovascular abnormalities, and skin lesions. Most of the symptoms were alleviated after 2 weeks sick leave. The highest radiofrequency (RF) field level at the working place was 1.72 V/m (7,852 μW/m^2). Maximum value for extremely low frequency electromagnetic field (ELF-EMF) from electric power at 50 Hz was measured to 285 nT (mean 241 nT). For electric train ELF-EMF at 16.7 Hz was measured to 383 nT (mean 76 nT). Exposure to EMFs at the working place could be the cause for developing EHS related symptoms. The association was strengthened by the symptom reduction outside the working place.

Keywords: electromagnetic hypersensitivity; EMF; radiofrequency radiation; symptoms.

Introduction

Exposure to extremely low frequency (ELF) electromagnetic fields (EMF) and radiofrequency (RF) EMF is in most cases involuntary and unknown to people. Both ELF-EMF and RF-EMF have been evaluated by IARC to be possible human carcinogens, Group 2B [1–3]. In fact EMFs should be regarded to be environmental pollutants that do not smell, have no taste and are invisible.

***Corresponding author: Lennart Hardell,** The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17, Örebro, Sweden, E-mail: lennart.hardell@environmentandcancer.com
Tarmo Koppel, Tallinn University of Technology, Tallinn, Estonia, E-mail: tarmo.koppel@taltech.ee

Already in the 1970s the 'microwave syndrome' was described in the former Soviet Union [4]. Persons working with radar or radio equipment reported symptoms of fatigue, headache, dizziness, disturbed sleep, concentration and memory problems.

In the 1980s similar symptoms were reported among Swedish persons working in front of cathode ray tube monitors [5]. In Finns such symptoms were attributed to exposure to EMF [6]. This syndrome was termed electromagnetic hypersensitivity (EHS), although still without an International Classification of Diseases (ICD-code) [7].

EHS consists of a wide range of different symptoms that may vary from person to person. EMF sensitivity varies among individuals from mild to severe. The prevalence has been reported to be 1.5% in Sweden [8], 3.2% in California [9], 5% in Switzerland [10], and 13% in Taiwan [11].

We report here on a person who developed symptoms consistent with those described among EHS subjects. The symptoms developed at a work place with exposure to EMFs. Our hypothesis is that the symptoms may be attributed to that exposure. We obtained informed consent by the person to publish the symptoms and work history anonymously.

Methods

The subject attributed the development of EHS symptoms to her office room where she had been working one year since April 2018 for a total of 183 working days. As the source of the adverse health effects was unknown, the investigators devised a broad spectrum approach for EMF measurements, to include all possible sources of EMFs.

The room was thoroughly measured encompassing different types of electromagnetic fields, including:

- Extremely low frequency (ELF) magnetic field (MF)
- Intermediate frequency (IF) magnetic field (MF)
- Radiofrequency (RF) electromagnetic field.

Three types of measurements approaches were utilized characterizing:

- Spatial field distribution
- Temporal field dynamics
- Spectrum analysis of EMF

World Health Organization, radiofrequency radiation and health - a hard nut to crack (Review)

LENNART HARDELL

Department of Oncology, Faculty of Medicine and Health, Örebro University, SE-701 82 Örebro, Sweden

Received April 1, 2017; Accepted June 6, 2017

DOI: 10.3892/ijo.2017.4046

Abstract. In May 2011 the International Agency for Research on Cancer (IARC) evaluated cancer risks from radiofrequency (RF) radiation. Human epidemiological studies gave evidence of increased risk for glioma and acoustic neuroma. RF radiation was classified as Group 2B, a possible human carcinogen. Further epidemiological, animal and mechanistic studies have strengthened the association. In spite of this, in most countries little or nothing has been done to reduce exposure and educate people on health hazards from RF radiation. On the contrary ambient levels have increased. In 2014 the WHO launched a draft of a Monograph on RF fields and health for public comments. It turned out that five of the six members of the Core Group in charge of the draft are affiliated with International Commission on Non-Ionizing Radiation Protection (ICNIRP), an industry loyal NGO, and thus have a serious conflict of interest. Just as by ICNIRP, evaluation of non-thermal biological effects from RF radiation are dismissed as scientific evidence of adverse health effects in the Monograph. This has provoked many comments sent to the WHO. However, at a meeting on March 3, 2017 at the WHO Geneva office it was stated that the WHO has no intention to change the Core Group.

Contents

Correspondence to: Dr Lennart Hardell, Department of Oncology, Faculty of Medicine and Health, Örebro University, SE-701 82 Örebro, Sweden
E-mail: lennart.hardell@regionorebrolan.se

Key words: electromagnetic fields, EMF, radiofrequency radiation, public exposure, cancer, WHO, monograph, conflict of interest, ICNIRP, non-thermal effects, health risks

1. Introduction

The use of wireless digital technology has grown rapidly during the last couple of decades (http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf). During use, mobile phones and cordless phones emit radiofrequency (RF) radiation. The brain is the main target organ for RF emissions from the handheld wireless phone (1,2). An evaluation of the scientific evidence on the brain tumour risk was made in May 2011 by the International Agency for Research on Cancer (IARC) at the World Health Organization (WHO). IARC is independently financed and has its own governing and scientific councils, which WHO staff only attend as observers (http://www.who.int/ionizing_radiation/research/iarc/en/).

Epidemiological studies provided supportive evidence of increased risk for head and brain tumours, i.e., acoustic neuroma and glioma. The working group reached the conclusion that RF radiation from devices that emit non-ionizing RF radiation in the frequency range 30 kHz-300 GHz, is a Group 2B, i.e. a 'possible', human carcinogen (3,4). Later studies have corroborated these findings and have thus strengthened the evidence (5-8).

Several laboratory studies have indicated mechanisms of action for RF radiation carcinogenesis such as on DNA repair, oxidative stress, down regulation of mRNA and DNA damage with single strand breaks (9-13). A report was released from The National Toxicology Program (NTP) under the National Institutes of Health (NIH) in USA on the largest ever animal study on cell phone RF radiation and cancer (14). An increased incidence of glioma in the brain and malignant schwannoma in the heart was found in rats. Acoustic neuroma or vestibular schwannoma is a similar type of tumour as the one found in the heart, although benign. Thus, this animal study supported human epidemiological findings on RF radiation and brain tumour risk (8).

The IARC cancer classification includes all sources of RF radiation. The exposure from mobile phone base stations, Wi-Fi access points, smart phones, laptops and tablets can be long-term, sometimes around the clock, both at home and at

High radiofrequency radiation at Stockholm Old Town: An exposimeter study including the Royal Castle, Supreme Court, three major squares and the Swedish Parliament

LENNART HARDELL[1], MICHAEL CARLBERG[1], TARMO KOPPEL[2] and LENA HEDENDAHL[3]

[1]Department of Oncology, Faculty of Medicine and Health, Örebro University, SE-701 82 Örebro, Sweden; [2]Department of Labour Environment and Safety, Tallinn University of Technology, 19086 Tallinn, Estonia; [3]Independent Environment and Health Research Luleå, SE-972 53 Luleå, Sweden

Received October 17, 2016; Accepted January 30, 2017

DOI: 10.3892/mco.2017.1180

Abstract. Exposure to radiofrequency (RF) radiation was classified as a possible human carcinogen, Group 2B, by the International Agency for Research on Cancer at WHO in 2011. The exposure pattern is changing due to the rapid development of technology. Outdoor RF radiation level was measured during five tours in Stockholm Old Town in April, 2016 using the EME Spy 200 exposimeter with 20 predefined frequencies. The results were based on 10,437 samples in total. The mean level of the total RF radiation was 4,293 μW/m^2 (0.4293 μW/cm^2). The highest mean levels were obtained for global system for mobile communications (GSM) + universal mobile telecommunications system (UMTS) 900 downlink and long-term evolution (LTE) 2600 downlink (1,558 and 1,265 μW/m^2, respectively). The town squares displayed highest total mean levels, with the example of Järntorget square with 24,277 μW/m^2 (min 257, max 173,302 μW/m^2). These results were in large contrast to areas with lowest total exposure, such as the Supreme Court, with a mean level of 404 μW/m^2 (min 20.4, max 4,088 μW/m^2). In addition, measurements in the streets surrounding the Royal Castle were lower than the total for the Old Town, with a mean of 756 μW/m^2 (min 0.3, max 50,967 μW/m^2). The BioInitiative 2012 Report defined the scientific benchmark for possible health risks as 30-60 μW/m^2. Our results of outdoor RF radiation exposure at Stockholm Old Town are significantly above that level. The mean exposure level at Järntorget square was 405-fold higher than 60 μW/m^2. Our results were below the reference level on 10,000,000 μW/m^2 established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which, however, are less credible, as they do not take non-thermal effects into consideration and are not based on sound scientific evaluation. Our highest measured mean level at Järntorget was 0.24% of the ICNIRP level. A number of studies have found adverse, non-thermal (no measurable temperature increase) health effects far below the ICNIRP guidelines.

Correspondence to: Professor Lennart Hardell, Department of Oncology, Faculty of Medicine and Health, Örebro University, Långhuset, Fakultetsgatan 1, SE-701 82 Örebro, Sweden
E-mail: lennart.hardell@regionorebrolan.se

Key words: radiofrequency radiation, radiofrequency electromagnetic field, base stations, exposimeter, public exposure, health, cancer

Introduction

The results of a study on public exposure to radiofrequency (RF) radiation at the Stockholm Central Railway Station in Sweden were recently published (1). The exposimeter EME Spy 200 that covers 20 different radiofrequency bands from 87 to 5,850 MHz was used. The results were based on 1,669 data points recorded in November, 2015. The median value for total exposure was 921 μW/m^2 (0.092 μW/cm^2), with certain outliers >95,544 μW/m^2 (6 V/m, which is the upper detection limit). One example of such very high measured power density was from a global system for mobile communications (GSM) + universal mobile telecommunications system (UMTS) 900 downlink band from a base station located at the Stockholm Central Station lower level (1). People standing at that area or passing by are involuntarily exposed to high RF radiation without their knowledge. It was concluded that this represented an improper location of a base station with an unnecessary high downlink level.

In European countries, the Old Town is a point of a national heritage, a place and source of cultural and historical development throughout centuries. Stockholm Old Town has already been retrofitted with several existing antennas to accommodate voice and data transmission. The aim of the present study was to characterize RF radiation already in place and its effect on the public. The antenna grid is expected to be further expanded to accommodate the rollout of 5G mobile networking as the next wave of mobile technology is implemented. As mobile base station antennas are placed on rooftops, outer walls of buildings and other places, visual perturbations appear in the form of antenna casings, cables and other peripheral devices. Not only does this damage the aesthetic appearance of the historic districts of the Old Town,

Radiofrequency radiation at Stockholm Central Railway Station in Sweden and some medical aspects on public exposure to RF fields

LENNART HARDELL[1], TARMO KOPPEL[2], MICHAEL CARLBERG[1], MIKKO AHONEN[3] and LENA HEDENDAHL[4]

[1]Department of Oncology, Faculty of Medicine and Health, Örebro University, SE-701 82 Örebro, Sweden; [2]Department of Labour Environment and Safety Tallinn University of Technology, SCO351 Ehitajate tee 5, 19086 Tallinn; [3]Institute of Environmental Health and Safety, 11615 Tallinn, Estonia; [4]Independent Environment and Health Research Luleå, SE-972 53 Luleå, Sweden

Received June 5, 2016; Accepted July 27, 2016

DOI: 10.3892/ijo.2016.3657

Abstract. The Stockholm Central Railway Station in Sweden was investigated for public radiofrequency (RF) radiation exposure. The exposimeter EME Spy 200 was used to collect the RF exposure data across the railway station. The exposimeter covers 20 different radiofrequency bands from 88 to 5,850 MHz. In total 1,669 data points were recorded. The median value for total exposure was 921 μW/m^2 (or 0.092 μW/cm^2; 1 μW/m^2=0.0001 μW/cm^2) with some outliers over 95,544 μW/m^2 (6 V/m, upper detection limit). The mean total RF radiation level varied between 2,817 to 4,891 μW/m^2 for each walking round. High mean measurements were obtained for GSM + UMTS 900 downlink varying between 1,165 and 2,075 μW/m^2. High levels were also obtained for UMTS 2100 downlink; 442 to 1,632 μW/m^2. Also LTE 800 downlink, GSM 1800 downlink, and LTE 2600 downlink were in the higher range of measurements. Hot spots were identified, for example close to a wall mounted base station yielding over 95,544 μW/m^2 and thus exceeding the exposimeter's detection limit. Almost all of the total measured levels were above the precautionary target level of 3-6 μW/m^2 as proposed by the BioInitiative Working Group in 2012. That target level was one-tenth of the scientific benchmark providing a safety margin either for children, or chronic exposure conditions. We compare the levels of RF radiation exposures identified in the present study to published scientific results reporting adverse biological effects and health harm at levels equivalent to, or below those measured in this Stockholm Central Railway Station project. It should be noted that these RF radiation levels give transient exposure, since people are generally passing through the areas tested, except for subsets of people who are there for hours each day of work.

Correspondence to: Dr Lennart Hardell, Department of Oncology, Faculty of Medicine and Health, Örebro University, SE-701 82 Örebro, Sweden
E-mail: lennart.hardell@regionorebrolan.se

Key words: electromagnetic fields, radiofrequency radiation, public exposure, base stations, exposimeter

Introduction

On 31 May 2011 the WHO International Agency for Research on Cancer (IARC) categorized the radiation fields from mobile phones, and from other devices that emit similar non-ionizing electromagnetic field (EMF) radiation in the frequency range 30 kHz to 300 GHz, as a Group 2B, i.e. a 'possible', human carcinogen (1,2). Nine years earlier IARC had also classified the electromagnetic fields from overhead electric power lines as a Group 2B carcinogen (3).

The IARC decision on mobile phones was based mainly on two sets of case-control human studies: the Hardell group of studies from Sweden (4-6) and the IARC Interphone study (7-9). Both provided complementary and generally mutually supportive evidence of increased risk for brain tumours, i.e. glioma and acoustic neuroma. Later published studies by us (10-13) and the French CERENAT study on glioma and meningioma published in 2014 (14) supported an increased risk for brain tumours and use of mobile phones. These results were further supported by a study on mice showing tumour-promoting effect from radiofrequency (RF) radiation at low to moderate levels (0.04 and 0.4 W/kg SAR), radiation well below exposure limits for users of mobile phones (15). Thus, implications of the study by Tillman *et al* (16) were successfully tested. It should be added that a long-term animal toxicity study at 900 MHz published in 1997 resulted in statistically significant increased lymphoma risk in mice (17).

Recently, a report was released from The National Toxicology Program (NTP) under the National Institutes of Health (NIH) in USA on the largest ever animal study on cell phone RF radiation and cancer (18). An increased incidence of glioma and malignant Schwannoma in the heart was found. Acoustic neuroma or vestibular Schwannoma is the same type of tumour as the one found in the heart, although benign.

The carcinogenicity findings evaluated by IARC in 2011 were related to personal wireless phone use, including mobile phones and DECT phones. The overall exposure including

ELECTROMAGNETIC BIOLOGY AND MEDICINE
https://doi.org/10.1080/15368378.2021.1881866

Taylor & Francis
Taylor & Francis Group

REVIEW

Genetic effects of non-ionizing electromagnetic fields

Henry Lai

Department of Bioengineering, University of Washington, Seattle, WA, USA

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.

ARTICLE HISTORY
Received 22 September 2020
Accepted 13 December 2020

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

Introduction

This is a review on studies on the genetic effects of non-ionizing electromagnetic fields (EMF). We will concentrate on two parts of the EMF spectrum which are common in our environment: static and extremely low-frequency electromagnetic fields (ELF-EMF) and radiofrequency radiation (RFR).

Studies are summarized in Supplements 1 (RFR) and 2 (static/ELF-EMF). Basically, there are two types of studies: genetic damages and gene expression. The research covers a wide area of biological systems: both in vitro and in vivo involving many animal and cell models, and various exposure conditions. First, a few words have to be said on the exposure set-ups used in these studies. It is relatively easy to set up a reliable exposure system for static and ELF-EMF. Most exposure systems used these studies are generally satisfactory. However, it is difficul to set up good exposure systems for RFR studies. In my opinion, most set-ups are relatively satisfactory, considering that there is no perfect guideline on what is a good system. However, preferably, incident power density and specific absorption rate should be provided in each study. These are generally lacking when telecommunication devices, such as cellular phones, are used in a study. It becomes difficul to compare the results of these studies with other studies using exposure systems. It is not totally without merit to use these devices for studies. If properly set up, these devices provide more realistic exposure parameters. A general problem is that some researchers generally showed ignorance on the independent variable, i.e., EMF, that they worked on.

Regarding biological measurements, with few exceptions, the researcher are generally knowledgeable in the methodology used. However, there are studies that showed that the researchers are not familiar with the methodology that they used in their studies. An example is the use of the "Comet assay" to determine DNA strand breaks. 31% of the studies listed in Supplements 1 and 2 used the "Comet assay". A few words have to be said on it. Different versions of the assay have been developed. These versions have different detection sensitivities and can be used to measure different aspects of DNA strand breaks. A comparison of data from experiments using different versions of the assay may be misleading. Another concern is that most of the 'comet assay' studies were carried out by experimenters who had no prior experience on the assay. My experience with the 'Comet assay' is that it is a very sensitive assay and requires great care in performing. Thus, different detection sensitivities could result from different

CONTACT Henry Lai hlai@uw.edu Department of Bioengineering,University of Washington, Seattle, WA 98195, USA
Supplemental data for this article can be accessed on the publisher's website.

J Cancer Sci Clin Ther 2021; 5 (2): 250-285 *DOI: 10.26502/jcsct.5079117*

Commentary

Aspects on the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2020 Guidelines on Radiofrequency Radiation

Lennart Hardell[1*], Mona Nilsson[2], Tarmo Koppel[3], Michael Carlberg[1]

[1]The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17, Örebro, Sweden

[2]Swedish Radiation Protection Foundation, Gredby 14, SE-178 92 Adelsö, Sweden

[3]Tallinn University of Technology, SOC353 Ehitajate tee 5, 19086 Tallinn, Estonia

[*]**Corresponding Author:** Lennart Hardell, The Environment and Cancer Research Foundation, Studievägen 35, SE 702 17, Örebro, Sweden

Received: 04 May 2021; **Accepted:** 10 May 2021; **Published**: 21 May 2021

Citation: Lennart Hardell, Mona Nilsson, Tarmo Koppel, Michael Carlberg. Aspects on the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2020 Guidelines on Radiofrequency Radiation. Journal of Cancer Science and Clinical Therapeutics 5 (2021): 250-285.

Abstract

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) published 2020 updated guidelines on radiofrequency (RF) radiation in the frequency range 100 kHz to 300 GHz. Harmful effects on human health and the environment at levels below the guidelines are downplayed although evidence is steadily increasing. Only thermal (heating) effects are acknowledged and therefore form the basis for the guidelines. Despite the increasing scientific evidence of non-thermal effects, the new ICNIRP guidelines are not lower compared with the previous levels. Expert groups from the WHO, the EU Commission and Sweden are to a large extent made up of members from ICNIRP, with no representative from the many scientists who are critical of the ICNIRP standpoint.

Keywords: EU; WHO; ICNIRP; 5G; Microwave radiation

Non-thermal Biological Effects of Microwaves

Igor Belyaev

List of Abbreviations - Anomalous viscosity time dependence (AVTD); blood-brain barrier (BBB); catalase (CAT); Digital Enhanced (former European) Cordless Telecommunications (DECT); circularly polarized (CP); continuous wave (CW); Digital Advanced Mobile Phone System (DAMPS); discontinuous transmission (DTX); electroencephalographic (EEG); electromagnetic field (EMF); embryonic stem (ES) cells; ethidium bromide (EtBr); extremely low frequency (ELF); Gaussian Minimum Shift Keying (GMSK); Ginkgo biloba (Gb); Global System for Mobile Communication (GSM); glutathione peroxidase (GSH-Px); International Commission for Non-Ionizing Radiation Protection (ICNIRP); linearly polarized (LP); malondialdehyde (MDA); micronucleus (MN) assay; microwaves (MWs); N-acetyl-beta-d-glucosaminidase (NAG); nitric oxide (NO); non-thermal (NT); ornithine decarboxylase (ODC); phorbol ester 12-myristate 13-acetate (PMA); phosphorylated H2AX histone (γ-H2AX); power density (PD); regional cerebral blood flow (rCBF); Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP); specific absorption rate (SAR); static magnetic field (SMF); superoxide dismutase (SOD); Time Division Multiple Access (TDMA); tumor suppressor p53 binding protein 1 (53BP1); ultraviolet (UV); Universal Mobile Telecommunications System (UMTS).

Abstract **- The aim of this paper is to overview the diverse biological effects of non-thermal microwaves (NT MWs) and complex dependence of these effects on various physical and biological parameters. Besides dependencies on frequency and modulation, the available data suggest dependencies of the NT MW effects on intermittence and coherence time of exposure, polarization, static magnetic filed, electromagnetic stray field, genotype, gender, physiological and individual factors, cell density during of exposure and indicate that duration of exposure may be not less important than power density (PD) for the NT MW effects. Further evaluation of these dependencies are needed for understanding the mechanisms by which NT MWs affect biological systems, planning in vivo and epidemiological studies, developing medical treatments, setting safety standards, and minimizing the adverse effects of MWs from mobile communication.**

Key words **- non-thermal effects of microwaves, mobile (cellular) phones.**

I. INTRODUCTION

Electromagnetic exposures vary in many parameters: power (specific absorption rate, incident power density), wavelength/frequency, near field - far field, polarization (linear, circular) continues wave (CW) and pulsed fields (pulse repetition rate, pulse width or duty cycle, pulse shape, pulse to average power, etc.), modulation (amplitude, frequency, phase, complex), static magnetic field (SMF) and electromagnetic stray field at the place of exposure, overall duration and intermittence of exposure (continuous, interrupted), acute and chronic exposures. With increased absorption of energy, so-called thermal effects of microwaves (MWs) are usually observed that deal with MW-induced heating. Specific absorption rate (SAR) or power density (PD) is a main determinate for the thermal MW effects. Many other physical parameters of exposure may be important for so-called non-thermal (NT) biological effects, which are induced by MWs at intensities well below any heating [1-11]. An important question is how these physical parameters should be taken into account in safety standards.

Most often, the current safety standards are based on the thermal effects of MWs obtained in short-term (acute) exposures. In some countries, such as Russia, the NT MW effects, especially those induced during prolonged (chronic) exposures, are accepted and taken into account for establishment of the national safety standards [10-12]. It should be stressed, that in contrast to the ICNIRP (International Commission for Non-Ionizing Radiation Protection) safety standards [13], which are based on the acute thermal effects of MWs, the standards adopted by the Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP) are based on the experimental data from chronic (up to 4 month) exposures of animals to MWs at various physical parameters including intensity, frequency and modulation, which were performed in the former Soviet Union and Russia [10-12]. Since establishment of the current safety standards, the situation with exposure of general population to MWs has been changed significantly. Nowadays, most part of population is chronically exposed to MW signals from various sources including mobile phones and base stations. These exposures are characterized by low intensities, varieties of signals, and long-term durations of exposure that are comparable with a lifespan. So far, the "dose" (accumulated absorbed energy that is measured in radiobiology as the dose rate multiplied by the exposure time) is not adopted for the MW exposures and SAR or PD is usually used for the guidelines. To what degree SAR/PD can be applied to the nowadays NT MW chronic exposures is not known and the current state of research demands reevaluation of the safety standards [12].

There are two main approaches to treat numerous data regarding the NT MW effects. The first one is based on the consideration of these effects dependent on various physical parameters and biological variables as has consistently been described in many experimental studies and will be partially reviewed in this paper. The second approach is based on neglecting or minimizing the experimentally observed NT MW effects based on the current state of theoretical physical science that is insufficient for comprehensive explanation of the NT MWs effects. As a result of such various treatments of

Igor Y. Belyaev, Ph.D., D.Sc. Department of Genetics, Microbiology and Toxicology The Arrhenius Laboratories for Natural Sciences Stockholm University S-106 91 Stockholm, Sweden Tel: +46-8-16 4108 FAX: +46-8-16 4315 Mob: +46-0739590339 E. mail: Igor.Belyaev@gmt.su.se

Radiofrequency radiation from nearby base stations gives high levels in an apartment in Stockholm, Sweden: A case report

LENNART HARDELL[1,2,4], MICHAEL CARLBERG[1,2] and LENA K. HEDENDAHL[2,3]

[1]Department of Oncology, Faculty of Medicine and Health, Örebro University, SE-701 82 Örebro; [2]The Environment and Cancer Research Foundation, SE-702 17 Örebro; [3]Independent Environment and Health Research Luleå, SE-972 53 Luleå, Sweden

Received November 16, 2017; Accepted February 22, 2018

DOI: 10.3892/ol.2018.8285

Abstract. Exposure to radiofrequency (RF) radiation was classified in 2011 as a possible human carcinogen, Group 2B, by the International Agency for Research on Cancer of the World Health Organisation. Evidence of the risk of cancer risk has since strengthened. Exposure is changing due to the rapid development of technology resulting in increased ambient radiation. RF radiation of sufficient intensity heats tissues, but the energy is insufficient to cause ionization, hence it is called non-ionizing radiation. These non-thermal exposure levels have resulted in biological effects in humans, animals and cells, including an increased cancer risk. In the present study, the levels of RF radiation were measured in an apartment close to two groups of mobile phone base stations on the roof. A total of 74,531 measurements were made corresponding to ~83 h of recording. The total mean RF radiation level was 3,811 μW/m^2 (range 15.2-112,318 μW/m^2) for the measurement of the whole apartment, including balconies. Particularly high levels were measured on three balconies and 3 of 4 bedrooms. The total mean RF radiation level decreased by 98% when the measured down-links from the base stations for 2, 3 and 4 G were disregarded. The results are discussed in relation to the detrimental health effects of non-thermal RF radiation. Due to the current high RF radiation, the apartment is not suitable for long-term living, particularly for children who may be more sensitive than adults. For a definitive conclusion regarding the effect of RF radiation from nearby base stations, one option would be to turn them off and repeat the measurements. However, the simplest and safest solution would be to turn them off and dismantle them.

Correspondence to: Professor Lennart Hardell, Department of Oncology, Faculty of Medicine and Health, Örebro University, 1 Fakultetsgatan, SE-701 82 Örebro, Sweden
E-mail: lennart.hardell@environmentandcancer.com

[4]*Present address:* The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17 Örebro, Sweden

Key words: radiofrequency radiation, microwaves, measurement, exposure, health, cancer

Introduction

The use of wireless digital technology has grown rapidly during the last couple of decades. While in use, mobile and cordless phones emit radiofrequency (RF) radiation. The brain is the main target of exposure to RF radiation with handheld wireless phones (mobile and cordless) (1,2). An increased risk for brain tumors has been of concern for a long time. In May 2011, RF radiation in the range 30-300 GHz could be categorized in Group 2B, i.e., a 'possible' human carcinogen, by the International Agency for Research on Cancer (IARC) of WHO (3,4). The decision was based mainly on case-control human studies on the use of wireless phones by the Hardell group in Sweden (mobile and cordless phones; DECT) and the IARC Interphone study (mobile phones), which showed an increased risk for brain and head tumours, i.e., glioma and acoustic neuroma (3-6), which has since been confirmed (7-10), resulting in a recommendation to upgrade IARC's 2011 classification of RF radiation to Group 1, a human carcinogen. This conclusion was published in our up-dated review in 2013 (11) using the so-called Hill viewpoints on the association or causation put forward at the height of the tobacco and lung cancer controversy (12).

Due to the increasing use of the wireless technology, environmental exposure to RF radiation has been increasing, but there has been no systematic study of ambient exposure. We have measured RF radiation at Stockholm Central Station (13) and the Stockholm Old Town in Sweden (14). The results generally exceeded the levels known to have adverse biological effects. By contrast, low levels were measured at certain places in the WHO building in Geneva (15).

We have measured RF radiation in an apartment with a central location at Östermalm in Stockholm. The apartment is located on the 6th floor, with a tower including a bedroom on the first floor of the tower (7th floor) and a conference room on the second and highest floor (8th) of the tower, at the same level as the roof of the building. The measurements did not involve any human subjects, and therefore no ethical permission was needed. We also discuss laboratory studies on RF-radiation and biological effects relative to the levels of RF in question. Of particular interest are the non-thermal levels of RF radiation and

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

LENNART HARDELL[1,2] and MICHAEL CARLBERG[1,2]

[1]Department of Oncology, University Hospital, SE-701 85 Örebro;
[2]The Environment and Cancer Research Foundation, SE 702 17 Örebro, Sweden

Received July 6, 2018; Accepted October 3, 2018

DOI: 10.3892/ijo.2018.4606

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.

Correspondence to: Dr Lennart Hardell, *Present address:* The Environment and Cancer Research Foundation, Studievägen 35, SE 702 17 Örebro, Sweden
E-mail: lennart_hardell@hotmail.com

Key words: National Toxicology Program study, carcinogenesis, radiofrequency radiation, glioma, acoustic neuroma, cancer

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

Microwaves from Mobile Phones Inhibit 53BP1 Focus Formation in Human Stem Cells More Strongly Than in Differentiated Cells: Possible Mechanistic Link to Cancer Risk

Eva Markovà,[1,2] Lars O.G. Malmgren,[3] and Igor Y. Belyaev[1,2,4]

[1]Department of Genetics, Microbiology and Toxicology, Stockholm University, Stockholm, Sweden; [2]Laboratory of Molecular Genetics, Cancer Research Institute, Bratislava, Slovak Republic; [3]MAX-lab, Lund University, Lund, Sweden; [4]Laboratory of Radiobiology, General Physics Institute, Russian Academy of Science, Moscow, Russia

Background: It is widely accepted that DNA double-strand breaks (DSBs) and their misrepair in stem cells are critical events in the multistage origination of various leukemias and tumors, including gliomas.

Objectives: We studied whether microwaves from mobile telephones of the Global System for Mobile Communication (GSM) and the Universal Global Telecommunications System (UMTS) induce DSBs or affect DSB repair in stem cells.

Methods: We analyzed tumor suppressor TP53 binding protein 1 (53BP1) foci that are typically formed at the sites of DSB location (referred to as DNA repair foci) by laser confocal microscopy.

Results: Microwaves from mobile phones inhibited formation of 53BP1 foci in human primary fibroblasts and mesenchymal stem cells. These data parallel our previous findings for human lymphocytes. Importantly, the same GSM carrier frequency (915 MHz) and UMTS frequency band (1947.4 MHz) were effective for all cell types. Exposure at 905 MHz did not inhibit 53BP1 foci in differentiated cells, either fibroblasts or lymphocytes, whereas some effects were seen in stem cells at 905 MHz. Contrary to fibroblasts, stem cells did not adapt to chronic exposure during 2 weeks.

Conclusions: The strongest microwave effects were always observed in stem cells. This result may suggest both significant misbalance in DSB repair and severe stress response. Our findings that stem cells are most sensitive to microwave exposure and react to more frequencies than do differentiated cells may be important for cancer risk assessment and indicate that stem cells are the most relevant cellular model for validating safe mobile communication signals.

Key words: 53BP1 foci, DNA double-strand breaks, microwaves, mobile phones, stem cells. *Environ Health Perspect* 118:394–399 (2010). doi:10.1289/ehp.0900781 available via *http://dx.doi.org/* [Online 23 October 2009]

The intensity levels of exposure to microwaves (MWs) from mobile telephones are lower than the International Commission on Non-ionizing Radiation Protection (ICNIRP) standards, which are based on thermal effects of acute MW exposures (ICNIRP 1998). However, effects of prolonged exposure to nonthermal (NT) MWs at intensities comparable with those of mobile phones have also been observed in many studies that indicate a relationship between NT MW exposure and permeability of the brain–blood barrier (Nittby et al. 2008), cerebral blood flow (Huber et al. 2005), stress response (Blank and Goodman 2004), and neuronal damage (Salford et al. 2003). The data obtained by the comet assay (Diem et al. 2005; Lai and Singh 1997) and the micronuclei assay (d'Ambrosio et al. 2002; Trosic et al. 2002; Zotti-Martelli et al. 2005) imply possible genotoxic effects of NT MWs, whereas other studies did not support this genotoxicity (Meltz 2003). Experimental data have indicated that the NT MW effects occur depending on several physical parameters, including carrier frequency, polarization, modulation, and intermittence (Belyaev 2005a). Differences in these physical parameters and biological variables, including genetic background and physiologic state, may explain various outcomes of studies with NT MWs (Belyaev 2005b; Huss et al. 2007).

A recent review of available epidemiologic studies concluded that the use of mobile phones for > 10 years is associated with increased risk of ipsilateral gliomas and acoustic neurinomas (Hardell et al. 2008). For a long time stem cells have been considered an important cellular target for origination of cancer—both tumors and leukemia (Feinberg et al. 2006; Soltysova et al. 2005). Gliomas are believed to originate from stem cells in the brain (Altaner 2008). DNA double-strand breaks (DSBs) and their misrepair are critical molecular events resulting in chromosomal aberrations, which have often been associated with origination of various leukemias and tumors, including gliomas (Fischer and Meese 2007). Only one study on possible MW-induced DSBs in stem cells is available (Nikolova et al. 2005). Surprisingly, the data obtained in that study by the neutral comet assay suggested that prolonged exposure time abolished the DSB formation observed at the shorter exposure time. Furthermore, the neutral comet assay has limited applicability to detect DSBs because similar increases in comet tails may be also caused by nongenotoxic effects that imply changes in chromatin conformation, such as relaxation of DNA loops (Belyaev et al. 1999).

Several proteins involved in DSB repair, such as phosphorylated histone 2A family member X (γ-H2AX) and tumor suppressor TP53 binding protein 1 (53BP1), have been shown to produce discrete foci that colocalize to DSBs, referred to as DNA repair foci (Kao et al. 2003; Sedelnikova et al. 2002). Analysis of DNA repair foci is currently accepted as the most sensitive and specific technique for measuring DSBs in untreated cells, as well as in cells exposed to cytotoxic agents (Bocker and Iliakis 2006; Bonner et al. 2008). By analysis of the DNA repair foci in normal human fibroblasts, we were able to detect DSBs induced by a very low dose of ionizing radiation, 1 cGy, which results in only 0.4 DSB/cell on average (Markovà et al. 2007). We have also used this technique to analyze 53BP1/γ-H2AX foci in human lymphocytes exposed to MWs from Global System for Mobile Communication (GSM)/Universal Global Telecommunications System (UMTS) phones (Belyaev et al. 2005, 2009; Markovà et al. 2005). We have found that MW exposure inhibited formation of endogenous 53BP1/γ-H2AX foci (Belyaev et al. 2005, 2009; Markovà et al. 2005). This inhibition might be caused by a decrease in accessibility of DSBs to proteins because of stress-induced chromatin condensation (Belyaev et al. 2009). Inability to form DNA repair foci has been correlated to radiosensitivity, genomic instability, and other

Address correspondence to I.Y. Belyaev, Department of Genetics, Microbiology and Toxicology, Stockholm University, S-106 91 Stockholm, Sweden. Telephone: 46-8-16-41-08. Fax: 46-8-6129552. E-mail: Igor.Belyaev@gmt.su.se

Supplemental Material is available online (doi:10.1289/ehp.0900781.S1 via http://dx.doi.org/).

We thank C. Altaner for valuable discussions at the initial stages of this study and R. Sarimov for help with statistical analysis.

This study was supported by the Swedish Council for Working Life and Social Research, Swedish Animal Welfare Agency, Swedish Radiation Protection Authority, VEGA Grant Agency (2/0167/08) of the Slovak Republic, and National Scholarship Program of the Slovak Republic.

The authors declare they have no competing financial interests.

Received 10 March 2009; accepted 22 October 2009.

scientific reports

Check for updates

OPEN

Changes in the excitability of primary hippocampal neurons following exposure to 3.0 GHz radiofrequency electromagnetic fields

Ibtissam Echchgadda[1]✉, Jody C. Cantu[2], Gleb P. Tolstykh[2], Joseph W. Butterworth[2], Jason A. Payne[1] & Bennett L. Ibey[1]

Exposures to radiofrequency electromagnetic fields (RF-EMFs, 100 kHz to 6 GHz) have been associated with both positive and negative effects on cognitive behavior. To elucidate the mechanism of RF-EMF interaction, a few studies have examined its impact on neuronal activity and synaptic plasticity. However, there is still a need for additional basic research that further our understanding of the underlying mechanisms of RF-EMFs on the neuronal system. The present study investigated changes in neuronal activity and synaptic transmission following a 60-min exposure to 3.0 GHz RF-EMF at a low dose (specific absorption rate (SAR) < 1 W/kg). We showed that RF-EMF exposure decreased the amplitude of action potential (AP), depolarized neuronal resting membrane potential (MP), and increased neuronal excitability and synaptic transmission in cultured primary hippocampal neurons (PHNs). The results show that RF-EMF exposure can alter neuronal activity and highlight that more investigations should be performed to fully explore the RF-EMF effects and mechanisms.

Effects of exposure to radiofrequency electromagnetic fi lds (RF-EMFs, 100 kHz to 6 GHz) at low levels (whole body specific absorption rate (wbSAR) ≤ 4 W/kg) has been linked to changes in cognitive function[1,2]. While still debated because of lack of matching replications, both detrimental and benefic al changes in memory, learning, and task performance due to RF-EMF exposures have been reported[3–20]. These effects were shown to depend on exposure duration (either short-term or chronic) and field intensity.

Neuronal activity and plasticity, which play a central role in cognitive function such as learning and memory[21,22], have been examined in cultured neuronal cells to investigate low-level RF-EMF underlying cellular mechanisms of interaction. El Khoueiry et al. reported a dose-dependent decrease in neurons electrical activity during 15-min exposures to 1800 MHz RF-EMF signals. Using 60-electrode multielectrode arrays (MEAs), the group measured a dose-dependent decrease in spontaneous bursting rates in cultured cortical neurons during both pulse-modulated Global System for Mobile Communication (GSM) and continuous wave (CW) RF-EMF exposures at SAR ranging from 0.01 to 9.2 W/kg[23]. Moreover, Xu et al. showed a decrease in excitability of cultured hippocampal neurons demonstrated by a reduction in the amplitude of α-amino-3-hydroxy-5-methyl-4-soxazole propionic acid (AMPA) miniature excitatory postsynaptic currents (mEPSCs) following a chronic exposure to 1800 MHz GSM at an average SAR of 2.4 W/kg for 15 min per day for 8 days[24]. They reported that the exposure also resulted in a slight reduction in the expression of postsynaptic density 95 and a decrease in the number of spines[24,25]. In the same line of changes in components of synaptic plasticity, Chen et al. also reported inhibition of neurite outgrowth of embryonic neuronal stem cells differentiated neurons following a continuous 3-day exposure to 1800 MHz at average SAR of 4.0 W/kg[26]. The authors reported that the exposure, however, did not affect cell apoptosis, proliferation, and cell cycle[26]. A decrease in number of neurites has also been observed with an extended exposure, up to 6 days, of developing rat primary cortical neurons and murine SN56 cholinergic cell line when exposed to 900 MHz continuous GSM-modulated EMF at a lower dose of 1.0 W/kg[27].

[1]Air Force Research Laboratory, 711Th Human Performance Wing, Airman Systems Directorate, Bioeffects Division, Radio Frequency Bioeffects Branch, JBSA Fort Sam Houston, 4141 Petroleum Road, San Antonio, TX 78234, USA. [2]General Dynamics Information Technology, JBSA Fort Sam Houston, 4141 Petroleum Road, San Antonio, TX 78234, USA. ✉email: ibtissam.echchgadda.1@us.af.mil

Environmental Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Environmental Research

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

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

L. Falcioni, L. Bua, E. Tibaldi, M. Lauriola, L. De Angelis, F. Gnudi, D. Mandrioli, M. Manservigi, F. Manservisi, I. Manzoli, I. Menghetti, R. Montella, S. Panzacchi, D. Sgargi, V. Strollo, A. Vornoli, F. Belpoggi*

Cesare Maltoni Cancer Research Center, Ramazzini Institute, Castello di Bentivoglio, via Saliceto 3, Bentivoglio, 40010 Bologna, Italy

ARTICLE INFO

Keywords:
RF
Sprague-Dawley rats
Life-span bioassay
Mobile phone
Carcinogenicity

ABSTRACT

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.

1. Introduction

Early warnings on the potential carcinogenic risks of mobile phone radiofrequency radiation (RFR) raised in the early 2000 when, for the first time, it was published that people using mobile phones had a significant increased risk to develop vestibular Schwannoma and brain tumors (Hardell et al., 2003, 2002). In 2011, the International Agency for Research on Cancer (IARC) classified RFR as possible human carcinogen (Group 2B) based on limited evidence both in humans and experimental animals (Baan et al., 2011; IARC, 2013). Two epidemiological case-control studies resulted more informative for the IARC evaluation, showing that the risk to develop brain tumors and vestibular Schwannoma was increased in people with the highest cumulative use of mobile phones, in people who had used mobile phones on the

* Corresponding author.
E-mail address: belpoggif@ramazzini.it (F. Belpoggi).

https://doi.org/10.1016/j.envres.2018.01.037
Received 9 October 2017; Received in revised form 19 December 2017; Accepted 23 January 2018

frontiers in Public Health

REVIEW
published: 17 August 2021
doi: 10.3389/fpubh.2021.691880

Effects of Radiofrequency Electromagnetic Radiation on Neurotransmitters in the Brain

Cuicui Hu[1,2], *Hongyan Zuo*[2*] *and Yang Li*[1,2*]

[1] *Anhui Medical University, Academy of Life Sciences, Hefei, China,* [2] *Department of Experimental Pathology, Beijing Institute of Radiation Medicine, Beijing, China*

With the rapid development of electronic information in the past 30 years, technical achievements based on electromagnetism have been widely used in various fields pertaining to human production and life. Consequently, electromagnetic radiation (EMR) has become a substantial new pollution source in modern civilization. The biological effects of EMR have attracted considerable attention worldwide. The possible interaction of EMR with human organs, especially the brain, is currently where the most attention is focused. Many studies have shown that the nervous system is an important target organ system sensitive to EMR. In recent years, an increasing number of studies have focused on the neurobiological effects of EMR, including the metabolism and transport of neurotransmitters. As messengers of synaptic transmission, neurotransmitters play critical roles in cognitive and emotional behavior. Here, the effects of EMR on the metabolism and receptors of neurotransmitters in the brain are summarized.

Keywords: EMR, brain, neurotransmitter, metabolism, transmission, receptor

OPEN ACCESS

Edited by:
Lei Zhang,
Third Military Medical University, China

Reviewed by:
Yael Stein,
Hadassah Medical Center, Israel
Sareesh Naduvil Narayanan,
Ras al-Khaimah Medical and Health Sciences University, United Arab Emirates
Gui Rong Ding,
Fourth Military Medical University, China

***Correspondence:**
Hongyan Zuo
zuohy2005@126.com
Yang Li
leeyoung109@hotmail.com

Specialty section:
This article was submitted to Radiation and Health, a section of the journal Frontiers in Public Health

Received: *07 April 2021*
Accepted: *13 July 2021*
Published: *17 August 2021*

Citation:
Hu C, Zuo H and Li Y (2021) Effects of Radiofrequency Electromagnetic Radiation on Neurotransmitters in the Brain. Front. Public Health 9:691880. doi: 10.3389/fpubh.2021.691880

BACKGROUND

Electromagnetic radiation (EMR) is closely related to human life and originates from various electrical systems, such as mobile phones, microwave ovens, communication base stations, high-voltage lines, electronic instruments and other electromagnetic equipment. EMR produces various electromagnetic waves of different frequencies, resulting in the increasing EMR intensity in human living spaces. The high-frequency waves such as cosmic, gamma and X-rays, have enough energy to cause ionization. Non-ionizing electromagnetic waves, including ultraviolet, visible region, infrared, microwave, and radio waves are frequently used in daily life, especially radiofrequency electromagnetic fields (RF-EMFs, 30 kHz-300 GHz) for communications, and extremely low-frequency EMFs (ELF-EMFs, 3 Hz-3 kHz) generated by electricity. RF is also commonly referred to as microwave (MW) radiation. The impact of EMR on human health has also gradually attracted attention, and the modulation of brain functional connectivity was observed in human body (1–3). This review summarizes the effects of RF-EMF on neurotransmitters in the brain.

The effects of EMR on body systems might depend on the frequency, intensity and power of radiation, so the parameters of EMR provide a challenge for a literature review. Specific absorption rate (SAR) measures the rate of energy absorbed by the human body when exposed to electromagnetic fields between 100 kHz and 10 GHz. With the unit of watt per kilogram (W/kg), SAR reflects the power absorbed per mass of tissue. The SAR value depends on the frequency, incident direction, E-polarization direction, and the structure of different tissues.So far, the SAR values range from 10^{-4} to 35 W/kg in those reported studies on the bioeffects of microwave radiation.

Review Article

Lennart Hardell* and Tarmo Koppel

Electromagnetic hypersensitivity close to mobile phone base stations – a case study in Stockholm, Sweden

https://doi.org/10.1515/reveh-2021-0169
Received December 9, 2021; accepted February 13, 2022;
published online March 2, 2022

Abstract: A previously healthy worker developed symptoms assigned to electromagnetic hypersensitivity (EHS) after moving to an office with exposure to high levels of anthropogenic electromagnetic fields (EMFs). These symptoms consisted of e.g. headache, arthralgia, tinnitus, dizziness, memory loss, fatique, insomnia, transitory cardiovascular abnormalities, and skin lesions. Most of the symptoms were alleviated after 2 weeks sick leave. The highest radiofrequency (RF) field level at the working place was 1.72 V/m (7,852 μW/m^2). Maximum value for extremely low frequency electromagnetic field (ELF-EMF) from electric power at 50 Hz was measured to 285 nT (mean 241 nT). For electric train ELF-EMF at 16.7 Hz was measured to 383 nT (mean 76 nT). Exposure to EMFs at the working place could be the cause for developing EHS related symptoms. The association was strengthened by the symptom reduction outside the working place.

Keywords: electromagnetic hypersensitivity; EMF; radiofrequency radiation; symptoms.

Introduction

Exposure to extremely low frequency (ELF) electromagnetic fields (EMF) and radiofrequency (RF) EMF is in most cases involuntary and unknown to people. Both ELF-EMF and RF-EMF have been evaluated by IARC to be possible human carcinogens, Group 2B [1–3]. In fact EMFs should be regarded to be environmental pollutants that do not smell, have no taste and are invisible.

***Corresponding author: Lennart Hardell,** The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17, Örebro, Sweden, E-mail: lennart.hardell@environmentandcancer.com
Tarmo Koppel, Tallinn University of Technology, Tallinn, Estonia, E-mail: tarmo.koppel@taltech.ee

Already in the 1970s the 'microwave syndrome' was described in the former Soviet Union [4]. Persons working with radar or radio equipment reported symptoms of fatigue, headache, dizziness, disturbed sleep, concentration and memory problems.

In the 1980s similar symptoms were reported among Swedish persons working in front of cathode ray tube monitors [5]. In Finns such symptoms were attributed to exposure to EMF [6]. This syndrome was termed electromagnetic hypersensitivity (EHS), although still without an International Classification of Diseases (ICD-code) [7].

EHS consists of a wide range of different symptoms that may vary from person to person. EMF sensitivity varies among individuals from mild to severe. The prevalence has been reported to be 1.5% in Sweden [8], 3.2% in California [9], 5% in Switzerland [10], and 13% in Taiwan [11].

We report here on a person who developed symptoms consistent with those described among EHS subjects. The symptoms developed at a work place with exposure to EMFs. Our hypothesis is that the symptoms may be attributed to that exposure. We obtained informed consent by the person to publish the symptoms and work history anonymously.

Methods

The subject attributed the development of EHS symptoms to her office room where she had been working one year since April 2018 for a total of 183 working days. As the source of the adverse health effects was unknown, the investigators devised a broad spectrum approach for EMF measurements, to include all possible sources of EMFs.

The room was thoroughly measured encompassing different types of electromagnetic fields, including:

- Extremely low frequency (ELF) magnetic field (MF)
- Intermediate frequency (IF) magnetic field (MF)
- Radiofrequency (RF) electromagnetic field.

Three types of measurements approaches were utilized characterizing:

- Spatial field distribution
- Temporal field dynamics
- Spectrum analysis of EMF

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.

Environmental Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Environmental Research

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

Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102)☆

Anthony B. Miller[a,*], L. Lloyd Morgan[b], Iris Udasin[c], Devra Lee Davis[d,e]

[a] Dalla Lana School of Public Health, University of Toronto, Canada
[b] Environmental Health Trust, Berkeley, CA, United States
[c] Rutgers University School of Public Health, United States
[d] Environmental Health Trust, Teton Village, WY, United States
[e] Hebrew University of Jerusalem, Israel

ARTICLE INFO

Keywords:
Brain cancer
Vestibular schwannoma
Salivary gland tumor
Electric hypersensitivity
Glioma
Meningioma
Radio frequency fields
Cell phones
Mobile phones

ABSTRACT

Epidemiology studies (case-control, cohort, time trend and case studies) published since the International Agency for Research on Cancer (IARC) 2011 categorization of radiofrequency radiation (RFR) from mobile phones and other wireless devices as a possible human carcinogen (Group 2B) are reviewed and summarized. Glioma is an important human cancer found to be associated with RFR in 9 case-control studies conducted in Sweden and France, as well as in some other countries. Increasing glioma incidence trends have been reported in the UK and other countries. Non-malignant endpoints linked include acoustic neuroma (vestibular Schwannoma) and meningioma. Because they allow more detailed consideration of exposure, case-control studies can be superior to cohort studies or other methods in evaluating potential risks for brain cancer. When considered with recent animal experimental evidence, the recent epidemiological studies strengthen and support the conclusion that RFR should be categorized as carcinogenic to humans (IARC Group 1). Opportunistic epidemiological studies are proposed that can be carried out through cross-sectional analyses of high, medium, and low mobile phone users with respect to hearing, vision, memory, reaction time, and other indicators that can easily be assessed through standardized computer-based tests. As exposure data are not uniformly available, billing records should be used whenever available to corroborate reported exposures.

1. Introduction

With rapidly increasing applications for wireless devices targeting populations of all ages, exposures to the associated radiofrequency radiation (RFR) are increasing in number and diversity. Radiation sources include communications devices such as mobile (cell) or cordless phones, laptops and tablets, baby monitors, wearable devices and associated infrastructure (e.g. routers, antennae on towers, and distributed antennae systems (DAS) that can employ directional couplers or wireless amplifiers to enhance accessibility). Thus, the technology entails direct and growing personal exposures to an expanding array of wireless transmitting devices (WTDs).

In 2011, a Working Group of the World Health Organization's International Agency for Research on Cancer (IARC) classified RFR as a possible human carcinogen (Group 2B) (IARC, 2013). In this paper we review the human epidemiology and some other relevant studies published since the IARC Working Group meeting.

1.1. Wireless phone types

The principal sources of exposure of humans to RFR are cell and cordless phones. The radiated power and technologies for cell phones have evolved over the years, as summarized in Table 1 (Hardell and Carlberg, 2015).

2. Case-control studies; glioma

Aydin et al. (2011) reported the results of CEFALO, a multicenter

☆ This paper was prepared for and revised with the Epidemiology Working Group of the Expert Forum: Wireless Radiation and Human Health at the Hebrew University, January 23–26, 2017. sponsored by the Israel Institute for Advanced Study and Environmental Health Trust, with support from the U.S. National Institutes of Health/ National Institute of Environmental Health Sciences and Dr. Lucy R. Wiletzky.

* Corresponding author.
E-mail addresses: ab.miller@utoronto.ca (A.B. Miller), lloyd.l.morgan@gmail.com (L.L. Morgan), iu22@eohsi.rutgers.edu (I. Udasin), ddavis@ehtrust.org (D.L. Davis).

https://doi.org/10.1016/j.envres.2018.06.043
Received 5 September 2017; Received in revised form 14 June 2018; Accepted 20 June 2018

Environmental Research 214 (2022) 113851

Contents lists available at ScienceDirect

Environmental Research

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

Evidence for a health risk by RF on humans living around mobile phone base stations: From radiofrequency sickness to cancer

A. Balmori [1]

C/ Rigoberto Cortejoso, 14 47014, Valladolid, Spain

ARTICLE INFO

Keywords:
Base station
Cell tower
Health
Mast
RF radiation
Microwave syndrome
Radar
Radio antennas

ABSTRACT

The objective of this work was to perform a complete review of the existing scientific literature to update the knowledge on the effects of base station antennas on humans. Studies performed in real urban conditions, with mobile phone base stations situated close to apartments, were selected. Overall results of this review show three types of effects by base station antennas on the health of people: radiofrequency sickness (RS), cancer (C) and changes in biochemical parameters (CBP). Considering all the studies reviewed globally (n = 38), 73.6% (28/38) showed effects: 73.9% (17/23) for radiofrequency sickness, 76.9% (10/13) for cancer and 75.0% (6/8) for changes in biochemical parameters. Furthermore, studies that did not meet the strict conditions to be included in this review provided important supplementary evidence. The existence of similar effects from studies by different sources (but with RF of similar characteristics), such as radar, radio and television antennas, wireless smart meters and laboratory studies, reinforce the conclusions of this review. Of special importance are the studies performed on animals or trees near base station antennas that cannot be aware of their proximity and to which psychosomatic effects can never be attributed.

1. Introduction

During the last few decades, hundreds of thousands of mobile phone base stations and other types of wireless communications antennas have been installed around the world, in cities and in nature, including protected natural areas, in addition to pre-existing antennas (television, radio broadcasting, radar, etc.). Only the aesthetic aspects or urban regulations have been generally considered in this deployment, while the biological, environmental and health impacts of the associated non-ionizing electromagnetic radiation emissions have not been assessed so far. Therefore, the effects on humans living around these anthropogenic electromagnetic field sources (antennas) have not been considered.

In France, there is a significant contribution of mobile phone base stations in the exposure to radiofrequency electromagnetic fields (RF-EMF) of urban citizens living nearby (De Giudici et al., 2021). Some studies from India indicate that more than 15% of people have levels of EMF strength above 12 V/m due to their proximity to antennas (Premlal and Eldhose, 2017). Exposure estimates have shown that RF-EMF from mobile telephone systems is stronger in urban than in rural areas. For instance, in Sweden the levels of RF radiation have increased considerably in recent years, both outdoor and indoor, due to new telecommunication technologies, and the median power density measured for RF fields between 30 MHz and 3 GHz was 16 $\mu W/m^2$ in rural areas, 270 $\mu W/m^2$ in urban areas and 2400 $\mu W/m^2$ in city areas (Hardell et al., 2018). Total exposure varies not only between urban and rural areas but also, depending on residential characteristics, between different floors of a building, with a tendency for building exposure to increase at higher floors (Breckenkamp et al., 2012).

Over the past five decades, and more intensively since the beginning of this century, many studies and several reviews have been published on the effects of anthropogenic electromagnetic radiation on humans living around the antennas. The first studies were carried out with radio and television antennas, investigating increases in cancer and leukaemia (Milham, 1988; Maskarinec et al., 1994; Hocking et al., 1996; Dolk et al., 1997a, 1997b; Michelozzi et al., 1998; Altpeter et al., 2000), as well as around radars (Kolodynski and Kolodynska, 1996; Goldsmith, 1997).

Regarding base station antennas, there are scientific discrepancies in their effects: some studies concluded that there are no health-related effects (e.g. Augner and Hacker, 2009; Blettner et al., 2009; Röösli et al., 2010; Baliatsas et al., 2016) whereas others found increases in cancer and other health problems in humans living around antennas (e.g. Santini et al., 2002; Navarro et al., 2003; Bortkiewicz et al., 2004;

E-mail address: abalmorimartinez@gmail.com.
[1] Independent researcher

https://doi.org/10.1016/j.envres.2022.113851
Received 15 April 2022; Received in revised form 26 June 2022; Accepted 5 July 2022
Available online 14 July 2022

Science of the Total Environment xxx (2011) xxx–xxx

Contents lists available at ScienceDirect

Science of the Total Environment

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

Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil ☆

Adilza C. Dode [a,b,e,*], Mônica M.D. Leão [c], Francisco de A.F. Tejo [d], Antônio C.R. Gomes [e], Daiana C. Dode [e,f], Michael C. Dode [e], Cristina W. Moreira [b], Vânia A. Condessa [b], Cláudia Albinatti [b], Waleska T. Caiaffa [g]

[a] Minas Methodist University Center Izabela Hendrix, Belo Horizonte City, Minas Gerais State, Brazil
[b] Municipal Government of Belo Horizonte, Municipal Health Department, Belo Horizonte City, Minas Gerais State, Brazil
[c] UFMG—Universidade Federal de Minas Gerais-Belo Horizonte, Environmental and Sanitary Engineering Department, Belo Horizonte City, Minas Gerais State, Brazil
[d] UFCG—Universidade Federal de Campina Grande, Center of Electrical Engineering and Informatics, Academic Unit of Electrical Engineering, Paraíba State, Brazil
[e] MRE Engenharia (Electromagnetic Radiations Measurement—Engineering), Belo Horizonte City, Minas Gerais State, Brazil
[f] Faculty of Medical Sciences, Medicine-Belo Horizonte, Belo Horizonte City, Minas Gerais State, Brazil
[g] UFMG—Universidade Federal de Minas Gerais-Belo Horizonte, Urban Health Observatory, Belo Horizonte City, Minas Gerais State, Brazil

ARTICLE INFO

Article history:
Received 14 January 2011
Received in revised form 25 May 2011
Accepted 25 May 2011
Available online xxxx

Keywords:
Assessment and management of impacts and environmental risks
Non-ionizing electromagnetic radiation
Public health
Radio base station
Environmental electromagnetic pollution
Environmental electromagnetic field monitoring

ABSTRACT

Pollution caused by the electromagnetic fields (EMFs) of radio frequencies (RF) generated by the telecommunication system is one of the greatest environmental problems of the twentieth century. The purpose of this research was to verify the existence of a spatial correlation between base station (BS) clusters and cases of deaths by neoplasia in the Belo Horizonte municipality, Minas Gerais state, Brazil, from 1996 to 2006 and to measure the human exposure levels to EMF where there is a major concentration of cellular telephone transmitter antennas. A descriptive spatial analysis of the BSs and the cases of death by neoplasia identified in the municipality was performed through an ecological–epidemiological approach, using georeferencing. The database employed in the survey was composed of three data banks: 1. death by neoplasia documented by the Health Municipal Department; 2. BSs documented in ANATEL ("Agência Nacional de Telecomunicações": 'Telecommunications National Agency'); and 3. census and demographic city population data obtained from official archives provided by IBGE ("Instituto Brasileiro de Geografia e Estatística": 'Brazilian Institute of Geography and Statistics'). The results show that approximately 856 BSs were installed through December 2006. Most (39.60%) of the BSs were located in the "Centro-Sul" ('Central-Southern') region of the municipality. Between 1996 and 2006, 7191 deaths by neoplasia occurred and within an area of 500 m from the BS, the mortality rate was 34.76 per 10,000 inhabitants. Outside of this area, a decrease in the number of deaths by neoplasia occurred. The greatest accumulated incidence was 5.83 per 1000 in the Central-Southern region and the lowest incidence was 2.05 per 1000 in the Barreiro region. During the environmental monitoring, the largest accumulated electric field measured was 12.4 V/m and the smallest was 0.4 V/m. The largest density power was 40.78 μW/cm^2, and the smallest was 0.04 μW/cm^2.

1. Introduction

Mobile phone radio base stations (RBSs) are now found in cities and communities worldwide. They can be found near or even on top of homes, schools, hospitals, daycare centers and offices. In Brazil, the number of mobile phone users is estimated to be over 200 million and there are more than 5 billion users worldwide. In the municipality of Belo Horizonte, the capital of the state of Minas Gerais, there are approximately 1000 base stations (BSs) with 128.77 accesses by mobile phones per 100 inhabitants and in Brazil, there are 49,979 BSs licensed through April 2011 (ANATEL, 2011).

The non-ionizing electromagnetic radiation from the BSs is of low intensity compared to the current guidelines on human exposure limits. However, its emission is continuous. This raises concerns as to whether the health and well-being of people living or working close to the BSs are at risk Khurana et al., 2010; Alanko et al., 2008.

The *emission* of a BS is usually described by its effectively radiated power in watts (W), which describes the total amount of radiation emitted by the antenna of the BS. Their intensity, called the power density, is commonly measured in milliwatts per square centimeter (mW/cm^2) or microwatt per square centimeter (μW/cm^2) and it expresses the power per unit area impinging normally to the external surface of the subject. The *immission* (absorption) of the subject is measured by the specific absorption rate (SAR), which is reported in

☆ All the authors declare that they have no conflicts of interest.

* Corresponding author at: Rua Desembargador Assis Rocha, 279, Bairro Belvedere, 30320-250, Belo Horizonte (MG), Brazil. Tel.: +55 031 3286 1892.
E-mail addresses: adilzadode@terra.com.br (A.C. Dode), monica@desa.ufmg.br (M.M.D. Leão).

0048-9697/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.scitotenv.2011.05.051

Clinical Biochemistry xxx (2011) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Clinical Biochemistry

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

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

Hormones Department, Medical Research Division, National Research Centre, Cairo, Egypt

ARTICLE INFO

Article history:
Received 9 December 2010
received in revised form 2 November 2011
accepted 6 November 2011
Available online xxxx

Keywords:
Mobiles
Base stations
Radio frequency radiation
Hormone profiles

ABSTRACT

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 with human's hormone profiles.

Design and methods: All volunteers' samples were collected for hormonal analysis.

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

Conclusion: The present study revealed that high RFR effects on pituitary–adrenal axis.

Introduction

Because of the increase in the usage of wireless communication devices of mobile phones in recent years, there is an anxious concern on the possible hazardous effects of prolonged exposure to radio frequency radiation (RFR) [1]. In considering the biological effects of RFR, the intensity and frequency of the radiation and exposure duration are important determinants of the responses.

It has been reported that exposure to RFR could affect the nervous system [2]. Hardell et al. found that cell phone users had an increased risk of malignant gliomas [3]. Subjecting human spermatozoa to RFR showed decrease in sperms motility and vitality and increase in DNA fragmentation [4]. The authors hypothesize that the high sporadic incidence of the clinical symptoms of the autoimmune multiple Sclerosis disease [5] may be a result of long exposure to RFR from mobiles.

This study is concerned with assessing the effect of RFR emitted from mobile phones and base stations on human hormone profiles, with anticipation to offer recommendations to assure health care and safety for humans continuously exposed to radio frequency radiation.

Design and methods

Study subjects

This study was conducted for 6 years on 82 mobile phone volunteers with age ranges 14–22 years ($n=41$) and 25–60 years ($n=41$). Those users were divided into three subgroups according to the time of their exposure to RFR: (weak $n=19$), (moderate $n=9$), and (strong $n=13$) per day, in addition to 20 negative control subjects.

On the other hand, volunteers exposed to RFR emitted from base stations ($n=34$) were selected with age ranges 14–22 years ($n=17$), and 25–60 years ($n=17$) and living at distances 20–100 m and 100–500 m apart from the base station. Additional 10 subjects of each age range living at a distance more than 500 m apart from the base station were considered as negative control group.

The source of the RFR (base stations or mobile phones) was GSM-950 MHz magnetic field and the ICNIRP-Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic field (up to 300 GHz) (International Commission on Non-Ionizing Radiation Protection). The present study was approved by the Ethics Committee of National Research Centre.

Volunteers inclusion criteria

Volunteers participated in the study fulfilled the following inclusion criteria: age 14–60 years, mobile phone users, or living at distances 20–100 m and 100–500 m apart from the base station.

* Corresponding author at: Hormones Department, Medical Research Division, National Research Centre, Cairo, 12622, Egypt. Fax: +20 2 33370931.
E-mail address: gysi_pharma@yahoo.com (E.F. Eskander).

0009-9120/$ – see front matter © 2011 The Canadian Society of Clinical Chemists. Published by Elsevier Inc. All rights reserved.
doi:10.1016/j.clinbiochem.2011.11.006

Please cite this article as: Eskander EF, et al, How does long term exposure to base stations and mobile phones affect human hormone profiles?, Clin Biochem (2011), doi:10.1016/j.clinbiochem.2011.11.006

ELECTROMAGNETIC BIOLOGY AND MEDICINE

http://informahealthcare.com/ebm
ISSN: 1536-8378 (print), 1536-8386 (electronic)

Electromagn Biol Med, 2014; 33(3): 206–210
 DOI: 10.3109/15368378.2013.801352

informa healthcare

ORIGINAL ARTICLE

Health effects of living near mobile phone base transceiver station (BTS) antennae: a report from Isfahan, Iran

Daryoush Shahbazi-Gahrouei, Mojtaba Karbalae, Habib allah Moradi, and Milad Baradaran-Ghahfarokhi

Department of Medical Physics and Medical Engineering, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran

Abstract

Background: In recent years, by tremendous use of mobile phone telecommunication, a growing concern about the possible health hazards has increased greatly among public and scientists. The mobile phone exposure has been shown to have many effects upon the immune functions, stimulating hormones, mammalian brain, sperm motility and morphology, and neurological pathologies syndrome. The aim of this study was to find out the psychological and psychobiological reactions of the people who are living near mobile phone base transceiver stations (BTS) antenna, in Isfahan, Iran. *Materials and methods*: A cross-sectional study on 250 randomly selected inhabitants (133 women and 117 men) was performed in October 2012 till November 2012. The inhabitants were requested to complete a standardized questionnaire that focused on the relevant psychological and psychobiological reactions parameters. A computer program (SPSS version16.0, Chicago, IL) was used for statistical analysis using the Chi-square test with Yates correction. All the data were tested using a criterion level of $p = 0.05$. *Results*: The results showed that most of the symptoms such as nausea, headache, dizziness, irritability, discomfort, nervousness, depression, sleep disturbance, memory loss and lowering of libido were statistically significant in the inhabitants living near the BTS antenna (<300 m distances) compared to those living far from the BTS antenna (>300 m). *Conclusion*: It is suggested that cellular phone BTS antenna should not be sited closer than 300 m to populations to minimize exposure of neighbors.

Keywords

Electromagnetic field, health effects, microwave radiation, mobile phone BTS

History

Received 13 January 2013
Accepted 24 April 2013
Published online 19 June 2013

Introduction

In recent years, use of mobile phone telecommunication has drastically increased the amount of human exposition from the microwaves (MWs) radiation in everyday life. Because it became impossible to imagine a world without mobile communication, a growing concern about the possible health hazards have increased greatly among public, even on those who do not use such phones (Repacholi, 2001).

In this regard, the World Health Organization (WHO) established a project to assess environmental and health effects of Electro Magnetic Field (EMF) in the frequency of 0 to 300 Giga Hertz (GHz) (Dasdag et al., 2003; Hamblin et al., 2006). The mobile phones technology uses 880 and 1800 MHz frequency range (Valberg et al., 2007). Accordingly, the term Electromagnetic Hypersensitivity (EHS) was created for symptoms possibly related to EMF. However, the definition and diagnosis remains controversial (Hansson et al., 2006).

Address correspondence to Mojtaba Karbalae, Medical Physics and Medical Engineering Department, Isfahan University of Medical Sciences (IUMS), Isfahan 81746, Iran. Tel: +98 311 7922432. Fax: +98 311 6688597. E-mail: mehdi_karbalaee@yahoo.com

The emitted microwaves have been shown to have many effects upon the immune functions (Repacholi, 2001), stimulating hormones (Fattahi-asl et al., 2012, 2013; Shahbazi-Gahrouei et al., 2012), mammalian brain (de Tommaso et al., 2009), sperm motility and morphology (Agarwal et al., 2009) and neurological pathologies syndrome (Leszczynski et al., 2002).

According to the results gained in a number of experiments, for most of the people, a linear physiological dose-response relationship between EMF field density and the symptoms seemed to be unlikely (Roosli, 2008). Diem et al. reported DNA single- and double-strand induced breaks due to 1800 MHz RF-EMF exposure at 1.2 W/kg SAR (Diem et al., 2005). Nittby et al. have investigated that albumin extravasation enhanced in the rats due to exposer to mobile phones at 12 mW/kg SAR (Nittby et al., 2009). Ammari et al. investigated the effects of a chronic GSM 900 MHz exposure on glia in the rat brain (Ammari et al., 2008). While Rubin et al. found no differences between people with EHS and controls with regard to psychopathological diagnoses (Rubin et al., 2008). Gurisik et al. also found no significant differences between RF-exposed cells and sham-exposed in any of the conditions examined or assays (Gurisik et al., 2006). Lee et al. reported that 1763 MHz RF radiation alone did not reflect any stress response (Lee et al., 2006).

Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations

VINI G. KHURANA, LENNART HARDELL, JORIS EVERAERT, ALICJA BORTKIEWICZ, MICHAEL CARLBERG, MIKKO AHONEN

Human populations are increasingly exposed to microwave/radiofrequency (RF) emissions from wireless communication technology, including mobile phones and their base stations. By searching PubMed, we identified a total of 10 epidemiological studies that assessed for putative health effects of mobile phone base stations. Seven of these studies explored the association between base station proximity and neurobehavioral effects and three investigated cancer. We found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations. None of the studies reported exposure above accepted international guidelines, suggesting that current guidelines may be inadequate in protecting the health of human populations. We believe that comprehensive epidemiological studies of long-term mobile phone base station exposure are urgently required to more definitively understand its health impact. *Key words*: base stations; electromagnetic field (EMF); epidemiology; health effects; mobile phone; radiofrequency (RF); electromagnetic radiation.

INT J OCCUP ENVIRON HEALTH 2010;16:263–267

INTRODUCTION

Mobile phone base stations are now found ubiquitously in communities worldwide. They are frequently found near or on shops, homes, schools, daycare centers, and hospitals (Figure 1). The radiofrequency (RF) electromagnetic radiation from these base stations is regarded as being low power; however, their output is continuous.[1] This raises the question as to whether the health of people residing or working in close proximity to base stations is at any risk.

Received from: Department of Neurosurgery, The Canberra Hospital, The Australian National University Medical School, Garran, Australia (VGK); Department of Oncology, University Hospital, Orebro, Sweden (LH, MC); Research Institute for Nature and Forest [INBO], Brussels, Belgium (JE); Department of Work Physiology and Ergonomics, Nofer Institute of Occupational Medicine, Lodz, Poland (AB); Department of Computer Science, University Hospital, Orebro, Sweden (MA). Send correspondence to: Dr. Vini G. Khurana, Department of Neurosurgery, The Canberra Hospital, PO Box 103, Woden ACT 2606, Australia; email: <vgkhurana@gmail.com>.

Disclosures: The authors declare no conflicts of interest.

METHODS

By searching PubMed and using keywords such as base station, mast, electromagnetic field (EMF), radiofrequency (RF), epidemiology, health effects, mobile phone, and cell phone, and by searching the references of primary sources, we were able to find only 10 human population studies from seven countries that examined the health effects of mobile phone base stations. Seven of the studies explored the association between base station proximity and neurobehavioral symptoms via population-based questionnaires; the other three retrospectively explored the association between base station proximity and cancer via medical records. A meta-analysis based on this literature is not possible due to differences in study design, statistical measures/risk estimates, exposure categories, and endpoints/outcomes. The 10 studies are therefore summarized in chronological order (Table 1).

RESULTS AND DISCUSSION

We found epidemiological studies pertaining to the health effects of mobile phone base station RF emissions to be quite consistent in pointing to a possible adverse health impact. Eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations. The studies by Navarro et al.,[2] Santini et al.,[3] Gadzicka et al.,[4] and Hutter et al.[5] reported differences in the distance-dependent prevalence of symptoms such as headache, impaired concentration, and irritability, while Abdel-Rassoul et al.[6] also found lower cognitive performance in individuals living ≤ 10 meters from base stations compared with the more distant control group. The studies by Eger et al.[7] and Wolf and Wolf[8] reported increased incidence of cancer in persons living for several years < 400 meters from base stations. By contrast, the large retrospective study by Meyer et al.[9] found no increased incidence of cancer near base stations in Bavaria. Blettner et al.[10] reported in Phase 1 of their study that more health problems were found closer to base stations, but in Phase 2[11] concluded that measured EMF emissions were not related to adverse health effects (Table 1).

Each of the 10 studies reviewed by us had various strengths and limitations as summarized in Table 1. Per-

Figure 1—Mobile phone base stations ("antennae" or "masts") in Australia. Upper left: Community shop roof showing plethora of flat panel antennae. Upper right: Hospital roof with flat panel antennae painted to blend in. Lower left: Top of a street light pole. Lower center: Mast erected next to a daycare center. Lower right: Antennae mounted on an office block top floor.

taining to those base station studies in which EMF measurements were not carried out,[3,4,7,9] it should be noted that distance is not the most suitable classifier for exposure to RF-EMF. Antennae numbers and configurations, as well as the absorption and reflection of their fields by houses, trees, or other geographic hindrances may influence the exposure level. Further, self-estimation of distance to nearest base station is not the best predictor of exposure since the location of the closest base station is not always known. Such exposure misclassification inevitably biases any association towards null. Multiple testing might also produce spurious results if not adjusted for,[3,5] as might failure to adjust for participant age and gender.[7] Latency is also an important consideration in the context of cancer incidence following or during a putative environmental exposure. In this regard, the study by Meyer et al.[9] found no association between mobile phone base station exposure and cancer incidence, but had a relatively limited observation period of only two years. On the other hand, the studies by Eger et al.[7] and Wolf and Wolf[8] found a significant association between mobile phone base station exposure and increased cancer incidence, although the approximate five-year latency between base station exposure and cancer diagnosis appears to be unexpectedly short in both of these studies.

Other problems in several population-based questionnaires are the potential for bias, especially selection[8] and participation[2,3,5,6,11] biases, and self-reporting of outcomes in combination with the exposure assessment methods used. For example, regarding limitations in exposure assessment, in a large two-phase base station study from Germany,[12,13]of the Phase 1 participants (n = 30,047), only 1326 (4.4%) participated with a single "spot" EMF measurement recorded in the bedroom for Phase 2. Further, health effect contributions from all relevant EMF sources and other non-EMF environmental sources need to be taken into account.[12] We acknowledge that participant concern instead of exposure could be the triggering factor of adverse health effects, however this "nocebo effect" does not appear to fully explain the findings.[4,5] Further, the biological relevance of the overall adverse findings (Table 1) is supported by the fact that some of the symptoms in these base-station studies have also been reported among mobile phone users, such as headaches, concentration difficulties, and sleep disorders.[13,14] Finally, none of the studies that found adverse health effects of base stations reported RF exposures above accepted international guidelines, the implication being that if such findings continue to be reproduced, current exposure standards are inadequate in protecting human populations.[15]

TABLE 1 Summary of Epidemiological Studies of Mobile Phone Base Station Health Effects

Publication (Year; Country)	Clinical Assessment	Study Design	Base Station Details	Participants	EMF Measured	Key Findings	Strengths	Limitations
Navarro[2] (2003; Spain)	Neuro-behavioral	Survey-questionnaire	GSM-DCS 1800 MHz	101	Yes	More symptoms with closer proximity to base station (< 150 m)	Detailed questionnaire, EMF measured, distances studied[a]	Low participation, self-estimated distances, subjects aware[b]
Santini[2] (2003; France)	Neuro-behavioral	Survey-questionnaire	n/s	530	No	More symptoms with closer proximity to base station (< 300 m)	Detailed questionnaire, distances & other EMF exposures assessed	As above, plus no EMF measurements, no base station details
Eger[7] (2004; Germany)	Cancer incidence	Retrospective case review	GSM 935 MHz	967	No	3 x risk of cancer after 5 yrs of exposure (< 400 m); early age of cancer diagnosis	Maximum beam intensity calculated, reliable cancer data collection	Other environmental risk factors not assessed; analysis not adjusted for age and sex.
Wolf & Wolf[8] (2004; Israel)	Cancer incidence	Retrospective case review	TDMA 850 MHz	1844	Yes	> 4 x risk of cancer after 3–7 yrs exposure (< 350 m); early age of cancer diagnosis	Reliable cancer & demographic data, no other major environmental pollutant identified	Not all environmental risk factors assessed; possible selection bias; no age, sex adjustment.
Gadzicka[4] (2006; Poland)	Neuro-behavioral	Survey-questionnaire	n/s	500	No	More headache with proximity < 150 m; nocebo unlikely[c]	Detailed questionnaire, distances & EMF studied, nocebo studied	Subjects aware, no base station details
Hutter[5] (2006; Austria)	Neuro-behavioral	Cross-sectional	900 MHz	336	Yes	Headaches & impaired concentration at higher power density; nocebo unlikely	Detailed questionnaire and testing, EMF measured, distances studied; nocebo effect studied	Subjects aware, low participation rate
Meyer[9] (2006; Germany)	Cancer incidence	Retrospective case review	n/s	177,428	No	No increased cancer incidence in municipalities with or without base stations	Wide population assessed (Bavaria)	Observation period only 2 years, vague definitions of exposure, exposure onset unknown, distance to base station unknown
Abdel-Rassoul[6] (2007; Egypt)	Neuro-behavioral	Cross-sectional	n/s	165	Yes	More symptoms & lower cognitive performance if living under or < 10 m from base station	Detailed questionnaire and testing, EMF measured, distances studied, subjects unaware	Exact base station details n/s, low number of participants
Blettner[10] (2009; Germany)	Neuro-behavioral	Cross-sectional	n/s	30,047	No	More health complaints closer to base station (< 500 m)	Wide population assessed, detailed survey, nocebo effect assessed	EMF measurements not carried out (see phase II in Berg-Beckhoff et al., 2009; below)
Berg-Beckhoff[11] (2009; Germany)	Neuro-behavioral	Cross-sectional	GSM 900 MHz GSM 1800 MHz UMTS 1920–1980 MHz	1326	Yes	Health effects probably caused by stress and not by RF-EMF	Measured EMF emissions, standardized questionnaires	Low participation, no detailed list of symptoms published, single "spot" measurement in one place in dwelling, no occupational exposure assessed, time lag from assessment of symptoms and EMF measurement

n / s = not specified.
[a]"Distance" refers to distance between base station and subjects' households.
[b]"Subjects aware" refers to study participants being aware of the nature of the study.
[c]"Nocebo" effect unlikely because the majority of subjects in the study reported little or no concern for base station proximity.

CONCLUSIONS

Despite variations in the design, size and quality of these studies as summarized in Table 1, it is the consistency of the base-station epidemiological literature from several countries that we find striking. In particular, the increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations found in 80% of the available studies. It should be pointed out that the overall findings of health problems associated with base stations might be based on methodological weaknesses, especially since exposure to RF electromagnetic radiation was not always measured.

There are some proposed mechanisms via which low-intensity EMF might affect animal and human health,[16,17] but full comprehensive mechanisms still remain to be determined.[18,19] Despite this, the accumulating epidemiological literature pertaining to the health effects of mobile phones[13,20] and their base stations (Table 1) suggests that previous exposure standards based on the thermal effects of EMF should no longer be regarded as tenable. In August 2007, an international working group of scientists, researchers, and public health policy professionals (the BioInitiative Working Group) released its report on EMF and health.[21] It raised evidence-based concerns about the safety of existing public limits that regulate how much EMF is allowable from power lines, cellular phones, base stations, and many other sources of EMF exposure in daily life. The BioInitiative Report[21] provided detailed scientific information on health impacts when people were exposed to electromagnetic radiation hundreds or even thousands of times below limits currently established by the FCC and International Commission for Non-Ionizing Radiation Protection in Europe (ICNIRP). The authors reviewed more than 2000 scientific studies and reviews, and have concluded that: (1) the existing public safety limits are inadequate to protect public health; and (2) from a public health policy standpoint, new public safety limits and limits on further deployment of risky technologies are warranted based on the total weight of evidence.[21] A precautionary limit of 1 mW/m^2 (0.1 $microW/cm^2$ or 0.614 V/m) was suggested in Section 17 of the BioInitiative Report to be adopted for outdoor, cumulative RF exposure.[21] This limit is a cautious approximation based on the results of several human RF-EMF studies in which no substantial adverse effects on well being were found at low exposures akin to power densities of less than 0.5 – 1 mW/m^2.[2,5,22–26] RF-EMF exposure at distances > 500 m from the types of mobile phone base stations reviewed herein should fall below the precautionary limit of 0.614 V/m.

References

1. Khurana VG, Teo C, Kundi M, Hardell L, Carlberg M. Cell phones and brain tumors: A review including the long-term epidemiologic data. Surg Neurol. 2009;72:205-214.
2. Navarro EA, Segura J, Portolés M, Gómez-Perretta C. The microwave syndrome: A preliminary study in Spain. Electromag Biol Med. 2003;22:161–169.
3. Santini R, Santini P, Le Ruz P, Danze JM, Seigne M. Survey study of people living in the vicinity of cellular phone base stations. Electromag Biol Med. 2003;22:41-49.
4. Gadzicka E, Bortkiewicz A, Zmyslony M, Szymczak W, Szyjkowska A. Assessment of subjective complaints reported by people living near mobile phone base stations [Abstract]. Biuletyn PTZE Warszawa. 2006;14:23-26.
5. Hutter HP, Moshammer H, Wallner P, Kundi M. Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup Environ Med. 2006;63:307-313.
6. Abdel-Rassoul G, El-Fateh OA, Salem MA, Michael A, Farahat F, El-Batanouny M, Salem E. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology. 2007;28:434-440.
7. Eger H, Hagen KU, Lucas B, Vogel P, Voit H. Einfluss der raumlichen nahe von mobilfunksendeanlagen auf die krebsinzidenz. [The influence of being physically near to a cell phone transmission mast on the incidence of cancer]. Umwelt-Medizin-Gesellschaft. 2004;17:326-332.
8. Wolf R, Wolf D. Increased incidence of cancer near a cell-phone transmitter station. Int J Cancer Prev. 2004;1:123-128.
9. Meyer M, Gartig-Daugs A, Radespiel-Troger M. Cellular telephone relay stations and cancer incidence. Umweltmed Forsch Prax. 2006;11:89-97.
10. Blettner M, Schlehofer B, Breckenkamp J, Kowall B, Schmiedel S, Reis U, Potthoff P, Schüz J, Berg-Beckhoff G. Mobile phone base stations and adverse health effects: Phase 1 of a population-based, cross-sectional study in Germany. Occup Environ Med. 2009;66:118-123.
11. Berg-Beckhoff G, Blettner M, Kowall B, Breckenkamp J, Schlehofer B, Schmiedel S, Bornkessel C, Reis U, Potthoff P, Schüz J. Mobile phone base stations and adverse health effects: Phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. Occup Environ Med. 2009; 66:124-130.
12. Neubauer G, Feychting M, Hamnerius Y, Kheifets L, Kuster N, Ruiz I, Schüz J, Uberbacher R, Wiart J, Röösli M. Feasibility of future epidemiological studies on possible health effects of mobile phone base stations. Bioelectromagnetics. 2007;28:224-230.
13. Khan MM. Adverse effects of excessive mobile phone us. Int J Occup Environ Health. 2008;21:289-293.
14. Söderqvist F, Carlberg M, Hardell L. Use of wireless telephones and self-reported health symptoms: A population-based study among Swedish adolescents aged 15-19 years. Environ Health 2008;7:18.
15. Hardell L, Sage C. Biological effects from electromagnetic field exposure and public exposure standards. Biomed Pharmacother. 2008;62:104-109.
16. Salford LG, Nittby H, Brun A, Grafström G, Malmgren L, Sommarin M, Eberhardt J, Widegren B, Persson BRR. The mammalian brain in the electromagnetic fields designed by man with special reference to blood-brain barrier function, neuronal damage and possible physical mechanisms. Prog Theor Phys Suppl. 2008;173:283-309.
17. Sheppard AR, Swicord ML, Balzano Q. Quantitative evaluations of mechanisms of radiofrequency interactions with biological molecules and processes. Health Phys. 2008;95:365-396.
18. Khurana VG. Cell phone and DNA story overlooked studies. Science. 2008;322:1325.
19. Yang Y, Jin X, Yan C, Tian Y, Tang J, Shen X. 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. 2008; 49:2344-2350.

20. Hardell L, Carlberg M, Soderqvist F, Hansson Mild K. Meta-analysis of long-term mobile phone users and the association with brain tumours. Int J Oncol. 2008;32:1097-1103.
21. Sage C, Carpenter D, eds. BioInitiative Report: A rationale for a biologically-based public exposure standard for electromagnetic fields (ELF and RF) [Internet]. 2007 [cited April 3, 2009]. Available from: http://www.bioinitiative.org.
22. Kundi M, Hutter HP. Mobile phone base stations - Effects on wellbeing and health. Pathophysiol. 2009;16:123-35.
23. Henrich S, Ossig A, Schlittmeier S, Hellbrück J. Elektromagnetische Felder einer UMTS-Mobilfunkbasisstation und mögliche Auswirkungen auf die Befindlichkeit—eine experimentelle Felduntersuchung [Electromagnetic fields of a UMTS mobile phone base station and possible effects on health – results from an experimental field study]. Umwelt Med Forsch Prax. 2007;12:171-180.
24. Thomas S, Kühnlein A, Heinrich S, Praml G, Nowak D, von Kries R, Radon K. Personal exposure to mobile phone frequencies and well-being in adults: A cross-sectional study based on dosimetry. Bioelectromagnetics. 2008;29:463-470.
25. Zwamborn APM, Vossen SHJA, van Leersum BJAM, Ouwens MA, Makel WN. Effects of global communication system radio-frequency fields on well being and cognitive functions of human subjects with and without subjective complaints. Organization for Applied Scientific Research (TNO), Physics and Electronics Laboratory: The Hague, Netherlands, 2003.
26. Regel SJ, Negovetic S, Röösli M, Berdinas V, Schuderer J, Huss A, Lott U, Kuster N, Achermann P. UMTS base station like exposure, well being and cognitive performance. Environ Health Perspect. 2006;114:1270-1275.

Available online at www.sciencedirect.com

ScienceDirect

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

Mobile phone infrastructure regulation in Europe: Scientific challenges and human rights protection

Claudia Roda [a,*], *Susan Perry* [b]

[a] *Computer Science Department, The American University of Paris, 147 rue de Grenelle, 75007 Paris, France*
[b] *International Politics Department, The American University of Paris, 6 rue du Colonel Combes, 75007 Paris, France*

ARTICLE INFO

Article history:
Received 27 March 2013
Received in revised form
16 September 2013
Accepted 17 September 2013
Available online 11 November 2013

Keywords:
EMF
Human rights
Technology and health
Mobile phones

ABSTRACT

As the progress of mobile phone technology accelerates throughout Europe, the regulatory framework necessary for its safe and extended use has been slow to develop. This article analyses the relationship between scientific knowledge and regulation concerning the heath effects of increasing emissions of electromagnetic fields (EMF). From a conservationist perspective, no other example of industrial impact on the natural environment has achieved such extended penetration so quickly. From a theoretical standpoint, stakeholders are faced with a difficult choice between comprehensive risk assessment versus immediate application of the precautionary principle. By exploring the interaction between citizens, governments, and international bodies, we first analyze the challenges faced by regulators in the presence of uncertain scientific knowledge and standards of measurement. We then highlight the inadequacy of current risk assessment parameters. Lastly, within the context of State and European regulation of EMF exposure, we expand scholarship on the human rights framework to protect vulnerable populations from environmental pollution. We conclude that, because scientific knowledge is incomplete, a precautionary approach is better suited to State obligations under international human rights law.

1. Introduction

The use of mobile phones is ubiquitous, and is estimated to have reached 96% penetration worldwide (ITU, 2013, p. 1). Mobile broadband, used for wireless access to the Internet, has more than 2 billion subscriptions worldwide, with penetration levels that reach 68% in Europe (ITU, 2013, p. 6). Scientific research has attempted to determine whether exposure to electromagnetic fields (EMF) during mobile phone use is dangerous to human health. Yet, while the public remains focused on the possible dangers of the mobile device itself, the rapidly growing infrastructure necessary for mobile communication is interfering with human physiology, as 'the antennae of broadcast stations are the most powerful continuous sources of RF energy intentionally radiated into free space' (ICNIRP, 2009, p. 11). From a conservationist perspective, no other example of industrial impact on the natural environment has achieved such extended penetration so quickly.

Base transceiver stations (BTS) – equipment normally connected to elevated structures that relay electromagnetic signals between mobile devices and a network – emit electromagnetic energy. EMF emission is widespread; the European Union, for example, requires maximal coverage for its citizens.[1] However, virtually no national legislation exists to protect the same consumers from the possible effects of prolonged EMF exposure via BTS, nor do most governments

* *Corresponding author*. Tel.: +33 1 40620701.
E-mail addresses: croda@aup.edu (C. Roda), sperry@aup.edu (S. Perry).

[1] The Digital Agenda for Europe (DAE) required Member States to devise and make operational by 2012 national broadband plans with the objective of meeting the broadband targets for Europe by 2020.

1462-9011/$ – see front matter
http://dx.doi.org/10.1016/j.envsci.2013.09.009

Int. J. Environ. Res. Public Health **2015**, *12*, 14519-14528; doi:10.3390/ijerph121114519

OPEN ACCESS

International Journal of
Environmental Research and Public Health
ISSN 1660-4601
www.mdpi.com/journal/ijerph

Article

Association of Exposure to Radio-Frequency Electromagnetic Field Radiation (RF-EMFR) Generated by Mobile Phone Base Stations with Glycated Hemoglobin (HbA1c) and Risk of Type 2 Diabetes Mellitus

Sultan Ayoub Meo [1,*], Yazeed Alsubaie [1], Zaid Almubarak [1], Hisham Almutawa [1], Yazeed AlQasem [1] and Rana Muhammed Hasanato [2]

[1] Department of Physiology, College of Medicine, King Saud University, P.O. Box 2925, Riyadh 11461 Saudi Arabia; E-Mails: yazeed-1992-@hotmail.com (Y.A.); z-almubarak@hotmail.com (Z.A.); hisham-001@hotmail.com (H.A.); yazeed.alq@gmail.com (Y.A.)

[2] Department of Clinical Bio-Chemistry, College of Medicine, King Saud University, P.O. Box 2925, Riyadh 11461 Saudi Arabia; E-Mail: rhasanato@ksu.edu.sa

* Author to whom correspondence should be addressed; E-Mail: sultanmeo@hotmail.com; Tel.: +96-611-467-1604; Fax: +96-611-467-2567.

Academic Editor: Omorogieva Ojo

Received: 15 September 2015 / Accepted: 11 November 2015 / Published: 13 November 2015

Abstract: Installation of mobile phone base stations in residential areas has initiated public debate about possible adverse effects on human health. This study aimed to determine the association of exposure to radio frequency electromagnetic field radiation (RF-EMFR) generated by mobile phone base stations with glycated hemoglobin (HbA1c) and occurrence of type 2 diabetes mellitus. For this study, two different elementary schools (school-1 and school-2) were selected. We recruited 159 students in total; 96 male students from school-1, with age range 12–16 years, and 63 male students with age range 12–17 years from school-2. Mobile phone base stations with towers existed about 200 m away from the school buildings. RF-EMFR was measured inside both schools. In school-1, RF-EMFR was 9.601 nW/cm^2 at frequency of 925 MHz, and students had been exposed to RF-EMFR for a duration of 6 h daily, five days in a week. In school-2, RF-EMFR was 1.909 nW/cm^2 at frequency of 925 MHz and students had been exposed for 6 h daily, five days in a week. 5–6 mL blood was collected from all the students and HbA1c was

Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.47750/jptcp.2022.934

Estimation of some antioxidants in people exposed to electromagnetic waves from Internet towers in Samarra

Methaq Nazhan Mahmood[1], Asmaa Hashim Shaker[2], Humam E. Mohammed[3]

[1]Department of Applied Chemistry, College of Applied Science, University of Samarra, Samarra, Iraq

[2]Department of Chemistry, College of Education for Women, University of Tikrit, Tikrit, Iraq

[3]Department of Pathological Analyses, College of Applied Sciences, University of Samarra, Samarra, Iraq

Corresponding author: Methaq Nazhan Mahmood, Department of Applied Chemistry, College of Applied Science, University of Samarra, Samarra, Iraq. Email: Charter61@uosamarra.edu.iq

Submitted: 21 January 2022; Accepted: 31 March 2022; Published: 16 June 2022

ABSTRACT

The current study was conducted as a preliminary study in the Samarra city of Iraq. The study explored direct and indirect impact on people exposed to Internet network towers on residential premises in the cities of Iraq. The study included collection of samples from people exposed to radioactive frequencies of Internet towers for a period ranging from 1 to 10 years. In all, 43 blood samples of males and female participants (age: 20–35 years) were collected exposed to radioactive frequencies (present at the places where constellations were located); also, 20 samples were collected from those (20–35-year old) not exposed to radioactive frequencies (from places far from the Internet towers), which acted as a control group. Measurements and analyses were made for antioxidants that included the following enzymes: glutathione peroxidase (GPx), superoxide dismutase (SOD), glutathione (GSH), *malondialdehyde* (MDA), and peroxynitrate (or peroxonitrite [$ONOO^-$]). Antioxidants are one of the most essential lines of defense against free radicals that cause diseases and premature aging. The results demonstrated a significant increase in the levels of GPx and SOD concentrations and a decrease in the levels of GSH concentration in the blood serum of participants exposed to electromagnetic waves of Internet towers compared to the control group. The results also showed a significant increase in the concentrations of both MDA and $ONOO^-$ compared to the non-exposed subjects of the control group.

Keywords: *antioxidants; electromagnetic waves; Internet towers; Samarra*

J Popul Ther Clin Pharmacol Vol 29(2):e79–e87; 16 June 2022.

ELECTROMAGNETIC BIOLOGY AND MEDICINE

http://www.tandfonline.com/iebm
ISSN: 1536-8378 (print), 1536-8386 (electronic)

Electromagn Biol Med, 2015; 34(4): 344–354
 DOI: 10.3109/15368378.2014.933349

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station

Gursatej Gandhi, Gurpreet Kaur, and Uzma Nisar

Department of Human Genetics, Guru Nanak Dev University, Amritsar, Punjab, India

Abstract

Mobile phone base stations facilitate good communication, but the continuously emitting radiations from these stations have raised health concerns. Hence in this study, 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. The power density in the area within 300 m from the base station exceeded the permissive limits and was significantly ($p = 0.000$) higher compared to the area from where control samples were collected. The study participants comprised 63 persons with residences near a mobile phone tower, and 28 healthy controls matched for gender, age, alcohol drinking and occupational sub-groups. Genetic damage parameters of DNA migration length, damage frequency (DF) and damage index were significantly ($p = 0.000$) elevated in the sample group compared to respective values in healthy controls. The female residents ($n = 25$) of the sample group had significantly ($p = 0.004$) elevated DF than the male residents ($n = 38$). The linear regression analysis further revealed daily mobile phone usage, location of residence and power density as significant predictors of genetic damage. The genetic damage evident in the participants of this study needs to be addressed against future disease-risk, which in addition to neurodegenerative disorders, may lead to cancer.

Keywords

DNA damage, radiofrequency radiations, peripheral blood leukocytes

History

Received 17 January 2014
Revised 21 April 2014
Accepted 27 April 2014
Published online 3 July 2014

Introduction

The wireless technology has seen unprecedented expansion the world over and has become all pervasive. Though on one hand, there has been indispensable improvement in the quality of communication, yet it has also emerged as an unceasing source of radiofrequency radiations (RFRs) being emitted, both from mobile (cell) phone base stations and the cell phone itself, which acts as a two-way radio, i.e. transceiver (Kwan-Hoong, 2005), generally operating in the frequency range of 900 MHz–1.9 GHz (Levitt and Lai, 2010). According to the Telecom Industry of India (Telecom sector in India, 2012), the Indian Telecommunications network is the third largest in the world and the second largest among the emerging economies of Asia; the industry continues to grow having 540 000 communication towers with more and more towers being erected (DoT, 2012). There is also correspondingly high mobile phone subscribers' base, being second after China (Das, 2012). The need for an expansive network to maintain the escalating mobile phone subscribers' base has resulted in the proliferation of antennas atop masts, both in urban as well as rural areas, adding to the quagmire of environmental pollutants as the RFRs.

The continuous emission of RFR has prompted concerns about its effect and the potential risks to those living near mobile phone base stations despite the fact that the microwaves in the RFR spectrum are of low frequency (ARPANSA, 2011). Besides affecting the well-being and performance of the population, headaches, sleep disturbances, discomfort, irritability, depression, memory loss and concentration problems have been documented in France (Santini et al., 2002), Spain (Navarro et al., 2003), Poland (Bortkiewicz et al., 2004) and Egypt (Abdel-Rassoul et al., 2006). In Austria, where the exposure limits (0.001 W/m^2) are among the lowest in the world, health symptoms included buzzing in the head, heart palpitations, unwellness, lightheadedness, anxiety, breathlessness, respiratory problems, nervousness, agitation, headaches, tinnitus, heat sensation and depression (Oberfeld et al., 2004). Of more concern are studies on the occurrence of cancers among those residing near mobile phone base stations. A four-fold increase in the incidence of cancers of all kinds among residents living within 300-m radius of a mobile phone mast from three to seven years has been reported (Wolf and Wolf, 2004). In another study, a three-fold increase in the incidence of malignant tumors of blood, breast, ovary, pancreas, stomach, lung, kidney, bowel, prostate and skin melanoma was found after five years' exposure in people

Address correspondence to Dr Gursatej Gandhi, Department of Human Genetics, Guru Nanak Dev University, Amritsar 143 005, Punjab, India. Tel: (O): +91-183-2258802-09 Extn.3444. Fax (Univ.): +91-183-2258820. E-mail: gandhig07@hotmail.com

Bioelectromagnetics 18:455–461 (1997)

RF Radiation–Induced Changes in the Prenatal Development of Mice

Ioannis N. Magras[1]* and Thomas D. Xenos[2]

[1]*Department of Anatomy, Histology, and Embryology, School of Veterinary Medicine, Aristotle University of Thessaloniki, Thessalonike, Greece*
[2]*Department of Telecommunications, School of Electrical Engineering and Computer Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece*

The possible effects of radiofrequency (RF) radiation on prenatal development has been investigated in mice. This study consisted of RF level measurements and in vivo experiments at several places around an ''antenna park.'' At these locations RF power densities between 168 nW/cm^2 and 1053 nW/cm^2 were measured. Twelve pairs of mice, divided in two groups, were placed in locations of different power densities and were repeatedly mated five times. One hundred eighteen newborns were collected. They were measured, weighed, and examined macro- and microscopically. A progressive decrease in the number of newborns per dam was observed, which ended in irreversible infertility. The prenatal development of the newborns, however, evaluated by the crown-rump length, the body weight, and the number of the lumbar, sacral, and coccygeal vertebrae, was improved. *Bioelectromagnetics 18:455–461, 1997.* © 1997 Wiley-Liss, Inc.

Key words: RF radiation effects; prenatal development; mice development

Five years ago the ''antenna-park of Thessaloniki'' progressively developed on the top of the nearby mountain Chortiatis, 1.5 km away from a small village of the same name. Today, almost 100 commercial TV and FM-radio broadcasting transmitters in the VHF and the UHF bands are situated there. The antennas are installed on towers well visible from a large part of the village. Living so close to the antennae and the vast amount of RF power they transmit, which is of the order of 300 kW, the people of the village Chortiatis, anxious for their health, encouraged the author to undertake a research program.

The hypothesis that RF radiation may adversely affect the health of the animal organism is still under consideration in public and scientific forums. One of the critical issues seems to be the RF effects on the reproductive process [Chernoff et al., 1992]. Numerous studies dealing with this subject ended up with seemingly contradictory results. Therefore, an ''in vivo'' study on experimental animals sensitive to RF radiation, was chosen. Based on the relevant literature, this research investigated RF radiation effects on the reproductive system, particularly on prenatal development. The mouse was selected as the experimental animal, because it is easily manipulated in the environment in which the experiments had to take place. Of course, experimenting at the mountain sites, far from the easily controlled laboratory conditions, might add a certain amount of uncertainty; therefore, these experiments should be considered preliminary.

MATERIALS AND METHODS

We used a total of 36 mice (18 females and 18 males), 2 months old and sexually mature (BALB/c/f breed colony). Breeding colony virgin males and females were obtained from the ''Theageneion Anticancer Institute of Thessaloniki.'' The use of these experimental animals was approved by the Veterinary Service of the Municipality of Thessaloniki, according to the provisions of the laws 1197/81 and 2015/92 and the Presidential Decree 160/91 of the Greek Democracy. Upon arrival, all experimental animals were quarantined for 2 weeks to discover and to allow them to acclimatise the mountain environment, an altitude ranging between 570 (position h) and 730 m (position d) above sea level. All the mice were healthy at the end of this period and showed no signs of illness during

*Correspondence to: Ioannis N. Magras, Department of Anatomy, Histology, and Embryology, School of Veterinary Medicine, Aristotle University of Thessaloniki, 540-06 Thessaloniki, Greece.

Received for review 9 June 1996; revision received 30 January 1997

Environmental Pollution 242 (2018) 643–658

Contents lists available at ScienceDirect

Environmental Pollution

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

Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective☆

Dominique Belpomme [a, b, 1], Lennart Hardell [a, c, 1, 2], Igor Belyaev [a, d, e, 1], Ernesto Burgio [a, f], David O. Carpenter [a, g, h, *, 1]

[a] European Cancer Environment Research Institute, Brussels, Belgium
[b] Paris V University Hospital, Paris, France
[c] Department of Oncology, Orebro University Hospital, Faculty of Medicine, Orebro, Sweden
[d] Department of Radiobiology, Cancer Research Institute, Biomedical Research Center, Slovak Academy of Science, Bratislava, Slovak Republic
[e] Laboratory of Radiobiology, Institute of General Physics, Russian Academy of Science, Moscow, Russian Federation
[f] Instituto Scientifico Biomedico Euro Mediterraneo, Mesagne, Italy
[g] Institute for Health and the Environment, University at Albany, Albany, NY, USA
[h] Child Health Research Centre, The University of Queensland, Faculty of Medicine, Brisbane, Australia

ARTICLE INFO

Article history:
Received 6 April 2018
Received in revised form
31 May 2018
Accepted 4 July 2018
Available online 6 July 2018

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.

☆ This paper has been recommended for acceptance by Payam Dadvand.
* Corresponding author. Institute for Health and the Environment, University at Albany, Renneselaer, NY 12144, USA.
E-mail address: dcarpenter@albany.edu (D.O. Carpenter).
[1] These authors contributed equally to this work.
[2] Current address: The Environment and Cancer Research Foundation, Örebro, Sweden.

https://doi.org/10.1016/j.envpol.2018.07.019
0269-7491/

The Influence of Being Physically Near to a Cell Phone Transmission Mast on the Incidence of Cancer

Horst Eger, Klaus Uwe Hagen, Birgitt Lucas, Peter Vogel, Helmut Voit

Published in *Umwelt·Medizin·Gesellschaft* 17,4 2004, as:
'Einfluss der räumlichen Nähe von Mobilfunksendeanlagen auf die Krebsinzidenz'

Summary

Following the call by Wolfram König, President of the Bundesamt für Strahlenschutz (Federal Agency for radiation protection), to all doctors of medicine to collaborate actively in the assessment of the risk posed by cellular radiation, the aim of our study was to examine whether people living close to cellular transmitter antennas were exposed to a heightened risk of taking ill with malignant tumors.

The basis of the data used for the survey were PC files of the case histories of patients between the years 1994 and 2004. While adhering to data protection, the personal data of almost 1,000 patients were evaluated for this study, which was completed without any external financial support. It is intended to continue the project in the form of a register.

The result of the study shows that the proportion of newly developing cancer cases was significantly higher among those patients who had lived during the past ten years at a distance of up to 400 metres from the cellular transmitter site, which has been in operation since 1993, compared to those patients living further away, and that the patients fell ill on average 8 years earlier.

In the years 1999-2004, *ie* after five years' operation of the transmitting installation, the relative risk of getting cancer had trebled for the residents of the area in the proximity of the installation compared to the inhabitants of Naila outside the area.

Key words: cellular radiation, cellular transmitter antennas, malignant tumours

The rapid increase in the use of mobile telephony in the last few years has led to an increasing number of cell phone transmission masts being positioned in or near to residential areas. With this in mind, the president of the German governmental department for protection against electromagnetic radiation (Bundesamtes für Strahlenschutz) Wolfram König, has challenged all doctors to actively help in the work to estimate the risks from such cell phone masts. The goal of this investigation was therefore to prove whether on not people living near to cell phone masts have a higher risk of developing cancerous tumours.

The basic data was taken from the medical records held by the local medical authority (Krankenkasse) for the years 1994 to 2004. This material is stored on computer. In this voluntary study the records of roughly 1,000 patients from Naila (Oberfranken) were used, respecting the associated data protection laws. The results from this study show a significantly increased likelihood of developing cancer for the patients that have lived within 400 metres of the cell phone transmission mast (active since 1993) over the last ten years, in comparison to those patients that live further away. In addition, the patients that live within 400 metres tend to develop the cancers at a younger age. For the years 1999 to 2004 (*ie* after five or more years of living with the cell phone transmission mast), the risk of developing cancer for those living within 400 metres of the mast in comparison to those living outside this area, was three times as high.

Introduction

A series of studies available before this investigation provided strong evidence of health risks and increased cancer risk associated with physical proximity to radio transmission masts. Haider *et al.* reported in 1993 in the Moosbrunn study frequent psychovegetive symptoms below the current safety limit for electromagnetic waves (1). In 1995, Abelin *et al.* in the Swiss- Schwarzenburg study found dose dependent sleep problems (5:1) and depression (4:1) at a shortwave transmitter station that has been in operation since 1939 (2).

In many studies an increased risk of developing leukaemia has been found; in children near transmitter antennas for Radio and Television in Hawaii (3); increased cancer cases and general mortality in the area of Radio and Television transmitter antennas in Australia (4); and in England, 9 times more leukaemia cases were diagnosed in people who live in a nearby

Science of the Total Environment xxx (2011) xxx–xxx

Contents lists available at ScienceDirect

Science of the Total Environment

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

Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil ☆

Adilza C. Dode [a,b,e,*], Mônica M.D. Leão [c], Francisco de A.F. Tejo [d], Antônio C.R. Gomes [e], Daiana C. Dode [e,f], Michael C. Dode [e], Cristina W. Moreira [b], Vânia A. Condessa [b], Cláudia Albinatti [b], Waleska T. Caiaffa [g]

[a] Minas Methodist University Center Izabela Hendrix, Belo Horizonte City, Minas Gerais State, Brazil
[b] Municipal Government of Belo Horizonte, Municipal Health Department, Belo Horizonte City, Minas Gerais State, Brazil
[c] UFMG—Universidade Federal de Minas Gerais-Belo Horizonte, Environmental and Sanitary Engineering Department, Belo Horizonte City, Minas Gerais State, Brazil
[d] UFCG—Universidade Federal de Campina Grande, Center of Electrical Engineering and Informatics, Academic Unit of Electrical Engineering, Paraíba State, Brazil
[e] MRE Engenharia (Electromagnetic Radiations Measurement—Engineering), Belo Horizonte City, Minas Gerais State, Brazil
[f] Faculty of Medical Sciences, Medicine-Belo Horizonte, Belo Horizonte City, Minas Gerais State, Brazil
[g] UFMG—Universidade Federal de Minas Gerais-Belo Horizonte, Urban Health Observatory, Belo Horizonte City, Minas Gerais State, Brazil

ARTICLE INFO

Article history:
Received 14 January 2011
Received in revised form 25 May 2011
Accepted 25 May 2011
Available online xxxx

Keywords:
Assessment and management of impacts and environmental risks
Non-ionizing electromagnetic radiation
Public health
Radio base station
Environmental electromagnetic pollution
Environmental electromagnetic field monitoring

ABSTRACT

Pollution caused by the electromagnetic fields (EMFs) of radio frequencies (RF) generated by the telecommunication system is one of the greatest environmental problems of the twentieth century. The purpose of this research was to verify the existence of a spatial correlation between base station (BS) clusters and cases of deaths by neoplasia in the Belo Horizonte municipality, Minas Gerais state, Brazil, from 1996 to 2006 and to measure the human exposure levels to EMF where there is a major concentration of cellular telephone transmitter antennas. A descriptive spatial analysis of the BSs and the cases of death by neoplasia identified in the municipality was performed through an ecological–epidemiological approach, using georeferencing. The database employed in the survey was composed of three data banks: 1. death by neoplasia documented by the Health Municipal Department; 2. BSs documented in ANATEL ("Agência Nacional de Telecomunicações": 'Telecommunications National Agency'); and 3. census and demographic city population data obtained from official archives provided by IBGE ("Instituto Brasileiro de Geografia e Estatística": 'Brazilian Institute of Geography and Statistics'). The results show that approximately 856 BSs were installed through December 2006. Most (39.60%) of the BSs were located in the "Centro-Sul" ('Central-Southern') region of the municipality. Between 1996 and 2006, 7191 deaths by neoplasia occurred and within an area of 500 m from the BS, the mortality rate was 34.76 per 10,000 inhabitants. Outside of this area, a decrease in the number of deaths by neoplasia occurred. The greatest accumulated incidence was 5.83 per 1000 in the Central-Southern region and the lowest incidence was 2.05 per 1000 in the Barreiro region. During the environmental monitoring, the largest accumulated electric field measured was 12.4 V/m and the smallest was 0.4 V/m. The largest density power was 40.78 μW/cm^2, and the smallest was 0.04 μW/cm^2.

1. Introduction

Mobile phone radio base stations (RBSs) are now found in cities and communities worldwide. They can be found near or even on top of homes, schools, hospitals, daycare centers and offices. In Brazil, the number of mobile phone users is estimated to be over 200 million and there are more than 5 billion users worldwide. In the municipality of Belo Horizonte, the capital of the state of Minas Gerais, there are approximately 1000 base stations (BSs) with 128.77 accesses by mobile phones per 100 inhabitants and in Brazil, there are 49,979 BSs licensed through April 2011 (ANATEL, 2011).

The non-ionizing electromagnetic radiation from the BSs is of low intensity compared to the current guidelines on human exposure limits. However, its emission is continuous. This raises concerns as to whether the health and well-being of people living or working close to the BSs are at risk Khurana et al., 2010; Alanko et al., 2008.

The *emission* of a BS is usually described by its effectively radiated power in watts (W), which describes the total amount of radiation emitted by the antenna of the BS. Their intensity, called the power density, is commonly measured in milliwatts per square centimeter (mW/cm^2) or microwatt per square centimeter (μW/cm^2) and it expresses the power per unit area impinging normally to the external surface of the subject. The *immission* (absorption) of the subject is measured by the specific absorption rate (SAR), which is reported in

☆ All the authors declare that they have no conflicts of interest.

* Corresponding author at: Rua Desembargador Assis Rocha, 279, Bairro Belvedere, 30320-250, Belo Horizonte (MG), Brazil. Tel.: +55 031 3286 1892.
E-mail addresses: adilzadode@terra.com.br (A.C. Dode), monica@desa.ufmg.br (M.M.D. Leão).

0048-9697/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.scitotenv.2011.05.051

Annals of Case Reports
Hardell L and Nilsson M. Ann Case Rep: 8: 1112
www.doi.org/10.29011/2574-7754.101112
www.gavinpublishers.com

Case Report

Case Report: The Microwave Syndrome after Installation of 5G Emphasizes the Need for Protection from Radiofrequency Radiation

Lennart Hardell[1*], Mona Nilsson[2]

[1]Department of Oncology, Orebro University Hospital, Sweden (retired), The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17, Örebro, Sweden

[2]Swedish Radiation Protection Foundation, Gredby 14, SE-178 92 Adelsö, Sweden

[*]**Corresponding author:** Lennart Hardell, Department of Oncology, Orebro University Hospital, Sweden (retired), The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17, Örebro, Sweden

Citation: Hardell L and Nilsson M (2023) Case Report: The Microwave Syndrome after Installation of 5G Emphasizes the Need for Protection from Radiofrequency Radiation. Ann Case Report. 8: 1112. DOI: 10.29011/2574-7754.101112

Received Date: 28 December 2022; **Accepted Date**: 02 January 2023; **Published Date**: 10 January 2023

Abstract

In this case, report two previously healthy persons, a man aged 63 years and a woman aged 62 years, developed symptoms of the microwave syndrome after installation of a 5G base station for wireless communication on the roof above their apartment. A base station for previous telecommunication generation technology (3G/4G) was present at the same spot since several years. Very high radiofrequency (RF) radiation with maximum (highest measured peak value) levels of 354 000, 1 690 000, and >2 500 000 μW/m^2 were measured at three occasions in the bedroom located only 5 meters below the new 5G base station, compared to maximum (peak) 9 000 μW/m^2 prior to the 5G deployment. The rapidly emerging symptoms after the 5G deployment were typical for the microwave syndrome with e.g., neurological symptoms, tinnitus, fatigue, insomnia, emotional distress, skin disorders, and blood pressure variability. The symptoms were more pronounced in the woman. Due to the severity of symptoms, the couple left their dwelling and moved to a small office room with maximum (peak) RF radiation 3 500 μW/m^2. Within a couple of days, most of their symptoms alleviated or disappeared completely. This medical history can be regarded as a classic provocation test. The RF radiation levels in the apartment were well below the limit proposed to be "safe" below which no health effects would occur, recommended by the International Commission on Non-Ionizing Radiation (ICNIRP). These now presented symptoms of the microwave syndrome were caused by non-thermal effects from RF radiation and highlight that the ICNIRP guidelines used in most countries including Sweden do not protect human health. Guidelines based on all biological negative effects from RF radiation are urgently needed, as well as monitoring human health, not the least due to rapidly increasing levels of exposure.

Keywords: Base station; 5G; Radiofrequency radiation; Electromagnetic hypersensitivity; Microwave syndrome; Health

Introduction

In recent years, human exposure to pulse-modulated microwave radiation [also called radiofrequency (RF) radiation] from wireless technology has increased exponentially. Microwaves are frequencies in the range of 300 MHz to 300 GHz within the radiofrequency (RF) spectrum [1]. The increase is mainly a result of the expansion of 4G+ and 5G as well as an increased amount of consumer products based on technologies that emit microwave radiation.

In parallel with this exploding RF radiation exposure, regulations and so-called safety limits applicable to the permitted RF radiation in most countries are based on a severely outdated approach from the 1950s. These 'safety" limits (or guidelines) only protect people against harmful effects that occur as a result of acute heating, also called thermal effects. These occur when

Review Rev Environ Health. 2020 Aug 24;35(4):493-515. doi: 10.1515/reveh-2020-0056.
Print 2020 Nov 18.

Physiological effects of millimeter-waves on skin and skin cells: an overview of the to-date published studies

Dariusz Leszczynski [1]

Affiliations

PMID: 32829319 DOI: 10.1515/reveh-2020-0056

Abstract

The currently ongoing deployment if the fifth generation of the wireless communication technology, the 5G technology, has reignited the health debate around the new kind of radiation that will be used/emitted by the 5G devices and networks - the millimeter-waves. The new aspect of the 5G technology, that is of concern to some of the future users, is that both, antennas and devices will be continuously in a very close proximity of the users' bodies. Skin is the only organ of the human body, besides the eyes, that will be directly exposed to the mm-waves of the 5G technology. However, the whole scientific evidence on the possible effects of millimeter-waves on skin and skin cells, currently consists of only some 99 studies. This clearly indicates that the scientific evidence concerning the possible effects of millimeter-waves on humans is insufficient to devise science-based exposure limits and to develop science-based human health policies. The sufficient research has not been done and, therefore, precautionary measures should be considered for the deployment of the 5G, before the sufficient number of quality research studies will be executed and health risk, or lack of it, scientifically established.

Keywords: 5G technology; limited deployment; millimeter-waves; precautionary approach; skin.

Related information

MedGen

LinkOut - more resources

Full Text Sources

De Gruyter

DOI 10.1007/s10517-023-05689-2
Bulletin of Experimental Biology and Medicine, Vol. 174, No. 2, December, 2022

EXPERIMENTAL BIOLOGY

Status of the Neuroendocrine System in Animals Chronically Exposed to Electromagnetic Fields of 5G Mobile Network Base Stations

S. Yu. Perov, N. B. Rubtsova, and O. V. Belaya

Translated from Byulleten' Eksperimental'noi Biologii i Meditsiny, Vol. 174, No. 8, pp. 249-252, August, 2022
Original article submitted July 1, 2022

We studied the biological effect of chronic exposure to multifrequency electromagnetic fields simulating the effects of 5G NR/IMT-2020 mobile communication systems. Male Wistar rats were exposed to 24-h radiation (250 μW/cm^2) for 4 months. The exploratory activity of the animals and blood concentrations of ACTH and corticosterone were evaluated at the end of each month of exposure and 1 month after exposure. The results suggest that exposure to multifrequency electromagnetic field simulating the effects of 5G systems affected functional activity of the hypothalamus–pituitary–adrenal axis and was stressful in nature.

Key Words: electromagnetic field; neuroendocrine system; adrenocorticotropic hormone; corticosterone; 5G mobile communication systems

Anthropogenic radiofrequency electromagnetic fields (EMF) mainly generated by mobile communications base stations are an essential environmental factor. Many citizens are exposed by multifrequency EMF, a complex mixture of signals of different intensity, and this is the rule rather than the exception [1,2]. The problem of possible general effects of EMF of promising 5G NR/IMT-2020 standard base stations with level exceeding of national hygienic norms on the population has not yet been discussed in our country [3,4].

Single foreign epidemiological studies revealed no adverse effects associated with 5G systems EMF exposure on human health [5,6]. However, it should be accepted that experimental data on biological effects of EMF from 5G communication systems in available literature are more than limited, and the studies are fragmentary and do not cover the whole range of operation standards from units to tens of GHz [7]. All this shows the necessity of experimental study of possible adverse effects of 5G communication systems EMF, especially biological effects of long-term multifrequency exposure, on human health [8].

There are practically no published reports about the biological effect of EMF at ranges and generation modes corresponding to 5G NR/IMT-2020 standards on experimental animals. The latter necessitates experimental studies on animals for evaluation of the biological effects of EMF generated by 5G systems with levels that can be comparable to the possible threshold of adverse effects on humans. From this point of view, it is interesting to study CNS reactions to EMF exposure, which can cause changes in functional activity of the hypothalamic–pituitary system of animals [9-11].

The aim of this study was experimental evaluation of biological effect chronic exposure to EMF simulating the real 5G NR/IMT-2020 mobile communication systems base stations.

N. F. Izmerov Research Institute of Occupational Health, Moscow, Russia. ***Address for correspondence:*** perov@irioh.ru. S. Yu. Perov

Review Article

Lennart Hardell* and Tarmo Koppel

Electromagnetic hypersensitivity close to mobile phone base stations – a case study in Stockholm, Sweden

https://doi.org/10.1515/reveh-2021-0169
Received December 9, 2021; accepted February 13, 2022;
published online March 2, 2022

Abstract: A previously healthy worker developed symptoms assigned to electromagnetic hypersensitivity (EHS) after moving to an office with exposure to high levels of anthropogenic electromagnetic fields (EMFs). These symptoms consisted of e.g. headache, arthralgia, tinnitus, dizziness, memory loss, fatique, insomnia, transitory cardiovascular abnormalities, and skin lesions. Most of the symptoms were alleviated after 2 weeks sick leave. The highest radiofrequency (RF) field level at the working place was 1.72 V/m (7,852 μW/m^2). Maximum value for extremely low frequency electromagnetic field (ELF-EMF) from electric power at 50 Hz was measured to 285 nT (mean 241 nT). For electric train ELF-EMF at 16.7 Hz was measured to 383 nT (mean 76 nT). Exposure to EMFs at the working place could be the cause for developing EHS related symptoms. The association was strengthened by the symptom reduction outside the working place.

Keywords: electromagnetic hypersensitivity; EMF; radiofrequency radiation; symptoms.

Introduction

Exposure to extremely low frequency (ELF) electromagnetic fields (EMF) and radiofrequency (RF) EMF is in most cases involuntary and unknown to people. Both ELF-EMF and RF-EMF have been evaluated by IARC to be possible human carcinogens, Group 2B [1–3]. In fact EMFs should be regarded to be environmental pollutants that do not smell, have no taste and are invisible.

***Corresponding author: Lennart Hardell,** The Environment and Cancer Research Foundation, Studievägen 35, SE-702 17, Örebro, Sweden, E-mail: lennart.hardell@environmentandcancer.com
Tarmo Koppel, Tallinn University of Technology, Tallinn, Estonia, E-mail: tarmo.koppel@taltech.ee

Already in the 1970s the 'microwave syndrome' was described in the former Soviet Union [4]. Persons working with radar or radio equipment reported symptoms of fatigue, headache, dizziness, disturbed sleep, concentration and memory problems.

In the 1980s similar symptoms were reported among Swedish persons working in front of cathode ray tube monitors [5]. In Finns such symptoms were attributed to exposure to EMF [6]. This syndrome was termed electromagnetic hypersensitivity (EHS), although still without an International Classification of Diseases (ICD-code) [7].

EHS consists of a wide range of different symptoms that may vary from person to person. EMF sensitivity varies among individuals from mild to severe. The prevalence has been reported to be 1.5% in Sweden [8], 3.2% in California [9], 5% in Switzerland [10], and 13% in Taiwan [11].

We report here on a person who developed symptoms consistent with those described among EHS subjects. The symptoms developed at a work place with exposure to EMFs. Our hypothesis is that the symptoms may be attributed to that exposure. We obtained informed consent by the person to publish the symptoms and work history anonymously.

Methods

The subject attributed the development of EHS symptoms to her office room where she had been working one year since April 2018 for a total of 183 working days. As the source of the adverse health effects was unknown, the investigators devised a broad spectrum approach for EMF measurements, to include all possible sources of EMFs.

The room was thoroughly measured encompassing different types of electromagnetic fields, including:

- Extremely low frequency (ELF) magnetic field (MF)
- Intermediate frequency (IF) magnetic field (MF)
- Radiofrequency (RF) electromagnetic field.

Three types of measurements approaches were utilized characterizing:

- Spatial field distribution
- Temporal field dynamics
- Spectrum analysis of EMF

T. Wu, T. S. Rappaport, C. M. Collins, "The Human Body and Millimeter-Wave Wireless Communication Systems: Interactions and Implications," accepted in *2015 IEEE International Conference on Communications (ICC)*, Jun. 2015.

The Human Body and Millimeter-Wave Wireless Communication Systems: Interactions and Implications

Ting Wu[1,2], Theodore S. Rappaport[1,2,3], Christopher M. Collins[1,3]
[1]NYU WIRELESS, [2]NYU Polytechnic School of Engineering, Brooklyn, NY 11201
[3]NYU Department of Radiology, 660 First Ave, New York, NY 10016
ting.wu@nyu.edu, tsr@nyu.edu, c.collins@nyumc.org

***Abstract*—With increasing interest in millimeter-wave wireless communications, investigations on interactions between the human body and millimeter-wave devices are becoming important. This paper gives examples of today's regulatory requirements, and provides an example for a 60 GHz transceiver. Also, the propagation characteristics of millimeter-waves in the presence of the human body are studied, and four models representing different body parts are considered to evaluate thermal effects of millimeter-wave radiation on the body. Simulation results show that about 34% to 42% of the incident power is reflected at the skin surface at 60 GHz. This paper shows that power density is not suitable to determine exposure compliance when millimeter wave devices are used very close to the body. A temperature-based technique for the evaluation of safety compliance is proposed in this paper.**

***Index Terms*—body area networks (BAN), radiation, health effects, millimeter-wave, mmWave heating, RF exposure.**

I. Introduction

THE millimeter-wave (mmWave) band is part of the radio frequency (RF) spectrum, comprised of frequencies between 30 GHz and 300 GHz, corresponding to a wavelength range of 10 to 1 mm. The photon energy of mmWaves ranges from 0.1 to 1.2 milli-electron volts (meV). Unlike ultraviolet, X-ray, and gamma radiation, mmWave radiation is non-ionizing, and the main safety concern is heating of the eyes and skin caused by the absorption of mmWave energy in the human body [1][2][3]. The massive amount of raw bandwidth and potential multi-Gigabit-per-second (Gbps) data rates in the mmWave band make it a promising candidate for future broadband mobile communication networks [3][4]. The increasing investigations on mmWave applications and technologies, particularly on wireless devices, have stimulated interest in understanding how propagation of mmWaves impact the human body, as well as the inquiry of potential health effects related to mmWave exposures.

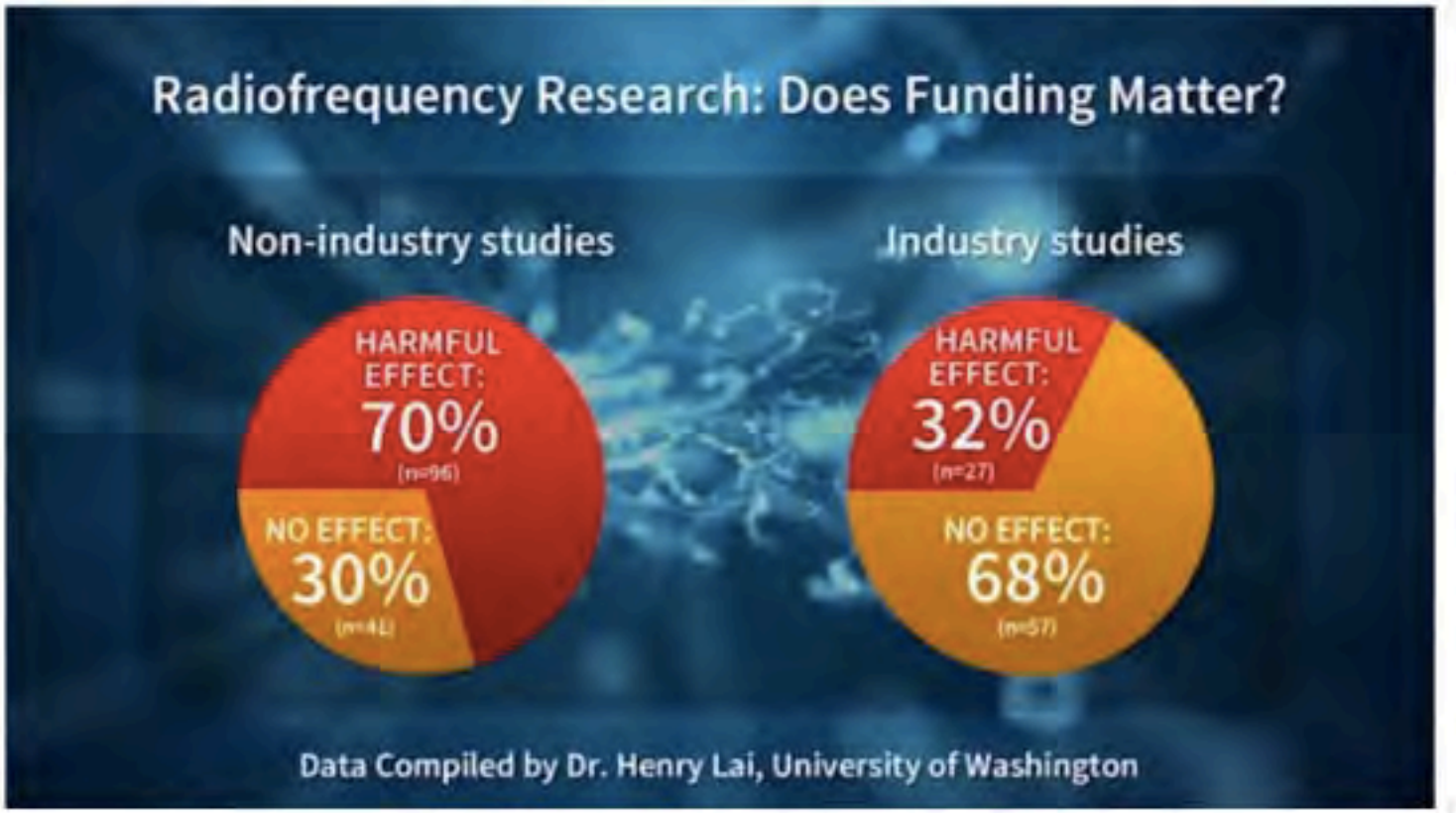
MmWave devices should be evaluated to comply with government exposure guidelines before they are introduced to the consumer market. At frequencies below 6 GHz for the Federal Communications Commission (FCC) or 10 GHz for the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the specific absorption rate (SAR) is used as a metric for exposure compliance determination. However, at higher frequencies, energy absorption is increasingly confined to the surface layers of the skin, and it is difficult to define a meaningful volume for SAR evaluation. Thus, power density (PD), rather than SAR, is currently preferred in determining compliance at above 6 GHz (FCC) or 10 GHz (ICNIRP) [1][2][3].

The ICNIRP specifies basic restrictions on PD to be 10 W/m^2 and 50 W/m^2 for the general public, and the occupational group, respectively, for frequencies between 10 and 300 GHz [1]. The limit values are to be averaged over any 20 cm^2 of exposed area and any $68/f^{1.05}$ minutes period (where f is in GHz), while the spatial peak power densities averaged over 1 cm^2 should not exceed 20 times the given limits, which are 200 W/m^2 and 1000 W/m^2, respectively.

The FCC adopts maximum permissible exposure (MPE) in terms of PD for frequencies between 6 and 100 GHz [5]. The numerical values of the FCC PD restrictions are also 10 W/m^2 and 50 W/m^2 for the general public, and occupational group, respectively, while the exposure area to be averaged for the FCC is equivalent to the vertical cross section of the human body (projected area) at a distance no closer than 20 cm from the field source. The averaging time is 6 minutes for occupational exposures, and 30 minutes for general population exposures.

Regarding localized peak power density, FCC OET Bulletin No.65 [6] states that "although the FCC did not explicitly adopt limits for peak power density, guidance on these types of exposure can be found in Section 4.4 of the ANSI/IEEE C95.1-1992 standard." The ANSI/IEEE C95.1-1992 standard specifies relaxation of PD limits for exposure of all parts of the body except the eyes and the testes [7]. For frequencies between 3 and 15 GHz, the averaging time is $90{,}000/f$ (where f is in MHz), and for frequencies between 15 and 300 GHz, the appropriate averaging time is $616{,}000/f^{1.2}$ minutes (where f is in MHz). For occupational/controlled exposures, the peak power density

Independent Studies vs. Industry Funded Research.



Most non-industry funded studies report harmful effects from RF radiation.

On the other hand, most industry-funded research doesn't report any effects.

SCIENTIFIC REPORTS
nature research

OPEN

Propagation of THz irradiation energy through aqueous layers: Demolition of actin filaments in living cells

Shota Yamazaki[1]✉, Masahiko Harata[2], Yuya Ueno[2], Masaaki Tsubouchi[3], Keiji Konagaya[4], Yuichi Ogawa[4], Goro Isoyama[5], Chiko Otani[1] & Hiromichi Hoshina[1]✉

The effect of terahertz (THz) radiation on deep tissues of human body has been considered negligible due to strong absorption by water molecules. However, we observed that the energy of THz pulses transmits a millimeter thick in the aqueous solution, possibly as a shockwave, and demolishes actin filaments. Collapse of actin filament induced by THz irradiation was also observed in the living cells under an aqueous medium. We also confirmed that the viability of the cell was not affected under the exposure of THz pulses. The potential of THz waves as an invasive method to alter protein structure in the living cells is demonstrated.

Due to the development of terahertz (THz) light sources, industrial and medical applications have been proposed in this decades. Also, toxicity of THz radiation for human health has attracted keen interest among researchers working in this frequency region[1]. Two projects, the European THz-BRIDGE and the International EMF project in the SCENIHR[2], summarize recent studies about THz radiation effects for human body. For example, non-thermal impacts on DNA stability[3–5] was induced by THz wave, which could cause chromosomal aberrations in human lymphocytes[6]. The transcriptional activation of wound-responsive genes in mouse skin[7] and DNA damage in an artific al human 3D skin tissue model[8] have also been demonstrated. Most of those studies focus on epithelial and corneal cell lines, because THz photons are totally absorbed at the surface of the tissues due to the intense absorbance of liquid water in this frequency region.

However, if the THz radiation is converted to the other type of energy fl w which can propagate into water, irradiation of THz wave may cause damage inside the tissues. In fact, the THz photon energy is once absorbed on the body surface, and converted to the thermal and mechanical energies. We recently observed that THz pulses generate shockwaves at the surface of liquid water[9]. The generated shockwaves propagate several millimeters in depth. Similar phenomena may occur at the human body. The THz-induced shockwaves may induce mechanical stress to the biomolecules and change their morphology. Such indirect effects of the THz irradiation have not been investigated.

To reveal the effect of THz-induced shockwaves to the biological molecules, we focused on morphology of the actin proteins. Actin has two functional forms, monomeric globular (G)-actin and polymerized filamentous (F)-actin. The actin filament forms the elaborate cytoskeleton network, which plays crucial roles in cell shape, motility, and division[10]. One advantage of using actin is that we can easily obtain enough purifi d G-actin from tissues[11] to reconstruct polymerization reactions *in vitro*. Actin filaments can be directly observed by fluorescence microscopy by staining with silicon-rhodamine (SiR)-actin[12]. Because actin has pivotal roles in normal and pathological cell function, including transcriptional regulation, DNA repair, cancer cell metastasis, and gene reprogramming[13–16], various chemical compounds and regulatory proteins have been analyzed for research and therapeutic purposes[17]. In this study, we investigated the effect of THz-induced shockwaves on actin filaments

[1]RIKEN, Center for Advanced Photonics, 519-1399 Aramaki-Aoba, Aoba-ku, Sendai, Miyagi, 980-0845, Japan. [2]Laboratory of Molecular Biology, Graduate School of Agricultural Science, Tohoku University, 468-1 Aramaki-Aoba, Aoba-ku, Sendai, Miyagi, 980-0845, Japan. [3]Kansai Photon Science Institute, National Institutes for Quantum and Radiological Science and Technology, Kyoto, 619-0215, Japan. [4]Department of Physics, Graduate School of Science, Kyoto University, Kitashirakawa-oiwakecho, Sakyo-ku, Kyoto, 606-8502, Japan. [5]Institute of Scientific and Industrial Research, Osaka University, 8-1 Mihogaoka, Ibaraki, Osaka, 567-0047, Japan. ✉e-mail: shota.yamazaki.fc@riken.jp; hoshina@riken.jp

Environmental Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Environmental Research

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

Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102)☆

Anthony B. Miller[a,*], L. Lloyd Morgan[b], Iris Udasin[c], Devra Lee Davis[d,e]

[a] Dalla Lana School of Public Health, University of Toronto, Canada
[b] Environmental Health Trust, Berkeley, CA, United States
[c] Rutgers University School of Public Health, United States
[d] Environmental Health Trust, Teton Village, WY, United States
[e] Hebrew University of Jerusalem, Israel

ARTICLE INFO

Keywords:
Brain cancer
Vestibular schwannoma
Salivary gland tumor
Electric hypersensitivity
Glioma
Meningioma
Radio frequency fields
Cell phones
Mobile phones

ABSTRACT

Epidemiology studies (case-control, cohort, time trend and case studies) published since the International Agency for Research on Cancer (IARC) 2011 categorization of radiofrequency radiation (RFR) from mobile phones and other wireless devices as a possible human carcinogen (Group 2B) are reviewed and summarized. Glioma is an important human cancer found to be associated with RFR in 9 case-control studies conducted in Sweden and France, as well as in some other countries. Increasing glioma incidence trends have been reported in the UK and other countries. Non-malignant endpoints linked include acoustic neuroma (vestibular Schwannoma) and meningioma. Because they allow more detailed consideration of exposure, case-control studies can be superior to cohort studies or other methods in evaluating potential risks for brain cancer. When considered with recent animal experimental evidence, the recent epidemiological studies strengthen and support the conclusion that RFR should be categorized as carcinogenic to humans (IARC Group 1). Opportunistic epidemiological studies are proposed that can be carried out through cross-sectional analyses of high, medium, and low mobile phone users with respect to hearing, vision, memory, reaction time, and other indicators that can easily be assessed through standardized computer-based tests. As exposure data are not uniformly available, billing records should be used whenever available to corroborate reported exposures.

1. Introduction

With rapidly increasing applications for wireless devices targeting populations of all ages, exposures to the associated radiofrequency radiation (RFR) are increasing in number and diversity. Radiation sources include communications devices such as mobile (cell) or cordless phones, laptops and tablets, baby monitors, wearable devices and associated infrastructure (e.g. routers, antennae on towers, and distributed antennae systems (DAS) that can employ directional couplers or wireless amplifiers to enhance accessibility). Thus, the technology entails direct and growing personal exposures to an expanding array of wireless transmitting devices (WTDs).

In 2011, a Working Group of the World Health Organization's International Agency for Research on Cancer (IARC) classified RFR as a possible human carcinogen (Group 2B) (IARC, 2013). In this paper we review the human epidemiology and some other relevant studies published since the IARC Working Group meeting.

1.1. Wireless phone types

The principal sources of exposure of humans to RFR are cell and cordless phones. The radiated power and technologies for cell phones have evolved over the years, as summarized in Table 1 (Hardell and Carlberg, 2015).

2. Case-control studies; glioma

Aydin et al. (2011) reported the results of CEFALO, a multicenter

☆ This paper was prepared for and revised with the Epidemiology Working Group of the Expert Forum: Wireless Radiation and Human Health at the Hebrew University, January 23–26, 2017. sponsored by the Israel Institute for Advanced Study and Environmental Health Trust, with support from the U.S. National Institutes of Health/ National Institute of Environmental Health Sciences and Dr. Lucy R. Wiletzky.

* Corresponding author.
E-mail addresses: ab.miller@utoronto.ca (A.B. Miller), lloyd.l.morgan@gmail.com (L.L. Morgan), iu22@eohsi.rutgers.edu (I. Udasin), ddavis@ehtrust.org (D.L. Davis).

https://doi.org/10.1016/j.envres.2018.06.043
Received 5 September 2017; Received in revised form 14 June 2018; Accepted 20 June 2018

Human-made electromagnetic fields: Ion forced-oscillation and voltage-gated ion channel dysfunction, oxidative stress and DNA damage (Review)

DIMITRIS J. PANAGOPOULOS[1-3], ANDREAS KARABARBOUNIS[4], IGOR YAKYMENKO[5,6] and GEORGE P. CHROUSOS[2]

[1]Laboratory of Health Physics, Radiobiology and Cytogenetics, Institute of Nuclear and Radiological Sciences and Technology, Energy and Safety, National Center for Scientific Research 'Demokritos', 15310 Athens; [2]Choremeion Research Laboratory, Medical School, National and Kapodistrian University of Athens, 11527 Athens; [3]Electromagnetic Field-Biophysics Research Laboratory, 10681 Athens; [4]Department of Physics, Section of Nuclear and Particle Physics, National and Kapodistrian University of Athens, 15784 Athens, Greece; [5]Institute of Experimental Pathology, Oncology and Radiobiology of National Academy of Science of Ukraine, 03022 Kyiv; [6]Department of Public Health, Kyiv Medical University, 02000 Kyiv, Ukraine

Received July 9, 2021; Accepted August 23, 2021

DOI: 10.3892/ijo.2021.5272

Abstract. Exposure of animals/biological samples to human-made electromagnetic fields (EMFs), especially in the extremely low frequency (ELF) band, and the microwave/radio frequency (RF) band which is always combined with ELF, may lead to DNA damage. DNA damage is connected with cell death, infertility and other pathologies, including cancer. ELF exposure from high-voltage power lines and complex RF exposure from wireless communication antennas/devices are linked to increased cancer risk. Almost all human-made RF EMFs include ELF components in the form of modulation, pulsing and random variability. Thus, in addition to polarization and coherence, the existence of ELFs is a common feature of almost all human-made EMFs. The present study reviews the DNA damage and related effects induced by human-made EMFs. The ion forced-oscillation mechanism for irregular gating of voltage-gated ion channels on cell membranes by polarized/coherent EMFs is extensively described. Dysfunction of ion channels disrupts intracellular ionic concentrations, which determine the cell's electrochemical balance and homeostasis. The present study shows how this can result in DNA damage through reactive oxygen species/free radical overproduction. Thus, a complete picture is provided of how human-made EMF exposure may indeed lead to DNA damage and related pathologies, including cancer. Moreover, it is suggested that the non-thermal biological effects attributed to RF EMFs are actually due to their ELF components.

Correspondence to: Dr Dimitris J. Panagopoulos, Laboratory of Health Physics, Radiobiology and Cytogenetics, Institute of Nuclear and Radiological Sciences and Technology, Energy and Safety, National Center for Scientific Research 'Demokritos', Patr. Grigoriou E' and 27 Neapoleos Street, Agia Paraskevi, 15310 Athens, Greece
E-mail: dpanagop@biol.uoa.gr

Abbreviations: DECT, digitally enhanced cordless telecommunications; ELF, extremely low frequency; EMF, electromagnetic field; MT, mobile telephony; OS, oxidative stress; RF, radio frequency; ROS, reactive oxygen species; ULF, ultra low frequency; VGICs, voltage-gated ion channels; VGCCs, voltage-gated calcium channels; WC, wireless communications; Wi-Fi, wireless fidelity; 2G/3G/4G/5G, second/third/fourth/fifth-generation of mobile telephony

Key words: EMF, ion forced-oscillation, VGICs, free radicals, OS, ROS, DNA damage, cancer

Contents

1. Introduction

Experimental and epidemiological findings connecting exposure of living organisms to ELF and complex RF human-made EMFs with genetic damage, infertility and cancer. There is a plethora of experimental findings connecting the *in vivo* or *in vitro* exposure of experimental animals or cells to extremely low frequency (ELF) (3-3000 Hz) or radio-frequency (RF)/microwave (300 kHz-300 GHz) electromagnetic fields (EMFs), with genetic damage/alterations

Environmental Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Environmental Research

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

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

Cindy L. Russell

PO Box 7443, Menlo Park, CA 94026, USA

ARTICLE INFO

Keywords:
Wireless technology
Public health
Radiofrequency radiation
Environmental pollution

ABSTRACT

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

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

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

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

1. Introduction

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

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

☆ The author has read and approved the paper and it has not been published previously nor is it being considered by any other peer-reviewed journal. The author has no conflicts of interest. There was no financial support for the research, design, analysis, interpretation or writing of this article nor for the decision to publish this article.

E-mail address: cindyleerussell@gmail.com.

https://doi.org/10.1016/j.envres.2018.01.016
Received 3 October 2017; Accepted 16 January 2018
0013-9351/

Environmental Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Environmental Research

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

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

L. Falcioni, L. Bua, E. Tibaldi, M. Lauriola, L. De Angelis, F. Gnudi, D. Mandrioli, M. Manservigi, F. Manservisi, I. Manzoli, I. Menghetti, R. Montella, S. Panzacchi, D. Sgargi, V. Strollo, A. Vornoli, F. Belpoggi*

Cesare Maltoni Cancer Research Center, Ramazzini Institute, Castello di Bentivoglio, via Saliceto 3, Bentivoglio, 40010 Bologna, Italy

ARTICLE INFO

Keywords:
RF
Sprague-Dawley rats
Life-span bioassay
Mobile phone
Carcinogenicity

ABSTRACT

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.

1. Introduction

Early warnings on the potential carcinogenic risks of mobile phone radiofrequency radiation (RFR) raised in the early 2000 when, for the first time, it was published that people using mobile phones had a significant increased risk to develop vestibular Schwannoma and brain tumors (Hardell et al., 2003, 2002). In 2011, the International Agency for Research on Cancer (IARC) classified RFR as possible human carcinogen (Group 2B) based on limited evidence both in humans and experimental animals (Baan et al., 2011; IARC, 2013). Two epidemiological case-control studies resulted more informative for the IARC evaluation, showing that the risk to develop brain tumors and vestibular Schwannoma was increased in people with the highest cumulative use of mobile phones, in people who had used mobile phones on the

* Corresponding author.
E-mail address: belpoggif@ramazzini.it (F. Belpoggi).

https://doi.org/10.1016/j.envres.2018.01.037
Received 9 October 2017; Received in revised form 19 December 2017; Accepted 23 January 2018

ELECTROMAGNETIC BIOLOGY AND MEDICINE
https://doi.org/10.1080/15368378.2017.1350584

Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations

Zothansiama, Mary Zosangzuali, Miriam Lalramdinpuii, and Ganesh Chandra Jagetia

Department of Zoology, Cancer and Radiation Biology Laboratory, Mizoram University, Aizawl, Mizoram, India

ABSTRACT

Radiofrequency radiations (RFRs) emitted by mobile phone base stations have raised concerns on its adverse impact on humans residing in the vicinity of mobile phone base stations. Therefore, the present study was envisaged to evaluate the effect of RFR on the DNA damage and antioxidant status in cultured human peripheral blood lymphocytes (HPBLs) of individuals residing in the vicinity of mobile phone base stations and comparing it with healthy controls. The study groups matched for various demographic data including age, gender, dietary pattern, smoking habit, alcohol consumption, duration of mobile phone use and average daily mobile phone use. The RF power density of the exposed individuals was significantly higher ($p < 0.0001$) when compared to the control group. The HPBLs were cultured and the DNA damage was assessed by cytokinesis blocked micronucleus (MN) assay in the binucleate lymphocytes. The analyses of data from the exposed group ($n = 40$), residing within a perimeter of 80 m of mobile base stations, showed significantly ($p < 0.0001$) higher frequency of micronuclei when compared to the control group, residing 300 m away from the mobile base station/s. The analysis of various antioxidants in the plasma of exposed individuals revealed a significant attrition in glutathione (GSH) concentration ($p < 0.01$), activities of catalase (CAT) ($p < 0.001$) and superoxide dismutase (SOD) ($p < 0.001$) and rise in lipid peroxidation (LOO) when compared to controls. Multiple linear regression analyses revealed a significant association among reduced GSH concentration ($p < 0.05$), CAT ($p < 0.001$) and SOD ($p < 0.001$) activities and elevated MN frequency ($p < 0.001$) and LOO ($p < 0.001$) with increasing RF power density.

ARTICLE HISTORY
Received 27 April 2017
Accepted 30 June 2017

KEYWORDS
Antioxidants; genotoxicity; humans; micronucleus; power density

Introduction

The mobile phone base stations are one of the essential parts of mobile telecommunication as they transmit the signals in the form of radiofrequency radiations (RFRs) that are received by the mobile phones, acting as a two-way radio, i.e. transceiver (Kwan-Hoong, 2005), generally operating in the frequency range of 900 MHz to 1.9 GHz (Levitt and Lai, 2010). The ever-increasing subscription of mobile phones has led to a phenomenal increase in the mobile phone base stations required to cater to the needs of increasing demand of the mobile subscribers. For decades, there has been an increasing concern on the possible adverse effects of RFR on humans living near mobile phone base stations despite the fact that RFR spectrum are of low frequency (ARPANSA, 2011). There has been a link between the RFR exposures and several human health disorders including cancer, diabetes, cardiovascular and neurological diseases (Bortkiewicz et al., 2004; Eger et al., 2004; Havas, 2013; Lerchl et al., 2015; Wolf and Wolf, 2004). The International Agency for Research on Cancer (IARC, 2011) has classified RFR as a possible carcinogen to humans (group 2B), based on the increased risk for glioma, a malignant type of brain cancer associated with wireless phone use (Hardell et al., 2013).

RFR may change the fidelity of DNA as the increased incidence of cancer has been reported among those residing near mobile phone base stations (Abdel-Rassonl et al., 2007; Bortkiewicz et al., 2004; Cherry, 2000; Eger et al., 2004; Hardell et al., 1999; Hutter et al., 2006; Wolf and Wolf, 2004). RFR emitted from mobile base stations is also reported to increase the DNA strand breaks in lymphocytes of mobile phone users and individuals residing in the vicinity of a mobile base station/s (Gandhi and Anita, 2005; Gandhi et al., 2014). Exposure of human fibroblasts and rat granulosa cells to RFR (1800 MHz, SAR 1.2 or 2 W/kg) has been reported to induce DNA single- and double-strands breaks (Diem et al., 2005). Irreversible DNA damage was also reported in cultured human lens epithelial cells exposed to microwave generated by mobile phones (Sun et al., 2006). The adverse health effects of RFR are still debatable as many studies indicated above have found a positive correlation between the DNA

CONTACT Ganesh Chandra Jagetia gc.jagetia@gmail.com Department of Zoology, Mizoram University, Aizawl 796 004, Mizoram, India.

IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received June 8, 2016, accepted August 1, 2016, date of publication August 17, 2016, date of current version November 18, 2016.

Digital Object Identifier 10.1109/ACCESS.2016.2601145

Exposure to RF EMF From Array Antennas in 5G Mobile Communication Equipment

BJÖRN THORS[1], DAVIDE COLOMBI[1], ZHINONG YING[2], (Senior Member, IEEE), THOMAS BOLIN[2], AND CHRISTER TÖRNEVIK[1], (Member, IEEE)

[1]Ericsson Research, Ericsson AB, SE-16480 Stockholm, Sweden
[2]Network Technology Laboratory, Research and Technology, Sony Mobile Communications AB, SE-221 88 Lund, Sweden

Corresponding author: B. Thors (bjorn.thors@ericsson.com)

ABSTRACT In this paper, radio-frequency (RF) electromagnetic field (EMF) exposure evaluations are conducted in the frequency range 10–60 GHz for array antennas intended for user equipment (UE) and low-power radio base stations in 5G mobile communication systems. A systematic study based on numerical power density simulations considering effects of frequency, array size, array topology, distance to exposed part of human body, and beam steering range is presented whereby the maximum transmitted power to comply with RF EMF exposure limits specified by the International Commission on Non-Ionizing Radiation Protection, the US Federal Communications Commission, and the Institute of Electrical and Electronics Engineers is determined. The maximum transmitted power is related to the maximum equivalent isotropically radiated power to highlight the relevance of the output power restrictions for a communication channel. A comparison between the simulation and measurement data is provided for a canonical monopole antenna. For small distances, with the antennas transmitting directly toward the human body, it is found that the maximum transmitted power is significantly below the UE power levels used in existing third and fourth generation mobile communication systems. Results for other conceivable exposure scenarios based on technical solutions that could allow for larger output power levels are also discussed. The obtained results constitute valuable information for the design of future mobile communication systems and for the standardization of EMF compliance assessment procedures of 5G devices and equipment.

INDEX TERMS 5G mobile communication, antenna arrays, beam steering, mobile device, mobile user equipment, radio base station, RF EMF exposure.

I. INTRODUCTION

The total amount of mobile traffic is expected to increase dramatically in the coming years [1]. The next generation of wireless access systems (5G), set for commercial availability around 2020 [2], is expected to constitute a key enabler for the larger system capacity and higher data rates of the future. Various research activities are currently ongoing to lay the foundation for this new technology, see e.g. [3], [4], which apart from mobile broadband will involve a range of different use cases and challenging requirements on latency, security, reliability, availability, energy performance, and device cost [5]. In terms of spectrum, 5G systems will need to be able to operate over a very wide frequency range from below 1 GHz up to and including millimeter wave (mmW) frequencies [1]. The available spectrum above 10 GHz will be a key component to fulfill long-term traffic demands and to enable the very wide transmission bandwidths needed to provide the desired multi-Gbps data rates in an efficient manner [5].

Products emitting radio-frequency (RF) electromagnetic fields (EMF) need to be designed and tested to comply with relevant regulatory requirements and limits on human exposure to EMF [6]–[9]. The most widely adopted exposure limits worldwide are the guidelines specified by the International Commission on Non-Ionizing Radiation (ICNIRP) [7] in 1998. In the US, exposure limits specified by the Federal Communications Commission (FCC) are applicable [9]. The exposure limits published by the IEEE [10], [11] are of a more recent date but has so far not been adopted in any national regulations.

For the frequencies used by existing second, third, and fourth generation (2G, 3G, and 4G) mobile communication systems, basic restrictions on RF EMF exposure are specified in terms of the specific absorption rate (*SAR*) to prevent, with wide safety margins, from established adverse health effects associated with excessive localized tissue heating and whole-body heat stress [7], [9], [10]. At higher frequencies,

American Journal of Men's Health
1–6

DOI: 10.1177/1557988318816914
journals.sagepub.com/home/jmh
SAGE

Mobile Phone Base Station Tower Settings Adjacent to School Buildings: Impact on Students' Cognitive Health

Sultan Ayoub Meo, MBBS, PhD[1], Mohammed Almahmoud, MBBS[1], Qasem Alsultan, MBBS[1], Nawaf Alotaibi, MBBS[1], Ibrahim Alnajashi, MBBS[1], and Waseem M. Hajjar, MD, FRCS[2]

Abstract

The use of mobile phones has remarkably increased and become a basic need of daily life. Increasing subscriptions of mobile phones boost the installation of mobile phone base station towers (MPBSTs) in crowded commercial and residential areas including near school buildings. This study investigated the impact of exposure to radiofrequency electromagnetic field (RF-EMF) radiation generated by MPBSTs on cognitive functions. Two hundred and seventeen volunteer male students aged between 13 and 16 registered from two different intermediate schools: 124 students were from School 1 and 93 students were from School 2. The MPBSTs were located within 200 m from the school buildings. In School 1, RF-EMF was 2.010 μW/cm^2 with a frequency of 925 MHz and in School 2, RF-EMF was 10.021 μW/cm^2 with a frequency of 925 MHz. Students were exposed to EMFR for 6 hr a day, 5 days a week for a total period of 2 years. The Narda Safety Test Solution device SRM-3006 was used to measure RF-EMF in both schools, and cognitive functions tasks were measured by the Cambridge Neuropsychological Test Automated Battery (CANTAB). Significant impairment in Motor Screening Task (MOT; $p = .03$) and Spatial Working Memory (SWM) task ($p = .04$) was identified among the group of students who were exposed to high RF-EMF produced by MPBSTs. High exposure to RF-EMF produced by MPBSTs was associated with delayed fine and gross motor skills, spatial working memory, and attention in school adolescents compared to students who were exposed to low RF-EMF.

Keywords

Electromagnetic Field Radiation, Mobile Phones Base Station Tower, Cognitive function

Received August 10, 2018; revised October 20, 2018; accepted November 8, 2018

In recent years, tremendous developments in mobile phones have revolutionized the telecom industry by making telecommunication faster, economical, and more convenient (D'Silva, Swer, Anbalagan, & Bhargavan, 2014). With the introduction of new applications and multifunctional technology in mobile phones, the telecom industry is appealing to both youth and adults. The usage of mobile phones has dramatically increased, which is considered as a basic tool in daily life (Al-Khlaiwi & Meo, 2004). Worldwide, the number of subscriptions of mobile phones is about 7.52 billion. This number is more than the worldwide population, as many users own more than one mobile phone (World Bank, 2018). The extensive usage of cellular phones has led to the growing installation of mobile phone base station towers (MPBSTs) in crowded commercial and residential areas, which raises community concerns (Buckus et al., 2017; Meo et al., 2015; Wiedemann, Freudenstein, F., Böhmert, Wiart, & Croft, 2017; Zhang et al., 2017; Figure 1).

[1]Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia
[2]Department of Thoracic Surgery, College of Medicine, King Saud University, Riyadh, Saudi Arabia

Corresponding Author:
Prof. Sultan Ayoub Meo, MBBS, PhD, Professor and Consultant in Clinical Physiology, Department of Physiology, College of Medicine, King Saud University, PO Box 2925, Riyadh 11461, Kingdom of Saudi Arabia.
Email: sultanmeo@hotmail.com, smeo@ksu.edu.sa

To Whom It May Concern:

Dear Sirs/Madams:

I am Scientist Emeritus and Former Director of the National Institute of Environmental Health Sciences and National Toxicology Program of the National Institutes of Health. I am currently a Scholar in Residence at the Nicholas School of the Environment at Duke University.

Wireless networks, cell towers and cell phones create radiofrequency radiation emissions. U.S. FCC limits for human exposure to radiofrequency were last reviewed in 1996 and based on the assumption that heating is the only harmful effect. Aware that the FCC's 1996 limits lacked the underpinning of solid scientific data regarding long term health effects, the FDA requested large-scale studies by the National Toxicology Program (NTP) and in 2018 the NTP studies found clear evidence of an association with cancer in male rats. Additionally, the NTP found heart damage and DNA damage, despite the fact that the animals were carefully exposed to non-heating RFR levels long assumed to be safe. The Ramazzini Institute animal studies used even lower RFR lower exposures to approximate cell tower emissions and also found increases of the same tumor type. The NTP studies were carefully controlled to ensure exposures did not significantly heat the animals. The animal study findings in combination with human studies indicate adverse effects from non heating levels of radiofrequency.

I document the importance of the NTP findings of effects from non thermal exposures in my declaration in an Amicus Brief for the case Environmental Health Trust et al v. the FCC. The August 13, 2021 judgment ordered the FCC to address several issues including the health implications of long term exposures.

A mounting body of published studies associates radiofrequency radiation with adverse negative health effects. FCC limits need to be strengthened to protect the public, especially children and vulnerable populations, from long term exposures.

Linda S. Birnbaum, PhD
Scientist Emeritus and Former Director
National Institute of Environmental Health Sciences and National Toxicology Program
Scholar in Residence, Duke University, Former President, Society of Toxicology
Adjunct Professor, Yale University and UNC, Chapel Hill, Visiting Professor, Queensland University (Australia)

National Toxicology Program Radiofrequency Radiation
https://ntp.niehs.nih.gov/whatwestudy/topics/cellphones/index.html

Amicus Brief of Joe Sandri, August 5, 2020
https://ehtrust.org/wp-content/uploads/20-1025-Amicus-Brief-Joe-Sandri.pdf

Falcioni 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, Environmental Research, Volume 165, 2018,
Pages 496-503 DOI: 10.1016/j.envres.2018.01.037

Priyanka Bandara, David O Carpenter, Planetary electromagnetic pollution: it is time to assess its impact, The Lancet Planetary Health, Volume 2, Issue 12, 2018, Pages e512-e514,ISSN 2542-5196, https://doi.org/10.1016/S2542-5196(18)30221-3.

Schuermann D, Mevissen M. Manmade Electromagnetic Fields and Oxidative Stress—Biological Effects and Consequences for Health.International Journal of Molecular Sciences. 2021; 22(7):3772. https://doi.org/10.3390/ijms22073772

Smith-Roe SL., 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): 276-290

Human Exposure to RF Fields in 5G Downlink

Imtiaz Nasim and Seungmo Kim
{in00206, seungmokim}@georgiasouthern.edu
Department of Electrical Engineering, Georgia Southern University
Statesboro, GA 30460, USA

***Abstract*—While cellular communications in millimeter wave (mmW) bands have been attracting significant research interest, their potential harmful impacts on human health are not as significantly studied. Prior research on human exposure to radio frequency (RF) fields in a cellular communications system has been focused on uplink only due to the closer physical contact of a transmitter to a human body. However, this paper claims the necessity of thorough investigation on human exposure to downlink RF fields, as cellular systems deployed in mmW bands will entail (i) deployment of more transmitters due to smaller cell size and (ii) higher concentration of RF energy using a highly directional antenna. In this paper, we present human RF exposure levels in downlink of a Fifth Generation Wireless Systems (5G). Our results show that 5G downlink RF fields generate significantly higher power density (PD) and specific absorption rate (SAR) than a current cellular system. This paper also shows that SAR should also be taken into account for determining human RF exposure in the mmW downlink.**

***Index Terms*—5G; mmW; Downlink; Human RF exposure; PD; SAR.**

I. Introduction

It is acknowledged that exposure to RF has negative impacts on human body. The rapid proliferation of mobile telecommunications has occurred amidst controversy over whether the technology poses a risk to human health [1]. At mmW frequencies where future mobile telecommunications systems will likely operate, two changes that will likely occur have the potential to increase the concern on exposure of human users to RF fields. First, *larger numbers of transmitters* will operate. More base stations (BSs) will be deployed due to proliferation of small cells [2]-[4] and mobile devices accordingly. This will increase chance of human exposure to RF fields. Second, *narrower beams* will be used as a solution for the higher attenuation in higher frequency bands [3]-[7]. Very small wavelengths of mmW signals combined with advances in RF circuits enable very large numbers of miniaturized antennas. These multiple antenna systems can be used to form very high gains. Such higher concentration of RF energy will increase the potential to more deeply penetrate into a human body.

A. Related Work

This paper is motivated from the fact that prior work is not enough to address such potential increase in threats.

1) Measurement of Human RF Exposure: Being aware of the health hazards due to electromagnetic (EM) emissions in mmW spectrum, international agencies such as the Federal Communications Commission (FCC) [8] or the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [9] set the maximum radiation allowed to be introduced in the human body without causing any health concern. Possibilities of skin cancer due to RF emissions at higher frequency spectrum are reported [10]. Heating due to EM exposure in mmW is absorbed within the first few millimeters (mm) within the human skin; for instance, the heat is absorbed within 0.41 mm for 42.5 GHz [11]. The mmW induced burns are more likely to be conventional burns as like as a person touching a hot object as reported in [1]. The normal temperature for the skin outer surface is typically around 30 to 35°C. The pain detection threshold temperature for human skin is approximately 43°C as reported and any temperature over that limit can produce long-term injuries.

One problem is that the literature on the impact of cellular communications on human health is not mature enough. The three major quantities used to measure the intensity and effects of RF exposure are SAR, PD, and the steady state or transient temperature [12][13]. However, selection of an appropriate metric evaluating the human RF exposure still remains controversial. The FCC suggests PD as a metric measuring the human exposure to RF fields generated by devices operating at frequencies higher than 6 GHz [8], whereas a recent study suggested that the PD standard is not efficient to determine the health issues especially when devices are operating very close to human body in mmW [14]. Therefore, this paper examines the human RF exposure by using both PD and SAR.

2) Reduction of Human RF Exposure: Very few prior studies in the literature paid attention to human RF exposure in communications systems [1][14]-[17]. Propagation characteristics at different mmW bands and their thermal effects were investigated for discussion on health effects of RF exposure in mmW radiation [14]. Emission reduction scheme and models for SAR exposure constraints are studied in recent work [15][16].

However, health impacts of mmW RF emissions in *downlink* of a cellular communications system have not been studied so far, which this paper targets to discuss.

B. Contributions

Three contributions of this paper can be highlighted and distinguished from the prior art.

Firstly, this paper analyzes the human RF exposure in the *downlink*. All the prior work studied an uplink only, while paid almost no attention to suppression of RF fields generated by access points (APs) and BSs in a 5G nor Release 9 network,

Electromagnetic Biology and Medicine, Early Online: 1–25, 2012

ISSN: 1536-8378 print / 1536-8386 online
DOI: 10.3109/15368378.2011.631068

informa
healthcare

Brain proteome response following whole body exposure of mice to mobile phone or wireless DECT base radiation

Adamantia F. Fragopoulou[1], Athina Samara[2], Marianna H. Antonelou[1], Anta Xanthopoulou[3], Aggeliki Papadopoulou[3], Konstantinos Vougas[3], Eugenia Koutsogiannopoulou[2], Ema Anastasiadou[2], Dimitrios J. Stravopodis[1], George Th. Tsangaris[3] & Lukas H. Margaritis[1]

[1]Department of Cell Biology and Biophysics, Athens University, Athens, Greece, [2]Genetics and Gene Therapy Division, Center of Basic Research II, Biomedical Research Foundation of the Academy of Athens, Athens, Greece, and [3]Proteomics Research Unit, Center of Basic Research II, Biomedical Research Foundation of the Academy of Athens, Athens, Greece

The objective of this study was to investigate the effects of two sources of electromagnetic fields (EMFs) on the proteome of cerebellum, hippocampus, and frontal lobe in Balb/c mice following long-term whole body irradiation. Three equally divided groups of animals (6 animals/group) were used; the first group was exposed to a typical mobile phone, at a SAR level range of 0.17–0.37 W/kg for 3 h daily for 8 months, the second group was exposed to a wireless DECT base (Digital Enhanced Cordless Telecommunications/Telephone) at a SAR level range of 0.012–0.028 W/kg for 8 h/day also for 8 months and the third group comprised the sham-exposed animals. Comparative proteomics analysis revealed that long-term irradiation from both EMF sources altered significantly ($p < 0.05$) the expression of 143 proteins in total (as low as 0.003 fold downregulation up to 114 fold overexpression). Several neural function related proteins (i.e., Glial Fibrillary Acidic Protein (GFAP), Alpha-synuclein, Glia Maturation Factor beta (GMF), and apolipoprotein E (apoE)), heat shock proteins, and cytoskeletal proteins (i.e., Neurofilaments and tropomodulin) are included in this list as well as proteins of the brain metabolism (i.e., Aspartate aminotransferase, Glutamate dehydrogenase) to nearly all brain regions studied. Western blot analysis on selected proteins confirmed the proteomics data. The observed protein expression changes may be related to brain plasticity alterations, indicative of oxidative stress in the nervous

Authors' contributions: AFF and LHM conceived the concept and design of the experiments, made the literature survey and the final biologically valid interpretation of the EMF impact upon the brain, wrote and finalized the manuscript. AFF carried out all animal handling, welfare, EMF exposure, part of brain dissection and immunoassays. AS performed the brain dissection and brain regions' separation, contributed to the non-EMF writing of the manuscript and together with MHA, EK and EA carried out a part of the immunoassays and contributed to the data evaluation related to neuroproteomics. AX, AP and KV were involved in 2-DE experiments, Maldi ToF/MS, protein identification and statistical analysis. DJS participated in the conception of the design and contributed to the interpretation and evaluation of the overall data. GThT participated in the experimental design and experimental protocols optimization, coordinated the proteomics study, carried out the overall differential proteomics analysis and data evaluation and contributed to the proteomics writing of the manuscript. All authors read and approved the final manuscript.

Address correspondence to Lukas H. Margaritis, Adamantia F. Fragopoulou, Department of Cell Biology and Biophysics, Faculty of Biology, Athens University, Panepistimiopolis, 15784 Athens, Greece. E-mails: lmargar@biol.uoa.gr, madofrag@biol.uoa.gr

Health Effects of Mobile Tower Radiation on Human — Case Study

Lalrinthara Pachuau*, Zaithanzauva Pachuau
Dept. of Physics, Mizoram University, Tanhril, India.

* Corresponding author. Tel.: +91-9862358768; email: rinapachuau@yahoo.com
Manuscript submitted November 4, 2015; accepted March 16, 2016.
doi: 10.17706/ijapm.2016.6.2. 72-79

Abstract: In the present paper, we presented the study of complaints on thirteen (13) different health symptoms faced by inhabitants living near mobile tower – Global System for Mobile Communication (GSM 900 & 1800) and those inhabitants living in the area where there is no mobile tower. The study was conducted in fourteen different localities in Aizawl city and four different localities outside Aizawl city in the year 2014 & 2015. Questionnaires were conducted in all the localities. Power densities were measured in different places in all the localities. Health complaints between the localities were compared with that of the locality where there is no mobile tower. It was found that power density is much higher in the area where there is mobile tower than the area where there is no mobile tower. Questionnaire responses from all the localities were statistically analysed and compared by performing t-test. Out of the thirteen (13) different symptoms studied it was found that the comparisons are statistically significant with $p < 0.05$ in six symptoms. Significant Health complaints start to occur when average power density of the locality is more than 2.145 mW/m^2. Women were statistically more affected ($p < 0.05$) than male. It was found that there was strong positive correlation between power density and health complaints with R^2 value 0.853.

Key words: Health symptoms, power density, RF radiation.

1. Introduction

The introduction in the 1990s of mobile phone using the digital Global System for Mobile Communication (GSM) bandwidths 900 and 1800 megahertz (MHz) and the subsequent introduction of the Universal Mobile Telecommunications System (UMTS) have led to widespread use of this technology. This development has raised public concerns and substantial controversy about the potential health effects of the radiofrequency electromagnetic field emissions of this technology [1]. It is believed that mobile phones produce RF energy of non-ionizing radiation which is too low to heat the body's tissues, and hence is unlikely to have the same impact on human health as those produced by ionizing radiations such as X-rays [2]. A small portion of the population attributes non specific symptoms of ill health, such as sleep disturbance, headache, fatigue etc. Ref. [3] to exposure to electromagnetic fields. This phenomenon is described as electromagnetic hypersensitivity or 'idiopathic environmental intolerance with attribution to electromagnetic fields [4]. Additionally, individuals who are hypersensitive to electromagnetic fields often claim to be able to perceive radiofrequency electromagnetic fields in their daily life [5]. With the significant increase in mobile phone usage, possible health risks related to RF exposure have become the subject of considerable attention [6].

People are generally exposed to mobile tower radiation under far-fields conditions, i.e. radiation from a

Electromagnetic fields, 5G and health: what about the precautionary principle?

John William Frank

Usher Institute, University of Edinburgh, Edinburgh, UK

Correspondence to
Professor John William Frank; john.frank@ed.ac.uk

Received 2 December 2019
Revised 13 October 2020
Accepted 16 October 2020

ABSTRACT

New fifth generation (5G) telecommunications systems, now being rolled out globally, have become the subject of a fierce controversy. Some health protection agencies and their scientific advisory committees have concluded that there is no conclusive scientific evidence of harm. Several recent reviews by independent scientists, however, suggest that there is significant uncertainty on this question, with rapidly emerging evidence of potentially harmful biological effects from radio frequency electromagnetic field (RF-EMF) exposures, at the levels 5G roll-out will entail. This essay identifies four relevant sources of scientific uncertainty and concern: (1) lack of clarity about precisely what technology is included in 5G; (2) a rapidly accumulating body of laboratory studies documenting disruptive in vitro and in vivo effects of RF-EMFs—but one with many gaps in it; (3) an almost total lack (as yet) of high-quality epidemiological studies of adverse human health effects from 5G EMF exposure specifically, but rapidly emerging epidemiological evidence of such effects from past generations of RF-EMF exposure; (4) persistent allegations that some national telecommunications regulatory authorities do not base their RF-EMF safety policies on the latest science, related to unmanaged conflicts of interest. The author, an experienced epidemiologist, concludes that one cannot dismiss the growing health concerns about RF-EMFs, especially in an era when higher population levels of exposure are occurring widely, due to the spatially dense transmitters which 5G systems require. Based on the precautionary principle, the author echoes the calls of others for a moratorium on the further roll-out of 5G systems globally, pending more conclusive research on their safety.

BACKGROUND

Fifth generation (5G) technology is being widely promoted by politicians, government officials, and private sector interests.[1–3] They contend that its advent will bring clear economic and lifestyle benefits, through massive increases in wireless and mobile connectivity at home, work, school and in the community. Examples of these 5G benefits include driverless vehicles and 'The Internet of Things'—automated and continuous communication between the machines in our daily lives.[4 5] On the other hand, the public health response to this wave of communications innovation has become a sense of deep concern, related to widespread scientific uncertainties, as well as a lack of use of existing evidence, in the current international safety guidelines for 5G and related radio frequency electromagnetic field (RF-EMF) exposures.[5–8] This commentary sets out the reasons for such concern.

WHAT IS 5G AND WHY IS IT DIFFERENT FROM PAST EMF EXPOSURES?

Developed over just the last decade, radio frequency (wireless) transmission systems in the 5G category are being rolled out throughout the world. These systems will massively increase the volume, speed and spatial reach of digital data transfer.[4–6] The four successive previous generations (1G, 2G, 3G and 4G) of wireless transmission systems were deployed initially for wireless and mobile phones (1980s and 1990s), followed by WiFi (2000s), and then smart metres and the Internet of Things (2010s). Each successive generation of transmission systems has used higher frequencies of electromagnetic waves to carry ever-larger volumes of data, faster, in more ubiquitous locations. 5G is widely acknowledged to be a step change in this sequence, since it additionally uses much higher frequency (3 to 300 GHz) radio waves than in the past. 5G will also make use of very new—and thus relatively unevaluated, in terms of safety—supportive technology (including pulsing, beaming, phased arrays and massive input/massive output (MIMO)—see below) to enable this higher data transmission capacity.[4–6]

However—unlike prior generations of wireless transmission systems—5G ultrahigh-frequency waves are easily interrupted by vegetation foliage (and building walls, often requiring additional signal boosting within each building). This inherent fragility of 5G high-frequency waves means that transmission boosting 'cell' antennae are generally required every 100–300 m or less—far more spatially dense than the miles-apart transmission masts required for older 2G, 3G and 4G technology using lower frequency waves.[4–6]

This dense transmission network is also required in order to achieve the 'everywhere/anytime' connectivity promised by 5G developers, and necessitated by new technology such as driverless cars, which must never be out of internet contact, for safety reasons. Critics of 5G agree[6–8]—but its supporters do not[9 10]—that the overall population levels of exposure to RF-EMFs will be greatly increased by the 5G roll-out. One compelling argument for that view is the 'inverse square law' of EMF exposure: intensity varies as the inverse of the square of the distance from the emitting source.[11] With plans afoot internationally to put a 5G booster antenna on 'every second or third lamp-post', it is difficult to believe that overall population exposures will not increase substantially. Existing 4G

To cite: Frank JW. *J Epidemiol Community Health* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/jech-2019-213595

systems can service up to 4000 radio frequency using devices per square kilometre; 5G systems will connect up to one million devices per square kilometre—greatly increasing the speed of data transfer (by a factor of 10) and the volume of data transmitted (by a factor of 1000).[6]

THE CURRENT CONTROVERSY

International health protection agencies and their scientific advisory bodies have published several reviews over the last decade, of varying scientific quality, of the research evidence regarding potential adverse biological and health effects of RF-EMFs.[5 12–15] These reviews—by Health Protection England,[12] the International Agency for Research on Cancer (IARC),[13] an Expert European Union (EU) Committee[14] and the International Commission on Non-Ionising Radiation Protection (ICNIRP)[15]—have, with one exception, not converged around a strong warning about such effects. IARC is the outlier in this respect, having determined in 2011 that EMFs are 'possibly carcinogenic to humans'.[13] Meanwhile, independent radiation and health scientists have published serious concerns about the current roll-out of 5G transmission systems.[6–8 16–18] Their reasoning is twofold: (1) these systems have an unprecedented potential to create human and non-human RF-EMF exposures orders of magnitude more intense (eg, in terms of 'power flux density') than was the case only a few decades ago (16); (2) there is a remarkable dearth of evidence on the safety of 5G-specific EMF emissions, but a growing body of research suggestive of harms from other RF-EMF exposures, which have been studied for much longer.[6–8 17 18]

Moreover, a growing number of engineers, scientists, and doctors internationally have been calling on governments to raise their safety standards for RF-EMFs, commission more and better research, and hold off on further increases in public exposure, pending clearer evidence of safety.[18–21] Some politicians have listened: France, Israel, Cyprus and Russia have banned WiFi in preschool and restricted its use in primary schools. Belgium has banned the sale of mobile phones to children under seven. In response to such concerns, several jurisdictions have recently blocked the installation of 5G antennae systems in their communities: Brussels, Florence, Rome, as well as Glastonbury, Frome and Totnes in the UK; and widespread anti-5G campaigns are now emerging in Australia, North America and elsewhere.[21]

Some countries have lowered allowable RF-EMF exposure levels far below those permitted in the UK and USA. Powerwatch, a non-profit, independent organisation in the UK, has published comparisons of international recommendations on permitted maximum exposure levels to EMFs.[22] Those comparisons show that the highest permitted RF-EMF exposures which are used globally, as the basis for national safety guidelines, are those used in the USA, the UK and most of the EU. These exposure limits are derived from the recommendations to WHO in 1998 (recently updated, but essentially not changed, in March 2020) by the ICNIRP.[15] These international comparisons show that the safety limit for RF-EMF exposure set by ICNIRP is 10-fold higher than that set by the next most liberal guidelines, found in Israel and India, and 100-or-more-fold higher than the limits set by other guidelines, spanning 14 EU jurisdictions as well as China. As discussed in detail below, one reason that ICNIRP's permitted exposures are so high is that they are based solely on the acute thermogenic (heat-producing) effects of RF-EMF in animal tissues; this is unlike more conservative jurisdictions' guidelines, which are based on a wider variety of biological and health effects documented in recent decades, including effects resulting from chronic rather than acute exposures, and effects not mediated by thermogenesis.

KEY CONTENTIOUS ISSUES AND SCIENTIFIC UNCERTAINTIES

Lack of clarity about precisely what sorts of EMFs will result from 5G roll-out

A striking feature of this public controversy is that various commentators—even those with advanced training in telecommunications physics and engineering—inconsistently refer to quite different specific technologies when they discuss the pros and cons of '5G'. American authors tend to state that the 5G system roll outs already underway in that part of the world are using very high-frequency (24–100 GHz)/short-wavelength RF transmission—so-called 'millimetre range' waves.[6] However, some UK/EU industry websites[9] state that 'no new frequencies are required' (at present) beyond those already in use in existing 4G mobile networks, WiFi, smart metres. However, independent authors commenting on current private sector plans in the EU, to extend 5G networks more widely in the future, tell a different story.[23 24] These commentaries imply that the use of millimetre wave frequencies—about which we have very few conclusive studies of human health effects—is already planned and inevitable in the EU, and eventually globally, in order to accommodate anticipated consumer requirements—especially the 'Internet of Things' and driverless vehicles. Tellingly, the Guardian (one of the UK's most respected newspapers) reported last year[25] that UK lamp posts were becoming the subject of expensive legal battles, over 'who can charge what' for mounting 5G booster cell antennae on them. Cash-strapped Local Councils had hoped to profit from such charges to telecom companies. These companies have taken local governments to court to block those charges. The USA provides a cautionary tale in this respect: nearly 25 years ago national legislation there took local authorities completely out of the telecommunications regulatory system, leaving local 5G installation and similar decisions entirely in the hands of central authorities—that is, the Federal Communications Commission.[6]

Equally inconsistently described in writings about 5G is the complex set of special signal modulations, pulses, polarisation, phased arrays and novel equipment designs—for example, 'massive MIMO antennas'—which represent the cutting edge technologies that accompany 5G system installation—many of them proprietary. As some commentators on potential health effects from such exposures have pointed out, it is highly likely that each of these many forms of transmission causes somewhat different biological effects—making sound, comprehensive and up-to-date research on those effects virtually impossible.[5–7 26 27]

In short, '5G systems' is not a consistently defined term. This confusion has not helped clarify the health and safety issues surrounding 5G roll outs internationally.

An emerging preponderance of laboratory studies indicating RF-EMFs' disruptive biological effects: with many knowledge gaps

The lack of a consistent definition of '5G' matters enormously. This is clearly demonstrated in a sophisticated recent review of the laboratory science evidence of RF-EMF effects in diverse biological systems.[26] That review shows that the existing scientific literature on the biological effects of more recently developed technology is quite limited, in that there is hardly any study replication—the hallmark of reliable research. We often have only one extant study of any given biological effect of a specified combination of radio frequencies, modulation and

pulse patterns. The literature that does exist identifies remarkably heterogeneous biological effects, across hundreds of such specific RF-EMF exposure patterns. Furthermore, a comprehensive Canadian review of the same evidence states that some of the new RF-EMF technologies—such as innovations in radio frequency 'pulsing,' 'polarisation' and 'modulation'—are so new that biological scientists have not been able to keep up—that is, no studies yet exist of these new technologies' biological effects.[27]

These recent reviews of laboratory (ie, non-epidemiological) studies of the biological effects of RF-EMFs do identify diverse, multibody system effects, operating by a range of physicochemical pathways which are not mediated by thermogenesis.[6 8 26 27] The reviewers document a growing body of evidence that RF-EMF exposures produce effects spanning reproductive/teratogenic, oncological, neuropsychiatric, skin, eye and immunological body systems. In addition, there are many fundamental effects at the subcellular level, in terms of oxidation, DNA alteration, gene expression and bacterial antibiotic resistance. Particularly striking is a 2018 study from Israel documenting the capacity of the sweat ducts in human skin to act as 'helical antennae' receptive to 5G frequencies of RF-EMF. When sweat ducts are exposed to these RF-EMFs, there are remote systemic effects, through the skin's established capacity to secrete and send hormones and other signals to the entire body.[28] This report alters one's sense of the potential risks from such high frequency waves, since they have long been thought to be 'inherently less dangerous', because they are largely absorbed in the top few millimetres of exposed tissue (thus limiting any adverse effects, in theory, to the skin or eye).

Finally, it is instructive to look at the two widely cited NIH toxicological studies of specific EMFs' effects on thousands of rodents,[29 30] conducted by experienced and highly respected laboratory scientists at a world-leading institution. Since their publication in 2018, epidemiologists and other scientists have pointed out several methodological weaknesses in the conduct and analysis of these studies that make their unequivocal interpretation almost impossible, particularly in terms of their relevance to human health: excessive statistical inference testing of multiple (over 1000) hypotheses, without appropriate adjustment of p values considered 'statistically significant'; reporting of results 'often ignoring statistical tests'; failure to explain major internal inconsistencies of findings across EMF doses, tumour types and rodent sexes; use of experimental EMF exposures far in excess of any known human ones; uncontrolled confounding by direct thermogenesis effects—the list goes on.[31 32]

In short, laboratory studies of EMF exposure are fraught with both internal and external validity issues, and cannot replace high-quality human epidemiological studies—though, as we will now discuss, these are also hard to come by.

Lack of conclusive human epidemiological studies of 5G-specific health effects (but increasing epidemiological evidence of serious health effects from previous generations of RF-EMF exposures)

Canada's most senior cancer epidemiologist, Miller *et al* have last year summarised the human epidemiological evidence[33] linking human breast and brain tumours, male reproductive outcomes and child neurodevelopmental conditions to RF-EMF exposures resulting from the use of past generations of transmission systems. Critically, this evidence is not about exposure to the high radio frequency/short wavelength 5G systems. These systems are too newly deployed to have been extensively studied, especially by the highest-quality epidemiological study designs for establishing evidence of causation: prospective cohort studies. Such studies typically require decades of follow-up to detect delayed health effects, such as most cancers.

Miller *et al* find compelling evidence of carcinogenesis, especially in the brain and acoustic nerve, as well as the breast, from strong RF-EMF exposures to previous generations of mobile phone transmissions. Perhaps the most convincing evidence they cite comes from the oldest and most-often-maligned study design—case reports. While admittedly old-fashioned, case reports can, when they involve pathognomonic effects (ie, pathological features absolutely specific to a particular exposure) provide useful evidence of exposure/outcome specificity—a valuable but often unobtainable epidemiological criterion for inferring causation, according to the standard epidemiological criteria first enunciated by Sir Austin Bradford Hill over 50 years ago.[34 35] Strikingly localised breast tumours, of unusual morphology, have been diagnosed in several women with particularly strong exposures to previous generations of mobile phones: they habitually placed their phones in their bras, on the same side of the body where the tumour has developed. Miller *et al* call for an urgent update of the last (2011) review of EMFs and cancer by the International Agency for Research on Cancer.[13] They predict that such an update would now rate RF-EMFs as, at minimum, 'probable' (not merely 'possible' as in 2011) carcinogens, based on current evidence.

Persistent allegations of unscientific bases for existing health protection guidelines on RF-EMFs and unmanaged conflicts of interest on expert advisory panels

A senior epidemiologist from Sweden, Hardell, has repeatedly published in peer-reviewed journals detailed allegations regarding the main WHO scientific advisory body on EMF health effects and safety—the previously mentioned ICNIRP. Hardell contends that ICNIRP's membership includes over-representation of vested interests, especially the giant multinational telecommunications firms who are heavily invested in the roll out of 5G systems internationally.[36 37] ICNIRP has long been influential in EMF regulation: its scientific recommendations to WHO were first issued in 1998, updated in 2009, and revised and updated again in March 2020.[15] Hardell points out that ICNIRP's pro-industry bias may explain its continued reliance only on studies of the thermogenic (heat-producing) effect of RF-EMFs in biological tissues: these studies would be expected to paint an overly benign picture of RF-EMF safety. This narrow ICNIRP focus flies in the face of published reviews by independent scientists (6, 8, 13, 26, 27) citing compelling research evidence, accumulating steadily over the last few decades, of non-thermogenic adverse effects of RF-EMFs, affecting diverse human and animal subcellular function, tissues and organ systems (see above). In detailed, almost lawyer-like publications,[36 37] Hardell fastidiously documents the ICNIRP's 20 years of dogged defiance, in the face of widespread criticism by other scientists, that the scientific base for their recommendations remains dated and narrow, rendering their guidelines on 'safe' RF-EMF exposure unsafe.

The most damning evidence adduced by Hardell is a table of the cross-appointments held by six members of the WHO Monograph Group, across five major international advisory panels on the health effects of non-ionising radiation [36 – page 408]. Hardell also describes these scientists' strong personal links to the telecommunications industry, a situation likely arising from the fact that the ICNIRP itself is a 'private organisation (non-governmental organisation; NGO) based in Germany. New

expert members can only be elected by members of ICNIRP.' Hardell contrasts the ICNIRP's reports to the publications of the 'BioInitiative 2012'[38] group, of nearly 30 international experts in this field, whose operations are not only wholly independent of any such 'vested interests,' but also entirely transparent. The current version (March 2020) of the BioInitiative 2012 website[38] provides detailed descriptions of 988 peer-reviewed scientific studies of adverse potential health and biological effects of EMFs arising from RF and similar non-ionising sources. The vast majority (84.6%) of these 988 studies document disruptive biological effects from such EMFs, almost all of them operating via non-thermogenic pathways. (This writer would have preferred to see more 'critical appraisal' of the quality of the studies than the BioInitiative 2012 website provides. However, the major effort entailed in assembling this massive body of scientific evidence, and updating it regularly since 2012, is impressive).

Finally, Carpenter has recently published a well-researched analysis of how source of funding correlates with study findings, across many peer-reviewed publications over the last few decades, of the relationship between various kinds of EMF exposure and several cancers.[39] He shows convincingly that studies funded by private sector entities, with strong vested interests in maintaining their current use of the sources of EMFs under study, tend to find no association—whereas studies funded by public sector or independent sources find the opposite. As Carpenter points out, this suggests that many systematic reviews and meta-analyses in this field, having failed to correct for this 'source of funding bias,' likely underestimated the evidence for causation.

CONCLUSIONS AND RECOMMENDATION

In assessing causal evidence in environmental epidemiology, Bradford Hill himself pointed out that 'the whole picture matters;' he argued against prioritising any subset of his famous nine criteria for causation. One's overall assessment of the likelihood that an exposure causes a health condition should take into account a wide variety of evidence, including 'biological plausibility'.[34 35] After reviewing the evidence cited above, the writer, an experienced physician-epidemiologist, is convinced that RF-EMFs may well have serious human health effects. While there is also increasing scientific evidence for RF-EMF effects of ecological concern in other species,[6–8 16–18 23] both plant and animal, these have not been reviewed here, for reasons of space and the author's disciplinary limitations. In addition, there is convincing evidence, cited above, that several nations' regulatory apparatus, for telecommunications innovations such as the 5G roll-out, is not fit for purpose. Indeed, significant elements in that apparatus appear to have been captured by vested interests. Every society's public health—and especially the health of those most likely to be susceptible to the hazard in question (in the case of EMFs, children and pregnant women)—needs to be protected by evidence-based regulations, free from significant bias.

Finally, this commentary would be remiss if it did not mention a widely circulating conspiracy theory, suggesting that 5G and related EMF exposures somehow contributed to the creation or spread of the current COVID-19 pandemic. There are knowledgeable commentators' reports on the web debunking this theory, and no respectable scientist or publication has backed it.[40 41] Indeed, combatting it is widely viewed by the scientific community as critical to dealing with the pandemic, as conspiracy theorists holding this view have already carried out violent attacks on mobile phone transmission facilities and other symbolic targets, distracting the public and authorities at a time when pandemic control actions are paramount.[42] This writer completely supports that view of the broader scientific community: the theory that 5G and related EMFs have contributed to the pandemic is baseless.

It follows that, for the current 5G roll-out, there is a sound basis for invoking 'the precautionary principle'.[43] This is the environmental and occupation health principle by which significant doubt about the safety of a new and potentially widespread human exposure should be a reason to call a moratorium on that exposure, pending adequate scientific investigation of its suspected adverse health effects. In short, one should 'err on the side of caution'. In the case of 5G transmission systems, there is no compelling public health or safety rationale for their rapid deployment. The main gains being promised are either economic (for some parties only, not necessarily with widely distributed financial benefits across the population) or related to increased consumer convenience. Until we know more about what we are getting into, from a health and ecological point of view, those putative gains need to wait.

Contributors JWF is the sole author of this essay, responsible for all aspects of its conceptualisation, background research and writing.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data sharing not applicable as no datasets generated and/or analysed for this study. No data were collected, or repurposed/used in the writing of this essay.

ORCID iD

John William Frank http://orcid.org/0000-0003-3912-4214

REFERENCES

1 Scottish Government. 5G: strategy for Scotland. Available: https://www.gov.scot/publications/forging-digital-future-5g-strategy-scotland/ [Accessed 8 Oct 2020].
2 Negreiro M. Towards a European Gigabit Society: Connectivity Targets and 5G. European Parliament Research Service (EPRS)/ Brussels, European Parliament, 2017. Available: https://www.europarl.europa.eu/RegData/etudes/BRIE/2017/603979/EPRS_BRI(2017)603979_EN.pdf [Accessed 8 Oct 2020].
3 Directorate-General for Internal Policies, European Parliament. *5G deployment: state of play in Europe, USA and Asia*. Brussels: European Parliament, 2019. https://www.europarl.europa.eu/RegData/etudes/IDAN/2019/631060/IPOL_IDA(2019)631060_EN.pdf
4 Nordrum, Amy; Clark, Kristen (January 27, 2017). Everything you need to know about 5G. IEEE *Spectrum Magazine*. Institute of Electrical and Electronic Engineers, 2019. Available: https://www.fitce.gr/everything-need-know-5g/ [Accessed 8 Oct 2020].
5 Karaboytscheva M. Effects of 5G Wireless Communication on Human Health. European Parliament Research Service (EPRS)/ Brussels, European Parliament, 2020March. Available: https://europarl.europa.eu/RegData/etudes/BRIE/2020/646172/EPRS_BRI(2020)646172_EN.pdf [Accessed Oct. 8, 2020].
6 Russell CL. 5 G wireless telecommunications expansion: public health and environmental implications. *Environ Res* 2018;165:484–95.
7 Moskowitz JM. We have no reason to believe 5G is safe. *Scientific American* blogs, 2019. Available: https://blogs.scientificamerican.com/observations/we-have-no-reason-to-believe-5g-is-safe/ [Accessed 8 Oct 2020].
8 Di Ciaula A. Towards 5G communication systems: are there health implications? *Int J Hyg Environ Health* 2018;221:367–75.
9 Vodaphone UK. Is 5G safe? Available: https://newscentre.vodafone.co.uk/5g/is-5g-safe/ [Accessed 24 Mar 2020].
10 Foster KR. 5G Is Coming: How Worried Should We Be about the Health Risks? So far, at least, there's little evidence of danger. *Scientific American* blogs, 2019. Available: https://blogs.scientificamerican.com/observations/5g-is-coming-how-worried-should-we-be-about-the-health-risks/?print=true [Accessed 24 Mar 2020].
11 Powerwatch UK. Radiofrequency EMFs and health risks. Available: https://www.powerwatch.org.uk/library/downloads/rf-emfs-1-intro-2018-11.pdf [Accessed Oct. 8, 2020].
12 AGNIR. Health effects from radiofrequency electromagnetic fields. Report from the Independent Advisory Group on Non-Ionising Radiation. In: *Documents of the health*

protection agency R, chemical and environmental hazards. RCE 20. London: Health Protection Agency UK, 2012: 1–348.
13 International Agency for Research on Cancer. *Non-ionizing radiation, part 2: radiofrequency electromagnetic fields. IARC Monographs on the evaluation of carcinogenetic risks to humans, volume 102*. Lyon, France: IARC, 2013: 1–460.
14 SCENIHR [Scientific Committee on Emerging and Newly Identified Health Risks]. *Potential Health Risks of Exposure to Electromagnetic Fields [EMF]*. Luxembourg: European Commission, 2015: 1–288. https://ec.europa.eu/health/sites/health/files/scientific_committees/emerging/docs/scenihr_o_041.pdf
15 International Commission on Non-Ionizing Radiation Protection (ICNIRP). *ICNIRP rf EMF guidelines 2020*. Oberschleissheim, Germany: ICNIRP, 2020: 1–44. https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html
16 Bandara P, Carpenter DO. Planetary electromagnetic pollution: it is time to assess its impact. *Lancet Planet Health* 2018;2:e512–4.
17 Pall ML. 5G risks 8 types of harm. Available: https://www.radiationresearch.org/articles/5g-risks-8-types-of-harm-martin-pall-2018/ [Accessed 9 Oct 2020].
18 International EMF scientists appeal statement, 2020. Available: https://www.emfscientist.org/ [Accessed 8 Oct 2020].
19 Carpenter DO. Open letter about the risks of the intensively pulsed EMFs from "smart meters", 2012. Available: https://www.saferemr.com/2015/02/health-experts-caution-about-smart.html [Accessed 8 Oct 2020].
20 International appeal: stop 5G on earth and in space. Available: https://www.5gspaceappeal.org/ [Accessed 8 Oct 2020].
21 Physicians for safe technology. Available: https://mdsafetech.org/2019/04/28/stop-5g-may-15-2019-day-of-action/ [Accessed 8 Oct 2020].
22 Powerwatch UK. International guidance levels. Available: https://www.powerwatch.org.uk/science/intguidance.asp [Accessed 8 Oct 2020].
23 Physicians' Health Initiative for Radiation and Environment (PHIRE). Safety limits and political conflicts of interest. Available: http://phiremedical.org/safety-limits-and-political-conflicts-of-interest/ [Accessed 8 Oct 2020].
24 Zieszczynski D. Response to blog "5G Misinformation campaign by the Mobile and Wireless Forum",. Available: https://betweenrockandhardplace.wordpress.com/2019/09/12/5g-misinformation-campaign-by-the-mobile-wireless-forum-mwf/ [Accessed 8 Oct 2020].
25 Weaver M. Revealed: 5G rollout is being stalled by rows over lampposts. *The Guardian*, 2019. Available: https://www.theguardian.com/technology/2019/may/19/revealed-5g-rollout-is-being-stalled-by-rows-over-lampposts [Accessed 12 Oct 2020].
26 Simkó M, Mattsson M-O. 5G wireless communication and health effects-A pragmatic review based on available studies regarding 6 to 100 GHz. *Int J Environ Res Public Health* 2019;16:3406–28.
27 Kostoff RN, Heroux P, Aschner M, *et al*. Adverse health effects of 5G mobile networking technology under real-life conditions. *Toxicol Lett* 2020;323:35–40.
28 Betzalel N, Ben Ishai P, Feldman Y. The human skin as a sub-THz receiver - Does 5G pose a danger to it or not? *Environ Res* 2018;163:208–16.
29 National Toxicological Programme. *NTP Technical Report on the Toxicology and Carcinogenesis Studies in Sprague Dawley Rats Exposed to Whole-Body Radio Frequency Radiation at a Frequency (900 MHz) and Modulations (GSM And CDMA) Used by Cell Phones [NTP 595]*. Bethesda: National Institutes of Health/ Public Health Service, U.S. Department of Health and Human Services, 2018.
30 National Toxicological Programme. *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 596]*. Bethesda: National Institutes of Health/ Public Health Service, U.S. Department of Health and Human Services, 2018.
31 International Commission on Non-Ionizing Radiation Protection (ICNIRP)1. ICNIRP note: critical evaluation of two radiofrequency electromagnetic field animal carcinogenicity studies published in 2018. *Health Phys* 2020;118:525–32.
32 Elwood M, Wood AW. Animal studies of exposures to radiofrequency fields. *N Z Med J* 2019;132:98–100.
33 Miller AB, Sears ME, Morgan LL, *et al*. Risks to health and well-being from radio-frequency radiation emitted by cell phones and other wireless devices. *Front Public Health* 2019;7:1–10.
34 Hill AB, Bradford Hill A. The environment and disease: association or causation? *Proc R Soc Med* 1965;58:295–300.
35 Carlberg M, 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;2017:1–17.
36 Hardell L. World Health Organization, radiofrequency radiation and health - a hard nut to crack (Review). *Int J Oncol* 2017;51:405–13.
37 Hardell L, Nyberg R. Appeals that matter or not on a moratorium on the deployment of the fifth generation, 5G, for microwave radiation. *Mol Clin Oncol* 2020;12:247–57.
38 BioInitiative 2012 (updated 2017 and 2019). A rationale for biologically based exposure standards for low-intensity electromagnetic radiation. Available: https://bioinitiative.org/updated-research-summaries/ [Accessed 24 Mar 2020].
39 Carpenter DO. Extremely low frequency electromagnetic fields and cancer: how source of funding affects results. *Environ Res* 2019;178:108688.
40 Lewis K. Full fact. 2020 MAR 31. 5G is not accelerating the spread of the new coronavirus. available at. Available: https://fullfact.org/health/5G-not-accelerating-coronavirus/ [Accessed 12 Oct 2020].
41 Shanapinda S. The Conversation. 2020 Apr 07. No, 5G radiation doesn't cause or spread the coronavirus. Saying it does is destructive. Available: https://tinyurl.com/uppng7w https://theconversation.com/no-5g-radiation-doesnt-cause-or-spread-the-coronavirus-saying-it-does-is-destructive-135695 [Accessed 12 Oct 2020].
42 Waterson J, Hern A. The guardian. 2020 Apr 06. at least 20 UK phone masts vandalised over false 5G coronavirus claims. Available: https://www.theguardian.com/technology/2020/apr/06/at-least-20-uk-phone-masts-vandalised-over-false-5g-coronavirus-claims [Accessed 12 Oct 2020].
43 Health and Safety Executive. *Reducing Risks, Protecting People: HSE's Decision-Making Process*. London: Health and Safety Executive, 2001: 1–88. https://www.hse.gov.uk/risk/theory/r2p2.pdf

Clinical Biochemistry xxx (2011) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Clinical Biochemistry

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

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

Hormones Department, Medical Research Division, National Research Centre, Cairo, Egypt

ARTICLE INFO

Article history:
Received 9 December 2010
received in revised form 2 November 2011
accepted 6 November 2011
Available online xxxx

Keywords:
Mobiles
Base stations
Radio frequency radiation
Hormone profiles

ABSTRACT

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 with human's hormone profiles.

Design and methods: All volunteers' samples were collected for hormonal analysis.

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

Conclusion: The present study revealed that high RFR effects on pituitary–adrenal axis.

Introduction

Because of the increase in the usage of wireless communication devices of mobile phones in recent years, there is an anxious concern on the possible hazardous effects of prolonged exposure to radio frequency radiation (RFR) [1]. In considering the biological effects of RFR, the intensity and frequency of the radiation and exposure duration are important determinants of the responses.

It has been reported that exposure to RFR could affect the nervous system [2]. Hardell et al. found that cell phone users had an increased risk of malignant gliomas [3]. Subjecting human spermatozoa to RFR showed decrease in sperms motility and vitality and increase in DNA fragmentation [4]. The authors hypothesize that the high sporadic incidence of the clinical symptoms of the autoimmune multiple Sclerosis disease [5] may be a result of long exposure to RFR from mobiles.

This study is concerned with assessing the effect of RFR emitted from mobile phones and base stations on human hormone profiles, with anticipation to offer recommendations to assure health care and safety for humans continuously exposed to radio frequency radiation.

Design and methods

Study subjects

This study was conducted for 6 years on 82 mobile phone volunteers with age ranges 14–22 years ($n=41$) and 25–60 years ($n=41$). Those users were divided into three subgroups according to the time of their exposure to RFR: (weak $n=19$), (moderate $n=9$), and (strong $n=13$) per day, in addition to 20 negative control subjects.

On the other hand, volunteers exposed to RFR emitted from base stations ($n=34$) were selected with age ranges 14–22 years ($n=17$), and 25–60 years ($n=17$) and living at distances 20–100 m and 100–500 m apart from the base station. Additional 10 subjects of each age range living at a distance more than 500 m apart from the base station were considered as negative control group.

The source of the RFR (base stations or mobile phones) was GSM-950 MHz magnetic field and the ICNIRP-Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic field (up to 300 GHz) (International Commission on Non-Ionizing Radiation Protection). The present study was approved by the Ethics Committee of National Research Centre.

Volunteers inclusion criteria

Volunteers participated in the study fulfilled the following inclusion criteria: age 14–60 years, mobile phone users, or living at distances 20–100 m and 100–500 m apart from the base station.

* Corresponding author at: Hormones Department, Medical Research Division, National Research Centre, Cairo, 12622, Egypt. Fax: +20 2 33370931.
E-mail address: gysi_pharma@yahoo.com (E.F. Eskander).

0009-9120/$ – see front matter © 2011 The Canadian Society of Clinical Chemists. Published by Elsevier Inc. All rights reserved.
doi:10.1016/j.clinbiochem.2011.11.006

Please cite this article as: Eskander EF, et al, How does long term exposure to base stations and mobile phones affect human hormone profiles?, Clin Biochem (2011), doi:10.1016/j.clinbiochem.2011.11.006

INTERNATIONAL JOURNAL OF RADIATION BIOLOGY
2021, VOL. 97, NO. 11, 1505–1515
https://doi.org/10.1080/09553002.2021.1969055

Taylor & Francis
Taylor & Francis Group

REVIEW

Threshold of radiofrequency electromagnetic field effect on human brain

Hiie Hinrikus, Jaanus Lass, and Maie Bachmann

Tallinn University of Technology, Tallinn, Estonia

ABSTRACT

Purpose: This review aims to estimate the threshold of radiofrequency electromagnetic field (RF EMF) effects on human brain based on analyses of published research results. To clarify the threshold of the RF EMF effects, two approaches have been applied: (1) the analyses of restrictions in sensitivity for different steps of the physical model of low-level RF EMF mechanism and (2) the analyses of experimental data to clarify the dependence of the RF EMF effect on exposure level based on the results of published original neurophysiological and behavioral human studies for 15 years 2007–2021.

Conclusions: The analyses of the physical model of nonthermal mechanisms of RF EMF effect leads to conclusion that no principal threshold of the effect can be determined. According to the review of experimental data, the rate of detected RF EMF effects is 76.7% in resting EEG studies, 41.7% in sleep EEG and 38.5% in behavioral studies. The changes in EEG probably appear earlier than alterations in behavior become evident. The lowest level of RF EMF at which the effect in EEG was detected is 2.45 V/m (SAR = 0.003 W/kg). There is a preliminary indication that the dependence of the effect on the level of exposure follows rather field strength than SAR alterations. However, no sufficient data are available for clarifying linearity-nonlinearity of the dependence of effect on the level of RF EMF. The finding that only part of people are sensitive to RF EMF exposure can be related to immunity to radiation or hypersensitivity. The changes in EEG caused by RF EMF appeared similar in the majority of analyzed studies and similar to these in depression. The possible causal relationship between RF EMF effect and depression among young people is highly important problem.

ARTICLE HISTORY
Received 16 June 2021
Revised 29 July 2021
Accepted 9 August 2021

KEYWORDS
Low-level RF EMF; nonthermal model; threshold; linearity; depression

Introduction

The world population has been exposed to man-made coherent electromagnetic radiation, different from the natural radiation emitted by the Sun, over a very long period of time without remarkable effects on health. The people are adapted to the level of radio and TV broadcasting radiofrequency electromagnetic field (RF EMF) about 0.1 V/m. During recent decades, the applications of mobile telecommunication technology have drastically changed the situation. The sources of RF EMF have moved closer to people and the levels of exposure are much higher. The current guidelines recommend health protection limits up to 61 V/m (ICNIRP 2020). Hundreds of studies have detected biological RF EMF effects in humans, animals and cells at the levels of exposure much less than existing health protection limits. According to the Ericsson Mobility Report, the number of mobile subscriptions by technology is over eight billion in 2020 (Ericsson Mobility Report 2020). This number is higher than the world population. The wide applications of RF EMF rise concern about possible consequences on health.

The increased oxidative stress caused by RF EMF exposure has been reported in many animal and cellular studies (Schuermann and Mevissen 2021). The relevant consequences on health (genome stability, immune system, neurodegeneration, reproduction) are likely. The radiofrequency electromagnetic field was classified as possibly carcinogenic to humans (class 2B) by the International Agency for Research on Cancer (IARC 2013).

The RF EMF effects on brain bioelectrical activity, cognition and behavior, not obligatory related to genome instability, have been a topic of interest over the past decades. The neurophysiological effects on humans have been detected in many experimental studies but the results are controversial (Valentini et al. 2007; Marino and Carruba 2009; Kwon and Hämäläinen 2011). The large variations in applied methods, different frequencies, levels of exposure and modulation parameters cause high diversity of the effects and results. The recent cohort study does not provide sufficient confirmation about the correlation between more extensive use of mobile phones and the reported symptoms nor sleep quality (Auvinen et al. 2019; Tettamanti et al. 2020). It is complicated to determine causal relationship between RF EMF biological effects and its health consequences due to diversity of exposure conditions and numerous concomitant other factors.

CONTACT Hiie Hinrikus hiie.hinrikus@gmail.com Department of Health Technologies, Tallinn University of Technology, Tallinn, Estonia.

Radiation Analysis in a Gradual 5G Network Deployment Strategy

Ahmad M. El-Hajj
Electrical & Computer Eng. Department
Beirut Arab University
Beirut, Lebanon
a.elhajj@bau.edu.lb

Tarek Naous
Electrical & Computer Eng. Department
Beirut Arab University
Beirut, Lebanon
tareknaous@ieee.org

***Abstract*—In a world where many overlapping 2G, 3G, and 4G electromagnetic radiation sources already exist, concerns regarding the potential increase in these radiation levels following the roll-out of 5G networks are growing. The deployment of 5G is expected to increase power density levels drastically, given the limitations of mmWave communications that impose a notably higher number of base stations to cover a given area of interest. In this paper, we propose a gradual deployment strategy of a 5G network for a small area in downtown Austin, Texas, using the already existing 4G LTE sites of the area. The radiated power density of the proposed 5G network is then analyzed according to several electromagnetic field (EMF) exposure limits and compared to the radiation levels of the same area where only the LTE network is present. Simulation results for the selected area demonstrate the significant increase in radiation levels resulting from the addition of 5G cell towers.**

***Index Terms*—5G, Network Planning, Radiation Analysis**

I. Introduction

The notably large bandwidth available in the millimeter-wave (mmWave) band and the potential multi-gigabit-per-second (Gbps) data rates that can be achieved for future communication services have made mmWave communications a key part of Fifth Generation (5G) mobile networks. Despite the promising advantages of millimeter wave communications in terms of improved quality of service requirements, its usage for the 5G wireless standards comes at significant costs. First, working with such high frequencies will reduce coverage ranges of base transceiver stations (BTS). For proper coverage of an area, a densification of 5G BTSs is required to achieve the same coverage provided for this same area by today's 4G BTSs. Also, high propagation loss and increased signal blockage occurs, motivating the introduction of multi-antenna approaches such as Massive MIMO [1], [2].

This potential addition of a large number of transmitters gives rise to another problem that needs to be considered, which is the increase in radiation levels in the rolled-out 5G network. Although these transmissions are non-ionizing radiations, they cause thermal heating at the eyes and skin level. Extensive heating for long periods of time is when adverse health effects may occur. These health concerns have stimulated interest in the biological safety of mmWave transmissions. In this respect, several exposure limits have been specified in standards and regulations developed by commissions and organizations that many governments will rely on when future 5G networks are deployed. However, these regulations have contradicting limits, many of which have remained the same before the year 2000. Therefore, designing a 5G network with radiation levels that complies with all the safety limits is a difficult task given the current regulations.

Despite the ongoing standardization of 5G technology, several works in the literature have presented 5G network deployment studies. The cost and coverage implications of deploying a 5G network in Britain has been presented in [3] where it was shown that full coverage had exponentially rising costs due to network densification. Additional 5G network designs for different cities were presented in [4]–[6] without any consideration for the constraints of electromagnetic radiations or the implications of the environment in mmWave propagation. Network design has been studied under such radiation constraints in [7], [8] but for 4G networks. Power density assessment of 5G cellular nodes in an indoor environment has been presented in [9] where results showed that the peak power density remained below the specified threshold and can thus be deemed safe for the general public. However, not all of the guidelines and exposure limits were considered in this work and the simulation did not represent a real-world scenario.

To the best of our knowledge, no work has provided a thorough analysis of the deployment of 5G networks in terms of its impact on the increase in radiation levels. Existing work in the literature has either focused on the cost (e.g., [3]) or radiation levels for older standards (e.g., [7]). To this end, this paper presents a mmWave-based 5G network deployment strategy given pre-existing LTE nodes in a small geographical area in Austin, Texas. We then approximate the power density levels that would be experienced in such outdoor environments and analyze their variations and compliance with the specified exposure limits for different transmission powers and transmit antenna gains. We also compare this radiated power density in the deployed 5G network to the power density levels of the same area when only the pre-existing LTE BTSs are present.

The rest of this paper is organized as follows: Section II presents the 5G simulation environment considered in this work. The proposed deployment strategy of the 5G network in a small area in downtown Austin, Texas is presented in Section III. Radiation analysis of the deployed network is performed

in Section IV. Concluding remarks follow in Section V.

II. 5G Environment Setup

A. Pathloss Model

The close-in free space reference distance (CI) path loss model [10] is considered. It is defined by the following equation:

$$PL^{CI}(f,d)[\text{dB}] = FSPL(f,1m) + 10n\log_{10}\left(\frac{d}{d_0}\right) + X_\sigma^{CI} \tag{1}$$

where the free space path loss (FSPL) for a frequency of operation f is given by:

$$FSPL(f,1m) = 20\log_{10}\left(\frac{4\pi f}{c}\right) \tag{2}$$

The CI path loss model can be rewritten as:

$$PL^{CI}(f,d)[\text{dB}] = 20\log_{10}\left(\frac{4\pi f}{c}\right) + 10n\log_{10}\left(\frac{d}{d_0}\right) + X_\sigma^{CI} \tag{3}$$

where:

- n: is the single model parameter or the path loss exponent
- d_0**:** is the reference distance taken as 1 meter
- d: is the distance in meters between the BTS and the mobile station
- X_σ^{CI}: a zero mean Gaussian random variable with standard deviation σ in dB. It represents large scale channel fluctuations due to shadow fading (SF). The standard deviation of this random variable is given by:

$$\begin{aligned}\sigma^{CI} &= \sqrt{\sum X_\sigma^{CI^2}/N} \\ &= \sqrt{(PL^{CI} - FSPL - n10\log_{10}(d))/N}\end{aligned} \tag{4}$$

where N represents the number of measured path loss data points

The values for parameters n and SF vary from one scenario to another. Table I presents the values of these model parameters in different environmental setups, which have been obtained by ray tracing and measurements in [11].

TABLE I: CI Model parameters for different environments [12]

Scenario	CI Model Parameters
UMa-LOS	n = 2.0, SF = 4.1 dB
UMa-NLOS	n = 3.0, SF = 6.8 dB
UMi-S.C.-LOS	n = 1.98, SF = 3.1 dB
UMi-S.C.-NLOS	n = 3.19, SF = 8.2 dB
UMi-O.S.-LOS	n = 1.85, SF = 4.2 dB
UMi-O.S.-NLOS	n = 2.89, SF = 7.1 dB

UMa: denotes Urban Macrocell (Tx Heights $>$ 25 m), **UMi:** denotes Urban Microcell (Tx Heights $<$ 25 m), **LOS:** denotes line-of-sight, **NLOS:** denotes no line-of-sight, **S.C.:** denotes Street Canyon, **O.C.:** denotes Open Square

B. mmWave Specific Attenuation Factors

In mmWave propagation, attenuation due to atmospheric and weather conditions constitutes an important factor to consider [13]. Specifically, we will consider oxygen attenuation $O(d)$ and rain attenuation $R(d)$, which are both dependant on the separation distance d. Oxygen attenuation has been observed to be equal 16dB/km in [14], and hence can be obtained by the following:

$$O(d)[\text{dB}] = \frac{16d}{1000} = 0.016d \tag{5}$$

The rain attenuation factor depends on the climate of the zone under study. The International Telecommunication Union (ITU) have segmented these zones and provide measurements for the rain rates of each zone [15]. Based on these measurements and considering that the area under study in this paper will be in Austin, Texas, the rain attenuation rate will be taken to be 3.5 dB/Km. This loss can then be obtained using:

$$R(d)[\text{dB}] = \frac{3.5d}{1000} = 0.0035d \tag{6}$$

C. Link Budget Estimation

The link budget equation upon which the cell radius will be estimated can now be defined as:

$$P_{Rx}[\text{dBm}] = EIRP[\text{dBm}] - PL^{CI} - O(d) - R(d) + G_{Rx} \tag{7}$$

where P_{Rx} is the power received by the mobile station, G_{Rx} is the antenna gain in dBi of the mobile station, and the effective isotropic radiated power (EIRP) is given by:

$$EIRP[\text{dBm}] = P_{Tx} + G_{Tx} - L_{Tx} \tag{8}$$

where P_{Tx} is the transmission power in dBm of the BTS, G_{Tx} is the transmitting antenna gain in dBi, and L_{Tx} is the cable loss in dB due to possible antenna mismatch. Table II lists the values chosen for each parameter of the link budget equation.

TABLE II: Simulation Parameters

Parameter	Value
Frequency f	28 GHz
Max EIRP	43 dBm
Antenna Gain G_{Tx}	24 dBi
Transmission Power P_{Tx}	19 dBm
Receiver Antenna Gain G_{Rx}	0 dBi
Cable Losses L_{Tx}	0 dB

D. Identifying Cell Ranges

By using the link budget equation in (7) and considering the simulation parameters given in Table II, the separation distance can be found for several receiver sensitivities. The calculated distance constitutes the cell range for a given BTS that satisfies the received power requirement. These calculations are summarized in Table III. A main observation is that the resulting cell ranges become significantly smaller when the

receiver sensitivity is higher. Cell ranges that are too small (below 10 meters) are not considered since such small ranges are not desirable for real deployment.

III. Network Deployment

We now consider a small geographical area in downtown Austin, Texas, to deploy the 5G network. A diagrammatic view of our proposed strategy is shown in Fig. 1. The selected area is shown in Fig. 2(a) and delimited in red on the map of Fig. 2(b). This area already contains several locations where LTE sites are already built and which will be the starting points of the gradual 5G network deployment strategy. The initial LTE cell tower locations are obtained from an online cell tower database (www.opencellid.org). We consider a worst case scenario where no line-of-sight components are available.

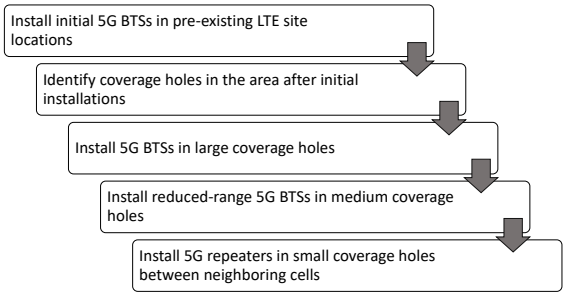
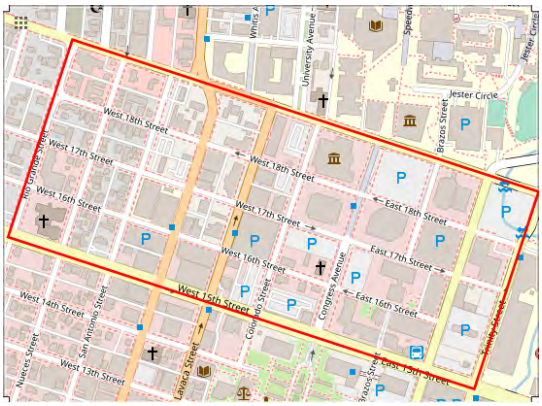


Fig. 1: Gradual Deployment Strategy

The first step of deployment starts by building 5G BTSs in the areas where LTE BTSs already exist, a technique known as co-siting. The main aim of co-siting is to reduce capital expenditures (CapEx) required to erect the 5G sites and minimize the operational expenditures (OpEx) needed to sustain their operation. UMa-NLOS towers will be placed in these locations. The receiver sensitivity is considered to be -78 dBm which, according to Table III, sets the cell range of each UMa to be 53 meters. The coverage of the initial BTSs installed is shown in Fig. 3, after slightly changing the location of the BTS within the same area it is built on, which may be any building rooftop, to lessen interference and provide better coverage. It can be noticed that these initial cells do not provide coverage to the whole area due to the small cell range of each BTS. Theoretically, this range can be increased but would demand the EIRP to be increased above the allowed limit of 43 dBm, by increasing the transmission power and selecting a higher-gain massive MIMO antenna configuration

The next step is the identification of coverage holes, as shown in Fig. 4. Large coverage holes are can be noticed, where several UMa towers can be distributed to provide good coverage. Smaller coverage hole are also be identified. Some of these holes are very small areas between neighboring cells where 5G repeaters, such as the one described in [16], can be placed to cover these small holes. Other small holes are not small enough to be fixed merely by the placement of a repeater, and are neither too big to place a BTS with a cell

(a)



(b)

Fig. 2: Geographical area of interest in Austin, Texas (a) Satellite View (b) Map View

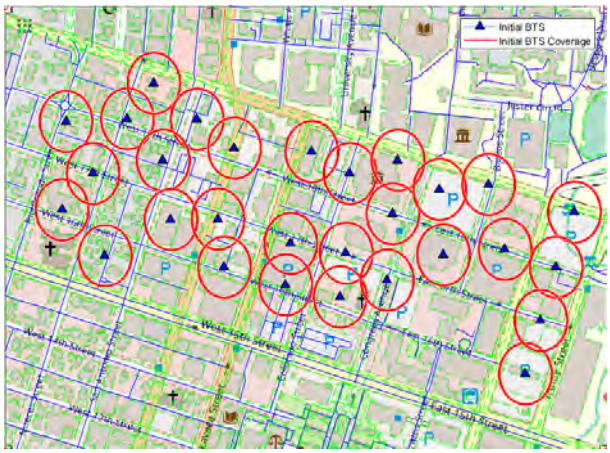


Fig. 3: Coverage of initial 5G BTSs built at the locations of pre-existing LTE cell towers

range of 53 meters. In such locations, reduced-range towers can be placed to provide coverage. The coverage range for these towers can be shrinked by reducing transmission power and choosing smaller MIMO antennas. We calculate the cell range for the reduced-range BTS towers to be approximately 30 meters and estimate the coverage of the 5G repeater to be 15 meters. The final design of the deployed 5G network is shown in Fig. 5. It can be observed that the deployment of a 5G network in an area as small as the one presented requires a densification of cell towers and signal repeaters, which in turn will cause much more radiation.

TABLE III: Calculated Cell Ranges for Several Receiver Sensitivities in Various Environments

	Cell Range (meters) for EIRP = 43 dBm					
Receiver Sensitivity	**UMa-LOS**	**UMa-NLOS**	**UMi-S.C.-LOS**	**UMi-S.C.-NLOS**	**UMi-O.S.-LOS**	**UMi-O.S.-NLOS**
-78 dBm	302	53	334	38.5	385	60
-70 dBm	165	29.7	186	22.3	216	33
-65 dBm	105.5	22	120	15.7	139	22.5
-60 dBm	65	14.1	74.5	11	85	15.3
-55 dBm	38.5	×	44.5	×	55	×
-50 dBm	22.6	×	26	×	27	×
-47 dBm	16.2	×	18.6	×	20	×

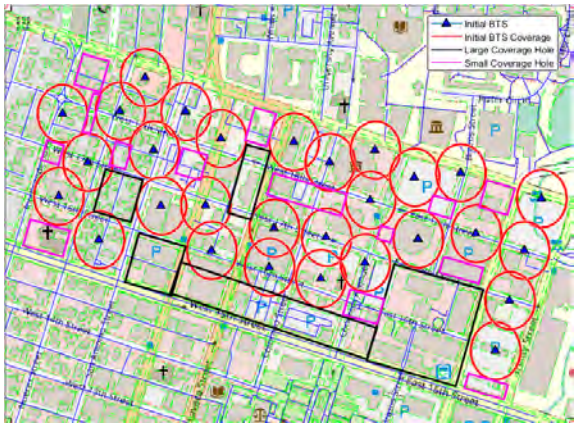


Fig. 4: Coverage holes identified after initial BTS installations

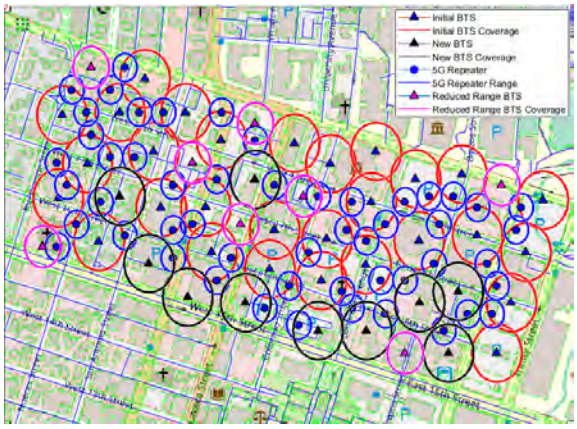


Fig. 5: Deployed 5G Network

IV. Radiation Analysis

A. Exposure Limits

Although mmWave radiation is non-ionizing, the absorption of mmWave energy in the human body causes heating to the skin and eyes. This has caused serious concerns in terms of potential health risks that might come along with the introduction of 5G networks [17]. For this reason, before introducing mmWave devices into the market, they need to comply to several exposure limits that have been specified in several standards and specifications. The specific absorption rate (SAR) has often been used as the metric to determine exposure compliance. The SAR measures the amount of energy absorbed by the human body while using a mobile phone. However, at high frequencies, this absorption is restricted to the skin level and thus it would be difficult to use the SAR as a measure for exposure limits at mmWave frequencies. The power density (P_D) measured in W/m^2 has been the preferred metric in the mmWave domain.

For the frequency range of 2 to 300 GHz, the IEEE C95.1-2019 standard [18] specifies a limit power density value of 10 W/m^2 in restricted environment and 50 W/m^2 in unrestricted environments. These correspond to an averaging time of 30 minutes. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2020 guidelines for limiting exposure to electromagnetic fields [19] specify the general public exposure limit at 10 W/m^2 for frequencies between 2 and 300 GHz with the averaging time being 30 minutes. Similar limits are specified by the Federal Communications Commission (FCC) in [20] where a restriction of 10 W/m^2 for the general public has been set. In contrast, the institute for building biology and sustainability (IBN) in Germany have specified the exposure limit to be less than 0.1 $\mu W/m^2$ in their 2015 Standard of Building Biology Measurement Technique (SBM-2015) [21], which is a million-fold lower than what is specified by the aforementioned guidelines. This suggests that negative health effects can occur at levels much lower than 10 W/m^2. Finally, the Chinese ministry of health [22] have set the power density exposure limit to 0.1 W/m^2.

TABLE IV: General Public Power Density Restrictions for the Frequency Range of 2 to 300 GHz

	IEEE C95.1-2019	ICNIRP	FCC	China	SBM-2015
P_D Limit (W/m^2)	10	10	10	0.1	10^{-6}

B. Power Density Assessment

The power density P_D radiated by a transmit antenna can be expressed at a far-field distance d using the following:

$$P_D = \frac{G_{Tx} P_{Tx}}{4\pi d^2} \tag{9}$$

The far-field distance is defined as the Fraunhofer distance expressed by:

$$d_{far-field} = \frac{2D^2}{\lambda} \tag{10}$$

where D is the largest dimension of the antenna and λ is the wavelength that corresponds to a frequency of operation. For distances less than the far-field distance, the power density cannot be computed using (9) and there would be a need to resort to numerical modeling methods such as the finite element method or finite-difference time domain.

C. Results

Fig. 6 shows the value of the power density for several choices of transmission power and transmit antenna gain in the distance range of 1 to 5 meters. For the proposed 5G network, we considered a transmission power of 19 dBm and a transmit antenna gain of 24 dBi. This corresponds to a value of 1.59 W/m^2 at 1 meters which drops to 0.06 W/m^2 at 5 meters. These values comply with the limits set by IEEE, ICNIRP, and FCC, since they are much lower than 10 W/m^2, but do not comply with SBM-2015 and Chinese Ministry of Health regulations. Fig. 7 shows the variations of the power density over the range of 20 to 50 meters. At 50 meters, which is at proximity of the cell edge, the power density drops further to $6.35 \times 10^{-4} W/m^2$ which is still much higher than the limit of the SBM-2015 guidelines. As shown in both Fig. 6 and Fig. 7, increasing the transmission power or choosing an antenna with a higher gain leads to an increase in the radiated power density. To comply with the limit set by China, the total EIRP needs to be dropped to achieve a power density below 0.1 W/m^2 which comes at the expense of a reduced cell range (below 50 meters). This makes it more difficult to plan cost-efficient 5G networks.

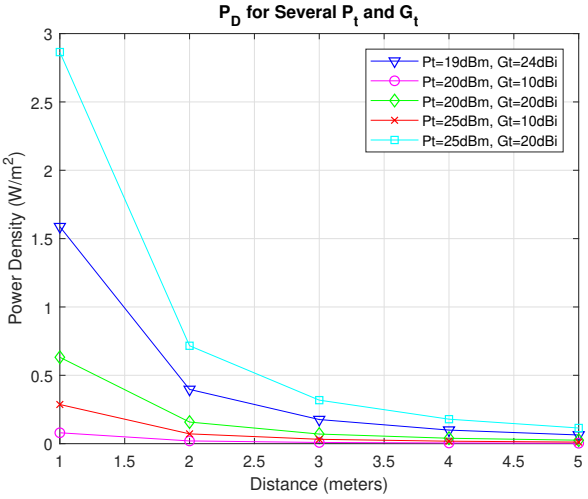


Fig. 6: Power Densities for Several Transmission Powers and Antenna Gains for the range of 1 to 5 meters

Cumulative Distribution Function (CDF) plots for the power density levels experienced in both the pre-existing LTE network and the newly deployed 5G network are shown in Fig. 8. The additional radiations imposed by the 5G network significantly increase the probability of being exposed to power density levels of more than 0.5 W/m^2 and that could reach up to the range of 2 to 2.5 W/m^2, while such power

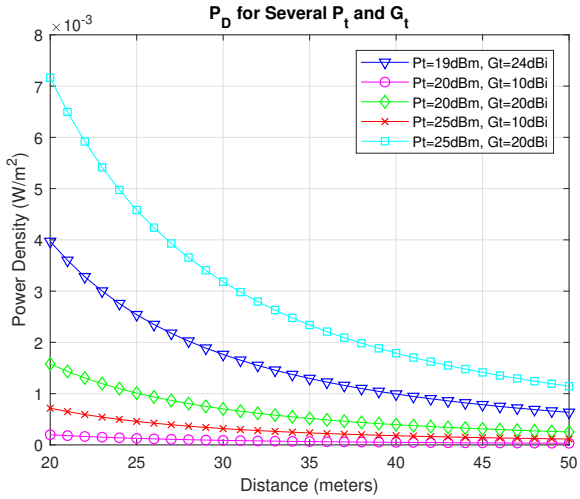


Fig. 7: Power Densities for Several Transmission Powers and Antenna Gains for the range of 20 to 50 meters

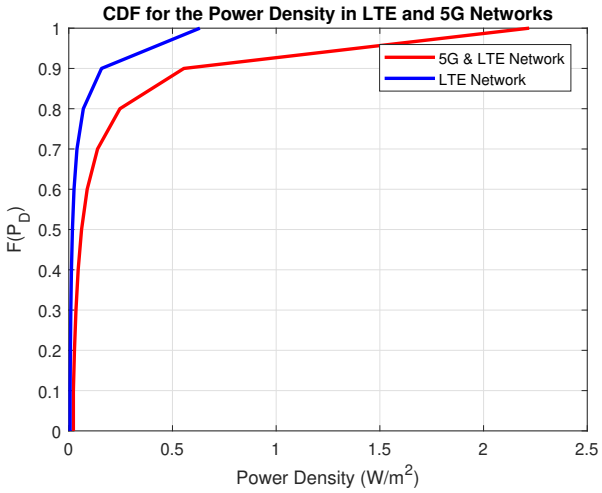


Fig. 8: CDF for the power densities levels for both pre-existing LTE and deployed 5G network

density levels were not experienced in the pre-existing LTE network. This is why the CDF of the power density in the pre-exisitng LTE network reaches the limiting factor of 1 for a power density around 0.65 W/m^2

Fig. 9 shows a heat-map representing the radiated power by the LTE BTSs in the area under study before deploying the 5G network, where a simplified path loss model [23] is considered for an urban macrocell. In Fig. 10, a similar heat-map is shown after the deployment of the 5G network. The remarkable increase in radiation levels after integrating 5G infrastructure with the original LTE network can be easily observed through the predominance of the red color in the heat map.

The presented results clearly show that the potential radiation levels that will be reached upon the roll out of 5G networks do not comply with all of the aforementioned

exposure limits. This suggests that 5G mobile networks can not yet be classified as safe for the public, and demands serious considerations before using mmWave communications for 5G networks, given the potential harms it could afflict on the public. This paves the way to the consideration of hybrid transmission techniques including traditional electromagnetic waves, free-space optics and visible light communication

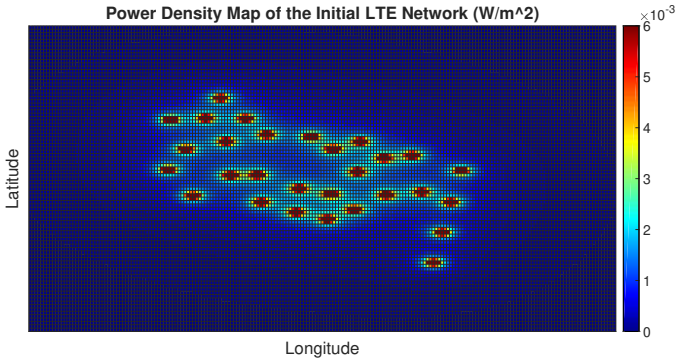


Fig. 9: Power Density Map of the Initial LTE Network

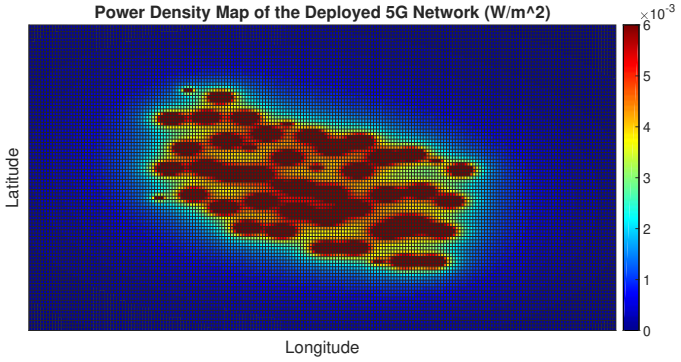


Fig. 10: Power Density Map of the Deployed 5G Network

V. Conclusion

This paper presented an analysis of the radiation levels in a deployed 5G network in an urban outdoor environment. Under the constraints of exposure limits, several challenges face the design and planning of such radiation aware 5G networks. Cell ranges need to be reduced to comply with the maximum allowed radiated power, requiring the densification of small cells in small areas and making it more costly to deploy these radiation-aware 5G networks. Although in this work we considered the maximum allowed EIRP prior to network deployment, results showed power density levels that do not satisfy all the exposure limits set by several sources. In this regard, a positive impact can be imposed by radiation-aware 5G networks on several levels. On a governmental level, the exposure limits for the power density need to be revised using today's data and approaches to bridge the gap between the thresholds specified by the different institutes and commissions. On a technological and scientific level, the radiation exposure constraint can open the door for innovative 5G solutions targeted to limit the health risks and economic barriers associated with this problem. This work can be extended by developing an analytical framework to efficiently rank and rate different cell allocation alternatives to minimize the potential radiations given a carefully chosen list of key performance indicators.

References

[1] M. Xiao, S. Mumtaz, Y. Huang, L. Dai, Y. Li, M. Matthaiou, G. K. Karagiannidis, E. Björnson, K. Yang, I. Chih-Lin, *et al.*, "Millimeter wave communications for future mobile networks," *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 9, pp. 1909–1935, 2017.

[2] H. El Misilmani and A. El-Hajj, "Massive mimo design for 5g networks: an overview on alternative antenna configurations and channel model challenges," *2017 International Conference on High Performance Computing & Simulation (HPCS)*, pp. 288–294, 2017.

[3] E. J. Oughton and Z. Frias, "The cost, coverage and rollout implications of 5g infrastructure in britain," *Telecommunications Policy*, vol. 42, no. 8, pp. 636–652, 2018.

[4] A. A. Al-Mekhlafi, O. M. Al-Kamali, R. Q. Shaddad, and M. A. Abduljalil, "Dense 5g network planning for coastal area at aden city, yemen," *2019 First International Conference of Intelligent Computing and Engineering (ICOICE)*, pp. 1–7, 2019.

[5] N. A. Jazea, H. Alyasiri, and A. H. Saloom, "Planning and optimization of 5g mobile network for al-najaf city (phase i)," *2019 International Engineering Conference (IEC)*, pp. 45–49, 2019.

[6] R. Q. Shaddad, F. S. Al-Kmali, M. A. Noman, N. K. Ahmed, E. M. Marish, A. M. Al-Duais, A. A. Al-Yafrsi, and F. A. Al-Sabri, "Planning of 5g millimeterwave wireless access network for dense urban area," *2019 First International Conference of Intelligent Computing and Engineering (ICOICE)*, pp. 1–4, 2019.

[7] D. Plets, W. Joseph, K. Vanhecke, and L. Martens, "Exposure optimization in indoor wireless networks by heuristic network planning," *Progress in Electromagnetics Research-PIER*, vol. 139, pp. 445–478, 2013.

[8] M. Deruyck, E. Tanghe, D. Plets, L. Martens, and W. Joseph, "Optimizing lte wireless access networks towards power consumption and electromagnetic exposure of human beings," *Computer Networks*, vol. 94, pp. 29–40, 2016.

[9] D. Basu and S. F. Hasan, "Approximating electromagnetic exposure in dense indoor environments," *2018 15th International Symposium on Wireless Communication Systems (ISWCS)*, pp. 1–5, 2018.

[10] G. R. Maccartney, T. S. Rappaport, S. Sun, and S. Deng, "Indoor office wideband millimeter-wave propagation measurements and channel models at 28 and 73 ghz for ultra-dense 5g wireless networks," *IEEE access*, vol. 3, pp. 2388–2424, 2015.

[11] Aalto University, BUPT, CMCC, Nokia, NTT DOCOMO, New York University, Ericsson, Qualcomm, Huawei, Samsung, Intel, University of Bristol, KT Corporation, University of Southern California,, "5G Channel Model for bands up to 100 GHz," *Tech. Rep. [Online]. Available: http://www.5gworkshops.com/5GCM.html*, Dec. 6, 2015.

[12] K. Haneda, J. Zhang, L. Tan, G. Liu, Y. Zheng, H. Asplund, J. Li, Y. Wang, D. Steer, C. Li, *et al.*, "5g 3gpp-like channel models for outdoor urban microcellular and macrocellular environments," *2016 IEEE 83rd Vehicular Technology Conference*, pp. 1–7, 2016.

[13] P. Series, "Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 mhz to 100 ghz," *tech. rep., ITU, Tech. Rep. ITU-R*, 2015.

[14] S. Singh, R. Mudumbai, and U. Madhow, "Interference analysis for highly directional 60-ghz mesh networks: The case for rethinking medium access control," *IEEE/ACM Transactions on networking*, vol. 19, no. 5, pp. 1513–1527, 2011.

[15] R. P. Series, "Itu,"characteristics of precipitation for propagation modelling,"," *Recommendation ITU-R P. 837*, vol. 6.

[16] S. K. Sharma, M. Patwary, S. Chatzinotas, B. Ottersten, and M. Abdel-Maguid, "Repeater for 5g wireless: A complementary contender for spectrum sensing intelligence," pp. 1416–1421, 2015.

[17] T. Wu, T. S. Rappaport, and C. M. Collins, "Safe for generations to come: Considerations of safety for millimeter waves in wireless communications," *IEEE Microwave Magazine*, vol. 16, no. 2, pp. 65–84, 2015.

[18] "Ieee standard for safety levels with respect to human exposure to electric, magnetic, and electromagnetic fields, 0 hz to 300 ghz," *IEEE Std C95.1-2019 (Revision of IEEE Std C95.1-2005/ Incorporates IEEE Std C95.1-2019/Cor 1-2019)*, pp. 1–312, 2019.

[19] I. C. on Non-Ionizing Radiation Protection *et al.*, "Guidelines for limiting exposure to electromagnetic fields (100 khz to 300 ghz)," *Health Physics*, vol. 118, no. 5, pp. 483–524, 2020.

[20] F. C. Commission *et al.*, "Report and order: Guidelines for evaluating the environmental effects of radiofrequency radiation," *FCC 96-326*, 1996.

[21] B. Maes, "Institut für baubiologie+ nachhaltigkeit (ibn). building biology evaluation guidelines for sleeping areas (sbm-2015). neuss, rosenheim (de): Baubiologie maes, ibn., 2015 may, 3p."

[22] H. Chiang, "Rationale for setting emf exposure standards," 2009.

[23] A. Goldsmith, *Wireless communications*. Cambridge university press, 2005.

Cureus

Open Access Review Article

DOI: 10.7759/cureus.17329

An Exploration of the Effects of Radiofrequency Radiation Emitted by Mobile Phones and Extremely Low Frequency Radiation on Thyroid Hormones and Thyroid Gland Histopathology

Tasnim Alkayyali [1], Olive Ochuba [2], Kosha Srivastava [3], Jasmine K. Sandhu [4], Christine Joseph [4], Sheila W. Ruo [5], Ashish Jain [2], Ahsan Waqar [4], Sujan Poudel [3]

1. Pathology, California Institute of Behavioral Neurosciences & Psychology, Fairfield, USA 2. Internal Medicine, California Institute of Behavioral Neurosciences & Psychology, Fairfield, USA 3. Neurology, California Institute of Behavioral Neurosciences & Psychology, Fairfield, USA 4. Family Medicine, California Institute of Behavioral Neurosciences & Psychology, Fairfield, USA 5. General Surgery, California Institute of Behavioral Neurosciences & Psychology, Fairfield, USA

Corresponding author: Tasnim Alkayyali, kayyali.tasnim@gmail.com

Abstract

The use of mobile phones has widely increased over the last two decades. Mobile phones produce a radiofrequency electromagnetic field (RF-EMF), a form of non-ionizing radiation. In contrast to the ionizing radiation proven to cause DNA damage, the harmful effects of non-ionizing radiation on the human body have not been discovered yet. The thyroid gland is among the most susceptible organs to mobile phone radiation due to its location in the anterior neck. Our purpose in this literature review is to explore the effects of the electromagnetic field (EMF), especially radiofrequency emitted from mobile phones, on thyroid hormones and thyroid gland histopathology. We searched PubMed and Google Scholar databases for relevant studies published after the year 2000, using the following keywords: ‘cell phones', ‘mobile phones', ‘telephones', ‘electromagnetic fields', ‘radiofrequency radiation', ‘microwaves', ‘thyroid gland', ‘thyroid hormones', and ‘thyroid cancer'. Our review revealed that mobile phone radiofrequency radiation (RFR) might be associated with thyroid gland insufficiency and alterations in serum thyroid hormone levels, with a possible disruption in the hypothalamic-pituitary-thyroid axis. The review also showed histopathological changes in the thyroid gland follicles after exposure of rats to non-ionizing radiation. The results were directly related to the amount and duration of exposure to EMF radiation. Further human studies exploring thyroid gland hormones, microscopic morphology, and thyroid cancer are highly recommended for future researches.

Categories: Endocrinology/Diabetes/Metabolism, Pathology, Radiology
Keywords: mobile phones, cell phones, electromagnetic field, radiofrequency, microwaves, low-frequency radiation, thyroid hormones, thyroid gland, thyroid cancer

Received 07/15/2021
Review began 07/25/2021
Review ended 08/10/2021
Published 08/20/2021

Introduction And Background

'I do not doubt in my mind that, at present, the greatest polluting element in the earth’s environment is the proliferation of electromagnetic fields (EMFs),' said Dr. Robert O. Becker (1923 – 2008), a researcher from the United States (US) in electromedicine and a Nobel Prize winner [1]. In 2021, mobile phone subscriptions surpassed eight billion users worldwide, and the number is expected to increase to 8.8 billion by 2026 [2]. Mobile phones use EMFs with frequencies ranging from 450-3800 MHz [3]. The EMF comprises both an electric field and a magnetic field; the electric field is produced between positive and negative electric charges and, in contrast, a magnetic field can be generated by the movement of electrons, known as electric current [4]. Electromagnetic waves are classified based on their frequencies, i.e., the number of cycles per second, measured in Hertz (Hz) [4]. High-frequency EMFs (HF-EMFs), including gamma rays, X-rays, and higher ultraviolet lights, are forms of ionizing radiation, therefore, capable of breaking the DNA bonds of human cells [5].

Non-ionizing forms of radiation include lower frequencies on the electromagnetic spectrum and are not proven to cause DNA damage directly (Figure *1*). Examples of extremely low frequency-EMFs (ELF-EMF) include electricity from power sockets at homes, power lines, and electrical devices such as hair dryers [5]. Radiofrequency-EMF (RF-EMF) is also a subtype of non-ionizing radiation with frequencies ranging from 30 kHz-300 GHz [6]. Radiofrequency-based technology has increased dramatically over the last few decades; it includes mobile phones, computer monitors, tablets, radio and television broadcasting antenna towers, wireless fidelity (Wi-Fi), radars, MRI, and microwave ovens [6].

How to cite this article
Alkayyali T, Ochuba O, Srivastava K, et al. (August 20, 2021) An Exploration of the Effects of Radiofrequency Radiation Emitted by Mobile Phones and Extremely Low Frequency Radiation on Thyroid Hormones and Thyroid Gland Histopathology. Cureus 13(8): e17329. DOI 10.7759/cureus.17329

EUR. J. ONCOL.; Vol. 20, n. 3/4, pp. 180-182, 2015

International Appeal: Scientists call for protection from non-ionizing electromagnetic field exposure

An introduction to the International EMF Scientist Appeal

The current issue of the European Journal of Oncology contains a document the "International EMF Scientist Appeal" (EMFscientist.org) that addresses the concerns of 215 scientists from 40 nations about the adverse health effects on the human population exposed to non-ionizing electromagnetic fields (EMF) from extremely-low frequency to radiofrequency. The Appeal has been submitted to the United Nations, to two of its sub-agencies, the World Health Organization (WHO) and the United Nations Environmental Programme (UNEP), and to all UN Member Nations.

We note that the overall weight of evidence reported in peer-reviewed, scientific studies strongly supports greater precautionary measures be taken to reduce or eliminate EMF exposure.

Coordinating and Advisory Committee for the "International EMF Scientist Appeal" (Martin Blank, Magda Havas, Elizabeth Kelley, Henry Lai, and Joel Moskowitz). We can be reached through Elizabeth Kelley at info@EMFscientist.org.

To: His Excellency Ban Ki-moon, Secretary-General of the United Nations;
Honorable Dr. Margaret Chan, Director-General of the World Health Organization; Honorable Achim Steiner, Executive Director of the U.N. Environmental Programme; U.N. Member Nations

Summary. We are scientists engaged in the study of biological and health effects of non-ionizing electromagnetic fields (EMF). Based upon peer-reviewed, published research, we have serious concerns regarding the ubiquitous and increasing exposure to EMF generated by electric and wireless devices. These include–but are not limited to–radiofrequency radiation (RFR) emitting devices, such as cellular and cordless phones and their base stations, Wi-Fi, broadcast antennas, smart meters, and baby monitors as well as electric devices and infra-structures used in the delivery of electricity that generate extremely-low frequency electromagnetic field (ELF EMF).

Scientific basis for our common concerns

Numerous recent scientific publications have shown that EMF 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.

These findings justify our appeal to the United Nations (UN) and, all member States in the world, to encourage the World Health Organization (WHO) to exert strong leadership in fostering the development of more protective EMF guidelines, encouraging precautionary measures, and educating the public about health risks, particularly risk to children and fetal development. By not taking action, the WHO is failing to fulfill its role as the preeminent international public health agency.

Inadequate non-ionizing EMF international guidelines

The various agencies setting safety standards have failed to impose sufficient guidelines to protect the general public, particularly children who are more vulnerable to the effects of EMF.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) established in 1998 the "Guidelines For Limiting Exposure To Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)" (1). These guidelines are accepted by the WHO and numerous countries around the world. The WHO is calling for all nations to adopt the ICNIRP guidelines to encourage international harmonization of standards. In 2009, the ICNIRP released a statement saying that it was reaffirming its 1998 guidelines, as in their opinion, the scientific literature published since that time "has provided no evidence of any adverse effects below the basic restrictions and does not necessitate an immediate revision of its guidance on limiting exposure to high frequency electromagnetic fields (2). ICNIRP continues to the present day to make these assertions, in spite of growing scientific evidence to the contrary. It is our opinion that, because the ICNIRP guidelines do not cover long-term exposure and low-intensity effects, they are insufficient to protect public health.

The WHO adopted the International Agency for Research on Cancer (IARC) classification of extremely low frequency electromagnetic field (ELF EMF) in 2002 (3) and radiofrequency radiation (RFR) in 2011 (4). This classification states that EMF is a *possible human carcinogen (Group 2B)*. Despite both IARC findings, the WHO continues to maintain that there is insufficient evidence to justify lowering these quantitative exposure limits.

Since there is controversy about a rationale for setting standards to avoid adverse health effects, we recommend that the United Nations Environmental Programme (UNEP) convene and fund an independent multidisciplinary committee to explore the pros and cons of alternatives to current practices that could substantially lower human exposures to RF and ELF fields. The deliberations of this group should be conducted in a transparent and impartial way. Although it is essential that industry be involved and cooperate in this process, industry should not be allowed to bias its processes or conclusions. This group should provide their analysis to the UN and the WHO to guide precautionary action.

Collectively we also request that:

1. children and pregnant women be protected;
2. guidelines and regulatory standards be strengthened;
3. manufacturers be encouraged to develop safer technology;
4. utilities responsible for the generation, transmission, distribution, and monitoring of electricity maintain adequate power quality and ensure proper electrical wiring to minimize harmful ground current;
5. the public be fully informed about the potential health risks from electromagnetic energy and taught harm reduction strategies;
6. medical professionals be educated about the biological effects of electromagnetic energy and be provided training on treatment of patients with electromagnetic sensitivity;
7. governments fund training and research on electromagnetic fields and health that is independent of industry and mandate industry cooperation with researchers;

Bioelectromagnetics 18:455–461 (1997)

RF Radiation–Induced Changes in the Prenatal Development of Mice

Ioannis N. Magras[1]* and Thomas D. Xenos[2]

[1]*Department of Anatomy, Histology, and Embryology, School of Veterinary Medicine, Aristotle University of Thessaloniki, Thessalonike, Greece*
[2]*Department of Telecommunications, School of Electrical Engineering and Computer Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece*

The possible effects of radiofrequency (RF) radiation on prenatal development has been investigated in mice. This study consisted of RF level measurements and in vivo experiments at several places around an ''antenna park.'' At these locations RF power densities between 168 nW/cm^2 and 1053 nW/cm^2 were measured. Twelve pairs of mice, divided in two groups, were placed in locations of different power densities and were repeatedly mated five times. One hundred eighteen newborns were collected. They were measured, weighed, and examined macro- and microscopically. A progressive decrease in the number of newborns per dam was observed, which ended in irreversible infertility. The prenatal development of the newborns, however, evaluated by the crown-rump length, the body weight, and the number of the lumbar, sacral, and coccygeal vertebrae, was improved. *Bioelectromagnetics 18:455–461, 1997.* © 1997 Wiley-Liss, Inc.

Key words: RF radiation effects; prenatal development; mice development

Five years ago the ''antenna-park of Thessaloniki'' progressively developed on the top of the nearby mountain Chortiatis, 1.5 km away from a small village of the same name. Today, almost 100 commercial TV and FM-radio broadcasting transmitters in the VHF and the UHF bands are situated there. The antennas are installed on towers well visible from a large part of the village. Living so close to the antennae and the vast amount of RF power they transmit, which is of the order of 300 kW, the people of the village Chortiatis, anxious for their health, encouraged the author to undertake a research program.

The hypothesis that RF radiation may adversely affect the health of the animal organism is still under consideration in public and scientific forums. One of the critical issues seems to be the RF effects on the reproductive process [Chernoff et al., 1992]. Numerous studies dealing with this subject ended up with seemingly contradictory results. Therefore, an ''in vivo'' study on experimental animals sensitive to RF radiation, was chosen. Based on the relevant literature, this research investigated RF radiation effects on the reproductive system, particularly on prenatal development. The mouse was selected as the experimental animal, because it is easily manipulated in the environment in which the experiments had to take place. Of course, experimenting at the mountain sites, far from the easily controlled laboratory conditions, might add a certain amount of uncertainty; therefore, these experiments should be considered preliminary.

MATERIALS AND METHODS

We used a total of 36 mice (18 females and 18 males), 2 months old and sexually mature (BALB/c/f breed colony). Breeding colony virgin males and females were obtained from the ''Theageneion Anticancer Institute of Thessaloniki.'' The use of these experimental animals was approved by the Veterinary Service of the Municipality of Thessaloniki, according to the provisions of the laws 1197/81 and 2015/92 and the Presidential Decree 160/91 of the Greek Democracy. Upon arrival, all experimental animals were quarantined for 2 weeks to discover and to allow them to acclimatise the mountain environment, an altitude ranging between 570 (position h) and 730 m (position d) above sea level. All the mice were healthy at the end of this period and showed no signs of illness during

*Correspondence to: Ioannis N. Magras, Department of Anatomy, Histology, and Embryology, School of Veterinary Medicine, Aristotle University of Thessaloniki, 540-06 Thessaloniki, Greece.

Received for review 9 June 1996; revision received 30 January 1997

Environmental Research 163 (2018) 208–216

Contents lists available at ScienceDirect

Environmental Research

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

The human skin as a sub-THz receiver – Does 5G pose a danger to it or not?

Noa Betzalel[a], Paul Ben Ishai[a,b], Yuri Feldman[a,*]

[a] Department of Applied Physics, The Rachel and Selim Benin School of Engineering and Computer Science, The Hebrew University of Jerusalem, Edmond J. Safra Campus, Jerusalem 91904, Israel

[b] Department of Physics, Ariel University, Ariel 40700, Israel

ARTICLE INFO

Keywords:
5G
Helical antenna
Human skin, Sub-Terahertz (sub-THz)
Specific Absorption Rate (SAR)
Sweat duct

ABSTRACT

In the interaction of microwave radiation and human beings, the skin is traditionally considered as just an absorbing sponge stratum filled with water. In previous works, we showed that this view is flawed when we demonstrated that the coiled portion of the sweat duct in upper skin layer is regarded as a helical antenna in the sub-THz band. Experimentally we showed that the reflectance of the human skin in the sub-THz region depends on the intensity of perspiration, i.e. sweat duct's conductivity, and correlates with levels of human stress (physical, mental and emotional). Later on, we detected circular dichroism in the reflectance from the skin, a signature of the axial mode of a helical antenna. The full ramifications of what these findings represent in the human condition are still unclear. We also revealed correlation of electrocardiography (ECG) parameters to the sub-THz reflection coefficient of human skin. In a recent work, we developed a unique simulation tool of human skin, taking into account the skin multi-layer structure together with the helical segment of the sweat duct embedded in it. The presence of the sweat duct led to a high specific absorption rate (SAR) of the skin in extremely high frequency band. In this paper, we summarize the physical evidence for this phenomenon and consider its implication for the future exploitation of the electromagnetic spectrum by wireless communication. Starting from July 2016 the US Federal Communications Commission (FCC) has adopted new rules for wireless broadband operations above 24 GHz (5 G). This trend of exploitation is predicted to expand to higher frequencies in the sub-THz region. One must consider the implications of human immersion in the electromagnetic noise, caused by devices working at the very same frequencies as those, to which the sweat duct (as a helical antenna) is most attuned. We are raising a warning flag against the unrestricted use of sub-THz technologies for communication, before the possible consequences for public health are explored.

1. Introduction

The world is galloping towards a bright new future, or at least so industry would like us to think. The advent of 5 G promises unforetold connectivity and unparalleled integration with the virtual world (Agiwal et al., 2016). Technology will interact with almost every aspect of our daily lives (Boccardi et al., 2014), as well as expose us to rich and varied data streaming on our cellular and Wi-Fi devices. While all of this may be true it comes with a price tag. To afford such heavy data traffic we must accept an expansion in data channels (Ben Ishai et al., 2016), something that is not possible in the currently used frequency channels, and an attendant explosion in base stations (Ge et al., 2016). This is the rational to move to 5 G, a FCC standard, which will start at 28 GHz (FCC Report 16–89), soon utilize frequencies up to 60 GHz and may eventually reach the sub - Terahertz range (FCC 50–50 Report).

Industry has assumed that there will be no health risks from this advance (T. Wu et al., 2015a, 2015b) and consequently it has based its planning on the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), published in 1998 (Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). International Commission on Non-Ionizing Radiation Protection," 1998). This recommendation limits exposure in the 5 G range to a power density of 10 W/m^2 for the general public and to 50 W/m^2 for occupational exposure ("Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). International Commission on Non-Ionizing Radiation Protection," 1998).

However, in recent years concerns have surfaced about possible non-thermal biological effects, and ensuing health issues, arising from cellular electromagnetic radiation (Adams et al., 2014; Blank and Goodman, 2009; Darbandi et al., 2017; Hardell and Sage, 2008; Liu et al., 2013; Panagopoulos, 2017; Sage and Carpenter, 2009; Terzi et al., 2016). These should raise a red flag for the implementation of the 5 G standard. One reason being that the modality of our interaction

* Corresponding author.
E-mail address: yurif@mail.huji.ac.il (Y. Feldman).

https://doi.org/10.1016/j.envres.2018.01.032
Received 2 September 2017; Received in revised form 18 December 2017; Accepted 23 January 2018

INCREASED INCIDENCE OF CANCER NEAR A CELL-PHONE TRANSMITTER STATION.

RONNI WOLF MD[1]

DANNY WOLF MD[2]

From:

The Dermatology Unit, Kaplan Medical Center, Rechovot, and the Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, ISRAEL.

The Pediatric Outpatient Clinic, Hasharon Region, Kupat Holim, ISRAEL.

Running title: Cancer near a cell-phone transmitter station.

Address for correspondence: Ronni Wolf, MD, Dermatology Unit, Kaplan Medical Center, Rechovot 76100, ISRAEL.
Fax 972-9-9560978. E-mail: wolf_r@netvision.net.il

International Journal of Cancer Prevention

VOLUME 1, NUMBER 2, APRIL 2004

Increased Incidence of Cancer near a Cell-Phone Transmitter Station
by Ronni Wolf and Danny Wolf

Abstract

Significant concern has been raised about possible health effects from exposure to radiofrequency (RF) electromagnetic fields, especially after the rapid introduction of mobile telecommunications systems. Parents are especially concerned with the possibility that children might develop cancer after exposure to the RF emissions from mobile telephone base stations erected in or near schools. The few epidemiologic studies that did report on cancer incidence in relation to RF radiation have generally presented negative or inconsistent results, and thus emphasize the need for more studies that should investigate cohorts with high RF exposure for changes in cancer incidence. The aim of this study is to investigate whether there is an increased cancer incidence in populations, living in a small area, and exposed to RF radiation from a cell-phone transmitter station.

This is an epidemiologic assessment, to determine whether the incidence of cancer cases among individuals exposed to a cell-phone transmitter station is different from that expected in Israel, in Netanya, or as compared to people who lived in a nearby area. Participants are people (n=622) living in the area near a cell-phone transmitter station for 3-7 years who were patients of one health clinic (of DW). The exposure began 1 year before the start of the study when the station first came into service. A second cohort of individuals (n=1222) who get their medical services in a clinic located nearby with very closely matched, environment, workplace and occupational characteristics was used for comparison.

In the area of exposure (area A) eight cases of different kinds of cancer were diagnosed in a period of only one year. This rate of cancers was compared both with the rate of 31 cases per 10,000 per year in the general population and the 2/1222 rate recorded in the nearby clinic (area B). Relative cancer rates for females were 10.5 for area A, 0.6 for area B and 1 for the whole town of Netanya. Cancer incidence of women in area A was thus significantly higher ($p<0.0001$) compared with that of area B and the whole city. A comparison of the relative risk revealed that there were 4.15 times more cases in area A than in the entire population.

The study indicates an association between increased incidence of cancer and living in proximity to a cell-phone transmitter station.

ARIEL UNIVERSITY

September 08, 2017

The Honorable Jerry Brown
Governor, State of California
c/o State Capitol, Suite 1173
Sacramento, CA 95814

RE: SB 649 (Hueso) – Small Cell Wireless Facilities

Honorable Governor Brown,

I have recently learned of proposed Bill SB 649 regarding the streamlining of small cell wireless facilities.

As a member of the Physics department of Ariel University, and before that the Hebrew University of Jerusalem, I have studied the subtle effects of electromagnetic radiation on biology and biological materials. I have published more than 50 articles in the field of Dielectrics (the study of the interaction of materials with radio waves), including many on the interaction of cellular frequencies with biological materials such as proteins and blood. My last article investigated the interaction of 5G electromagnetic radiation with human skin.[1] One could argue that I have a certain amount of expertise.

In light of our work and a growing number of publications showing the frequency range of 5G can have serious biological effects, we believe that current efforts to accelerate the implementation of 5G should be delayed until additional studies are made to assess the critical impact on human health.

It is not for me to lecture to elected officials on how cities should develop technologically, nor is it for me to try and stop the juggernaut that is the cellular industry. However, I would like to point out to you important information on the possible public health implications of the explosion in unregulated cellular phone and wireless device use.

The term "health" has never featured too heavily in the lexicon of the Cellular Industry. It has been assumed, conveniently, that any possible effects on the human anatomy from the use of cell phones would be only mild heating. And that this is something that the body could easily deal with. As a consequence, the governing safety limits were set in 1998 by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) based on the premise that if radiofrequency radiation limits protected human tissue from overheating, then the public was adequately protected. They considered that the effect to humans would at most cause the agitation of water inside cellular tissues that would dissipate as heat, similar to what a microwave oven does, but at far lower energies.

The trouble is that our knowledge has progressed in the last 19 years and we now understand that the interaction of microwave energy and our tissues is far more subtle. There is increasing evidence of non-thermal biological consequences arising from our interaction with cellular phone radiation. A few examples; in 2014 a team from the University of Exeter, UK published a report linking the effect of

[1] Betzalel, Noa, Yuri Feldman and Paul Ben Ishai. "The Modeling of the Absorbance of Sub-THz Radiation by Human Skin." *IEEE Transactions on Terahertz Science and Technology* PP.99 (2017): 1-9. doi: 10.1109/TTHZ.2017.2736345.

+972.3.9066111
Ariel 40700, Israel

cellular phones on declining sperm quality.[2] They based their research on over 1492 subjects from around the world. In 2009, Columbia University showed that radio frequencies were leading to stress in living cells.[3] This in turn seriously affects their ability to perform, as particular cellular pathways were disrupted. Further evidence along this direction was provided by a group from the University of Rennes.[4] I can add plenty more examples, but I think that it is summed up by a recent public announcement. Advisors to the World Health Organization International Agency for Research on Cancer (WHO/IARC), themselves well versed in radio frequencies and in cancer, have publicly stated that evidence has been met to classify cellular radiation as meeting scientific criteria for a Group 1 carcinogenic agent to humans.[5,6]

As I said above, it is not my job and neither is it realistic for me to stop the placing of thousands of antennas throughout your state. But it is my job to point out the health hazard to you before you make such a momentous decision.

Yours sincerely

Dr. Paul Ben Ishai
Department of Physics
Ariel University

CC
Tom Dyer, Chief Deputy Legislative Affairs Secretary

[2] Adams, J.A., et al. "Effect of mobile telephones on sperm quality: a systematic review and meta-analysis." *Environment International* 70 (2014): 106-12. doi: 10.1016/j.envint.2014.04.015.

[3] Blank, M. and R. Goodman. "Electromagnetic fields stress living cells." *Pathophysiology* 16.2-3 (2009): 71-8. doi: 10.1016/j.pathophys.2009.01.006.

[4] Habauzit, Denis, et al. "Transcriptome analysis reveals the contribution of thermal and the specific effects in cellular response to millimeter wave exposure." *PloS One* 9.10 (2014): e109435.

doi: 10.1371/journal.pone.0109435

[5] "Cancer Expert Declares Cell Phone and Wireless Radiation As Carcinogenic to Humans." Environmental Health Trust (2017). https://ehtrust.org/cancer-expert-declares-cell-phone-wireless-radiation-carcinogenic-humans/

[6] Carlberg, Michael and Lennart Hardell. "Evaluation of Mobile Phone and Cordless Phone Use and Glioma Risk Using the Bradford Hill Viewpoints from 1965 on Association or Causation." BioMed Research International 2017 (2017): 9218486. doi: 10.1155/2017/9218486.

+972.3.9066111
Ariel 40700, Israel

Evaluation of the Genotoxicity of Cell Phone Radiofrequency Radiation in Male and Female Rats and Mice Following Subchronic Exposure

Stephanie L. Smith-Roe[1], Michael E. Wyde[1], Matthew D. Stout[1], John W. Winters[2], Cheryl A. Hobbs[2], Kim G. Shepard[2], Amanda S. Green[2], Grace E. Kissling[1], Raymond R. Tice[1], John R. Bucher[1], Kristine L. Witt[1]

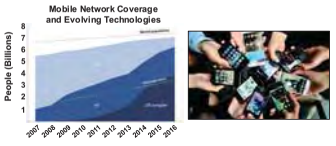
[1]Division of the National Toxicology Program/NIEHS, RTP, NC 27709, USA; [2] Integrated Laboratory Systems, Inc., RTP, NC, 27709, USA

Abstract

The National Toxicology Program tested the two common radiofrequency radiation (RFR) modulations emitted by cellular telephones in a 2-year rodent cancer bioassay that included additional animal cohorts for interim assessments of genotoxicity endpoints. Male and female Sprague Dawley rats and B6C3F1/N mice were exposed from gestation day 5 or postnatal day 35, respectively, to code division multiple access (CDMA) or global system for mobile (GSM) modulations semi-continuously for 18 h/day in 10 min intervals in reverberation chambers at specific absorption rates (SAR) of 1.5, 3, or 6 W/kg (rats) or 2.5, 5, or 10 W/kg (mice). Rats and mice were exposed at 900 MHz or 1900 MHz, respectively. The interim cohorts, 5 animals per treatment group, were examined after 19 (rats) or 13 (mice) weeks of exposure for evidence of RFR-induced genotoxicity. DNA damage was assessed in three brain regions (frontal cortex, hippocampus, and cerebellum), and in liver cells and blood leukocytes using the comet assay. Chromosomal damage was assessed in peripheral blood erythrocytes using the micronucleus assay. DNA damage was significantly increased in the frontal cortex of male mice (both modulations), peripheral leukocytes of female mice (CDMA only), and hippocampus of male rats (CDMA only). DNA damage was nominally elevated in several other tissues of RFR-exposed rats, although statistical significance was not achieved. No significant increases in micronucleated red blood cells were observed in rats or mice. These results suggest that exposure to RFR has the potential to induce measurable DNA damage under certain exposure conditions.

Introduction

- Cellular telephone use is nearly ubiquitous world-wide: cell phone subscriptions were estimated at 6.9 billion in 2014.



- Cell phones transmit radiofrequency radiation (RFR) signals; RFR is a form of electromagnetic radiation.
- Whether exposure to RFR via cell phones can cause cancer, particularly brain cancer, in humans has been of concern. IARC classified radiofrequency electromagnetic fields (RF-EMF), as "possibly carcinogenic to humans (Group 2B)," based on limited evidence in experimental animals and insufficient evidence in humans to support a conclusion on the association between RF-EMF and cancer.
- Results of previous rodent cancer and genotoxicity studies of varying RFR exposures and durations are inconsistent and inconclusive, and many of these studies used experimental protocols with significant limitations. Hence, there is still much uncertainty about the possible adverse effects of RFR, as reflected by the IARC classification.
- The Food and Drug Administration (FDA) Center for Device and Radiation Health nominated Radiofrequency Radiation Emissions of Wireless Communication Devices to the NTP as a high priority nomination in 1999.
- To help inform human health risk assessments, the NTP conducted a 2-year rodent cancer bioassay of the modulations of RFR most commonly emitted by cell phones.
- Genotoxicity testing was conducted using subsets of rats and mice exposed under the same experimental design as the cancer bioassay, albeit for shorter durations.

Study Design, Materials & Methods

Study Design

Male and Female Sprague Dawley Rats (5 rats per exposure group)
- 19 weeks of exposure beginning ~gestational day 5
- 1.5, 3.0, or 6.0 W/kg CDMA or GSM (900 MHz)
- One sham control for each sex

Male and Female B6C3F1/N Mice (5 mice per exposure group)
- 13 weeks of exposure beginning ~postnatal day 35
- 2.5, 5.0, or 10.0 W/kg GSM or CDMA (1900 MHz)
- One sham control for each sex

Whole Body Exposure

Please see Capstick et al. (2017) and Gong et al. (2017) for extensive details

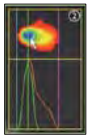
- Daily from 11:00 AM to 2:00 PM and 3:40 PM to 7:00 AM
- RFR cycled on and off every 10 min during exposure periods
  - Total duration of exposure of 9 h 10 min per 24 h period
- An upper limit of 1 °C (1.8 °F) was set as an acceptable increase in body temperature. In 5- and 28-day pilot studies, significant increases in body temperature were rare in rats and mice exposed to 6 or 10 W/kg, respectively (either modulation), and such increases, when they occurred, were < 1 °C. Body temperatue increases > 1 °C were expected to be highly unlikely in this study (Wyde et al., submitted)

RFR Exposure Facility at Illinois Industrial Research Institute (ITRI)

- Reverberation chambers and animal housing were developed in collaboration with the National Institute of Standards and Technology (NIST) and the Foundation for Research on Information Technologies in Society (IT'IS).
- Reverberation chambers created uniform fields of RFR and shielded animals from all other sources of RFR.
- Field uniformity was achieved by installing excitation antennas with rotating horizontal and vertical reflective surface paddles to ensure even distribution of statistically homogenous RFR fields.
- Cages, cage racks, and materials used to deliver food and water were designed to minimize interference with RFR exposure; e.g., specialized lixits were developed to prevent drinking tubes from acting as antennas for RFR.
- RFR field intensity, uniformity, quality of modulation, and numerous other parameters were validated by NIST.
- Consistency of exposure was monitored in real time by IT'IS.

Comet Assay

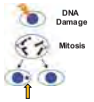
Frontal cortex, hippocampus, cerebellum, liver, and peripheral blood were analyzed in the comet assay. Single-cell suspensions were diluted in agarose and layered onto CometSlides™. Slides were incubated overnight in lysing solution at 4 °C, then treated with cold alkali solution for 20 min to allow DNA unwinding. Slides were then subjected to electrophoresis for 20 min. After staining with SYBR® Gold, slides were coded to mask treatment and scored using Comet Assay IV Imaging Software. DNA migration was measured in 100 non-overlapping comet images per animal/tissue and reported as % Tail DNA. Hedgehogs (HH; all DNA appears by visual inspection to be in the tail) were scored as a separate category.



Comet Assay IV imaging software identifies the left edge of the head of the comet and flips it to construct the right edge. % Tail DNA is calculated by dividing the fluorescence intensity of the tail by the total fluorescence intensity of the entire comet figure.

Micronucleus Assay

Flow cytometric analysis was performed using MicroFlow^{PLUS} Kit reagents and a FACSCalibur™ system. Reticulocytes (RET) and mature erythrocytes (E) were analyzed for micronuclei (MN). For each sample, ~20,000 RET were analyzed and ~1 x 10^6 mature erythrocytes were enumerated concurrently, allowing for calculation of the %RET among total erythrocytes as a measure of bone marrow toxicity. The protocol was consistent with OECD Guideline 474.



Results for MN-RETs, MN-Es, and %PCEs were negative for both species, both sexes, and both RFR modulations (data not shown).

Figure 1

Two Approaches for Scoring Comets

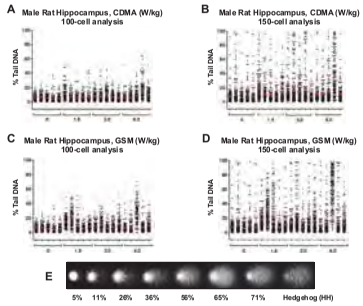


Fig. 1A, C: Comets were selected by a scorer (blind to treatment) for analysis *via* software to determine % Tail DNA. 100 cells were analyzed per animal/tissue and HH – identified by visual inspection – were tabulated but excluded from analysis. However, using this approach, % Tail DNA rarely exceeded 65%, yet for some tissues %HH values were markedly elevated. **Fig. 1B, D**: OECD TG 489 (OECD, 2014) recommends analyzing 150 cells. To be consistent with this new recommendation, and due to inter-animal variability observed in rats, rat slides were re-analyzed using this method; all scorable cells were analyzed with imaging software (i.e., visual inspection alone was not used to eliminate HH). This approach revealed a broader spectrum of DNA damage (Fig. 1B & D). There were few changes in statistically significant results based on scoring 100 vs. 150 cells. **Fig. 1E**: Representative images of DNA migration in the comet assay (% Tail DNA) from male rat frontal cortex.

Figure 2

Positive Results

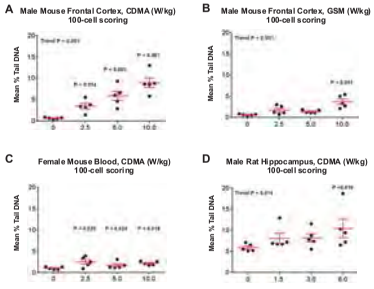
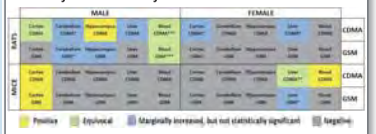


Fig. 2A-D: Of the 40 tissues examined (5 tissues, 2 species, 2 sexes, 2 modulations) using the 100-cell scoring approach, 4 showed positive results using the following criteria: significant trend test ($P < 0.025$) and at least one significant dose group ($P < 0.025$); or at least 2 significant dose groups. Similar results were obtained for these tissues when data were analyzed using the 150-cell method except for male rat hippocampus (means of all exposed groups were greater than the control, but did not reach statistical significance).

Tissues from rats tended to show greater inter-animal variability than those from mice. This inter-animal variability may reflect the genetic diversity of this outbred rat stock. However, % Tail DNA values from different tissues from the same rat rarely correlated, suggesting inter-tissue variability as well.

Figure 3

Summary of Comet Assay Results



Positive: Significant trend test ($P < 0.025$) and at least one significant dose group ($P < 0.025$); or at least 2 significant dose groups. **Equivocal**: Either a significant trend test or one significant dose group. **Marginally increased**: Means of all exposed groups were higher than the control and P values approached statistical significance. **Negative**: none of the above.

In summary, 8/40 tissues exhibited some degree of effect from RFR exposure when assessed using the 100-cell scoring approach. Five tissues exhibited marginal, but statistically non-significant increases when assessed using the 150-cell scoring approach (*). Female mouse liver (CDMA) went from marginal to an equivocal call using the 150-cell scoring approach (**). Two tissues, male rat blood (CDMA and GSM), went from negative to equivocal calls using the 150-cell scoring approach (***).

Conclusions

- When considering both scoring methods, 15/40 of the tissues examined showed some indication of response (positive, equivocal, or increases in % Tail DNA in the absence of statistical significance) in the comet assay. The comet assay is a hazard identification assay, and the damage detected by the assay represents a snapshot of the kinetics of DNA damage and repair processes.
- In the 2-year bioassay, a low incidence of malignant gliomas of the brain was observed in male, but not female, rats exposed to CDMA or GSM in the 2-year cancer bioassay (Wyde et al. 2016). Results are not yet available for mice. Considering that male rat brain tissue was more affected by RFR in the comet assay compared to female rats and male and female mice, it will be of interest to see whether there is a correlation between the comet assay results and the complete findings from the cancer bioassay.
- High exposure levels of RFR can cause hyperthermia in rats and mice, and hyperthermia is known to cause genotoxic effects in both the comet and micronucleus assays; however, the exposures used in the 2-year cancer bioassay (and therefore the genetic toxicity studies) were carefully selected, based on pilot study data, to avoid thermal effects.
- The mechanism by which RFR could induce biological effects other than by increasing body temperature is a matter of intense speculation. The NTP is currently in the process of acquiring smaller RFR whole body exposure chambers for follow-up studies. Initial studies will aim to explore potential mechanisms underlying the observed DNA damage in the comet assay and explore other biomarkers of genetic damage.

References

Capstick et al. (2017) A radio frequency radiation exposure system for rodents based on reverberation chambers. *IEEE Trans Electromag Compat*, 59(4): 1041-1052.

Gong et al. (2017) Life-time dosimetric assessment for mice and rats exposed in reverberation chambers for the two-year NTP cancer bioassay study on cell phone radiation. *IEEE Trans Electromag Compat, in press.*

International Agency for Research on Cancer (2013) Non-ionizing radiation, Part 2: Radiofrequency electromagnetic fields. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, vol. 102(Pt 2):1-460.

Organization for Economic Cooperation and Development (2014) Test No. 474: Mammalian Erythrocyte Micronucleus Test, OECD Guidelines for the Testing of Chemicals, Section 4, OECD Publishing, Paris.

Organization for Economic Cooperation and Development (2014) Nets No. 489: In Vivo Mammalian Alkaline Comet Assay, OECD Guidelines for the Testing of Chemicals, Section 4, OECD Publishing, Paris.

Wyde et al. (2016) Report of partial findings from the National Toxicology Program carcinogenesis studies of cell phone radiofrequency radiation in Hsd: Sprague Dawley rats (whole body exposure). bioRxiv, doi http://dx.doi.org/10.1101/055699

Wyde et al. (submitted) Design and validation of the National Toxicology Program's Cell Phone Radiofrequency Radiation Reverberation Chamber Exposure System. *Bioelectromagnetics.*

Dependence of non-thermal biological effects of microwaves on physical and biological variables: implications for reproducibility and safety standards

Igor Y Belyaev
Laboratory of Molecular Genetics, Cancer Research Institute, Bratislava, Slovak Republic
Laboratory of Radiobiology, General Physics Institute, Russian Academy of Science, Moscow, Russia
Department of Genetic and Cellular Toxicology, Stockholm University, Stockholm, Sweden

Abstract

Diverse biological responses, including adverse health effects, to non-thermal (NT) microwaves (MW) have been described by many research groups all over the world. The aim of this paper is to provide an overview of the complex dependence of these effects on various physical and biological parameters, which must be controlled in replication studies.
Besides well-known dependencies on carrier frequency and modulation, emerging data suggest dependencies of NT MW effects on polarization, intermittence and coherence time of exposure, static magnetic field, electromagnetic stray fields, genotype, gender, physiological and individual traits, cell density during exposure. Data also indicate that duration of exposure may be as important as power density (PD) and specific absorption rate (SAR). Further evaluation of these dependencies are needed for understanding the mechanisms by which NT MW affect biological systems, planning *in vivo* and epidemiological studies, developing medical treatments, setting safety standards, and minimizing the adverse effects of MW from mobile communication.

***Key words*: non-thermal effects of microwaves, mobile (cellular) phones, safety standards.**

List of abbreviations:
Anomalous viscosity time dependence (AVTD); blood-brain barrier (BBB); catalase (CAT); Digital Enhanced (former European) Cordless Telecommunications (DECT); circularly polarized (CP); continuous wave (CW); Digital Advanced Mobile Phone System (DAMPS); discontinuous transmission (DTX); electroencephalographic (EEG); electromagnetic field (EMF); embryonic stem (ES) cells; ethidium bromide (EtBr); extremely low frequency (ELF); Gaussian Minimum Shift Keying (GMSK); Ginkgo biloba (Gb); Global System for Mobile Communication (GSM); glutathione peroxidase (GSH-Px); International Commission for Non-Ionizing Radiation Protection (ICNIRP); linearly polarized (LP); malondialdehyde (MDA); micronucleus (MN) assay; microwaves (MWs); N-acetyl-beta-d-glucosaminidase (NAG); nitric oxide (NO); non-thermal (NT); ornithine decarboxylase (ODC); phorbol ester 12-myristate 13-acetate (PMA); phosphorylated H2AX histone (γ-H2AX); power density (PD);

Address: Igor Y Belyaev, Ph D, D Sc. Cancer Research Institute, Slovak Academy of Sciences, Vlárska 7, 833 91 Bratislava, Slovak Republic - Tel: +421 259327322 - Fax: +421 259327305
E-mail: Igor.Belyaev@gmt.su.se

Toxicology Letters 280S (2017) S31–S32

Contents lists available at ScienceDirect

Toxicology Letters

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

Toxicology and cellular mechanisms of electromagnetic fields (EMF)-Health aspects of exposure to EMF Emitted by wireless mobile systems and emerging technologies

S12-01
Two-year oncogenicity evaluations of cell phone radiofrequency radiation in Sprague-Dawley rats and B6C3F1 mice

David McCormick

IIT Research Institute, Chicago, IL, United States

Epidemiology data concerning possible health effects of exposure to radiofrequency fields (RF) are conflicting. For this reason, well-designed and controlled studies in predictive laboratory animal models provide the best prospective opportunity to identify effects of RF exposure that may translate into human health hazards. The U.S. National Toxicology Program supported a program in our laboratory to identify and characterize effects of acute, subchronic, and chronic exposure to non-thermal levels of RF in Sprague-Dawley rats and B6C3F1 mice. Five-day pilot studies were performed to identify the maximum Specific Absorption Ratios (SARs) to which juvenile, adult, and pregnant rodents can be exposed without increasing body temperature by >1.0 °C. Subsequent subchronic (ten-week) toxicity studies failed to identify any toxicologically significant effects of non-thermal RF on survival, body weight, clinical signs, hematology, or gross or microscopic pathology. Two-year studies were performed to determine if exposure to non-thermal levels of RF increases the incidence of neoplasia in any site. Male rats exposed to RF demonstrated significantly increased incidences of glioma (brain) and schwannoma (heart); these increases were not seen in female rats or in either sex of mice. Gliomas and schwannomas have been identified in some epidemiology studies as possible RF-induced neoplasms. Considering (a) the conflicting results of RF epidemiology studies and (b) the lack of generally accepted biophysical or molecular mechanisms through which RF could induce or promote neoplasia, data from animal bioassays will play a central role in "weight-of-the-evidence" assessments of the possible health effects of RF exposure.

Supported by HHSN29120055544.

http://dx.doi.org/10.1016/j.toxlet.2017.07.075

Environmental Research 164 (2018) 405–416

Contents lists available at ScienceDirect

Environmental Research

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

Wi-Fi is an important threat to human health☆

Martin L. Pall

Washington State University, 638 NE 41st Avenue, Portland, OR 97232-3312, USA

ARTICLE INFO

Keywords:
Electromagnetic field (EMF)
Brain impact
Testis/sperm count and quality
Impact of pulsation and polarization
Activation of voltage-gated calcium channels
Wi-Fi or WiFi

ABSTRACT

Repeated Wi-Fi studies show that Wi-Fi causes oxidative stress, sperm/testicular damage, neuropsychiatric effects including EEG changes, apoptosis, cellular DNA damage, endocrine changes, and calcium overload. Each of these effects are also caused by exposures to other microwave frequency EMFs, with each such effect being documented in from 10 to 16 reviews. Therefore, each of these seven EMF effects are established effects of Wi-Fi and of other microwave frequency EMFs. Each of these seven is also produced by downstream effects of the main action of such EMFs, voltage-gated calcium channel (VGCC) activation. While VGCC activation via EMF interaction with the VGCC voltage sensor seems to be the predominant mechanism of action of EMFs, other mechanisms appear to have minor roles. Minor roles include activation of other voltage-gated ion channels, calcium cyclotron resonance and the geomagnetic magnetoreception mechanism. Five properties of non-thermal EMF effects are discussed. These are that pulsed EMFs are, in most cases, more active than are non-pulsed EMFs; artificial EMFs are polarized and such polarized EMFs are much more active than non-polarized EMFs; dose-response curves are non-linear and non-monotone; EMF effects are often cumulative; and EMFs may impact young people more than adults. These general findings and data presented earlier on Wi-Fi effects were used to assess the Foster and Moulder (F&M) review of Wi-Fi. The F&M study claimed that there were seven important studies of Wi-Fi that each showed no effect. However, none of these were Wi-Fi studies, with each differing from genuine Wi-Fi in three distinct ways. F&M could, at most conclude that there was no statistically significant evidence of an effect. The tiny numbers studied in each of these seven F&M-linked studies show that each of them lack power to make any substantive conclusions. In conclusion, there are seven repeatedly found Wi-Fi effects which have also been shown to be caused by other similar EMF exposures. Each of the seven should be considered, therefore, as established effects of Wi-Fi.

1. Introduction

Wi-Fi (also known as WiFi or WLAN) is a wireless network involving at least one Wi-Fi antenna connected to the internet and a series of computers, laptops and/or other wireless devices communicating wirelessly with the Wi-Fi antenna. In this way, each such wireless communication device can communicate wirelessly with the internet. All the studies reviewed here were of Wi-Fi using the 2.4 GHz band, although there is also a 5 GHz band reserved for possible Wi-Fi use.

Telecommunications industry-linked individuals and groups have claimed that there are no and cannot possibly be any health impacts of Wi-Fi (Foster and Moulder, 2013; Berezow and Bloom, 2017). However with Wi-Fi exposures becoming more and more common and with many of our exposures being without our consent, there is much concern about possible Wi-Fi health effects. This paper is not focused on anecdotal reports but rather on 23 controlled, scientific studies of such health-related effects in animals, cells including human cells in culture and in human beings (Table 1).

Each of the effects reported above in from 2 to 11 studies, have an extensive literature for their occurrence in response to various other non-thermal microwave frequency EMFs, discussed in detail below. These include (see Table 1) findings that Wi-Fi exposures produce impacts on the testis leading to lowered male fertility; oxidative stress; apoptosis (a process that has an important causal role in neurodegenerative disease); cellular DNA damage (a process causing cancer and germ line mutations); neuropsychiatric changes including EEG changes; hormonal changes.

The discussion here focuses on those Wi-Fi effects which have been found by multiple Wi-Fi studies and have been previously confirmed by non-thermal exposures to other microwave frequency EMFs. The 1971/72 U.S. Office of Naval Medical Research study (Glaser, 1971) reported the following changes related to testis or sperm: 1. Decreased testosterone leading to lowered testis size. 2. Histological changes in testicular epithelial structure. 3. Gross testicular histological changes. 4.

☆ For submission to the Wireless Radiation and Health special issue of the journal Environmental Research.

E-mail address: martin_pall@wsu.edu.

https://doi.org/10.1016/j.envres.2018.01.035
Received 22 September 2017; Received in revised form 20 January 2018; Accepted 23 January 2018

June 26, 2017

The Honorable Cecilia Agular-Curry, Chair
Assembly Local Gov't Commission
Room 157, 1020 N Street
Sacramento, CA 95814

RE: SB 649 (Hueso) – Small Cell Wireless Facilities - -OPPOSE

Dear Chair Agular-Curry:

Environmental Working Group (EWG) opposes SB 649 by Senator Hueso. This bill would make the installation of small cell wireless facilities, such as those used to facilitate 5G networks, ministerial rather than discretionary at the local government level.

The health impacts of cellular transmissions have been debated more and more passionately the last ten years because there are studies that raise real concerns about the effects of radio frequency (RF) energy or radiation on humans. This is why EWG sponsored two bills by former Senator Leno (SB 1212 in 2010 and SB 932 in 2011) that would have required sellers of cell phones to inform consumers that minimizing exposure to cell phone radiation is prudent and in fact recommended by cell phone manufacturers in their included manuals.

Studies on the health impacts of cell phones and their transmission infrastructure are continuing. As new information becomes available, local government ought to be able to use it to help guide their decision-making, including locational issues such as proximity to homes, school, and hospitals. EWG believes that allowing cities and counties to weigh the potential impacts of transmission networks before permits are issued for their construction is essential and SB 649 would prevent them from doing so. And, if more definitive health concerns arise, state law would have to be changed in order to give local governments the flexiblity to do their due diligence.

For these reasons, we must oppose SB 649 and urge a "no" vote in the Local Government Committee.

Sincerely,

Bill Allayaud

Bill Allayaud
California Director of Government Affairs
Environmental Working Group

cc: Senator Hueso

SB 649 Would Eliminate the Ability of Communities to Promote their Interests and Priorities.

It is important to remember that the rights-of-way that providers use to build out their networks are **owned by communities and managed by municipalities**.[1] Currently, if a phone or broadband provider wants access to a local community's right-of-way, it can negotiate with that community for a franchise, paying fair-market value for that access. Additionally, communities can currently negotiate with providers to advance community priorities and interests in exchange for access to community-owned rights of way. For example, if a provider seeks access to build out its network in a high-income area, a community could grant access to that in exchange for that providers' providing high-speed broadband to anchor institutions in lower-income areas. SB 649 would eliminate communities' ability to manage their rights-of-way, unduly interfering with those communities' right to self-determination.

SB 649 Would Allow Providers to Use Community-Owned Property without Paying Just Compensation.

Phone and broadband providers already reap windfall profits from Californians. SB 649 limits communities to charging set prices and fees for access to their rights-of-way. These artificial restrictions distort the market and force consumers to subsidize providers' costs. SB 649 prevents communities from getting full market value in exchange for access to rights-of-way. Accordingly, SB 649 increases the power of providers to extract profits from local communities that already face monopoly or near-monopoly prices.

Greenlining supports any legislative measure that increases the availability of advanced communications services to communities of color. Unfortunately, SB 649 is not such a measure. The bill promises to widen the digital divide, place control over community-owned property in the hands of providers, and fail to compensate communities fairly. Accordingly, Greenlining OPPOSES SB 649.

If you have any questions, please do not hesitate to contact me.

Sincerely,

Stephanie Chen
Energy & Telecommunications Policy Director

[1] Frederick E. Ellrodd III & Nicholas P. Miller, Property Rights, Federalism, and Public Rights-of-Way (2003) 26 Seattle Univ. Law. Rev. 475, 477.

Alliance of Nurses for Healthy Environments

June 26, 2017

The Honorable Cecilia Agular-Curry,
Chair Assembly Local Gov't Commission
Room 157, 1020 N Street Sacramento,
CA 95814

RE: SB 649 (Hueso) – Small Cell Wireless Facilities - - OPPOSE

Dear Chair Agular-Curry:

I am a Professor of Public Health at the University of San Francisco and a Board Member of the national Alliance of Nurses for Healthy Environments. I am very concerned about moving forward with expanding the use of small-scale wireless technologies at the same time that there is mounting evidence of the potential for health risks from the associated radio frequency energy and radiation, particularly to children. The Alliance of Nurses for Healthy Environments ascribes to the precautionary principle as it applies to human health. We firmly believe that early warnings in the scientific literature should be heeded and that our policy development should reflect the synthesis of the best and latest scientific evidence.

At this point in time, we oppose SB 649 and believe that we need an exhaustive review of the science before we allow significant expansion of small cell wireless facilities, such as those to facilitate 5G networks. The results of the literature review should inform our policies. We must be sure that vulnerable populations such as pregnant women and young children will not be unduly harmed from their proximity to unnecessary radio frequency energy. It is important that we continue to examine what constitutes a safe distance and how we can continue to pivot when more information becomes available. We are concerned that the passage of SB 649 will entrench us in a policy for which we have insufficient assurances and which, if passed, will require the burden of effort to reverse.

For these reasons, we oppose SB 649 and urge a "no" vote in the Local Government Committee.

Thank you for considering our concerns.

Sincerely,

Barbara Sattler, RN, MPH, DrPH, FAAN
Board Member

August 15, 2017

The Honorable Cecilia Aguiar-Curry
Chair, Assembly Local Government Committee
State Capitol Building, Room 5144
Sacramento, CA 95814

SB 649 (Hueso)- Wireless Telecommunications Facilities- OPPOSE

Chair Aguiar-Curry,

On behalf of the undersigned, we write to register our opposition to SB 649 (Hueso) which would prohibit local discretionary review of "small cell" wireless antennas , including equipment collocated on existing structures or located on new "poles, structures, or non-pole structures," including those within the public right-of-way and buildings. The proposal preempts adopted local land use plans by mandating that "small cells" be allowed in all zones as a use by-right, including all residential zones. Because of this, this proposal essentially provides a CEQA exemption for installation of these facilities, undermining the ability for communities to comment and register their concerns associated with previously mentioned installation. These "small cell" installations not only can cause an aesthetic blight, but can release levels of radiation that we don't yet know conclusively the health impacts they can impose of humans, especially developing bodies and minds of children. These small cell boxes could pop up anywhere: grocery stores, outside school, playgrounds, communal places, with no requirement to mitigate effects or understand potential environmental and health hazards.

For these reasons, we urge your "no" vote in committee.

Thank you,

Jena Price, Legislative Affairs Manager
California League of Conservation Voters

Kyle Jones, Legislative Associate
Sierra Club California

Jane Williams, Executive Director
California Communities Against Toxics

ENVIRONMENTAL HEALTH TRUST
892 Arlington Av. Berkeley, CA, 94707 (307) 200-9358
www.ehtrust.org

June 28, 2017

The Honorable Cecilia Aguiar-Curry
Chair of the Local Government Committee
1020 N Street, Room 157
Sacramento, CA 95814

RE: SB 649 (Hueso) – Small Cell Wireless Facilities — OPPOSE

Dear Chair Aguiar-Curry:

As a nonprofit research and policy organization dedicated to identifying and reducing environmental health hazards, Environmental Health Trust (EHT) writes to advise you of serious scientific grounds to reject SB 649 as advanced by Senator Hueso. I have personally served as an expert advisor to the California Department of Health as well as the San Francisco and Berkeley City governments on matters relevant to this bill. EHT has been honored to work with California government and scientists for over a decade. At the invitation of the Israel Institute for Advanced Study of the Hebrew University of Jerusalem, EHT recently organized and chaired an Expert Forum on Wireless Radiation and Health, bringing together scientists and engineers from more than ten high tech nations. Reflecting these efforts, EHT provides independent scientific research and advice on avoidable environmental health hazards to local, state and national governments.

SB 649 will pave the way for widespread introduction of 5G microwave wireless radiation frequency (RF) that has never been tested for its impact of public health or the environment. Other RF microwave radiation such as that used by cellphones and other wireless devices has been classified as a 'possible carcinogen' by the International Agency for Research on Cancer in 2011 and more recently dubbed a 'probable carcinogen,' by expert researchers looking at newer information in 2015.[1, 2, 3] In addition, this bill could result in the loss of hundreds of millions of dollars in local revenue, as the San Francisco Chronicle noted today.

By ignoring growing scientific evidence of harm, the bill effectively will ensure the widespread exposures of millions of Californians to an agent that growing numbers of scientists and nations consider a serious

[1] World Health Organization. "IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans," WHO, Press Release, no. 208, 2011.
[2] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. "Non-ionizing radiation, Part 2: Radiofrequency electromagnetic fields." *IARC Monographs On The Evaluation of Carcinogenic Risks to Humans*, vol. 102, pt. 2, 2013.
[3] Morgan, L. Lloyd, et al. "Mobile phone radiation causes brain tumors and should be classified as a probable human carcinogen (2A)." *International Journal of Oncology,* vol. 46, no. 5, 2015, 1865-71.

health threat. Recently, studies have found that the frequencies which will be used in 5G and other future technologies can have harmful effects[4], as Dr. Cindy Russell, Vice President of Community Health for the Santa Clara Medical Association noted.[5] As articulated in their state Constitution, California cities and counties have a duty to protect the health and safety of their residents.

EHT has a longstanding history of research and policy advice to state, local and national governments regarding strategies to reduce disease and promote health by avoiding environmental health hazards. Our organization opposes the broad scale installation of untested wireless antennas and associated electrical equipment close to humans and through critical wildlife habitat and corridors. Both federal and local zoning controls are needed to assure that cellular equipment are installed to avoid significant and serious safety threats of electrical shock, fire, and radio frequency (RF) microwave radiation exposures, as well as chronic impacts on public health and the environment.

Consistent with public health concepts of preventing harm by reducing exposure to suspected carcinogens, EHT opposes the usurpation and preemption of local authority that will allow federal and state authorities to place what state reports of the bill indicate can be thirty thousand new radiating 5G cell antennas on city and county utility, light poles, and other right of ways in close proximity to city and county workers, children, residents and visitors. In some cases towers will need to be sited every 100 feet with antennas at a height of 30 feet or less. Local authority and duty should not be overridden by preemptive federal or state policies such as SB 649 which disregards scientific evidence on this matter as outlined below.

Regarding potential health risks from RF a number of corporations advise their shareholders that they face serious risks from RF. For instance, Crown Castle's 2016 10-K ANNUAL REPORT, states that,

> *"If radio frequency emissions from wireless handsets or equipment on our wireless infrastructure are demonstrated to cause negative health effects, potential future claims could adversely affect our operations, costs or revenues. The potential connection between radio frequency emissions and certain negative health effects, including some forms of cancer, has been the subject of substantial study by the scientific community in recent years. 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."*

Most wireless companies from AT&T to Nokia to T Mobile to Verizon Wireless have issued similar warnings to their shareholders.

Regarding public health impacts, recently released research findings from the premiere test program of the National Institute of Environmental Health Sciences (NIEHS) add to the body of scientific evidence

---

[4] Feldman, Yuri, et al. "Human Skin as Arrays of Helical Antennas in the Millimeter and Submillimeter Wave Range." *Physical Review Letters*, vol. 100, no. 128102, 2008.

[5] Russell, Cindy. "A 5G Wireless Future: Will it give us a Smart Nation or Contribute to an Unhealthy One?" Santa Clara Bulletin, Jan./Feb. 2017.

indicating that RF microwave radiation can be harmful. The 10 year $25 million NIEHS National Toxicology Program's Studies of the Toxicology and Carcinogenicity Cell Phone Radiation reports that RF produced increases rates of highly malignant very rare tumors: gliomas of the brain and schwannomas of the heart.[6] These experimental findings are consistent with human studies showing increased rates of gliomas and acoustic neuromas (schwann cells) among humans exposed to cell phone radiation. In addition to increased cancers, the NTP study also reported that prenatally exposed animals produced offspring with lower birth weight and evidence of direct genetic damage.

Since the 2011 WHO/IARC classification, the peer reviewed research connecting microwave exposure to cancer has significantly strengthened. In 2015, a study replicated a 2010 experiment that found that weak cell phone signals significantly promote the growth of tumors in mice, and that toxic chemical exposures combine with RF to more than double the tumor response.[7,8] The Ramazzini Institute is engaged in similar research with RF that is 1000 less than the NTP exposures—set to mimic radiation exposure levels caused by network equipment (e.g., cell tower antenna emissions).

Consistent with the NTP findings, the Ramazzini Institute team report significantly lower litter weights, as presented at the January 2017 Conference on Wireless and Health at Israel Institute for Advanced Study, Hebrew University of Jerusalem.[9] Findings of effects at such low levels is indication of the capability of low level electromagnetic radiation exposure to result in biological effects.

Other studies finding serious increased risk of glioma in regular cell phone users are of special relevance. In 2014, a French national study linked higher cell phone exposure to increased glioma in cell phone users.[10] A newly published research report in the *American Journal of Epidemiology* finds that Canadians who have used cell phones for 558 hours or more have more than a doubled risk of brain cancer.[11] Previous published re-analysis of the multi country Interphone study data has found stronger positive associations to glioma risk among long term users and heavy users and a statistically significant association between where tumors were located and how much radiation an individual received from their phone.[12,13]

---

[6] Wyde, Michael, 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)." *bioRxiv,* no. 055699, 2016.

[7] Lerchl, Alexander, et al. "Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans." *Biochemical and Biophysical Research Communications,* vol. 459, no. 4, 2015, pp. 585-90.

[8] Tillmann, Thomas, et al. "Indication of cocarcinogenic potential of chronic UMTS-modulated radiofrequency exposure in an ethylnitrosourea mouse model." *International Journal of Radiation Biology,* vol. 86, no. 7, 2010, pp. 529-41.

[9] Belpoggi, Fiorella. "Recent findings on wireless radiation and health from the Ramazzini Institute could reinforce the NTP results." *Conference on Wireless and Health*, 2017.

[10] Coureau, Gaëlle, et al. "Mobile phone use and brain tumours in the CERENAT case-control study." *Occupational Environmental Medicine,* vol. 71, no. 7, 2014, pp. 514-22.

[11] Momoli, F., et al. "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." *American Journal of Epidemiology*, 2017.

[12] Turner, Michelle C., et al. "Investigation of bias related to differences between case and control interview dates in five INTERPHONE countries." *Annals of Epidemiology,* vol. 26, 12, 2016, pp. 827-32.

More recently, research carried out by physicists in Israel and others have shown that the higher millimeter wave frequencies to be used in 5G applications uniquely interacts with sweat ducts of the human skin which can then function as antennas to amplify signals. This work extends studies first produced in 1986.[14] The potential long-term impact of such stimulation on precancerous skin growths should be evaluated carefully, including potential super-growth of bacteria.[15] A lecture by Paul Ben-Ishai, PhD, and published research on this issue can be found on the 2017 Conference website.[16, 17, 18]

Cancer is not the only health concern presented by wireless devices and infrastructure. Impacts on reproduction and brain development have also been repeatedly reported in the peer reviewed literature in addition to a myriad of other adverse effects.[19, 20, 21, 22]

In light of these developments showing growing evidence of the biological impact of RF, it is imperative that new infrastructure and 5G not be introduced widely into commerce at this time. The State of California needs to critically consider the potential impact of massive new and possibly carcinogenic wireless exposures to their population. Before introducing additional untested wireless technology into the environment, it is necessary to:

- model exposures to infants, children and pregnant women;
- conduct experimental tests on exposures' impacts on wildlife; and
- evaluate impacts on human systems through in vitro and in vivo toxicology

In 2015, the International EMF Scientist Appeal, now signed by over 225 scientists from 41 nations, was submitted to the Secretary-General of the United Nations, the Director-General of the World Health Organization and U.N. Member Nations urging the development of more protective guidelines for EMF (including RF-EMF), encouraging precautionary measures, and calling for education of the public about

---

[13] Grell, Kathrine, et al. "The intracranial distribution of gliomas in relation to exposure from mobile phones: analyses from the INTERPHONE study." *American Journal of Epidemiology*, vol. 184, no. 11, 2016, pp. 818-28.
[14] Gandhi OP, Riazi A. "Absorption of millimeter waves by human beings and its biological implications." *IEEE Transactions on Microwave Theory and Techniques*, vol. 34, no. 2, 1986, pp. 228-235.
[15] Soghomonyan D, K. Trchounian and A. Trchounian. "Millimeter waves or extremely high frequency electromagnetic fields in the environment: what are their effects on bacteria?" Applied Microbiology and Biotechnology, vol. 100, no. 11, 2016, pp. 4761-71.
[16] Feldman, Yuri and Paul Ben-Ishai. "Potential Risks to Human Health Originating from Future Sub-MM Communication Systems." *Conference on Wireless and Health*, 2017.
[17] Hayut, Itai, Paul Ben Ishai, Aharon J. Agranat and Yuri Feldman. "Circular polarization induced by the three-dimensional chiral structure of human sweat ducts." *Physical Review E*, vol. 89, no. 042715, 2014.
[18] Feldman, Yuri, et al. "Human Skin as Arrays of Helical Antennas in the Millimeter and Submillimeter Wave Range." *Physical Review Letters*, vol. 100, no. 128102, 2008.
[19] Adams, Jessica A., et al. "Effect of mobile telephones on sperm quality: a systematic review and meta-analysis." *Environment International,* 70, 2014, pp. 106-112.
[20] Deshmukh, P.S., et al. "Cognitive impairment and neurogenotoxic effects in rats exposed to low-intensity microwave radiation." *International Journal of Toxicology*, vol. 34, no. 3, 2015, pp. 284-90.
[21] Aldad, T.S., et al. "Fetal Radiofrequency Radiation Exposure From 800-1900 MHz-Rated Cellular Telephones Affects Neurodevelopment and Behavior in Mice." *Scientific Reports,* vol. 2, no. 312, 2012.
[22] Sonmez, O.F., et al. "Purkinje cell number decreases in the adult female rat cerebellum following exposure to 900 MHz electromagnetic field." *Brain Research,* vol. 1356, 2010, pp. 95-101.

health risks, particularly risks to children and fetal development.[23] Most recently, the EMF Scientists have submitted Comments to the FCC asking the FCC to critically consider the potential impact of the 5th generation wireless infrastructure on the health and safety of the U.S. population before proceeding to deploy this infrastructure.

California firefighters have lobbied to protect themselves and successfully received exemption on health grounds from the installation of these cell towers. Similarly cities and counties should be given the needed local controls to protect their citizens from the health and safety risks of these installations. As currently envisioned, transmitters can be placed in close proximity to bedrooms and schools without consideration of the health of their occupants. Research is critically needed to evaluate the public health and environmental impacts of proposed wireless facilities before deployment.

Worldwide, governments are acting to minimize exposures to children as they are most vulnerable. For example, the Supreme Court of India upheld the High Court of the State of Rajasthan's decision to remove all cell towers from the vicinity of schools, hospitals and playgrounds because of radiation "hazardous to life." In Chile, the 2012 "Antennae Law" prohibits cell antennae/towers in "sensitive areas".[24] Please learn more about international policy actions such as these in our online briefing.[25]

The assumption that all wireless technology is safe has been shown through recent studies to be incorrect. EHT strongly opposes the widespread installation of 5G antennas and towers and believes that the state should move forward on its commitment to support the installation of fiber optic cables buried in the ground to every business, home, school, and hospital in California. We urge the state not to ignore this evidence of harm from RF. Please vote "no" vote on SB 649 and uphold the rights of local government to protect public health and the environment.

Sincerely,

Devra Davis, PhD, MPH
Fellow, American College of Epidemiology
Visiting Prof. Hebrew Univ. Hadassah Medical Center & Ondokuz Mayis Univ. Medical School
Associate Editor, *Frontiers in Radiation and Health*
President, Environmental Health Trust

---

[23] Blank, M., et al. "International Appeal: Scientists call for protection from non-ionizing electromagnetic field exposure." *European Journal of Oncology,* vol. 20, no. 3/4, 2015, pp. 180-2.

[24] "New communications antenna law in Chile." *Communications Law: Newsletter of the International Bar Association Legal Practice Division*, vol. 20, no. 1, 2013, pp. 14-16.

[25] "International Policy Briefing: Cautionary Policy on Radiofrequency Radiation Actions by Governments, Health Authorities and Schools Worldwide." Environmental Health Trust, 2017.

July 26, 2017

The Honorable Ben Hueso
Member of the California State Senate
Room 4035, State Capitol
Sacramento, CA 95814

RE: SB 649 (Hueso) – Small Cell Wireless Facilities - OPPOSE

Dear Senator Hueso:

Environmental Working Group (EWG) respectfully opposes your SB 649, which would make the installation of small cell wireless facilities, such as those used to facilitate 5G networks, ministerial rather than discretionary at the local government level.

The health impacts of cellular transmissions have been debated for over ten years because there are studies that raise real concerns about the effects of radio frequency radiation on humans. This is why EWG sponsored two bills by former Senator Leno, SB 1212 (2010) and SB 932 (2011) that would have required sellers of cell phones to inform consumers to minimize exposure to cell phone radiation by reading the manual that comes with the phone, as this is in fact recommended by cell phone manufacturers in their included manuals.

Studies on the health impacts of cell phones and their transmission infrastructure are continuing, but there is already adequate existing sound science for government to proceed with caution on the roll-out of the new technology. In particular, the results of the $25 million National Toxicology Program study (2016) that showed tumors in rats caused by a typical amount of heavy cell phone use are to be reckoned with. And, most of the past science has analyzed older cellular technology like 2G and 4G, so we are moving into uncharted waters with 5G with its different wavelengths and energy levels.

Local governments must be able to evaluate science and respond to the wishes of their citizens and neighborhoods before permits are issued for this technology and SB 649 short-circuits that process. This includes important decisions about locating the technology near homes, schools, and hospitals. We simply cannot rely upon the word of the FCC (in terms of safety standards) to protect the health of Californians.

For these reasons, EWG will be urging a "no" vote for the Assembly floor. We will be writing a separate letter to the Assembly Appropriations Committee on fiscal concerns.

Sincerely,

Bill Allayaud
California Director of Government Affairs
Environmental Working Group

Martin Pall, PhD

August 7, 2017

Dear California Legislators,

I am Dr. Martin Pall, Professor Emeritus of Biochemistry and Basic Medical Sciences at Washington State University. I am a published and widely cited scientist on the biological effects of electromagnetic fields and speak internationally on this topic. I am particularly expert in how wireless radiation impacts the electrical systems in our bodies. I have published 7 studies showing there exists exquisite sensitivity to electromagnetic fields (EMFs) in the voltage sensor in each cell, such that the force impacting our cells at the voltage sensor has massive impact on the biology on the cells of our bodies [1-7]. These papers are discussed in over 360,000 web sites which can be easily found by Googling (Martin Pall electromagnetic). I received my PhD at Caltech, one of the top scientific institutions in the world.

EMFs act by activating channels in the membrane that surrounds each of our cells, called voltage-gated calcium channels (VGCCs). The EMFs put forces on the voltage sensor that controls the VGCCs of about 7.2 million times greater than the forces on other charged groups in our cells [4,6,7]. This is why weak EMFs have such large biological effects on the cells of our bodies! EMFs works this way not only on human and diverse animal cells [1-7] but also in plant cells [7] so that this is a universal or near universal mechanism of action.

Thousands of published studies show biological and health effects from electromagnetic fields. We now know the mechanism that can explain these effects. The mechanism is a function of the electromagnetics of each cell—not solely about heating effects from the radiation (on which present FCC guidelines are based).

This new understanding [1-7] means we can debunk the claims of the wireless industry that there cannot be a mechanism for effects produced by these weak EMFs. The 20 years plus of industry propaganda claims are false. Rather the thousands of studies showing diverse health impacts of these EMFs can be explained. We now have a mechanism, one that is supported by both the biology and the physics, both of which are pointing in exactly the same direction. I am sending as a separate document a list of 134 reviews, each of which provides from 12 to over a thousand individual citations showing health impacts of low intensity EMFs, EMFs that the telecommunications industry claims cannot have such effects. **These 134 reviews and thousands of primary scientific papers they cite show that the industry propaganda has no scientific support whatsoever.**

The consensus among independent scientists on this is further confirmed by the 2015 (and later) appeal made to the United Nations and member states, stating that the current EMF safety guidelines are inadequate because they do not take into consideration non-thermal effects. This was signed by 225 scientists from 41 countries, each of whom had

published peer reviewed studies on EMF health effects – a total of 2,000 papers published in this area by the signers, a substantial fraction of the total publications in this area.

According to industry, the forces electromagnetic fields place on electrically-charged groups in the cell are too weak to produce biological effects. However, the unique structural properties of the voltage-gated calcium channel (VGCC) protein can, it turns out, explain why the force on a cell's voltage sensor from low-intensity EMFs are millions of times stronger than are the forces on singly-charged groups elsewhere in the cell.

It would be a disaster for the health of Californians to be exposed to the antennas envisioned in SB.649. The State of California would be making a grave mistake to proceed with supporting the commercial interests of the wireless industry with this legislation. **Legislators would best pause to understand the gravity of the biological effects, and the ramifications for physical and mental health, as well as consequences from continual damage to human DNA, and learn the facts from scientists who are independent of the wireless industry, not from the industry lobbyists who have a gigantic conflict of interest.**

VGCC activation in cells produced by low intensity EMFs can explain long-reported findings that electromagnetic fields and a wide range of biological changes and health effects. The first 6 of these (see below) were well documented 46 years ago in the U.S. Office of Naval Medical Research report, published in 1971 [8]. The others that follow have been extensively documented subsequently in the peer-reviewed scientific literature:
1) Various neurological/neuropsychiatric effects, including changes in brain structure and function, changes in various types of psychological responses and changes in behavior.
2) At least eight different endocrine (hormonal) effects.
3) Cardiac effects influencing the electrical control of the heart, including changes in ECGs, producing arrhythmias, changes that can be life threatening.
4) Chromosome breaks and other changes in chromosome structure.
5) Histological changes in the testes.
6) Cell death (what is now called apoptosis, a process important in neurodegenerative diseases).
7) Lowered male fertility including lowered sperm quality and function and also lowered female fertility (less studied).
8) Oxidative stress.
9) Changes in calcium fluxes and calcium signaling.
10) Cellular DNA damage including single strand breaks and double strand breaks in cellular DNA and also 8-OHdG in cellular DNA.
11) Cancer which is likely to involve these DNA changes but also increased rates of tumor promotion-like events.
12) Therapeutic effects including stimulation of bone growth.
13) Cataract formation (previously thought to be thermal, now known not to be).
14) Breakdown of the blood-brain barrier.
15) Melatonin depletion and sleep disruption.

They may be low intensity but with regard to the VGCCs, electromagnetic fields can have a tremendously powerful impact on the cells of our bodies. Furthermore, published studies showing that calcium channel blocker drugs block or greatly lower biological effects from electromagnetic fields confirm there is a VGCC activation mechanism that is causing various effects. Higher frequency electromagnetic fields from 5G technologies on the horizon pose even greater biological concern than those to which we are exposed today. We should be moving, instead, to wired technologies at every opportunity, based on what we know in science today, not expanding and supporting the proliferation of wireless.

I want to make several additional points very clear:

1. The Physics and the Biology are both pointing in the same direction. Both show that EMFs act primarily via activating the VGCCs in the cells of our bodies.
2. DNA damage known to be produced by these EMFs occur in human sperm and may also occur in human eggs, leading to large increases in mutation in any children born. It is thought that an increase in mutation frequency of 2.5 to 3-fold will lead to extinction because of accumulation of large numbers of damaging mutations. We may already be over this level, and if so, simply continuing our current exposures will lead to eventual extinction. Further increases in exposures will be more rapidly self-destructive.
3. Pulsed EMFs are, in most cases, more biologically active and therefore more dangerous than are non-pulsed (continuous wave) EMFs. All cordless communication devices communicate via pulsations, because it is the pulsations that carry the information communicated. All the industry claims of safety are based on a theory (only thermal effects) that was known to be wrong back in 1971 [8] – and that was before many thousands of additional studies were published providing massive confirmation that industry claims are false.
4. The industry is trying to move to much higher frequencies because these much higher frequencies allow much higher pulsations and therefore much higher transmission of information. However, these higher pulsation rates make these ultra-high devices vastly more dangerous. This is part of the reasons why it is so important to vote down SB.649.
5. None of our wireless communication devices are ever tested biologically for safety – not cell phone towers, not cell phones, not Wi-Fi, not cordless phones, not smart meters and certainly not 5G phones, or radar units in cars – before they are put out to irradiate an unsuspecting public.
6. The telecommunications industry has corrupted the agencies that are supposed to be regulating them. The best example of this is that the FCC which regulates EMFs in the U.S. is a "captured agency", captured by the industry it is supposed to regulate, according to an 8 chapter document published by the Edmond J. Safra Center for Ethics at Harvard University [9]. Is it any wonder, therefore, that the industry keeps touting that their devices are within the safety guidelines set by the FCC?

I urge you to do the right thing on behalf of the health of Californians and future generations. Please let me know if I can provide further information. (503) 232-3883.

Sincerely,
Martin Pall, PhD (Caltech, 1968)
Professor Emeritus of Biochemistry and Basic Medical Sciences
Washington State University

Citations:

1. Pall ML. 2013 Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. J Cell Mol Med 17:958-965.
2. Pall ML. 2014 Electromagnetic field activation of voltage-gated calcium channels: role in therapeutic effects. Electromagn Biol Med. 2014 Apr 8.
3. Pall ML. 2015 Scientific evidence contradicts findings and assumptions of Canadian Safety Panel 6: microwaves act through voltage-gated calcium channel activation to induce biological impacts at non-thermal levels, supporting a paradigm shift for microwave/lower frequency electromagnetic field action. Rev Environ Health 30:99-116.
4. Pall ML. 2015 Elektromagnetische Felder wirken über die Aktivierung spannungsabhängiger Calciumkanäle, um günstige oder ungünstige Wirkungen zu erzeugen. Umwelt-Medizin-Gesellshaft 28: 22-31.
5. Pall ML. 2015 How to approach the challenge of minimizing non-thermal health effects of microwave radiation from electrical devices. International Journal of Innovative Research in Engineering & Management (IJIREM) ISSN: 2350-0557, Volume-2, Issue -5, September 2015; 71-76.
6. Pall ML. 2016 Microwave frequency electromagnetic fields (EMFs) produce widespread neuropsychiatric effects including depression. J Chem Neuroanat 75(Pt B):43-51. doi: 10.1016/j.jchemneu.2015.08.001. Epub 2015 Aug 21.
7. Pall ML. 2016 Electromagnetic fields act similarly in plants as in animals: Probable activation of calcium channels via their voltage sensor. Curr Chem Biol 10: 74-82.
8. Naval Medical Research Institute Research Report, June 1971. Bibliography of Reported Biological Phenomena ("Effects") and Clinical Manifestations, Revised, ZR Glaser.
9. Captured Agency: How the Federal Communications Commission Is Dominated by the Industries It Presumably Regulates, by Norm Alster. Published by Edmond J. Safra Center for Ethics, Harvard University. An e-book under the Creative Commons 4.0 License: https:/creativecommons.org/licences/by/4.0/

June 27, 2017

Assembly Member Cecilia M. Aguiar-Curry
Local Government Committee Chair
State Capitol
P.O. Box 942849
Sacramento, CA 94249-0004
Via email

Re: SB 649 - OPPOSE

Dear Chair Aguiar-Curry,

On behalf of The Greenlining Institute, I am writing to express our opposition to SB 649. SB 649 will not close the digital divide. Instead, it will allow phone and broadband providers to override community decisions about how those communities use public space. Additionally, SB 649 will allow providers to use community-owned property without paying just compensation.

Local Communities Fully Understand the Need for Advanced Phone and Broadband Services.

Every community in California is eager to see faster, more reliable, and more affordable phone and broadband service. Local governments are very aware that advanced telephone and broadband services are critical for access to educational, employment, and economic opportunities. Access to these opportunities is particularly critical for communities of color, who, as a result of the racial wealth and income divides, are more likely to live in areas that lack access to advanced phone and broadband services. State and local governments are particularly well-positioned to ensure that providers are serving communities equitably and non-discriminatorily and that community members have equitable access to economic opportunity.

SB 649 Would Not Help Close The Digital Divide.

Sadly, communications providers have repeatedly demonstrated that they will not make advanced services available to low-income or rural areas unless **they are required to do so**. SB 649 contains no such requirement, instead allowing providers to pick and choose where to build their networks without any community input. Under SB 649, it is likely that providers will focus any service improvements on high-income areas. SB 649 in no way guarantees that low-income communities and communities of color will gain increased access to advanced communications services. Accordingly, SB 649 will not help close the digital divide.

For Express Mail
7100 N Rachel Way
Unit 6 Eagles Rest
Teton Village WY 83025

ENVIRONMENTAL HEALTH TRUST

For U.S. Mail
P.O. Box 58
Teton Village WY 83025
www.ehtrust.org

The Honorable Jerry Brown
Governor, State of California
c/o State Capitol, Suite 1173
Sacramento, CA 95814
September 17, 2017

RE: SB 649 (Hueso) – Small Cell Wireless Facilities — OPPOSE

Honorable Governor Brown,

As a nonprofit research and policy organization dedicated to identifying and reducing environmental health hazards, Environmental Health Trust (EHT) writes to advise you of serious scientific grounds to veto SB 649 as advanced by Senator Hueso. I have personally served as an expert advisor to the California Department of Public Health as well as the city of San Francisco and Berkeley governments on matters relevant to this bill.

You are globally recognized as a champion of the environment and public health. I remain deeply grateful to you for your forward thinking on climate change and toxics policies which provide moral and political leadership at a time when it is sorely lacking. As someone who has been a presidential appointee confirmed by the US Senate, I fully understand the challenges that you face politically. You have provided leadership on the right side of history in too many ways to enumerate.

EHT has a longstanding history of research and policy advice to state, local and national governments regarding strategies to reduce disease and promote health by avoiding environmental health hazards. Our organization opposes the broad scale installation of untested wireless antennas and associated electrical equipment close to humans and through critical wildlife habitat and corridors.

The assumption that all wireless technology is safe has been shown through recent studies to be incorrect. EHT strongly opposes the widespread installation of 5G antennas and towers and believes that the state should move forward on its commitment to support the installation of fiber optic cables buried in the ground to every business, home, school, and hospital in California. We urge the state not to ignore this evidence of harm from wireless technologies.

Specific design standards must first be funded and created for 5G facilities for the more than thirty thousand expected new radiating 5G cell antennas to be constructed on city and county utility light poles and in the right of ways in close proximity to city and county workers, children, residents and visitors. Both federal and local zoning controls are absolutely needed to assure that cellular equipment are installed to avoid significant and serious safety threats of electrical shock, fire, and radio frequency (RF) microwave radiation exposures, as well as chronic impacts on public health and the environment.

Now the challenge before you is one of the most momentous you will have ever faced. The telecom industry is a global multi-trillion dollar phenomenon. They have provided massive amounts of political support throughout the political spectrum. Despite this, the weight of science has inexorably demonstrated that the experiment they

For Express Mail
7100 N Rachel Way
Unit 6 Eagles Rest
Teton Village WY 83025

ENVIRONMENTAL HEALTH TRUST

For U.S. Mail
P.O. Box 58
Teton Village WY 83025
www.ehtrust.org

have been conducting on ourselves and our progeny is without merit and has already exacted a serious toll for public health.

SB 649 will pave the way for widespread introduction of 5G microwave wireless radiation frequency (RF) that has never been tested for its impact of public health or the environment. Other RF microwave radiation such as that used by cellphones and other wireless devices has been classified as a 'possible carcinogen' by the International Agency for Research on Cancer in 2011 and more recently dubbed a 'probable carcinogen,' by expert researchers looking at newer information in 2015.[1,2,3] In addition, this bill could result in the loss of hundreds of millions of dollars in local revenue, as the San Francisco Chronicle noted today.

By ignoring growing scientific evidence of harm, the bill effectively will ensure the widespread exposures of millions of Californians to an agent that growing numbers of scientists and nations consider a serious health threat. Recently, studies have found that the frequencies which will be used in 5G and other future technologies can have harmful effects[4], as Dr. Cindy Russell, Vice President of Community Health for the Santa Clara Medical Association noted.[5] As articulated in their state Constitution, California cities and counties have a duty to protect the health and safety of their residents.

State and local authority and duty should not be overridden by any preemptive policies such as SB 649 which disregards scientific evidence on this matter as outlined below. Regarding potential health risks from RF a number of corporations advise their shareholders that they face serious risks from RF. For instance, Crown Castle's 2016 10-K ANNUAL REPORT, states that,

> *"If radio frequency emissions from wireless handsets or equipment on our wireless infrastructure are demonstrated to cause negative health effects, potential future claims could adversely affect our operations, costs or revenues. The potential connection between radio frequency emissions and certain negative health effects, including some forms of cancer, has been the subject of substantial study by the scientific community in recent years. 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."*

---

[1] World Health Organization. "IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans," WHO, Press Release, no. 208, 2011.
[2] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. "Non-ionizing radiation, Part 2: Radiofrequency electromagnetic fields." *IARC Monographs On The Evaluation of Carcinogenic Risks to Humans*, vol. 102, pt. 2, 2013.
[3] Morgan, L. Lloyd, et al. "Mobile phone radiation causes brain tumors and should be classified as a probable human carcinogen (2A)." *International Journal of Oncology,* vol. 46, no. 5, 2015, 1865-71.
[4] Feldman, Yuri, et al. "Human Skin as Arrays of Helical Antennas in the Millimeter and Submillimeter Wave Range." *Physical Review Letters*, vol. 100, no. 128102, 2008.
[5] Russell, Cindy. "A 5G Wireless Future: Will it give us a Smart Nation or Contribute to an Unhealthy One?" Santa Clara Bulletin, Jan./Feb. 2017.

For Express Mail
7100 N Rachel Way
Unit 6 Eagles Rest
Teton Village WY 83025

ENVIRONMENTAL HEALTH TRUST

For U.S. Mail
P.O. Box 58
Teton Village WY 83025
www.ehtrust.org

Most wireless companies from AT&T to Nokia to T Mobile to Verizon Wireless have issued similar warnings to their shareholders.

Regarding public health impacts, recently released research findings from the premiere test program of the National Institute of Environmental Health Sciences (NIEHS) add to the body of scientific evidence indicating that RF microwave radiation can be harmful. The 10 year $25 million NIEHS National Toxicology Program's Studies of the Toxicology and Carcinogenicity Cell Phone Radiation reports that RF produced increases rates of highly malignant very rare tumors: gliomas of the brain and schwannomas of the heart.[6] These experimental findings are consistent with human studies showing increased rates of gliomas and acoustic neuromas (schwann cells) among humans exposed to cell phone radiation. In addition to increased cancers, the NTP study also reported that prenatally exposed animals produced offspring with lower birth weight and evidence of direct genetic damage.

Since the 2011 WHO/IARC classification, the peer reviewed research connecting microwave exposure to cancer has significantly strengthened. In 2015, a study replicated a 2010 experiment that found that weak cell phone signals significantly promote the growth of tumors in mice, and that toxic chemical exposures combine with RF to more than double the tumor response.[7,8] The Ramazzini Institute is engaged in similar research with RF that is 1000 less than the NTP exposures—set to mimic radiation exposure levels caused by network equipment (e.g., cell tower antenna emissions).

Consistent with the NTP findings, the Ramazzini Institute team report significantly lower litter weights, as presented at the January 2017 Conference on Wireless and Health at Israel Institute for Advanced Study, Hebrew University of Jerusalem.[9] Findings of effects at such low levels is indication of the capability of low level electromagnetic radiation exposure to result in biological effects.

Other studies finding serious increased risk of glioma in regular cell phone users are of special relevance. In 2014, a French national study linked higher cell phone exposure to increased glioma in cell phone users.[10] A newly published research report in the *American Journal of Epidemiology* finds that Canadians who have used cell phones for 558 hours or more have more than a doubled risk of brain cancer.[11] Previous published re-analysis of the multi country Interphone study data has found stronger positive associations to glioma risk

---

[6] Wyde, Michael, 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)." *bioRxiv,* no. 055699, 2016.
[7] Lerchl, Alexander, et al. "Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans." *Biochemical and Biophysical Research Communications,* vol. 459, no. 4, 2015, pp. 585-90.
[8] Tillmann, Thomas, et al. "Indication of cocarcinogenic potential of chronic UMTS-modulated radiofrequency exposure in an ethylnitrosourea mouse model." *International Journal of Radiation Biology,* vol. 86, no. 7, 2010, pp. 529-41.
[9] Belpoggi, Fiorella. "Recent findings on wireless radiation and health from the Ramazzini Institute could reinforce the NTP results." *Conference on Wireless and Health*, 2017.
[10] Coureau, Gaëlle, et al. "Mobile phone use and brain tumours in the CERENAT case-control study." *Occupational Environmental Medicine,* vol. 71, no. 7, 2014, pp. 514-22.
[11] Momoli, F., et al. "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." *American Journal of Epidemiology*, 2017.

For Express Mail
7100 N Rachel Way
Unit 6 Eagles Rest
Teton Village WY 83025

ENVIRONMENTAL HEALTH TRUST

For U.S. Mail
P.O. Box 58
Teton Village WY 83025
www.ehtrust.org

among long term users and a statistically significant association between where tumors were located and how much radiation an individual received from their phone.[12,13] A 2017 review published by Hardell and Carlberg concludes that "RF radiation should be regarded as a human carcinogen causing glioma."[14] I invite you to view videos from Environmental Health Trust's expert forum in Jackson Hole, Wyoming on July 30, 2017 where longtime World Health Organization advisor Dr. Anthony Miller presented the scientific evidence for his updated opinion that RF is a human carcinogen.

More recently, research carried out by physicists in Israel and others have shown that the higher millimeter wave frequencies to be used in 5G applications uniquely interacts with sweat ducts of the human skin which can then function as antennas to amplify signals.[15] This work extends studies first produced in 1986.[16] The potential long-term impact of such stimulation on precancerous skin growths should be evaluated carefully, including potential super-growth of bacteria.[17] A lecture by Paul Ben-Ishai, PhD, and published research on this issue can be found on the 2017 Conference website.[18,19,20]

Cancer is not the only health concern presented by wireless devices and infrastructure. Impacts on reproduction and brain development have also been repeatedly reported in the peer reviewed literature in addition to a myriad of other adverse effects.[21, 22, 23, 24]

---

[12] Turner, Michelle C., et al. "Investigation of bias related to differences between case and control interview dates in five INTERPHONE countries." *Annals of Epidemiology,* vol. 26, 12, 2016, pp. 827-32.

[13] Grell, Kathrine, et al. "The intracranial distribution of gliomas in relation to exposure from mobile phones: analyses from the INTERPHONE study." *American Journal of Epidemiology*, vol. 184, no. 11, 2016, pp. 818-28.

[14] Carlberg, Michael, and Lennart Hardell. "Evaluation of Mobile Phone and Cordless Phone Use and Glioma Risk Using the Bradford Hill Viewpoints from 1965 on Association or Causation." *BioMed Research International* 2017.9218486 (2017).

[15] Betzalel, Noa, Yuri Feldman, and Paul Ben Ishai. "The Modeling of the Absorbance of Sub-THz Radiation by Human Skin." *IEEE Transactions on Terahertz Science and Technology* 7.5 (2017): 521-8.

[16] Gandhi OP, Riazi A. "Absorption of millimeter waves by human beings and its biological implications." *IEEE Transactions on Microwave Theory and Techniques*, vol. 34, no. 2, 1986, pp. 228-235.

[17] Soghomonyan D, K. Trchounian and A. Trchounian. "Millimeter waves or extremely high frequency electromagnetic fields in the environment: what are their effects on bacteria?" *Applied Microbiology and Biotechnology*, vol. 100, no. 11, 2016, pp. 4761-71.

[18] Feldman, Yuri and Paul Ben-Ishai. "Potential Risks to Human Health Originating from Future Sub-MM Communication Systems." *Conference on Wireless and Health*, 2017.

[19] Hayut, Itai, Paul Ben Ishai, Aharon J. Agranat and Yuri Feldman. "Circular polarization induced by the three-dimensional chiral structure of human sweat ducts." *Physical Review E*, vol. 89, no. 042715, 2014.

[20] Feldman, Yuri, et al. "Human Skin as Arrays of Helical Antennas in the Millimeter and Submillimeter Wave Range." *Physical Review Letters*, vol. 100, no. 128102, 2008.

[21] Adams, Jessica A., et al. "Effect of mobile telephones on sperm quality: a systematic review and meta-analysis." *Environment International,* 70, 2014, pp. 106-112.

[22] Deshmukh, P.S., et al. "Cognitive impairment and neurogenotoxic effects in rats exposed to low-intensity microwave radiation." *International Journal of Toxicology*, vol. 34, no. 3, 2015, pp. 284-90.

[23] Aldad, T.S., et al. "Fetal Radiofrequency Radiation Exposure From 800-1900 MHz-Rated Cellular Telephones Affects Neurodevelopment and Behavior in Mice." *Scientific Reports,* vol. 2, no. 312, 2012.

[24] Sonmez, O.F., et al. "Purkinje cell number decreases in the adult female rat cerebellum following exposure to 900 MHz electromagnetic field." *Brain Research,* vol. 1356, 2010, pp. 95-101.

For Express Mail
7100 N Rachel Way
Unit 6 Eagles Rest
Teton Village WY 83025

ENVIRONMENTAL HEALTH TRUST

For U.S. Mail
P.O. Box 58
Teton Village WY 83025
www.ehtrust.org

In light of these developments showing growing evidence of the biological impact of RF, it is imperative that new infrastructure and 5G not be introduced widely into commerce at this time. The State of California needs to critically consider the potential impact of massive new and possibly carcinogenic wireless exposures to their population. Before introducing additional untested wireless technology into the environment, it is necessary to:

- model exposures to infants, children and pregnant women;
- conduct experimental tests on exposures' impacts on wildlife; and
- evaluate impacts on human systems through in vitro and in vivo toxicology

In 2015, the International EMF Scientist Appeal, now signed by over 225 scientists from 41 nations, was submitted to the Secretary-General of the United Nations, the Director-General of the World Health Organization and U.N. Member Nations urging the development of more protective guidelines for EMF (including RF-EMF), encouraging precautionary measures, and calling for education of the public about health risks, particularly risks to children and fetal development.[23] The EMF Scientists later submitted Comments to the FCC asking the FCC to critically consider the health impact of the 5G.

Most recently, in September 2017, over 180 scientists and doctors from 35 countries sent a declaration to the European Union calling for a moratorium on 5G expansion citing potential neurological impacts, infertility, and cancer.[25]

California firefighters have lobbied to protect themselves and successfully received exemption on health grounds from the installation of these cell towers.[26] Similarly cities and counties should be given the needed local controls to protect their citizens from the health and safety risks of these installations. As currently envisioned, transmitters can be placed in close proximity to bedrooms and schools without consideration of the health of their occupants. Research is critically needed to evaluate the public health and environmental impacts of proposed wireless facilities before deployment.

The organization that I founded a decade ago, Environmental Health Trust, is not opposing cell phones. We are in favor of public health and we note that the California Department of Public Health has drafted guidelines for safer use of phones so that the public reduce radiofrequency exposure for more than a decade.

As my colleagues who have been supported by the US Department of Defense on 5G have written to you, the evidence is compelling that this technology can interact with human body in ways that have never been evaluated for their long-term impact on health and safety. Recently, studies have found that the frequencies which will be used in 5G and other future technologies can have harmful effects[27], as Dr. Cindy Russell, Vice

---

[25] "Appeal to the European Union: Scientists warn of potential serious health effects of 5G." 13 September 2017.
[26] ""The Firefighters Wake Up Call To Us All" By Susan Foster RE: SB 649 Opposing Cell Towers In Rights Of Way." *Environmental Health Trust* (2017).

[27] Feldman, Yuri, et al. "Human Skin as Arrays of Helical Antennas in the Millimeter and Submillimeter Wave Range." *Physical Review Letters*, vol. 100, no. 128102, 2008.

For Express Mail
7100 N Rachel Way
Unit 6 Eagles Rest
Teton Village WY 83025

ENVIRONMENTAL HEALTH TRUST

For U.S. Mail
P.O. Box 58
Teton Village WY 83025
www.ehtrust.org

President of Community Health for the Santa Clara Medical Association noted.[28] As articulated in their state Constitution, California cities and counties have a duty to protect the health and safety of their residents.

Cardiologists are reporting increased numbers of patients with atrial fibrillation and heart disease who have no inherited risk factors. A recent study by Professor Gemma Figtree, published in the European Journal of Preventive Cardiology, found that the rate of heart attacks and heart disease in persons with no known risk factors has more than doubled in less than a decade.[29] Similar rates of serious eye problems and attention deficit disorder continue to increase without any knowns. Certainly, the phenomenal growth in the use of wireless technology should be explored as one of the explanations for these serious public health.

Please veto SB 649 and uphold the rights of local government to protect public health and the environment.

Sincerely,

Devra Davis, PhD, MPH
Founder & President, Environmental Health Trust
Fellow, American College of Epidemiology
Visiting Professor of Medicine, Hebrew University of Jerusalem and Ondokuz Mayis University

CC
Tom Dyer, Chief Deputy Legislative Affairs Secretary

Letter from Dr. Paul Ben Ishai to Governor Brown
Order Instituting Rulemaking to update the Commission's policies and procedures related to Rulemaking 04-08-020 electromagnetic fields emanating from regulated (Filed August 19, 2004) utility facilities.

[28] Russell, Cindy. "A 5G Wireless Future: Will it give us a Smart Nation or Contribute to an Unhealthy One?" Santa Clara Bulletin, Jan./Feb. 2017.
[29] Vernon, Stephen T., et al. "Increasing proportion of ST elevation myocardial infarction patients with coronary atherosclerosis poorly explained by standard modifiable risk factors." *European Journal of Preventive Cardiology* (2017). doi: 10.1177/2047487317720287.

UNIVERSITY OF CALIFORNIA, SAN DIEGO UCSD

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

Beatrice Alexandra Golomb, MD, PhD
Professor of Medicine
UC San Diego School of Medicine
9500 Gilman Drive, #0995
La Jolla, CA 92093-0995
Phone: 858 558-4950 x201

August 18, 2017

To whom it may concern,

I urge in the strongest terms that you vigorously oppose California SB 649.

If this bill passes, many people will suffer greatly, and needlessly, as a direct result.

This sounds like hyperbole. It is not.
My research group at UC San Diego alone has received hundreds of communications from people who have developed serious health problems from electromagnetic radiation, following introduction of new technologies. Others with whom I am in communication, have independently received hundreds of similar reports. Most likely these are a tip of an iceberg of tens or perhaps hundreds of thousands of affected person. As each new technology leading to further exposure to electromagnetic radiation is introduced – and particularly introduced in a fashion that prevents vulnerable individuals from avoiding it – a new group become sensitized to health effects. This is particularly true for pulsed signals in the radiowave and microwave portion of the spectrum, the type for which the proposed bill SB 640 will bypass local control.

Mechanisms by which health effects are exerted have been shown to include oxidative stress (the type of injury against which antioxidants protect ,see optional section below), damage to mitochondria (the energy producing parts of cells), damage to cell membranes[1, 21], and via these mechanisms, an impaired "blood brain barrier"[3-5] (the blood brain barrier defends the brain against introduction of foreign substances and toxins; additionally, disruption can lead to brain edema[6]), constriction of blood vessels and impaired blood flow to the brain[7], and triggering of autoimmune reactions[8, 9]. Following a large exposure, that depresses antioxidant defenses, magnifying vulnerability to future exposures, some persons no longer tolerate many other forms and intensities of electromagnetic radiation that previously caused them no problem, and that currently cause others no problem. But this group deserves – nay needs -- the right to be able to avoid these exposures.

Affected individuals not only experience "symptoms" that "merely" cause them distress and suffering, when they are exposed – symptoms like headaches[10, 11], ringing ears[10, 11] and chest pain[10] from impaired blood flow, heart rhythm abnormalities[10, 11], and inability to sleep[10, 11]. These symptoms arise from physiological injury. Moreover, **many experience significant health problems that can include seizures[11], heart failure, hearing loss[12-14] and severe cognitive impairment[11, 15].** The mechanisms involved are those also involved in development and progression of neurodegenerative conditions including Alzheimer's disease[16].

Fully half who were employed when their problems developed lost their job because of the problem, among participants of a survey we conducted. They reported that their condition had cost them up to 2 million dollars to date. Many had lost their homes. A number became homeless, and have swelled the ranks of so-called "EMF refugees"[17-19]. Among those affected, many were previously high functioning individuals – engineers, doctors, lawyers. The best and the brightest are among those whose lives – and ability to contribute to society –will be destroyed. High profile individuals with acknowledged electrohypersensitivity include, for instance, Gro Harlem Brundtland – the former 3-time Prime Minister of Norway and former Director General of the World Health Organization[20]; Matti Niemela, former Nokia Technology chief[21]; as well as the wife of Frank Clegg[22], who formerly headed Microsoft Canada and is current head of Canadians for Safe Technology[23].

Each new roll-out of electromagnetic technology for which exposure is obligatory, swells the ranks of those who develop problems with electromagnetic fields (EMF).- particularly following a significant exposure to pulsed radiowave-microwave radiation, and particularly when people have no ability to avoid it.

Many state that they didn't give credence to the problem (if they had heard of it at all) **until they themselves fell prey to it.**

This is not a psychologically driven condition. Multiple objective physiological changes reflecting mechanisms of injury have been shown in persons with this condition[24, 25].

The role for oxidative stress, that has been shown in innumerable studies (below)**, is affirmed by evidence of a link of this condition to genetic variants in antioxidant defenses**, that are less avid in defending against oxidative stress[307]. People cannot manipulate their genes, to produce such an outcome by suggestibility.

An analysis by a University of Washington researcher showed that most studies funded by industry reported failure to show physiological effects. However, most studies without such industry bias affirmed effects. This is redolent of findings shown in medicine[26], regarding which the former editor in chief of the BMJ (the British Medical Journal), Richard Smith, noted, based on findings of a study, "This {result} suggests that, far from conflict of interest being unimportant in the objective and pure world of science where method and the quality of data is everything, it is the main factor determining the result of studies."[27]. So where articles deny injury from nonionizing radiowave-microwave radiation, there is commonly a stake aligned with financial benefit from such denial.

Those who are affected are in desperate need of *protection* by our elected officials. They need creation of safe spaces and housing, and roadways to allow travel, not removal of any prospect of one; protection of local rights to make decisions - **not removal of any recourse or ability to avoid what injures them**. They are far more strongly in need of protections than a great many protected classes – their problems arose due to actions of others, against which they were given no control – *and can be reversed,* in most cases, if the assault on them is rolled back. Through no fault of their own, and in some cases against their will (e.g. before opt out was permitted with smart meters), they were subjected to an

exposure that has altered their lives as they knew them, and forced them – needlessly - to the margins of society.

Let our focus be on safer, wired and well shielded technology – not more wireless.

This legislation, if passed, and the resulting unrestricted roll-out of this technology, will predictably and directly injure and disable a new group, and add depth of suffering to those already affected.

In other spheres we abridge freedoms to protect the vulnerable few. We require that every schoolchild be vaccinated, supposedly to protect the vulnerable few who may not respond effectively to a vaccine. The need to protect the vulnerable group is deemed to be so great that it justifies the decision to abridge individual rights.

In contrast, this bill seeks to abridge individual freedoms, and local rights, in the service of *harming* a vulnerable group, and creating a new one.
(The common factor appears to be that in both cases, the direction is aligned with a powerful industry that influences political decisions.)
Luckily, no abridgment of individual rights and freedoms is required to protect,t here.

If any group can opt out (such as, I understand, firefighters*)[28]; **then *every* group deserves that equal right**. Others should not be second class citizens, subject to fewer protections.

It would go far to helping this cause if anyone complicit in promoting or passing the legislation (and then after that, *their* families) were required to be the first subjected, for a substantial test period, to the *greatest* amount of exposure that anyone *else* (and their families) may be subjected to, when new policies of this type are rolled out. It will still not do them equal damage; because they may not represent the vulnerabilities that others will have; but such a policy might help them to think twice. *That* is a bill I would strongly endorse.

Most who are now affected – were not, until they were. This may become you – or your child or grandchild. Moreover, if you have a child, or a grandchild, his sperm, or her eggs (all of which she will already have by the time she is a fetus in utero), will be affected by the oxidative stress damage created by the electromagnetic radiation, in a fashion that may affect your future generations irreparably.

It was noted above that, among survey completers, fully half of those who were employed at the time they developed electrosensitivity, lost employment *due to* this problem. (This may understate the scope of the tragedy, since this most-affected group may be least likely to be able to respond to an online survey.) **Many who previously had no problem navigating in the world are now restricted from access to basic services** like hospital care, post offices and libraries because of these problems. With each new introduction of technology that exposes many to yet a new nondiscretionary source of electromagnetic radiation, particularly (but not exclusively) that which emits pulsed radiation in the radiowave-microwave part of the spectrum, a new group of people are affected; and the suffering of those who are already affected increases greatly.

Please, defend the public and our future. Protect the rights of the individual and the locality, against a form of incursion that will lead to serious harm to some – and set a terrible precedent. **Vote no on California SB 649**, and urge that everyone else do the same.

Sincerely,

Beatrice Alexandra Golomb, MD, PhD
Professor of Medicine
UC San Diego School of Medicine

*****Comment on the fire fighter exemption:"The legislature granted an exemption from SB 649 to the firefighters who requested it for health reasons. Throughout California firefighters have long complained of often disabling symptoms from cell towers on their stations. Cities frequently rent out space on fire stations to add to city revenue. …Symptoms experienced by the firefighters have included neurological impairment including severe headache, confusion, inability to focus, lethargy, inability to sleep, and inability to wake up for 911 emergency calls. Firefighters have reported getting lost on 911 calls in the same community they grew up in, and one veteran medic forgot where he was in the midst of basic CPR on a cardiac victim and couldn't recall how to start the procedure over again…Prior to the installation of the tower on his station, this medic had not made a single mistake in 20 years. A pilot study (2004) of California firefighters showed brain abnormalities, cognitive impairment, delayed reaction time, and lack of impulse control in all 6 firefighters tested (https://ecfsapi.fcc.gov/file/7022117660.pdf). This study led to the overwhelming passage of Resolution 15 by the International Association of Firefighters in Boston in August 2004. Res. 15 called for further study and was amended to impose a moratorium on the placement of cell towers on fire stations throughout the US and Canada."[15, 28]
Clearly, others who experience similar problems also deserve protections.

Optional – More on the Science

There is a robust literature showing that electromagnetic radiation, including in nonionizing frequencies, and at *levels*[29, 30] *below* those that are cause thermal effects (heating) – causes physiological effects, injury, and cell death –not only in humans but many animals and plants[3, 7, 31-49]. Unsurprisingly, industry has sought – against the tide of evidence to the contrary - to maintain that radiation must be ionizing or heating to cause injury.

Scores or hundreds of studies show that radiation, including specifically radiowave-microwave spectrum radiation, and including low-level exposure, can impair antioxidant defenses, increase "oxidative stress" (free radical injury) and damage mitochondria, the energy producing parts of cells[1, 2, 34, 50-6930, 70-104105-13646, 137-171]. These effects occur with ionizing and nonionizing radiation, at thermal and subthermal levels. (Indeed, much or most of the damage by ionizing radiation, and radiation above the thermal limit, occurs by mechanisms also documented to occur without ionization, and below the thermal limit.) These

mechanisms cohere with the mechanisms documented to play a role in symptoms and health conditions that are reported in those who are electrosensitive – extending to seizures[172-176], heart failure[177-184] and cognitive decline[5, 32, 57, 108, 185-195].

These mechanisms have known involvement in induction of **brain cancer, metabolic diseases like obesity and diabetes, autism, autoimmune disease, and neurodegenerative conditions**, conditions that have exploded. In each case these have been linked, or presumptively linked, in some studies to electromagnetic radiation[8, 9, 16, 34, 196-219].

Such radiation also has effects on sperm[33, 100, 220-228]; and the DNA of sperm[229] (consistent with recent news reports of marked recent declines in sperm counts and function)..

Such radiation also has toxic effects in pregnancy[230], to the fetus and subsequent offspring[231-235] including at low levels[236], and is tied to developmental problems in later life, including attention deficit and hyperactivity[31, 235-241]. It is critical to defend pregnant women (and eggs of girls who may at a later time become pregnant) from exposures with such toxicity.

Electromagnetic radiation across much or most of the spectrum (not excluding visible light) has been shown to depress levels of melatonin[40, 72, 242-252]**,** which is best known for its role in sleep (and indeed, impaired sleep is the most consistent symptom in affected individuals[10, 11]).

Melatonin is in fact a critical antioxidant that defends the body against harm from *many* toxic exposures[253-266] **including electromagnetic radiation itself** [61, 66, 67, 82, 101, 107, 118, 121, 138, 144, 151, 204, 249, 267-284]**- reducing the oxidative stress** that is implicated in cancer, metabolic diseases like obesity and diabetes, autism, autoimmune disease, bipolar disorder and neurodegenerative conditions, and that also plays a role in heart attack and stroke[9, 285-329330-343].

Radiation, and specifically radiation in the radiowave-microwave portion of the spectrum can also depress levels of other critical antioxidant systems that also defend the body against chemical, radiation, and other sources of injury. These other antioxidant systems include the glutathione system, superoxide dismutase and catalase[81, 102, 115, 116, 233, 344-358] - which are also involved in defending against health problems.

This suggests that depression of antioxidant defenses due to electromagnetic radiation may magnify risk of chemically induced health effects (and depression of antioxidant systems due to some chemicals may amplify risk of harm from electromagnetic radiation). Indeed just such effects have been reported[359, 360].

References.

1. Benderitter M, Vincent-Genod L, Pouget JP, Voisin P. The cell membrane as a biosensor of oxidative stress induced by radiation exposure: a multiparameter investigation. Radiat Res 2003;159:471-83.
2. Baureus Koch CL, Sommarin M, Persson BR, Salford LG, Eberhardt JL. Interaction between weak low frequency magnetic fields and cell membranes. Bioelectromagnetics 2003;24:395-402.
3. Tang J, Zhang Y, Yang L, et al. Exposure to 900 MHz electromagnetic fields activates the mkp-1/ERK pathway and causes blood-brain barrier damage and cognitive impairment in rats. Brain Res 2015;1601:92-101.
4. Nittby H, Brun A, Eberhardt J, Malmgren L, Persson BR, Salford LG. Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. Pathophysiology 2009;16:103-12.
5. Zhang. Exposure to 900 MHz electromagnetic fields activates the mpk-1/ERK pathway and causes blood-brain barrier damage and cognitive impairment in rats. Brain Res 2015;1609:92-101.
6. Adair JC, Baldwin N, Kornfeld M, Rosenberg GA. Radiation-induced blood-brain barrier damage in astrocytoma: relation to elevated gelatinase B and urokinase. J Neurooncol 1999;44:283-9.
7. Aalto S, Haarala C, Bruck A, Sipila H, Hamalainen H, Rinne JO. Mobile phone affects cerebral blood flow in humans. J Cereb Blood Flow Metab 2006;26:885-90.
8. Ivanov AA, Grigor'ev Iu G, Mal'tsev VN, et al. [Autoimmune processes after long-term low-level exposure to electromagnetic fields (the results of an experiment). Part 3. The effect of the long-term non-thermal RF EMF exposure on complement-fixation antibodies against homologenous tissue]. Radiats Biol Radioecol 2010;50:17-21.
9. Grigor'ev Iu G, Mikhailov VF, Ivanov AA, et al. [Autoimmune processes after long-term low-level exposure to electromagnetic fields (the results of an experiment). Part 4. Manifestation of oxidative intracellular stress-reaction after long-term non-thermal EMF exposure of rats]. Radiats Biol Radioecol 2010;50:22-7.
10. Lamech F. Self-reporting of symptom development from exposure to radiofrequency fields of wireless smart meters in victoria, australia: a case series. Altern Ther Health Med 2014;20:28-39.
11. Halteman E. Wireless utility meter safety impacts survey: Final Results Summary. Sept 13 2011;(http://emfsafetynetwork.org/wp-content/uploads/2011/09/Wireless-Utility-Meter-Safety-Impacts-Survey-Results-Final.pdf). 97.
12. Alsanosi AA, Al-Momani MO, Hagr AA, Almomani FM, Shami IM, Al-Habeeb SF. The acute auditory effects of exposure for 60 minutes to mobile`s electromagnetic field. Saudi Med J 2013;34:142-6.
13. Karaer I, Simsek G, Gul M, et al. Melatonin protects inner ear against radiation damage in rats. Laryngoscope 2015.
14. Celiker H, Ozgur A, Tumkaya L, et al. Effects of exposure to 2100MHz GSM-like radiofrequency electromagnetic field on auditory system of rats. Braz Otorhinolaryngol 2016;S1808-8694:302221.
15. Foster S. Health exemption for firefighters sends a message to the world. GALLERY;Posted on June 26, 2017.
16. Sobel E, Davanipour Z, Sulkava R, et al. Occupations with exposure to EMFs: a possible link for Alzheimer's disease. Amer J Epidemiol 1995;142:515-24.

17. Stein Y. Environmental refugees. UNESCO 10th World Conference on ZBioethics, Medical Ethics and Health Law 2015;Jerusalem, Israel:Jan 6-8.
18. Frompovich CJ. Environmental refugees: Electromagnetic hypersensitivity (EHS) sufferers. Naturalblazecom 2016;Jan 28.
19. http://www.emfanalysis.com/emf-refugee/.
20. ;http://articles.latimes.com/2010/feb/15/health/la-he-electromagnetic-syndrome1-2010feb15.
21. http://stopsmartmetersorguk/former-nokia-chief-mobile-phones-wrecked-my-health/.
22. ;http://www.huffingtonpost.ca/frank-clegg/post_5393_b_3745157.html.
23. Clegg F. Electrohypersensitivity Is Real. The Huffington Post, Canada 2013;June 12, 2013.
24. Belpomme D, Campagnac C, Irigaray P. Reliable disease biomarkers characterizing and identifying electrohypersensitivity and multiple chemical sensitivity as two etiopathogenic aspects of a unique pathological disorder. Rev Environ Health 2015;30:251-71.
25. Heuser G, Heuser SA. Functional brain MRI in patients complaining of electrohypersensitivity after long term exposure to electromagnetic fields. . Rev Environ Health 2017;Jul 5.
26. Golomb BA. Conflict of Interest in Medicine

http://thesciencenetwork.org/programs/beyond-belief-candles-in-the-dark/beatrice-golomb: Beyond Belief: Candles in the Dark, sponsored by The Science Network (tsntv.org), session entitled “This is Your Brain on Politics” Salk Institute. La Jolla, CA. Oct 5; 2008.

27. Smith R. Conflicts of interest: how money clouds objectivity. J R Soc Med 2006;99:292-7.
28. International Association of Fire Fighters Division of Occupational Health SaM. Position on the health effects from radio frequency/ microwave (RF/MW) radiation in fire department facilities from base stations for anttennas and towers for the conduction of cell phone transmissions. 2006.
29. Gurler HS, Bilgici B, Akar AK, Tomak L, Bedir A. Increased DNA oxidation (8-OHdG) and protein oxidation (AOPP) by low level electromagnetic field (2.45 GHz) in rat brain and protective effect of garlic. Int J Radiat Biol 2014;90:892-6.
30. Jajte J, Zmyslony M. [The role of melatonin in the molecular mechanism of weak, static and extremely low frequency (50 Hz) magnetic fields (ELF)]. Med Pr 2000;51:51-7.
31. Hardell L, Sage C. Biological effects from electromagnetic field exposure and public exposure standards. Biomed Pharmacother 2008;62:104-9.
32. Deshmukh PS, Nasare N, Megha K, et al. Cognitive impairment and neurogenotoxic effects in rats exposed to low-intensity microwave radiation. Int J Toxicol 2015;34:284-90.
33. Avendano C, Mata A, Sanchez Sarmiento CA, Doncel GF. Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. Fertil Steril 2012;97:39-45 e2.
34. Barnes F, Greenenbaum B. Some Effects of Weak Magnetic Fields on Biological Systems: RF fields can change radical concentrations and cancer cell growth rates. IEEE Power Electronics Magazine 2016;3:60-8.
35. Blank M, Goodman R. Comment: a biological guide for electromagnetic safety: the stress response. Bioelectromagnetics 2004;25:642-6; discussion 7-8.

36. Burlaka A, Selyuk M, Gafurov M, Lukin S, Potaskalova V, Sidorik E. Changes in mitochondrial functioning with electromagnetic radiation of ultra high frequency as revealed by electron paramagnetic resonance methodsX. Int J Radiat Biol 2014;90:357-62.
37. Derias EM, Stefanis P, Drakeley A, Gazvani R, Lewis-Jones DI. Growing concern over the safety of using mobile phones and male fertility {THERMAL + NONTHERMAL}. Arch Androl 2006;52:9-14.
38. Diem E, Schwarz C, Adlkofer F, Jahn O, Rudiger H. 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 2005;583:178-83.
39. Ferreira AR, Knakievicz T, Pasquali MA, et al. Ultra high frequency-electromagnetic field irradiation during pregnancy leads to an increase in erythrocytes micronuclei incidence in rat offspring. Life Sci 2006;80:43-50.
40. Halgamuge MN. Pineal melatonin level disruption in humans due to electromagnetic fields and ICNIRP limits. Radiat Prot Dosimetry 2013;154:405-16.
41. Mancinelli F, Caraglia M, Abbruzzese A, d'Ambrosio G, Massa R, Bismuto E. Non-thermal effects of electromagnetic fields at mobile phone frequency on the refolding of an intracellular protein: myoglobin. J Cell Biochem 2004;93:188-96.
42. Lai H. Research on the neurological effects of nonionizing radiation at the University of Washington. Bioelectromagnetics 1992;13:513-26.
43. Lerchl A, Kruger H, Niehaus M, Streckert JR, Bitz AK, Hansen V. Effects of mobile phone electromagnetic fields at nonthermal SAR values on melatonin and body weight of Djungarian hamsters (Phodopus sungorus) - BODY WT CHG. J Pineal Res 2008;44:267-72.
44. Leszczynski D, Joenvaara S, Reivinen J, Kuokka R. Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: molecular mechanism for cancer- and blood-brain barrier-related effects. Differentiation 2002;70:120-9.
45. Lixia S, Yao K, Kaijun W, et al. Effects of 1.8 GHz radiofrequency field on DNA damage and expression of heat shock protein 70 in human lens epithelial cells. Mutat Res 2006;602:135-42.
46. Sahin D, Ozgur E, Guler G, et al. The 2100MHz radiofrequency radiation of a 3G-mobile phone and the DNA oxidative damage in brain. J Chem Neuroanat 2016;75:94-8.
47. Song JM, Milligan JR, Sutherland BM. Bistranded oxidized purine damage clusters: induced in DNA by long-wavelength ultraviolet (290-400 nm) radiation? Biochemistry 2002;41:8683-8.
48. Yurekli AI, Ozkan M, Kalkan T, et al. GSM base station electromagnetic radiation and oxidative stress in rats. Electromagn Biol Med 2006;25:177-88.
49. Tafforeau M, Verdus MC, Norris V, et al. Plant sensitivity to low intensity 105 GHz electromagnetic radiation. Bioelectromagnetics 2004;25:403-7.
50. Ciejka E, Jakubowska E, Zelechowska P, Huk-Kolega H, Kowalczyk A, Goraca A. [Effect of extremely low frequency magnetic field on glutathione in rat muscles]. Med Pr 2014;65:343-9.
51. Consales C, Merla C, Marino C, Benassi B. Electromagnetic fields, oxidative stress, and neurodegeneration. Int J Cell Biol 2012;2012:683897.
52. Copeland ES. Production of free radicals in reduced glutathione and penicillamine by thermal hydrogen atoms and X-radiation. Int J Radiat Biol Relat Stud Phys Chem Med 1969;16:113-20.

53. Cravotto G, Binello A, Di Carlo S, Orio L, Wu ZL, Ondruschka B. Oxidative degradation of chlorophenol derivatives promoted by microwaves or power ultrasound: a mechanism investigation. Environ Sci Pollut Res Int 2010;17:674-87.
54. Crouzier D, Perrin A, Torres G, Dabouis V, Debouzy JC. Pulsed electromagnetic field at 9.71 GHz increase free radical production in yeast (Saccharomyces cerevisiae). Pathol Biol (Paris) 2009;57:245-51.
55. de Moraes Ramos FM, Schonlau F, Novaes PD, Manzi FR, Boscolo FN, de Almeida SM. Pycnogenol protects against Ionizing radiation as shown in the intestinal mucosa of rats exposed to X-rays. Phytother Res 2006;20:676-9.
56. Devi PU, Ganasoundari A. Modulation of glutathione and antioxidant enzymes by Ocimum sanctum and its role in protection against radiation injury. Indian J Exp Biol 1999;37:262-8.
57. Deshmukh PS, Banerjee BD, Abegaonkar MP, et al. Effect of low level microwave radiation exposure on cognitive function and oxidative stress in rats. Indian J Biochem Biophys 2013;50:114-9.
58. Dimri M, Joshi J, Chakrabarti R, Sehgal N, Sureshbabu A, Kumar IP. Todralazine protects zebrafish from lethal effects of ionizing radiation: role of hematopoietic cell expansion. Zebrafish 2015;12:33-47.
59. Dimri M, Joshi J, Shrivastava N, Ghosh S, Chakraborti R, Indracanti PK. Prilocaine hydrochloride protects zebrafish from lethal effects of ionizing radiation: role of hematopoietic cell expansion. Tokai J Exp Clin Med 2015;40:8-15.
60. Durovic B, Spasic-Jokic V. Influence of occupational exposure to low-dose ionizing radiation on the plasma activity of superoxide dismutase and glutathione level. Vojnosanit Pregl 2008;65:613-8.
61. El-Missiry MA, Fayed TA, El-Sawy MR, El-Sayed AA. Ameliorative effect of melatonin against gamma-irradiation-induced oxidative stress and tissue injury. Ecotoxicol Environ Saf 2007;66:278-86.
62. Falone S, Mirabilio A, Carbone MC, et al. Chronic exposure to 50Hz magnetic fields causes a significant weakening of antioxidant defence systems in aged rat brain. Int J Biochem Cell Biol 2008;40:2762-70.
63. Fitzgerald MP, Madsen JM, Coleman MC, et al. Transgenic biosynthesis of trypanothione protects Escherichia coli from radiation-induced toxicity. Radiat Res 2010;174:290-6.
64. Giannopoulou E, Katsoris P, Parthymou A, Kardamakis D, Papadimitriou E. Amifostine protects blood vessels from the effects of ionizing radiation. Anticancer Res 2002;22:2821-6.
65. Goraca A, Ciejka E, Piechota A. Effects of extremely low frequency magnetic field on the parameters of oxidative stress in heart. J Physiol Pharmacol 2010;61:333-8.
66. Goswami S, Haldar C. UVB irradiation severely induces systemic tissue injury by augmenting oxidative load in a tropical rodent: efficacy of melatonin as an antioxidant. J Photochem Photobiol B 2014;141:84-92.
67. Goswami S, Sharma S, Haldar C. The oxidative damages caused by ultraviolet radiation type C (UVC) to a tropical rodent Funambulus pennanti: role of melatonin. J Photochem Photobiol B 2013;125:19-25.
68. Groen HJ, Meijer C, De Vries EG, Mulder NH. Red blood cell glutathione levels in lung cancer patients treated by radiation and continuously infused carboplatin. Anticancer Res 1996;16:1033-7.
69. Guler G, Seyhan N, Aricioglu A. Effects of static and 50 Hz alternating electric fields on superoxide dismutase activity and TBARS levels in guinea pigs. Gen Physiol Biophys 2006;25:177-93.
70. Guler G, Turkozer Z, Tomruk A, Seyhan N. The protective effects of N-acetyl-L-cysteine and epigallocatechin-3-gallate on electric field-induced hepatic oxidative stress. Int J Radiat Biol 2008;84:669-80.

71. Gultekin FA, Bakkal BH, Guven B, et al. Effects of ozone oxidative preconditioning on radiation-induced organ damage in rats. J Radiat Res 2013;54:36-44.
72. Halgamuge MN. Critical time delay of the pineal melatonin rhythm in humans due to weak electromagnetic exposure. Indian J Biochem Biophys 2013;50:259-65.
73. Irmak MK, Fadillioglu E, Gulec M, Erdogan H, Yagmurca M, Akyol O. Effects of electromagnetic radiation from a cellular telephone on the oxidant and antioxidant levels in rabbits. Cell Biochem Funct 2002;20:279-83.
74. Jagetia G, Baliga M, Venkatesh P. Ginger (Zingiber officinale Rosc.), a dietary supplement, protects mice against radiation-induced lethality: mechanism of action. Cancer Biother Radiopharm 2004;19:422-35.
75. Jagetia GC, Malagi KJ, Baliga MS, Venkatesh P, Veruva RR. Triphala, an ayurvedic rasayana drug, protects mice against radiation-induced lethality by free-radical scavenging. J Altern Complement Med 2004;10:971-8.
76. Jagetia GC, Venkatesha VA, Reddy TK. Naringin, a citrus flavonone, protects against radiation-induced chromosome damage in mouse bone marrow. Mutagenesis 2003;18:337-43.
77. Jurkiewicz BA, Bissett DL, Buettner GR. Effect of topically applied tocopherol on ultraviolet radiation-mediated free radical damage in skin. J Invest Dermatol 1995;104:484-8.
78. Kalns J, Ryan KL, Mason PA, Bruno JG, Gooden R, Kiel JL. Oxidative stress precedes circulatory failure induced by 35-GHz microwave heating. Shock 2000;13:52-9.
79. Karslioglu I, Ertekin MV, Taysi S, et al. Radioprotective effects of melatonin on radiation-induced cataract. J Radiat Res (Tokyo) 2005;46:277-82.
80. Kim KC, Piao MJ, Cho SJ, Lee NH, Hyun JW. Phloroglucinol protects human keratinocytes from ultraviolet B radiation by attenuating oxidative stress. Photodermatol Photoimmunol Photomed 2012;28:322-31.
81. Klebanoff SJ. The effect of x-radiation on the glutathione metabolism of intact erythrocytes in vitro. J Gen Physiol 1958;41:725-36.
82. Koc M, Taysi S, Emin Buyukokuroglu M, Bakan N. The effect of melatonin against oxidative damage during total-body irradiation in rats. Radiat Res 2003;160:251-5.
83. Koiram PR, Veerapur VP, Kunwar A, et al. Effect of curcumin and curcumin copper complex (1:1) on radiation-induced changes of anti-oxidant enzymes levels in the livers of Swiss albino mice. J Radiat Res 2007;48:241-5.
84. Kowalski S. Changes of antioxidant activity and formation of 5-hydroxymethylfurfural in honey during thermal and microwave processing. Food Chem 2013;141:1378-82.
85. Koylu H, Mollaoglu H, Ozguner F, Naziroglu M, Delibas N. Melatonin modulates 900 Mhz microwave-induced lipid peroxidation changes in rat brain. Toxicol Ind Health 2006;22:211-6.
86. Koyu A, Ozguner F, Yilmaz H, Uz E, Cesur G, Ozcelik N. The protective effect of caffeic acid phenethyl ester (CAPE) on oxidative stress in rat liver exposed to the 900 MHz electromagnetic field. Toxicol Ind Health 2009;25:429-34.
87. Lai H, Singh NP. Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. Bioelectromagnetics 1997;18:446-54.
88. Lai H, Singh NP. Melatonin and N-tert-butyl-alpha-phenylnitrone block 60-Hz magnetic field-induced DNA single and double strand breaks in rat brain cells. J Pineal Res 1997;22:152-62.

89. Lai H, Singh NP. Magnetic-field-induced DNA strand breaks in brain cells of the rat. Environ Health Perspect 2004;112:687-94.

90. Lantow M, Schuderer J, Hartwig C, Simko M. Free radical release and HSP70 expression in two human immune-relevant cell lines after exposure to 1800 MHz radiofrequency radiation. Radiat Res 2006;165:88-94.

91. Lee BC, Johng HM, Lim JK, et al. Effects of extremely low frequency magnetic field on the antioxidant defense system in mouse brain: a chemiluminescence study. J Photochem Photobiol B 2004;73:43-8.

92. Lee JH, Park JW. The effect of alpha-phenyl-N-t-butylnitrone on ionizing radiation-induced apoptosis in U937 cells. Free Radic Res 2005;39:1325-33.

93. Li HT, Schuler C, Leggett RE, Levin RM. Differential effects of coenzyme Q10 and alpha-lipoic acid on two models of in vitro oxidative damage to the rabbit urinary bladder. Int Urol Nephrol 2011;43:91-7.

94. Li P, Zhao QL, Wu LH, et al. Isofraxidin, a potent reactive oxygen species (ROS) scavenger, protects human leukemia cells from radiation-induced apoptosis via ROS/mitochondria pathway in p53-independent manner. Apoptosis 2014;19:1043-53.

95. Lin SY, Chang HP. Induction of superoxide dismutase and catalase activity in different rat tissues and protection from UVB irradiation after topical application of Ginkgo biloba extracts. Methods Find Exp Clin Pharmacol 1997;19:367-71.

96. Lourencini da Silva R, Albano F, Lopes dos Santos LR, Tavares AD, Jr., Felzenszwalb I. The effect of electromagnetic field exposure on the formation of DNA lesions. Redox Rep 2000;5:299-301.

97. Low WK, Sun L, Tan MG, Chua AW, Wang DY. L-N-Acetylcysteine protects against radiation-induced apoptosis in a cochlear cell line. Acta Otolaryngol 2008;128:440-5.

98. Lulli M, Witort E, Papucci L, et al. Coenzyme Q10 protects retinal cells from apoptosis induced by radiation in vitro and in vivo. J Radiat Res 2012;53:695-703.

99. Maaroufi K, Save E, Poucet B, Sakly M, Abdelmelek H, Had-Aissouni L. Oxidative stress and prevention of the adaptive response to chronic iron overload in the brain of young adult rats exposed to a 150 kilohertz electromagnetic field. Neuroscience 2011;186:39-47.

100. Mailankot M, Kunnath AP, Jayalekshmi H, Koduru B, Valsalan R. Radio frequency electromagnetic radiation (RF-EMR) from GSM (0.9/1.8GHz) mobile phones induces oxidative stress and reduces sperm motility in rats. Clinics (Sao Paulo) 2009;64:561-5.

101. Manda K, Anzai K, Kumari S, Bhatia AL. Melatonin attenuates radiation-induced learning deficit and brain oxidative stress in mice. Acta Neurobiol Exp (Wars) 2007;67:63-70.

102. Manda K, Bhatia AL. Pre-administration of beta-carotene protects tissue glutathione and lipid peroxidation status following exposure to gamma radiation. J Environ Biol 2003;24:369-72.

103. Manda K, Reiter RJ. Melatonin maintains adult hippocampal neurogenesis and cognitive functions after irradiation. Prog Neurobiol 2010;90:60-8.

104. Martinez-Samano J, Torres-Duran PV, Juarez-Oropeza MA, Elias-Vinas D, Verdugo-Diaz L. Effects of acute electromagnetic field exposure and movement restraint on antioxidant system in liver, heart, kidney and plasma of Wistar rats: a preliminary report. Int J Radiat Biol 2010;86:1088-94.

105. Mathew ST, Bergstrom P, Hammarsten O. Repeated Nrf2 stimulation using sulforaphane protects fibroblasts from ionizing radiation. Toxicol Appl Pharmacol 2014;276:188-94.

106. McArdle AH. Protection from radiation injury by elemental diet: does added glutamine change the effect? Gut 1994;35:S60-4.

107. Meena R, Kumari K, Kumar J, Rajamani P, Verma HN, Kesari KK. Therapeutic approaches of melatonin in microwave radiations-induced oxidative stress-mediated toxicity on male fertility pattern of Wistar rats. Electromagn Biol Med 2014;33:81-91.

108. Megha K, Deshmukh PS, Banerjee BD, Tripathi AK, Abegaonkar MP. Microwave radiation induced oxidative stress, cognitive impairment and inflammation in brain of Fischer rats. Indian J Exp Biol 2012;50:889-96.

109. Mishra S, Reddy DS, Jamwal VS, et al. Semiquinone derivative isolated from Bacillus sp. INM-1 protects cellular antioxidant enzymes from gamma-radiation-induced renal toxicity. Mol Cell Biochem 2013;379:19-27.

110. Mitchell JB, Russo A. The role of glutathione in radiation and drug induced cytotoxicity. Br J Cancer Suppl 1987;8:96-104.

111. Molla M, Gironella M, Salas A, et al. Protective effect of superoxide dismutase in radiation-induced intestinal inflammation. Int J Radiat Oncol Biol Phys 2005;61:1159-66.

112. Morabito C, Rovetta F, Bizzarri M, Mazzoleni G, Fano G, Mariggio MA. Modulation of redox status and calcium handling by extremely low frequency electromagnetic fields in C2C12 muscle cells: A real-time, single-cell approach. Free Radic Biol Med 2010;48:579-89.

113. Moustafa YM, Moustafa RM, Belacy A, Abou-El-Ela SH, Ali FM. Effects of acute exposure to the radiofrequency fields of cellular phones on plasma lipid peroxide and antioxidase activities in human erythrocytes. J Pharm Biomed Anal 2001;26:605-8.

114. Musaev AV, Ismailova LF, Shabanova AB, Magerramov AA, Iusifov E, Gadzhiev AM. [Pro- and antioxidant effect of electromagnetic fields of extremely high frequency (460 MHz) on brain tissues in experiment]. Vopr Kurortol Fizioter Lech Fiz Kult 2004:19-23.

115. Mukundan H, Bahadur AK, Kumar A, et al. Glutathione level and its relation to radiation therapy in patients with cancer of uterine cervix. Indian J Exp Biol 1999;37:859-64.

116. Navarro J, Obrador E, Pellicer JA, Aseni M, Vina J, Estrela JM. Blood glutathione as an index of radiation-induced oxidative stress in mice and humans. Free Radic Biol Med 1997;22:1203-9.

117. Okano H. Effects of static magnetic fields in biology: role of free radicals. Front Biosci 2008;13:6106-25.

118. Oktem F, Ozguner F, Mollaoglu H, Koyu A, Uz E. Oxidative damage in the kidney induced by 900-MHz-emitted mobile phone: protection by melatonin. Arch Med Res 2005;36:350-5.

119. Oral B, Guney M, Ozguner F, et al. Endometrial apoptosis induced by a 900-MHz mobile phone: preventive effects of vitamins E and C. Adv Ther 2006;23:957-73.

120. Ozguner F, Altinbas A, Ozaydin M, et al. Mobile phone-induced myocardial oxidative stress: protection by a novel antioxidant agent caffeic acid phenethyl ester. Toxicol Ind Health 2005;21:223-30.

121. Ozguner F, Bardak Y, Comlekci S. Protective effects of melatonin and caffeic acid phenethyl ester against retinal oxidative stress in long-term use of mobile phone: a comparative study. Mol Cell Biochem 2006;282:83-8.

122. Ozguner F, Oktem F, Armagan A, et al. Comparative analysis of the protective effects of melatonin and caffeic acid phenethyl ester (CAPE) on mobile phone-induced renal impairment in rat. Mol Cell Biochem 2005;276:31-7.

123. Ozguner F, Oktem F, Ayata A, Koyu A, Yilmaz HR. A novel antioxidant agent caffeic acid phenethyl ester prevents long-term mobile phone exposure-induced renal impairment in rat. Prognostic value of malondialdehyde, N-acetyl-beta-D-glucosaminidase and nitric oxide determination. Mol Cell Biochem 2005;277:73-80.

124. Ozyurt H, Cevik O, Ozgen Z, et al. Quercetin protects radiation-induced DNA damage and apoptosis in kidney and bladder tissues of rats. Free Radic Res 2014;48:1247-55.

125. Pall ML. Scientific evidence contradicts findings and assumptions of Canadian Safety Panel 6: microwaves act through voltage-gated calcium channel activation to induce biological impacts at non-thermal levels, supporting a paradigm shift for microwave/lower frequency electromagnetic field action. Rev Environ Health 2015;30:99-116.

126. Patruno A, Tabrez S, Pesce M, Shakil S, Kamal MA, Reale M. Effects of extremely low frequency electromagnetic field (ELF-EMF) on catalase, cytochrome P450 and nitric oxide synthase in erythro-leukemic cells. Life Sci 2015;121:117-23.

127. Patwardhan RS, Sharma D, Checker R, Thoh M, Sandur SK. Spatio-temporal changes in glutathione and thioredoxin redox couples during ionizing radiation-induced oxidative stress regulate tumor radio-resistance. Free Radic Res 2015;49:1218-32.

128. Paul P, Bansal P, Nayak PG, Pannakal ST, Priyadarsini KI, Unnikrishnan MK. Polyphenolic fraction of Pilea microphylla (L.) protects Chinese hamster lung fibroblasts against gamma-radiation-induced cytotoxicity and genotoxicity. Environ Toxicol Pharmacol 2012;33:107-19.

129. Pei H, Chen W, Hu W, et al. GANRA-5 protects both cultured cells and mice from various radiation types by functioning as a free radical scavenger. Free Radic Res 2014;48:670-8.

130. Piao MJ, Hyun YJ, Oh TH, et al. Chondracanthus tenellus (Harvey) hommersand extract protects the human keratinocyte cell line by blocking free radicals and UVB radiation-induced cell damage. In Vitro Cell Dev Biol Anim 2012;48:666-74.

131. Pillai S, Oresajo C, Hayward J. Ultraviolet radiation and skin aging: roles of reactive oxygen species, inflammation and protease activation, and strategies for prevention of inflammation-induced matrix degradation - a review. Int J Cosmet Sci 2005;27:17-34.

132. Rabbani ZN, Salahuddin FK, Yarmolenko P, et al. Low molecular weight catalytic metalloporphyrin antioxidant AEOL 10150 protects lungs from fractionated radiation. Free Radic Res 2007;41:1273-82.

133. Regoli F, Gorbi S, Machella N, et al. Pro-oxidant effects of extremely low frequency electromagnetic fields in the land snail Helix aspersa. Free Radic Biol Med 2005;39:1620-8.

134. Reliene R, Pollard JM, Sobol Z, Trouiller B, Gatti RA, Schiestl RH. N-acetyl cysteine protects against ionizing radiation-induced DNA damage but not against cell killing in yeast and mammals. Mutat Res 2009;665:37-43.

135. Roginskaya M, Bernhard WA, Razskazovskiy Y. Protection of DNA against direct radiation damage by complex formation with positively charged polypeptides. Radiat Res 2006;166:9-18.

136. Saenko Y, Cieslar-Pobuda A, Skonieczna M, Rzeszowska-Wolny J. Changes of reactive oxygen and nitrogen species and mitochondrial functioning in human K562 and HL60 cells exposed to ionizing radiation. Radiat Res 2013;180:360-6.

137. Sainz RM, Reiter RJ, Tan DX, et al. Critical role of glutathione in melatonin enhancement of tumor necrosis factor and ionizing radiation-induced apoptosis in prostate cancer cells in vitro. J Pineal Res 2008;45:258-70.

138. Sener G, Jahovic N, Tosun O, Atasoy BM, Yegen BC. Melatonin ameliorates ionizing radiation-induced oxidative organ damage in rats. Life Sci 2003;74:563-72.

139. Sener G, Kabasakal L, Atasoy BM, et al. Ginkgo biloba extract protects against ionizing radiation-induced oxidative organ damage in rats. Pharmacol Res 2006;53:241-52.

140. Seyhan N, Guler G. Review of in vivo static and ELF electric fields studies performed at Gazi Biophysics Department. Electromagn Biol Med 2006;25:307-23.

141. Shafiee H, Mohammadi H, Rezayat SM, et al. Prevention of malathion-induced depletion of cardiac cells mitochondrial energy and free radical damage by a magnetic magnesium-carrying nanoparticle. Toxicol Mech Methods 2010;20:538-43.

142. Sharma R, Tiku AB. Emodin, an anthraquinone derivative, protects against gamma radiation-induced toxicity by inhibiting DNA damage and oxidative stress. Int J Radiat Biol 2014;90:275-83.

143. Shi S, Wang G, Wang Y, Zhang L, Zhang L. Protective effect of nitric oxide against oxidative stress under ultraviolet-B radiation. Nitric Oxide 2005;13:1-9.

144. Shirazi A, Mihandoost E, Mohseni M, Ghazi-Khansari M, Rabie Mahdavi S. Radio-protective effects of melatonin against irradiation-induced oxidative damage in rat peripheral blood. Phys Med 2013;29:65-74.

145. Simko M. Cell type specific redox status is responsible for diverse electromagnetic field effects. Curr Med Chem 2007;14:1141-52.

146. Simko M, Droste S, Kriehuber R, Weiss DG. Stimulation of phagocytosis and free radical production in murine macrophages by 50 Hz electromagnetic fields. Eur J Cell Biol 2001;80:562-6.

147. Sirerol JA, Feddi F, Mena S, et al. Topical treatment with pterostilbene, a natural phytoalexin, effectively protects hairless mice against UVB radiation-induced skin damage and carcinogenesis. Free Radic Biol Med 2015;85:1-11.

148. Smith-Pearson PS, Kooshki M, Spitz DR, Poole LB, Zhao W, Robbins ME. Decreasing peroxiredoxin II expression decreases glutathione, alters cell cycle distribution, and sensitizes glioma cells to ionizing radiation and H(2)O(2). Free Radic Biol Med 2008;45:1178-89.

149. Song L, Wang D, Cui X, Hu W. The protective action of taurine and L-arginine in radiation pulmonary fibrosis. J Environ Pathol Toxicol Oncol 1998;17:151-7.

150. Stevens RG. Electromagnetic fields and free radicals. Environ Health Perspect 2004;112:A726; author reply A.

151. Taysi S, Koc M, Buyukokuroglu ME, Altinkaynak K, Sahin YN. Melatonin reduces lipid peroxidation and nitric oxide during irradiation-induced oxidative injury in the rat liver. J Pineal Res 2003;34:173-7.

152. Thotala D, Chetyrkin S, Hudson B, Hallahan D, Voziyan P, Yazlovitskaya E. Pyridoxamine protects intestinal epithelium from ionizing radiation-induced apoptosis. Free Radic Biol Med 2009;47:779-85.

153. Tofani S, Barone D, Berardelli M, et al. Static and ELF magnetic fields enhance the in vivo anti-tumor efficacy of cis-platin against lewis lung carcinoma, but not of cyclophosphamide against B16 melanotic melanoma. Pharmacol Res 2003;48:83-90.

154. Tulard A, Hoffschir F, de Boisferon FH, Luccioni C, Bravard A. Persistent oxidative stress after ionizing radiation is involved in inherited radiosensitivity. Free Radic Biol Med 2003;35:68-77.

155. Tunez I, Drucker-Colin R, Jimena I, et al. Transcranial magnetic stimulation attenuates cell loss and oxidative damage in the striatum induced in the 3-nitropropionic model of Huntington's disease. J Neurochem 2006;97:619-30.

156. von Deutsch AW, Mitchell CD, Williams CE, et al. Polyamines protect against radiation-induced oxidative stress. Gravit Space Biol Bull 2005;18:109-10.

157. Vujaskovic Z, Batinic-Haberle I, Rabbani ZN, et al. A small molecular weight catalytic metalloporphyrin antioxidant with superoxide dismutase (SOD) mimetic properties protects lungs from radiation-induced injury. Free Radic Biol Med 2002;33:857-63.

158. Wolf FI, Torsello A, Tedesco B, et al. 50-Hz extremely low frequency electromagnetic fields enhance cell proliferation and DNA damage: possible involvement of a redox mechanism. Biochim Biophys Acta 2005;1743:120-9.

159. Xu Y, Parmar K, Du F, Price BD, Sun Y. The radioprotective agent WR1065 protects cells from radiation damage by regulating the activity of the Tip60 acetyltransferase. Int J Biochem Mol Biol 2011;2:295-302.

160. Yakymenko I, Tsybulin O, Sidorik E, Henshel D, Kyrylenko O, Kyrylenko S. Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. Electromagn Biol Med 2015;35:186-202.

161. Yang Y, Li B, Liu C, et al. Hydrogen-rich saline protects immunocytes from radiation-induced apoptosis. Med Sci Monit 2012;18:BR144-8.

162. Yokoyama H, Sato T, Ogata T, Ohya-Nishiguchi H, Kamada H. In vivo longitudinally detected ESR measurements at microwave regions of 300, 700, and 900 MHz in rats treated with a nitroxide radical. J Magn Reson 1997;129:201-6.

163. Yokus B, Cakir DU, Akdag MZ, Sert C, Mete N. Oxidative DNA damage in rats exposed to extremely low frequency electro magnetic fields. Free Radic Res 2005;39:317-23.

164. Yoshida T, Goto S, Kawakatsu M, Urata Y, Li TS. Mitochondrial dysfunction, a probable cause of persistent oxidative stress after exposure to ionizing radiation. Free Radic Res 2012;46:147-53.

165. Yoshikawa T, Tanigawa M, Tanigawa T, Imai A, Hongo H, Kondo M. Enhancement of nitric oxide generation by low frequency electromagnetic field. Pathophysiology 2000;7:131-5.

166. Zhang R, Kang KA, Piao MJ, et al. Eckol protects V79-4 lung fibroblast cells against gamma-ray radiation-induced apoptosis via the scavenging of reactive oxygen species and inhibiting of the c-Jun NH(2)-terminal kinase pathway. Eur J Pharmacol 2008;591:114-23.

167. Zhou BR, Yin HB, Xu Y, et al. Baicalin protects human skin fibroblasts from ultraviolet A radiation-induced oxidative damage and apoptosis. Free Radic Res 2012;46:1458-71.

168. Zhu W, Xu J, Ge Y, et al. Epigallocatechin-3-gallate (EGCG) protects skin cells from ionizing radiation via heme oxygenase-1 (HO-1) overexpression. J Radiat Res 2014;55:1056-65.

169. Zmyslony M, Palus J, Dziubaltowska E, et al. Effects of in vitro exposure to power frequency magnetic fields on UV-induced DNA damage of rat lymphocytes. Bioelectromagnetics 2004;25:560-2.

170. Zmyslony M, Politanski P, Rajkowska E, Szymczak W, Jajte J. Acute exposure to 930 MHz CW electromagnetic radiation in vitro affects reactive oxygen species level in rat lymphocytes treated by iron ions. Bioelectromagnetics 2004;25:324-8.

171. Zmyslony M, Rajkowska E, Mamrot P, Politanski P, Jajte J. The effect of weak 50 Hz magnetic fields on the number of free oxygen radicals in rat lymphocytes in vitro. Bioelectromagnetics 2004;25:607-12.

172. Petty RK, Harding AE, Morgan-Hughes JA. The clinical features of mitochondrial myopathy. Brain 1986;109 (Pt 5):915-38.

173. Frantseva MV, Velazquez JL, Hwang PA, Carlen PL. Free radical production correlates with cell death in an in vitro model of epilepsy. Eur J Neurosci 2000;12:1431-9.

174. DiMauro S, Andreu AL, De Vivo DC. Mitochondrial disorders. J Child Neurol 2002;17 Suppl 3:3S35-45; discussion 3S6-7.

175. Marin-Garcia J, Goldenthal MJ, Filiano JJ. Cardiomyopathy associated with neurologic disorders and mitochondrial phenotype. J Child Neurol 2002;17:759-65.

176. Kouchaki E, Motaghedifard M, Banafshe HR. Effect of mobile phne radiation on pentylenetetrazole-induced seizure threshold in mice. Iran J Basic Med Sci 2016;19:800-3.

177. Madmani ME, Yusuf Solaiman A, Tamr Agha K, et al. Coenzyme Q10 for heart failure. Cochrane Database Syst Rev 2014;6:CD008684.

178. Taub PR, Ramirez-Sanchez I, Ciaraldi TP, et al. Alterations in skeletal muscle indicators of mitochondrial structure and biogenesis in patients with type 2 diabetes and heart failure: effects of epicatechin rich cocoa. Clin Transl Sci 2012;5:43-7.

179. Indik JH, Goldman S, Gaballa MA. Oxidative stress contributes to vascular endothelial dysfunction in heart failure. Am J Physiol Heart Circ Physiol 2001;281:H1767-70.

180. Sharma R, Davidoff MN. Oxidative stress and endothelial dysfunction in heart failure. Congest Heart Fail 2002;8:165-72.

181. Wolfram R, Oguogho A, Palumbo B, Sinzinger H. Enhanced oxidative stress in coronary heart disease and chronic heart failure as indicated by an increased 8-epi-PGF(2alpha). Eur J Heart Fail 2005;7:167-72.

182. White M, Ducharme A, Ibrahim R, et al. Increased systemic inflammation and oxidative stress in patients with worsening congestive heart failure: improvement after short-term inotropic support. Clin Sci (Lond) 2006.

183. Kang D, Hamasaki N. Alterations of mitochondrial DNA in common diseases and disease states: aging, neurodegeneration, heart failure, diabetes, and cancer. Curr Med Chem 2005;12:429-41.

184. Kerimoglu G, Mercantepe T, Erol, H.S.

Turgut, A, Kaya H, Colakoglu S, Odaci E. Effects of long term exposure to 900 megahertz electromagnetic field on heart morphology and biochemistry of male adolescent rats. Biotech Histochem 2016;Aug 11: 1-10 {Epub ahead of print}.

185. Finsterer J. Cognitive decline as a manifestation of mitochondrial disorders (mitochondrial dementia). J Neurol Sci 2008;272:20-33.

186. Reiter RJ, Tan DX, Pappolla MA. Melatonin relieves the neural oxidative burden that contributes to dementias. Ann N Y Acad Sci 2004;1035:179-96.

187. Popescu BO, Toescu EC, Popescu LM, et al. Blood-brain barrier alterations in ageing and dementia. J Neurol Sci 2009;283:99-106.

188. Pappolla MA, Chyan YJ, Poeggeler B, et al. Alzheimer beta protein mediated oxidative damage of mitochondrial DNA: prevention by melatonin. J Pineal Res 1999;27:226-9.

189. Matsubara E, Bryant-Thomas T, Pacheco Quinto J, et al. Melatonin increases survival and inhibits oxidative and amyloid pathology in a transgenic model of Alzheimer's disease. J Neurochem 2003;85:1101-8.

190. Feng Z, Qin C, Chang Y, Zhang JT. Early melatonin supplementation alleviates oxidative stress in a transgenic mouse model of Alzheimer's disease. Free Radic Biol Med 2006;40:101-9.

191. Nittby H, Grafstrom G, Tian DP, et al. Cognitive impairment in rats after long-term exposure to GSM-900 mobile phone radiation. Bioelectromagnetics 2007.

192. Kim JY, Kim HJ, Kwon KN, Park MJ. Effects of radiofrequency field exposure on glutamate-induced oxidative stress in mouse hippocampal HT22 cells. Int J Radiat Biol 2016;Sept 20:1-22 {Epub ahead of print}.

193. Mugunthan N, Shanmugasamy K, Anbalagan J, Rajanarayanan S, Meenachi S. Effects of long term exposure of 9001800 MHz radiation emitted from 2G mobile phone on mice hippocampus - A histomorphometric study. J Clin Diagn Res 2016;10:AF01-6.

194. Killin LOJ, Starr JM, Shiue IJ, Russ TC. Environmental risk factors for demenita: a systematic review. BMC Geriatrics 2016;12 Oct:DOI: 10.1186/s12877-016-0342-y.

195. Sonmez OF, Odaci E, Bas O, Kaplan S. Purkinje cell number decreases in the adult female rat cerebellum following exposure to 900 MHz electromagnetic field. Brain Res 2010;1356:95-101.

196. Herbert MR, Sage C. Autism and EMF? Plausibility of a pathophysiological link – Part I. Pathophysiology 2013;20:191-209.

197. Zueva NA, Kovalenko AN, Gerasimenko TI, Man'kovskii BN, Korpachova TI, Efimov AS. [Analysis of irradiation dose, body mass index and insulin blood concentration in personnel cleaning up after the Chernobyl nuclear plant accident]. Lik Sprava 2001:26-8.

198. Grigor'ev Iu G, Grigor'ev OA, Ivanov AA, et al. [Autoimmune processes after long-term low-level exposure to electromagnetic fields (the results of an experiment). Part 1. Mobile communications and changes in electromagnetic conditions for the population. Needs for additional substantiation of the existing hygienic standards]. Radiats Biol Radioecol 2010;50:6-11.

199. Grigor'ev Iu G, Grigor'ev OA, Merkulov AV, Shafirkin AV, Vorob'ev AA. [Autoimmune processes after long-term low-level exposure to electromagnetic fields (the results of an experiment). Part 2. General scheme and conditions of the experiment. Development of RF exposure conditions complying with experimental tasks. Animal's status during the long-term exposure]. Radiats Biol Radioecol 2010;50:12-6.

200. Grigor'ev Iu G, Shafirkin AV, Nosocskii AM. [New data for proving the presence of significant effects of electromagnetic exposure (to autoimmune changes in rats)]. Radiats Biol Radioecol 2011;51:721-30.

201. Brainard GC, Kavet R, Kheifets LI. The relationship between electromagnetic field and light exposures to melatonin and breast cancer risk: a review of the relevant literature. J Pineal Res 1999;26:65-100.

202. Milham S. A cluster of male breast cancer in office workers. Am J Ind Med 2004;46:86-7.

203. Milham S, Ossiander E. Electric typewriter exposure and increased female breast cancer mortality in typists. Med Hypotheses 2007;68:450-1.

204. Naziroglu M, Tokat S, Demirci S. Role of melatonin on electromagnetic radiation-induced oxidative stress and Ca2+ signaling molecular pathways in breast cancer. J Recept Signal Transduct Res 2012;32:290-7.

205. Zhao G, Lin X, Zhou M, Zhao J. Relationship between exposure to extremely low-frequency electromagnetic fields and breast cancer risk: a meta-analysis. Eur J Gynaecol Oncol 2014;35:264-9.

206. Coureau G, Bouvier G, Lebailly P, et al. Mobile phone use and brain tumours in the CERENAT case-control study. Occup Environ Med;71:514-22.

207. Carlberg M, 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 2014;11:10790-805.

208. Carlberg M, 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;2017:9218486.

209. Carlberg M, Koppel T, Ahonen M, Hardell L. Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and glioma risk. Am J Ind Med 2017;April 10 (epub ahead of print).

210. Carlbert M, 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;Epub Mar 16:https://www.hindawi.com/journals/bmri/2017/9218486/

211. Hardell L, Carlberg M, Hansson Mild K. Use of mobile phones and cordless phones is associated with increased risk for glioma and acoustic neuroma. Pathophysiology 2013;20:85-110.

212. Hardell L, Carlberg M, Soderqvist F, 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 2013;43:1036-44.

213. Hardell L, Carlberg M. Use of mobile and cordless phones and survival of patients with glioma. Neuroepidemiology 2013;40:101-8.

214. Hardell L, 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 2013;28:97-106.

215. Hardell L, Carlberg M, 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 2011;38:1465-74.

216. Hardell L, Carlberg M, Soderqvist F, Mild KH. Case-control study of the association between malignant brain tumours diagnosed between 2007 and 2009 and mobile and cordless phone use. Int J Oncol 2013;43:1833-45.

217. Hardell L, 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 2015;22:1-13.

218. Lerchl A, Kruger H, Niehaus M, Streckert JR, Bitz AK, Hansen V. Effects of mobile phone electromagnetic fields at nonthermal SAR values on melatonin and body weight of Djungarian hamsters (Phodopus sungorus). J Pineal Res 2008;44:267-72.

219. Lerchl A, Klose M, Grote K, et al. Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans. Biochem Biophys Res Commun 2015;459:585-90.

220. Adams JA, Galloway TS, Mondal D, Esteves SC, Mathews F. Effect of mobile telephones on sperm quality: a systematic review and meta-analysis. Environ Int 2014;70:106-12.

221. Houston BJ, Nixon B, King BV, De Iuliis GN, Aitken RJ. The effects of radiofrequency electromagnetic radiation on sperm function. Reproduction 2016;152:R263-R76.

222. Atasoy HI, Gunal MY, Atasoy P, Elgun S, Bugdayci G. Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices. J Pediatr Urol;9:223-9.

223. Abeleva EA. [Changes of the Nature of Radiation-Induced Mutation in Spermatids of Drosophila under the Influence of Arginine]. Radiobiologiia 1964;4:426-31.

224. Hong R, Zhang Y, Liu Y, Weng EQ. [Effects of extremely low frequency electromagnetic fields on DNA of testicular cells and sperm chromatin structure in mice]. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi 2005;23:414-7.

225. Ugras MY, Kurus M, Ates B, Soylemez H, Otlu A, Yilmaz I. Prunus armeniaca L (apricot) protects rat testes from detrimental effects of low-dose x-rays. Nutr Res 2010;30:200-8.

226. Den Boer PJ, van Loon AA, Mackenbach P, van der Schans GP, Grootegoed JA. Effect of glutathione depletion on the cytotoxicity of xenobiotics and induction of single-strand DNA breaks by ionizing radiation in isolated hamster round spermatids. Journal of reproduction and fertility 1990;88:259-69.

227. Liu C, Duan W, Xu S, et al. Exposure to 1800 MHz radiofrequency electromagnetic radiation induces oxidative DNA base damage in a mouse spermatocyte-derived cell line. Toxicol Lett 2013;218:2-9.

228. Yan JG, Agresti M, Bruce T, Yan YH, Granlund A, Matloub HS. Effects of cellular phone emissions on sperm motility in rats. Fertil Steril 2007;88:957-64.

229. Aitken RJ, Bennetts LE, Sawyer D, Wiklendt AM, King BV. Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline. Int J Androl 2005;28:171-9.

230. Guler G, Tomruk A, Ozgur E, Seyhan N. The effect of radiofrequency radiation on DNA and lipid damage in non-pregnant and pregnant rabbits and their newborns. Gen Physiol Biophys 2010;29:59-66.

231. Borhani N, Rajaei F, Salehi Z, Javadi A. Analysis of DNA fragmentation in mouse embryos exposed to an extremely low-frequency electromagnetic field. Electromagn Biol Med 2011;30:246-52.

232. Sedeghi T, Ahmadi A, Javadian M, et al. Preterm birth among women living within 600 meters of high voltage overhead power lines: a case-control study. Rom J Intern Med 2017;Apr 18:{Epub ahead of print}.

233. Bahreymi Toossi MH, Sadeghnia HR, Mohammad Mahdizadeh Feyzabadi M, et al. Exposure to mobile phone (900-1800 MHz) during pregnancy: tissue oxidative stress after childbirth. J Matern Fetal Neonatal Med 2017;Apr 23 {Epub ahead of print}:1-6.

234. Sudan M, Kheifets L, Arah O, Olsen J, Zeltzer L. Prenatal and Postnatal Cell Phone Exposures and Headaches in Children. Open Pediatr Med Journal 2012;6:46-52.

235. Aldad TS, Gan G, Gao XB, Taylor HS. Fetal radiofrequency radiation exposure from 800-1900 mhz-rated cellular telephones affects neurodevelopment and behavior in mice. Sci Rep;2:312.

236. Shahin S, Singh VP, Shukla RK, et al. 2.45 GHz microwave irradiation-induced oxidative stress affects implantation or pregnancy in mice, Mus musculus. Appl Biochem Biotechnol 2013;169:1727-51.

237. Othman H, Ammari M, Sakly M, Abdelmelek H. Effects of prenatal exposure to WiFi signal on postnatal development and behavior in rat: Influence of maternal restraint. Behavioral Brain Research 2017;36:291-302.

238. Zarei S, Mortazavi SMJ, Mehdizadeh AR, et al. A Challenging Issue in the Etiology of Speech Problems: The Effect of Maternal Exposure to Electromagnetic Fields on Speech Problems in the Offspring. Journal of Biomedical Physics & Engineering 2015;5:151-4.

239. Divan HA, Kheifets L, Obel C, Olsen J. Prenatal and postnatal exposure to cell phone use and behavioral problems in children. Epidemiology 2008;19:523-9.

240. Divan HA, Kheifets L, Obel C, Olsen J. Cell phone use and behavioural problems in young children. J Epidemiol Community Health 2012;66:524-9.

241. Birks L, Guxens M, Papadopoulou E, et al. Maternal cell phone use during pregnancy and child behavioral problems in five birth cohorts. Environment International 2017.

242. Reiter RJ. Alterations of the circadian melatonin rhythm by the electromagnetic spectrum: a study in environmental toxicology. Regul Toxicol Pharmacol 1992;15:226-44.

243. Reiter RJ. Static and extremely low frequency electromagnetic field exposure: reported effects on the circadian production of melatonin. J Cell Biochem 1993;51:394-403.

244. Reiter RJ. Electromagnetic fields and melatonin production. Biomed Pharmacother 1993;47:439-44.

245. Reiter RJ. Melatonin suppression by static and extremely low frequency electromagnetic fields: relationship to the reported increased incidence of cancer. Rev Environ Health 1994;10:171-86.

246. Fernie KJ, Bird DM, Petitclerc D. Effects of electromagnetic fields on photophasic circulating melatonin levels in American kestrels. Environ Health Perspect 1999;107:901-4.

247. Griefahn B, Kunemund C, Blaszkewicz M, Lerchl A, Degen GH. Effects of electromagnetic radiation (bright light, extremely low-frequency magnetic fields, infrared radiation) on the circadian rhythm of melatonin synthesis, rectal temperature, and heart rate. Ind Health 2002;40:320-7.

248. Jarupat S, Kawabata A, Tokura H, Borkiewicz A. Effects of the 1900 MHz electromagnetic field emitted from cellular phone on nocturnal melatonin secretion. J Physiol Anthropol Appl Human Sci 2003;22:61-3.

249. [Melatonin in the environmental medicine diagnosis in connection with electromagnetic fields: statement of the commission "Methods and Quality Assurance in Environmental Medicine"]. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2005;48:1406-8.

250. Rapoport SI, Breus TK. [Melatonin as a most important factor of natural electromagnetic fields impacting patients with hypertensive disease and coronary heart disease. Part 1]. Klin Med (Mosk) 2011;89:9-14.

251. Dyche J, Anch AM, Fogler KA, Barnett DW, Thomas C. Effects of power frequency electromagnetic fields on melatonin and sleep in the rat. Emerg Health Threats J 2012;5.

252. Qin F, Zhang J, Cao H, et al. Effects of 1800-MHz radiofrequency fields on circadian rhythm of plasma melatonin and testosterone in male rats. J Toxicol Environ Health A 2012;75:1120-8.

253. Bagchi M, Balmoori J, Ye X, Bagchi D, Ray SD, Stohs SJ. Protective effect of melatonin on naphthalene-induced oxidative stress and DNA damage in cultured macrophage J774A.1 cells. Mol Cell Biochem 2001;221:49-55.

254. Abdel Moneim AE, Ortiz F, Leonardo-Mendonca RC, et al. Protective effects of melatonin against oxidative damage induced by Egyptian cobra (Naja haje) crude venom in rats. Acta Trop 2015;143:58-65.

255. Abd-Elghaffar S, El-Sokkary GH, Sharkawy AA. Aluminum-induced neurotoxicity and oxidative damage in rabbits: protective effect of melatonin. Neuro Endocrinol Lett 2005;26:609-16.

256. Abdel-Wahab MH, Arafa HM, El-Mahdy MA, Abdel-Naim AB. Potential protective effect of melatonin against dibromoacetonitrile-induced oxidative stress in mouse stomach. Pharmacol Res 2002;46:287-93.

257. Abdel-Wahhab MA, Abdel-Galil MM, El-Lithey M. Melatonin counteracts oxidative stress in rats fed an ochratoxin A contaminated diet. J Pineal Res 2005;38:130-5.

258. Abraham P, Kolli VK, Rabi S. Melatonin attenuates methotrexate-induced oxidative stress and renal damage in rats. Cell Biochem Funct 2010;28:426-33.

259. Agil A, Reiter RJ, Jimenez-Aranda A, et al. Melatonin ameliorates low-grade inflammation and oxidative stress in young Zucker diabetic fatty rats. J Pineal Res 2013;54:381-8.

260. Aksoy N, Vural H, Sabuncu T, Aksoy S. Effects of melatonin on oxidative-antioxidative status of tissues in streptozotocin-induced diabetic rats. Cell Biochem Funct 2003;21:121-5.

261. Aktas C, Kanter M, Erboga M, Mete R, Oran M. Melatonin attenuates oxidative stress, liver damage and hepatocyte apoptosis after bile-duct ligation in rats. Toxicol Ind Health 2014;30:835-44.

262. Albendea CD, Gomez-Trullen EM, Fuentes-Broto L, et al. Melatonin reduces lipid and protein oxidative damage in synaptosomes due to aluminium. J Trace Elem Med Biol 2007;21:261-8.

263. Al-Malki AL. Synergestic effect of lycopene and melatonin against the genesis of oxidative stress induced by cyclophosphamide in rats. Toxicol Ind Health 2014;30:570-5.

264. Aranda M, Albendea CD, Lostale F, et al. In vivo hepatic oxidative stress because of carbon tetrachloride toxicity: protection by melatonin and pinoline. J Pineal Res 2010;49:78-85.

265. Arushanian EB. [Limitation of oxidative stress as the main factor of the universal protective properties of melatonin]. Eksp Klin Farmakol 2012;75:44-9.

266. Bagheri F, Goudarzi I, Lashkarbolouki T, Elahdadi Salmani M. Melatonin prevents oxidative damage induced by maternal ethanol administration and reduces homocysteine in the cerebellum of rat pups. Behav Brain Res 2015;287:215-25.

267. Aynali G, Naziroglu M, Celik O, Dogan M, Yariktas M, Yasan H. Modulation of wireless (2.45 GHz)-induced oxidative toxicity in laryngotracheal mucosa of rat by melatonin. Eur Arch Otorhinolaryngol 2013;270:1695-700.

268. Bardak Y, Ozerturk Y, Ozguner F, Durmus M, Delibas N. Effect of melatonin against oxidative stress in ultraviolet-B exposed rat lens. Curr Eye Res 2000;20:225-30.

269. Argun M, Tok L, Uguz AC, Celik O, Tok OY, Naziroglu M. Melatonin and amfenac modulate calcium entry, apoptosis, and oxidative stress in ARPE-19 cell culture exposed to blue light irradiation (405 nm). Eye (Lond) 2014;28:752-60.

270. Ayata A, Mollaoglu H, Yilmaz HR, Akturk O, Ozguner F, Altuntas I. Oxidative stress-mediated skin damage in an experimental mobile phone model can be prevented by melatonin. J Dermatol 2004;31:878-83.

271. Bhatia AL, Manda K. Study on pre-treatment of melatonin against radiation-induced oxidative stress in mice. Environ Toxicol Pharmacol 2004;18:13-20.

272. Guney Y, Hicsonmez A, Uluoglu C, et al. Melatonin prevents inflammation and oxidative stress caused by abdominopelvic and total body irradiation of rat small intestine. Braz J Med Biol Res 2007;40:1305-14.

273. Jang SS, Kim HG, Lee JS, et al. Melatonin reduces X-ray radiation-induced lung injury in mice by modulating oxidative stress and cytokine expression. Int J Radiat Biol 2013;89:97-105.

274. Kim BC, Shon BS, Ryoo YW, Kim SP, Lee KS. Melatonin reduces X-ray irradiation-induced oxidative damages in cultured human skin fibroblasts. J Dermatol Sci 2001;26:194-200.

275. Koc M, Taysi S, Buyukokuroglu ME, Bakan N. Melatonin protects rat liver against irradiation-induced oxidative injury. J Radiat Res 2003;44:211-5.

276. Manda K, Ueno M, Anzai K. Melatonin mitigates oxidative damage and apoptosis in mouse cerebellum induced by high-LET 56Fe particle irradiation. J Pineal Res 2008;44:189-96.

277. Naziroglu M, Celik O, Ozgul C, et al. Melatonin modulates wireless (2.45 GHz)-induced oxidative injury through TRPM2 and voltage gated Ca(2+) channels in brain and dorsal root ganglion in rat. Physiol Behav 2012;105:683-92.

278. Oksay T, Naziroglu M, Dogan S, Guzel A, Gumral N, Kosar PA. Protective effects of melatonin against oxidative injury in rat testis induced by wireless (2.45 GHz) devices. Andrologia 2012.

279. Sener G, Atasoy BM, Ersoy Y, Arbak S, Sengoz M, Yegen BC. Melatonin protects against ionizing radiation-induced oxidative damage in corpus cavernosum and urinary bladder in rats. J Pineal Res 2004;37:241-6.

280. Sharma S, Haldar C. Melatonin prevents X-ray irradiation induced oxidative damagein peripheral blood and spleen of the seasonally breeding rodent, Funambulus pennanti during reproductively active phase. Int J Radiat Biol 2006;82:411-9.

281. Sokolovic D, Djindjic B, Nikolic J, et al. Melatonin reduces oxidative stress induced by chronic exposure of microwave radiation from mobile phones in rat brain. J Radiat Res 2008;49:579-86.

282. Taysi S, Memisogullari R, Koc M, et al. Melatonin reduces oxidative stress in the rat lens due to radiation-induced oxidative injury. Int J Radiat Biol 2008;84:803-8.

283. Tok L, Naziroglu M, Dogan S, Kahya MC, Tok O. Effects of melatonin on Wi-Fi-induced oxidative stress in lens of rats. Indian J Ophthalmol 2014;62:12-5.

284. Yilmaz S, Yilmaz E. Effects of melatonin and vitamin E on oxidative-antioxidative status in rats exposed to irradiation. Toxicology 2006;222:1-7.

285. Albers DS, Beal MF. Mitochondrial dysfunction and oxidative stress in aging and neurodegenerative disease. J Neural Transm Suppl 2000;59:133-54.

286. Ansari MA, Joshi G, Huang Q, et al. In vivo administration of D609 leads to protection of subsequently isolated gerbil brain mitochondria subjected to in vitro oxidative stress induced by amyloid beta-peptide and other oxidative stressors: relevance to Alzheimer's disease and other oxidative stress-related neurodegenerative disorders. Free Radic Biol Med 2006;41:1694-703.

287. Arumugam S, Thandavarayan RA, Arozal W, et al. Quercetin offers cardioprotection against progression of experimental autoimmune myocarditis by suppression of oxidative and endoplasmic reticulum stress via endothelin-1/MAPK signalling. Free Radic Res 2012;46:154-63.

288. Barnham KJ, Masters CL, Bush AI. Neurodegenerative diseases and oxidative stress. Nat Rev Drug Discov 2004;3:205-14.

289. Bashir S, Harris G, Denman MA, Blake DR, Winyard PG. Oxidative DNA damage and cellular sensitivity to oxidative stress in human autoimmune diseases. Ann Rheum Dis 1993;52:659-66.

290. Belch JJ, Mackay IR, Hill A, Jennings P, McCollum P. Oxidative stress is present in atherosclerotic peripheral arterial disease and further increased by diabetes mellitus. Int Angiol 1995;14:385-8.

291. Benz CC, Yau C. Ageing, oxidative stress and cancer: paradigms in parallax. Nat Rev Cancer 2008;8:875-9.

292. Bernstein AI, Miller GW. Oxidative signaling in experimental autoimmune encephalomyelitis. Toxicol Sci 2010;114:159-61.

293. Bonnefont-Rousselot D. Obesity and oxidative stress: potential roles of melatonin as antioxidant and metabolic regulator. Endocr Metab Immune Disord Drug Targets 2014;14:159-68.

294. Butterfield DA, Castegna A, Drake J, Scapagnini G, Calabrese V. Vitamin E and neurodegenerative disorders associated with oxidative stress. Nutr Neurosci 2002;5:229-39.

295. Butterfield DA, Howard BJ, LaFontaine MA. Brain oxidative stress in animal models of accelerated aging and the age-related neurodegenerative disorders, Alzheimer's disease and Huntington's disease. Curr Med Chem 2001;8:815-28.

296. Ceriello A, Motz E. Is oxidative stress the pathogenic mechanism underlying insulin resistance, diabetes, and cardiovascular disease? The common soil hypothesis revisited. Arterioscler Thromb Vasc Biol 2004;24:816-23.

297. Chang YC, Chuang LM. The role of oxidative stress in the pathogenesis of type 2 diabetes: from molecular mechanism to clinical implication. Am J Transl Res 2010;2:316-31.

298. Chauhan A, Chauhan V. Oxidative stress in autism. Pathophysiology 2006;13:171-81.

299. Chauhan A, Chauhan V, Brown WT, Cohen I. Oxidative stress in autism: increased lipid peroxidation and reduced serum levels of ceruloplasmin and transferrin--the antioxidant proteins. Life Sci 2004;75:2539-49.

300. Dhaun N, Kluth DC. Oxidative stress promotes hypertension and albuminuria during the autoimmune disease systemic lupus erythematosus. Hypertension 2012;59:e47; author reply e8.

301. Dobrian AD, Davies MJ, Schriver SD, Lauterio TJ, Prewitt RL. Oxidative stress in a rat model of obesity-induced hypertension. Hypertension 2001;37:554-60.

302. Donkena KV, Young CY, Tindall DJ. Oxidative stress and DNA methylation in prostate cancer. Obstet Gynecol Int 2010;2010:302051.

303. Facheris M, Beretta S, Ferrarese C. Peripheral markers of oxidative stress and excitotoxicity in neurodegenerative disorders: tools for diagnosis and therapy? J Alzheimers Dis 2004;6:177-84.

304. Gilgun-Sherki Y, Melamed E, Offen D. Oxidative stress induced-neurodegenerative diseases: the need for antioxidants that penetrate the blood brain barrier. Neuropharmacology 2001;40:959-75.

305. Henriksen EJ, Diamond-Stanic MK, Marchionne EM. Oxidative stress and the etiology of insulin resistance and type 2 diabetes. Free Radic Biol Med 2011;51:993-9.

306. Hoeldtke RD, Bryner KD, VanDyke K. Oxidative stress and autonomic nerve function in early type 1 diabetes. Clin Auton Res 2011;21:19-28.

307. Islam MT. Oxidative stress and mitochondrial dysfunction-linked neurodegenerative disorders. Neurol Res 2017;39:73-82.

308. James SJ, Cutler P, Melnyk S, et al. Metabolic biomarkers of increased oxidative stress and impaired methylation capacity in children with autism. Am J Clin Nutr 2004;80:1611-7.

309. Kaffe ET, Rigopoulou EI, Koukoulis GK, Dalekos GN, Moulas AN. Oxidative stress and antioxidant status in patients with autoimmune liver diseases. Redox Rep 2015;20:33-41.

310. Karbownik M, Reiter RJ. Melatonin protects against oxidative stress caused by delta-aminolevulinic acid: implications for cancer reduction. Cancer Invest 2002;20:276-86.

311. Karbownik M, Reiter RJ, Burkhardt S, Gitto E, Tan DX, Lewinski A. Melatonin attenuates estradiol-induced oxidative damage to DNA: relevance for cancer prevention. Exp Biol Med (Maywood) 2001;226:707-12.

312. Kern JK, Jones AM. Evidence of toxicity, oxidative stress, and neuronal insult in autism. J Toxicol Environ Health B Crit Rev 2006;9:485-99.

313. Khandrika L, Kumar B, Koul S, Maroni P, Koul HK. Oxidative stress in prostate cancer. Cancer Lett 2009.

314. Kovacic P, Jacintho JD. Systemic lupus erythematosus and other autoimmune diseases from endogenous and exogenous agents: unifying theme of oxidative stress. Mini Rev Med Chem 2003;3:568-75.

315. Kumagai S, Jikimoto T, Saegusa J. [Pathological roles of oxidative stress in autoimmune diseases]. Rinsho Byori 2003;51:126-32.

316. Kumagai S, Nobuhara Y, Saegusa J. [Oxidative stress and autoimmune diseases]. Nihon Naika Gakkai Zasshi 2003;92:1096-103.

317. Kupczyk D, Rybka J, Kedziora-Kornatowska K, Kedziora J. [Melatonin and oxidative stress in elderly patients with type 2 diabetes]. Pol Merkur Lekarski 2010;28:407-9.

318. Lin MT, Beal MF. Mitochondrial dysfunction and oxidative stress in neurodegenerative diseases. Nature 2006;443:787-95.

319. Mariani E, Polidori MC, Cherubini A, Mecocci P. Oxidative stress in brain aging, neurodegenerative and vascular diseases: an overview. J Chromatogr B Analyt Technol Biomed Life Sci 2005;827:65-75.

320. McGinnis WR. Oxidative stress in autism. Altern Ther Health Med 2005;11:19.

321. Moreno-Otero R. May oxidative stress contribute to autoimmune hepatitis pathogenesis, and can antioxidants be of value as adjuvant therapy for refractory patients? Dig Dis Sci 2013;58:1440-1.

322. Nguyen AM, Rao NA. Oxidative photoreceptor cell damage in autoimmune uveitis. J Ophthalmic Inflamm Infect 2011;1:7-13.

323. Pandi-Perumal SR, BaHammam AS, Brown GM, et al. Melatonin antioxidative defense: therapeutical implications for aging and neurodegenerative processes. Neurotox Res 2013;23:267-300.

324. Pereira EC, Ferderbar S, Bertolami MC, et al. Biomarkers of oxidative stress and endothelial dysfunction in glucose intolerance and diabetes mellitus. Clin Biochem 2008;41:1454-60.

325. Pillarisetti S, Saxena U. Role of oxidative stress and inflammation in the origin of Type 2 diabetes--a paradigm shift. Expert Opin Ther Targets 2004;8:401-8.

326. Rao AV, Balachandran B. Role of oxidative stress and antioxidants in neurodegenerative diseases. Nutr Neurosci 2002;5:291-309.

327. Rodrigues P, de Marco G, Furriol J, et al. Oxidative stress in susceptibility to breast cancer: study in Spanish population. BMC Cancer 2014;14:861.

328. Rose S, Melnyk S, Pavliv O, et al. Evidence of oxidative damage and inflammation associated with low glutathione redox status in the autism brain. Transl Psychiatry 2012;2:e134.

329. Rossignol DA, Frye RE. A review of research trends in physiological abnormalities in autism spectrum disorders: immune dysregulation, inflammation, oxidative stress, mitochondrial dysfunction and environmental toxicant exposures. Mol Psychiatry 2012;17:389-401.

330. Shah AA, Sinha AA. Oxidative stress and autoimmune skin disease. Eur J Dermatol 2013;23:5-13.

331. Sheridan J, Wang LM, Tosetto M, et al. Nuclear oxidative damage correlates with poor survival in colorectal cancer. Br J Cancer 2009;100:381-8.

332. Sondergaard ES, Gogenur I. [Oxidative stress may cause metastatic disease in patients with colorectal cancer.]. Ugeskr Laeger 2014;176.

333. Srinivasan V. Melatonin oxidative stress and neurodegenerative diseases. Indian J Exp Biol 2002;40:668-79.

334. Sun GY, Wood WG. Recent developments in understanding oxidative mechanisms and contributions of glial cell activation, mitochondrial dysfunction, and lipids and signaling pathways to neurodegenerative diseases. Preface. Mol Neurobiol 2010;41:53-4.

335. Udensi UK, Tchounwou PB. Dual effect of oxidative stress on leukemia cancer induction and treatment. J Exp Clin Cancer Res 2014;33:106.

336. Valko M, Rhodes CJ, Moncol J, Izakovic M, Mazur M. Free radicals, metals and antioxidants in oxidative stress-induced cancer. Chem Biol Interact 2006;160:1-40.

337. Vessby J, Basu S, Mohsen R, Berne C, Vessby B. Oxidative stress and antioxidant status in type 1 diabetes mellitus. J Intern Med 2002;251:69-76.

338. Wells PG, McCallum GP, Chen CS, et al. Oxidative stress in developmental origins of disease: teratogenesis, neurodevelopmental deficits, and cancer. Toxicol Sci 2009;108:4-18.

339. Yamamoto T. Autoimmune mechanisms of scleroderma and a role of oxidative stress. Self Nonself 2011;2:4-10.

340. Yao Y, Walsh WJ, McGinnis WR, Pratico D. Altered vascular phenotype in autism: correlation with oxidative stress. Arch Neurol 2006;63:1161-4.

341. Yu JH, Kim H. Oxidative stress and cytokines in the pathogenesis of pancreatic cancer. J Cancer Prev 2014;19:97-102.

342. Zephy D, Ahmad J. Type 2 diabetes mellitus: Role of melatonin and oxidative stress. Diabetes Metab Syndr 2015;9:127-31.

343. Zoroglu SS, Armutcu F, Ozen S, et al. Increased oxidative stress and altered activities of erythrocyte free radical scavenging enzymes in autism. Eur Arch Psychiatry Clin Neurosci 2004;254:143-7.

344. Torbenko VP, Bogdanova IA, Gerasimov AM. [Effect of a combined radiation lesion on the enzyme activity of the glutathione redox system of the rat liver]. Biull Eksp Biol Med 1983;95:48-50.

345. Erden M, Bor NM. Changes of reduced glutathion, glutathion reductase, and glutathione peroxidase after radiation in guinea pigs. Biochem Med 1984;31:217-27.

346. Evans JW, Taylor YC, Brown JM. The role of glutathione and DNA strand break repair in determining the shoulder of the radiation survival curve. Br J Cancer Suppl 1984;6:49-53.

347. Boyer TD, Vessey DA, Kempner E. Radiation inactivation of microsomal glutathione S-transferase. J Biol Chem 1986;261:16963-8.

348. Connor MJ, Wheeler LA. Depletion of cutaneous glutathione by ultraviolet radiation. Photochem Photobiol 1987;46:239-45.

349. Singh LR, Uniyal BP, Mukherjee SK, Sarkar SR, Sharma SK. Effect of whole body gamma-radiation on glutathione reductase of rat tissues. Strahlenther Onkol 1987;163:337-9.

350. Leus NF, Kolomiichuk SG, Lishchenko VB. [Activity of glutathione-S-transferase in the blood plasma, liver and crystalline lens tissues as affected by low doses of ionizing radiation and polychromatic light]. Ukr Biokhim Zh 1997;69:54-9.

351. Grande S, Luciani AM, Rosi A, et al. Radiation effects on soluble metabolites in cultured HeLa cells examined by 1H MRS: changes in concentration of glutathione and of lipid catabolites induced by gamma rays and proton beams. Int J Cancer 2001;96 Suppl:27-42.

352. Rathgen GH. [Radiation-induced changes of the glutathione content of some rat organs modified by cysteine]. Strahlentherapie 1970;139:243-50.

353. Rathgen GH, Lieser H. [Significance of glutathione in radiation effect studies and chemical radiation protection]. Strahlentherapie 1972;143:670-6.

354. Sarkar SR, Singh LR, Uniyal BP, Chaudhuri BN. Effect of whole body gamma radiation on reduced glutathione contents of rat tissues. Strahlentherapie 1983;159:32-3.

355. Rosi A, Grande S, Luciani AM, et al. Role of glutathione in apoptosis induced by radiation as determined by 1H MR spectra of cultured tumor cells. Radiat Res 2007;167:268-82.

356. Tanita J, Tsuchida S, Hozawa J, Sato K. Expression of glutathione S-transferase-pi in human squamous cell carcinomas of the pharynx and larynx. Loss after radiation therapy. Cancer 1993;72:569-76.

357. Vartanyan LS, Gurevich SM, Kozachenko AI, Nagler LG, Lozovskaya EL, Burlakova EB. Changes in superoxide production rate and in superoxide dismutase and glutathione peroxidase activities in subcellular organelles in mouse liver under exposure to low doses of low-intensity radiation. Biochemistry (Mosc) 2000;65:442-6.

358. Woodward GE. The effect of ultra-violet, radium and X-ray radiation on glutathione in pure solution. Biochem J 1933;27:1411-4.

359. Byun YH, Ha M, Kwon HJ, et al. Mobile phone use, blood lead levels, and attention deficit hyperactivity symptoms in children: a longitudinal study. PLoS One 2013;8:e59742.

360. Sanie-Jahromi F, Saadat Z, Saadat M. Effects of extremely low frequency electromagnetic fields and cisplatin on mRNA levels of some DNA repair genes. Life Sciences 2016;3205:30588-4.

List of 142 Reviews on Non-thermal Effects of Microwave/Intermediate Frequency EMFs
Martin L. Pall

Among the scientific reviews documenting these various non-thermal health effects are 142 that follow. Each of these reviews cites at least a dozen primary literature citations showing non-thermal effects, with many citing 100 or more going up to the 3rd reference which cites over 1000 such citations. It can be seen from this that the primary literature citations supporting the existence of various non-thermal health effects cited in these reviews go into several thousands. This list is not and is not intended to be a list of all important such reviews. However it gives some measure of the size of the literature that contradicts the industry contention that there are no non-thermal effects of microwave frequency EMFs.

1) Osipov YuA, 1965 [Labor hygiene and the effect of radiofrequency electromagnetic fields on workers]. Leningrad Meditsina Publishing House, 220 pp.
2) Pollack H, Healer J. 1967 Review of Information on Hazards to Personnel from High-Frequency Electromagnetic Radiation. Institute for Defense Analyses; Research and Engineering Support Division. IDA/HQ 67-6211, Series B, May 1967.
3) Naval Medical Research Institute Research Report, June 1971. Bibliography of Reported Biological Phenomena ("Effects") and Clinical Manifestations, Revised, ZR Glaser.
4) Frey AH. 1971 Biological Function as influenced by low power modulated RF energy. IEEE Trans Microw Theory Tech 19(2): 153-164.
5) Tolgskaya MS, Gordon ZV. 1973. Pathological Effects of Radio Waves, Translated from Russian by B Haigh. Consultants Bureau, New York/London, 146 pages.
6) WHO Document. 1974 Biologic Effects & Health Hazards of Microwave Radiation: Proceedings of an International Symposium, Warsaw, 15-18 October, 1973. http://mistic.heig-vd.ch/taillard/microwave_effects/
7) Dumanskij, J. D., and Shandala, M. G., 1974. The biologic action and hygienic significance of electromagnetic fields of super-high and ultrahigh frequencies in densely populated areas. Effects and Health Hazards of Microwave Radiation, Proceedings of an International Symposium, Warsaw, 15-18 Oct. 1973, P. Czerski et al., eds.
8) Dwyer, M. J., Leeper, D. B. 1978 A Current Literature Report on the Carcinogenic Properties of Ionizing and Nonionizing Radiation. DHEW Publication (NIOSH) 78-134, March 1978.
9) Bise W. 1978 Low power radio-frequency and microwave effects on human electroencephalogram and behavior. Physiol Chem Phys 10:387-398.
10) Lerner, E. J. 1980. RF radiation: Biological effects. IEEE Spectrum 17(Dec 1980), 51-59.
11) Leach WL. 1980 Genetic, growth and reproductive effects of microwave radiation. Bull N Y Acad Med 56:249-257.
12) Adey W. R. 1981 Tissue interactions with nonionizing electromagnetic fields. Physiol. Rev. 61, 435-514.
13) Raines, J. K. 1981. Electromagnetic Field Interactions with the Human Body: Observed Effects and Theories. Greenbelt, Maryland: National Aeronautics and Space Administration 1981; 116 p.
14) Adey WR. 1988 Cell membranes: the electromagnetic environment and cancer promotion. Neurochem Res.13:671-677.
15) Adey WR. 1990 Joint actions of environmental nonionizing electromagnetic fields and chemical pollution in cancer promotion. Environ Health Perspect 86:297-305.
16) Walleczek, J. 1992. Electromagnetic field effects on cells of the immune system: the role of calcium signaling. FASEB J. 6, 3177-3185.
17) Adey, WR. 1993 Biological effects of electromagnetic fields. J Cell Biochem 51:410-416.

18) Bolen, S. M. 1994 Radiofrequency/Microwave Radiation Biological Effects and safety standards: a review. AD-A282 886, Rome Laboratory, U.S. Air Force Material Command, Griffiss Air Force Base, New York.
19) Lai H. 1994 Neurological effects of radiofrequency electromagnetic radiation. In: Advances in Electromagnetic Fields in Living Systems, Vol. 1, J.C. Lin, Ed., Plenum Press, New York, pp. 27-88.
20) Goodman EM, Greenebaum B, Marron MT. 1995 Effects of electromagnetic fields on molecules and cells. Int Rev Cytol 158:279-338.
21) Grigoriev IUG. 1996 Role of modulation in biological effects of electromagnetic radiation. Radiats Biol Radioecol 36:659-670.
22) Lai, H. 1997. Neurological effects of radiofrequency electromagnetic radiation relating to wireless communication technology. Paper presented at the IBC-UK Conference: "Mobile Phones – Is There a Health Risk?" http://www.mapcruzin.com/radiofrequency/henry_lai1.htm
23) Adey WR, 1997 Bioeffects of mobile communications fields: possible mechanisms for cumulative dose. In: N Kuster, Q Balzano, JC Lin (Eds), Mobile Communications Safety, New York, Chapman and Hall, pp. 95-131.
24) Goldsmith JR. 1997 Epidemiologic evidence relevant to radar (microwave) effects. Env Health Perspect 105(Suppl 6):1579-1587.
25) Frey, A. H. 1998. Headaches from cellular telephones: are they real and what are the implications? Environ. Health Perspect. 106, 101-103.
26) Lai, H 1998 Neurological effects of radiofrequency electromagnetic radiation. www.papcruzin.com/radiofrequency/henry_lai1.htm
27) Hyland GJ. 1998 Non-thermal bioeffects induced by low-intensity microwave frequency microwave irradiation of living systems. Engineering Science Educ J 7(6):261-269.
28) Ryabi JT. 1998 Clinical effects of electromagnetic fields on fracture healing. Clin Orthop Relat Res 355(Suppl. l): S205–15.
29) Barnett SB. 1999 Radio-frequency radiation and birth defects: Is there a threat to human health? Cong Anom 39:59-73.
30) Belyaev IY, Shcheglov VS, Alipov ED, Ushakov VD. 2000 Nonthermal Effects of Extremely High-Frequency Microwaves on Chromatin Conformation in Cells in vitro—Dependence on Physical, Physiological, and Genetic Factors. IEEE Trans Microwave Theory Tech 48:2172-2179.
31) Betskii OV, Devyatkov ND, Kislov VV. 2000 Low intensity millimeter waves in medicine and biology. Crit Rev Biomed Eng. 2000;28(1-2):247-268.
32) Krewski D, Byus CV, Glickman BW, Lotz WG, Mandeville R, McBride ML, Prato FS, Weaver DF. 2001 Potential health risks of radiofrequency fields from wireless telecommunication devices. J Toxicol Environ Health B Crit Rev 4: 1-143.
33) Banik S, Bandyopadhyay S, Ganguly S. 2003 Bioeffects of microwave--a brief review. Bioresour Technol. 2003 Apr;87(2):155-9.
34) Blank M, Goodman R. 2004 Comment: a biological guide for electromagnetic safety : the stress response. Bioelectromagnetics 25(8):642-646.
35) Kundi M, Kild K, Hardell L, Mattsson M. 2004 Mobile telephones and cancer – a review of the epidemiological evidence. J Toxicol Env Health, Part B 7:351-384.
36) Kundi M. 2004 Mobile phone use and cancer. Occup Env Med 61:560-570.
37) Aaron RK, Ciombor DM, Simon BJ. 2004 Treatment of nonunions with electric and electromagnetic fields. Clin Orthop Relat Res 2004; 10: 579–593.
38) Belyaev I. 2005 Non-thermal biological effects of microwaves: current knowledge, further perspective and urgent needs. Electromagn Biol Med 24(3):375-403.
39) Belyaev I. 2005 Non-thermal biological effects of microwaves. Microwave Rev 11(2):13-29.
40) Barnes FS, Greenebaum B, (eds.) 2007 Biological and medical aspects of electromagnetic fields. 3rd, ed., CRC Press, Boca Raton, FL.
41) Behari J, Paulraj R. 2007 Biomarkers of induced electromagnetic field and cancer. Indian J Exp Biol 45:77-85.

42) Bioinitiative Working Group, Cindy Sage and David Carpenter (eds). 2007 Bioinitiative report: A rationale for a biologically-based public exposure standard for electromagnetic fields (ELF and RF). www.bioinitiative.org
43) Huss A, Egger M, Hug K, Huwiler-Müntener K, Röösli M. 2007 Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. Environ Health Perspect 115:1–4.
44) Markov MS. 2007 Pulsed electromagnetic field therapy: History, state of the art and future. The Environmentalist 27:465-475.
45) Nittby H, Grafstrom G, Eberhardt JL, Malmgren L, Brun A, Persson BR, Salford, LG. 2008 Radiofrequency and extremely low frequency electromagnetic field effects on the blood-brain barrier. Electromag Biol Med 2008; 27:103-126.
46) Hardell, L., Sage, C. 2008. Biological effects from electromagnetic field exposure and public exposure standards. Biomed. Pharmacother. 62, 104-109.
47) Genuis SJ. 2008 Fielding a current idea: explring the public health impact of electromagnetic radiation. Public Health 122:113-124.
48) Johansson O. 2009 Disturbance of the immune system by electromagnetic fields-A potentially underlying cause for cellular damage and tissue repair reduction which could lead to disease and impairment. Pathophysiology 16:157-177.
49) Blackman C. 2009 Cell phone radiation: Evidence from ELF and RF studies supporting more inclusive risk identification and assessment. Pathophysiology. 2009 Aug;16(2-3):205-216
50) Balmori A. 2009 Electromagnetic pollution from phone masts. Effects on wildlife. Pathophysiology 16:191-199.
51) Desai NR, Kesari KK, Agarwal A. 2009 Pathophysiology of cell phone radiation: oxidative stress and carcinogenesis with focus on the male reproductive system. Reproduct Biol Endocrinol 7:114.
52) Khurana VG, Teo C, Kundi M, Hardell L, Carlberg M. 2009 Cell phones and brain tumors: a review including the long-term epidemiologic data. Surg Neurol 72:205-214.
53) Martin Blank, Reba Goodman. 2009 Electromagnetic fields stress living cells. Pathophysiology 16:71-78.
54) Phillips JL, Singh NP, Lai H. 2009 Electromagnetic fields and DNA damage. Pathophysiology 16:79-88.
55) Makker K, Varghese A, Desai NR, Mouradi R, Agarwal A. 2009 Cell phones: modern man's nemesis? Reprod Biomed Online 18:148-157.
56) Ruediger HW. 2009 Genotoxic effects of radiofrequency electromagnetic fields. Pathophysiology. 16:89-102.
57) Yakymenko I, Sidorik E. 2010 Risks of carcinogenesis from electromagnetic radiation and mobile telephony devices. Exp Oncol 32:729-736.
58) Carpenter DO. 2010 Electromagnetic fields and cancer: the cost of doing nothing. Rev Environ Health 25:75-80.
59) 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.
60) Giuliani L, Soffriti M (Eds). 2010 NON-THERMAL EFFECTS AND MECHANISMS OF INTERACTION BETWEEN ELECTROMAGNETIC FIELDS AND LIVING MATTER, RAMAZZINI INSTITUTE EUR. J. ONCOL. LIBRARY Volume 5, National Institute for the Study and Control of Cancer and Environmental Diseases "Bernardino Ramazzini" Bologna, Italy 2010, 400 page monograph.
61) Fragopoulou A, Grigoriev Y, Johansson O, Margaritis LH, Morgan L, Richter E, Sage C. Scientific panel on electromagnetic field health risks: consensus points, recommendations, and rationales. Rev. Environ. Health 25, 307-317.
62) Batista Napotnik T, Reberšek M, Vernier PT, Mali B, Miklavčič D. 2010 Effects of high voltage nanosecond electric pulses on eukaryotic cells (in vitro): A systematic review. Bioelectrochemistry 110:1-12.
63) Levitt, B. B., Lai, H. 2010. Biological effects from exposure to electromagnetic radiation emitted by cell tower base stations and other antenna arrays. Environ. Rev. 18, 369-395.

64) Yu Y, Yao K. 2010 Non-thermal cellular effects of low power microwave radiation on the lens and lens epithelial cells. J Int Med Res 38:729-736.
65) 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(2), 62-70.
66) Kesari KK, Kuman S, Behari J. 2011 Effects of radiofrequency electromagnetic wave exposure from cellular phones on reproductive pattern in male Wistar rats. Appl Biochem Biotechnol 164:546-549.
67) Panagopoulos DJ. 2011 Analyzing the health impacts of modern telecommunication microwaves. Chapter 1 in Advances in Biology and Medicine, Vol. 17, Leon V. Berhardt, Ed., Nova Science Publishers.
68) Schidt-Rohlfing B, Silny J, Gavenis K, et al. 2011 Electromagnetic fields, electric current and bone healing – what is the evidence? Z Orthop Unfall. 149: 265–270.
69) Chalidis B, Sachinis N, Assiotis A, et al. 2011 Stimulation of bone formation and fracture healing with pulsed electromagnetic fields: biologic responses and clinical implica- tions. Int J Immunopathol Pharmacol. 2011; 24(1 Suppl. 2): 17020.
70) Pilla A, Fitzsimmons R, Muehsam D, et al. 2011 Electromagnetic fields as first messenger in biological signaling: application to calmodulin-dependent signaling in tissue repair. Biochim Biophys Acta 1810: 1236–1245.
71) Yakimenko IL, Sidorik EP, Tsybulin AS. 2011 [Metabolic changes in cells under electromagnetic radiation of mobile communication systems]. [Article in Russian] Ukr Biokhim Zh 83:20-28.
72) La Vignera, Condorelli RA, Vicari E, D'Agata R, Calogero AE. 2012 Effects of the exposure to mobile phones on male reproduction: a review of the literature. J Androl 33:350-356.
73) Zhong C, Zhao TF, Xu ZJ, et al. 2012 Effects of electromagnetic fields on bone regeneration in experimental and clinical studies: a review of the literature. Chin Med J 125: 367–372.
74) Biointiative Working Group, David Carpenter and Cindy Sage (eds). 2012 Bioinitiative 2012: A rationale for biologically-based exposure standards for electromagnetic radiation. http://www.bioinitiative.org/participants/why-we-care/
75) Gye MC, Park CJ. 2012 Effect of electromagnetic field exposure on the reproductive system. Clin Exp Reprod Med 39:1-9.
76) Trošić I, Pavičić I, Marjanović AM, Bušljeta I. 2012 Non-thermal biomarkers of exposure to radiofrequency/microwave radiation. Arh Hig Rada Toksikol 63 Suppl 1:67-73.
77) Consales, C., Merla, C., Marino, C., et al. 2012. Electromagnetic fields, oxidative stress, and neurodegeneration. Int. J. Cell Biol. 2012: 683897.
78) Havas, M. 2013. Radiation from wireless technology affects the blood, the heart, and the autonomic nervous system. Rev. Environ. Health. 28(Nov 2013), 75-84.
79) Herbert, M. R., Sage, C. 2013 Autism and EMF? Plausibility of a pathophysiological link – Part I. Pathophysiology 20, 191-209.
80) Herbert, M. R., Sage, C. 2013. Autism and EMF? Plausibility of a pathophysiological link part II. Pathophysiology 20, 211-234.
81) Kesari KK, Siddiqui MH, Meena R, Verma HN, Kumar S. 2013 Cell phone radiation exposure on brain and associated biological systems. Indian J Exp Biol 51:187-200.
82) Warnke U, Hensinger P. 2013 Increasing incidence of burnout due to magnetic fields of cell phone networks and other wireless communication technologies. Umwelt Medizin Gesellshaft 26: 31-38.
83) Panagopoulos, D. J., Johansson, O., Carlo, G. L. 2013. Evaluation of specific absorption rate as a dosimetric quantity for electromagnetic fields bioeffects. PloS ONE 8(6): e62663. doi:10:1371
84) Carpenter DO. 2013. Human disease resulting from exposure to electromagnetic fields. Rev Environ Health. 2013;28(4):159-72.
85) Ledoigt G, Belpomme D. 2013 Cancer induction molecular pathways and HF-EMF irradiation. Adv Biol Chem 3:177-186.
86) Pall, M. L. 2013. Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. J. Cell. Mol. Med. 17:958-965.

87) Pilla, A. A. 2013 Nonthermal electromagnetic fields: from first messenger to therapeutic applications. Electromagn. Biol. Med. 32, 123-136.
88) Panagopoulos, D. J., Johansson, O., Carlo, G. L. 2013. Evaluation of specific absorption rate as a dosimetric quantity for electromagnetic fields bioeffects. PloS ONE 8(6): e62663. doi:10:1371
89) Halgamuge MN. 2013 Pineal melatonin level disruption in humans due to electromagnetic fields and ICNIRP limits. Radiat Prot Dosimetr 154: 405-416
90) Szmigielski S. 2013 Reaction of the immune system to low-level RF/MW exposures. Sci Total Environ 2013 Jun 1;454-455:393-400.
91) Hardell L, Carlberg M, Hansson Mild K. 2013 Use of mobile phones and cordless phones is associated with increased risk for glioma and acoustic neuroma. Pathophysiology 2013;20(2):85-110.
92) Davis DL, Kesari S, Soskolne CL, Miller AB, Stein Y. 2013 Swedish review strengthens grounds for concluding that radiation from cellular and cordless phones is a probable human carcinogen. Pathophysiology 20:123-129.
93) Adams, J. A., Galloway, T. S., Mondal, D., Esteves, S. C. 2014 Effect of mobile telephones on sperm quality: A systematic review and meta-analysis. Environment. Int. 70, 106-112.
94) Murbach, M., Neufeld, E., Christopoulou, M., Achermann, P., Kuster, N. 2014. Modeling of EEG electrode artifacts and thermal ripples in human radiofrequency exposure studies. Bioelectromagnetics 35, 273-283.
95) Van Boxem K, Huntoon M, Van Zundert J, Patijn J, van Kleef M, Joosten EA. 2014 Pulsed radiofrequency: a review of the basic science as applied to the pathophysiology of radicular pain: a call for clinical translation. Reg Anesth Pain Med. 2014 Mar-Apr;39(2):149-59.
96) Liu K, Li Y, Zhang G, Liu J, Cao J, Ao L, Zhang S. 2014 Association between mobile phone use and semen quality: a systematic review and meta-analysis. Andrology 2:491-501.
97) Pilla, AA 2015 Pulsed electromagnetic fields: from signaling to healing. In: Markov, M. S., Ed. 2015. Electromagnetic Fields in Biology and Medicine. CRC Press, Taylor and Francis Group, Boca Raton, FL. , pp. 29-48.
98) Belyaev, I. 2015. Biophysical mechanisms for nonthermal microwave effects. In: Electromagnetic Fields in Biology and Medicine, Marko S. Markov, ed, CRC Press, New York, pp 49-67. (Please note: There are probably a dozen other reviews that from this volume that might be included here on non-thermal effects)
99) Sangün Ö, Dündar B, Çömlekçi S, Büyükgebiz A. 2015 The Effects of Electromagnetic Field on the Endocrine System in Children and Adolescents. Pediatr Endocrinol Rev 13:531-545.
100) Pall, M. L. 2015. Scientific evidence contradicts findings and assumptions of Canadian Safety Panel 6: microwaves act through voltage-gated calcium channel activation to induce biological impacts at non-thermal levels, supporting a paradigm shift for microwave/lower frequency electromagnetic field action. Rev. Environ. Health 3, 99-116.
101) Panagopoulos, D. J., Johansson, O., Carlo, G. L. 2015. Real versus simulated mobile phone exposures in experimental studies. BioMed. Res. Int. 2015, article ID 607053, 8 pages.
102) Mahdavi M, Yekta R, Tackallou SH. 2015 Positive correlation between ELF and RF electromagnetic fields on cancer risk. J Paramed Sci 6(3), ISSN 2008-4978.
103) Morgan LL, Miller AB, Sasco A, Davis DL. 2015 Mobile phone radiation causes brain tumors and should be classified as a probable human carcinogen (2A). Int J Oncol 46(5): 1865-71.
104) Vadalà M, Vallelunga A, Palmieri L, Palmieri B, Morales-Medina JC, Iannitti T. 2015 Mechanisms and therapeutic applications of electromagnetic therapy in Parkinson's disease. Behav Brain Funct. 2015 Sep 7;11:26. doi: 10.1186/s12993-015-0070-z.
105) Lim R, Lee SW, Tan PY, Liong ML, Yuen KH. 2015 Efficacy of electromagnetic therapy for urinary incontinence: A systematic review. Neurourol Urodyn 34(8):713-722.
106) Hedendahl L, Carlberg M, Hardell L. 2015 Electromagnetic hypersensitivity – an increasing challenge to the medical profession. Rev Environ Health 30:209-215.
107) Carpenter DO. 2015 The microwave syndrome or electro-hypersensitivity: historical background. Rev Environ Health. 30:217-222.

108) Yakymenko I, Tsybulin O, Sidorik E, Henshel D, Kyrylenko O, Kysylenko S. 2015 Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. Electromagnetic Biol Med: Early Online 1-16. ISSN: 1536-8378.
109) Panagopoulos DJ, Johansson O, Carlo GL. 2015 Polarization: A Key Difference between Man-made and Natural Electromagnetic Fields, in regard to Biological Activity. Sci Rep. 2015 Oct 12;5:14914. doi: 10.1038/srep14914.
110) Sage C. 2015 The implications of non-linear biological oscillations on human electrophysiology for electrohypersensitivity (EHS) and multiple chemical sensitivity (MCS). Rev Environ Health. 2015;30(4):293-303.
111) Kaszuba-Zwoińska J, Gremba J, Gałdzińska-Calik B, Wójcik-Piotrowicz K, Thor PJ. 2015 Electromagnetic field induced biological effects in humans. Przegl Lek. 2015;72(11):636-41.
112) K Sri N. 2015 Mobile Phone Radiation: Physiological & Pathophysiologcal Considerations. Indian J Physiol Pharmacol. 2015 Apr-Jun;59(2):125-35.
113) Redmayne M, Johansson O. 2015 Radiofrequency exposure in young and old: different sensitivities in light of age-relevant natural differences. Rev Environ Health 30: 323-335.
114) Pall, ML. 2016. Microwave frequency electromagnetic fields (EMFs) produce widespread neuropsychiatric effects including depression. J. Chem. Neuroanat. 75(Pt B):43-51.
115)
116) Warille AA, Onger ME, Turkmen AP, Deniz ÖG, Altun G, Yurt KK, Altunkaynak BZ, Kaplan S. 2016 Controversies on electromagnetic field exposure and the nervous systems of children. Histol Histopathol 31(5):461-468.
117) Vian A, Davies E, Gendraud M, Bonnet P. 2016 Plant Responses to High Frequency Electromagnetic Fields. Biomed Res Int. 2016;2016:1830262. doi: 10.1155/2016/1830262. Epub 2016 Feb 14.
118) Kaplan S, Deniz OG, Önger ME, Türkmen AP, Yurt KK, Aydın I, Altunkaynak BZ, Davis D. 2016 Electromagnetic field and brain development. J Chem Neuroanat 75(Pt B):52-61.
119) Altunkaynak BZ, Altun G, Yahyazadeh A, Kaplan AA, Deniz OG, Türkmen AP, Önger ME, Kaplan S. 2016 Different methods for evaluating the effects of microwave radiation exposure on the nervous system. J Chem Neuroanat. 2016 Sep;75(Pt B):62-9.
120) Dasdag S, Akdag MZ. 2016 The link between radiofrequencies emitted from wireless technologies and oxidative stress. J Chem Neuroanat. 2016 Sep;75(Pt B):85-93.
121) Terzi M, Osberk B, Deniz OG, Kaplan S. 2016 The role of electromagnetic fields in neurological disorders. . J Chem Neuroanat. 2016 Sep;75(Pt B):77-84.
122) Maziarz A, Kocan B, Bester M, Budzik S, Cholewa M, Ochiya T, Banas A. 2016 How electromagnetic fields can influence adult stem cells: positive and negative impacts. Stem Cell Res Ther 2016 Apr 18;7(1):54. doi: 10.1186/s13287-016-0312-5.
123) Soghomonyan D, Trchounian K, Trchounian A. 2016 Millimeter waves or extremely high frequency electromagnetic fields in the environment: what are their effects on bacteria? Appl Microbiol Biotechnol. 100:4761-4771.
124) Maes A, Verschaeve L. 2016 Genetic damage in humans exposed to extremely low-frequency electromagnetic fields. Arch Toxicol. 2016 Jun 23. [Epub ahead of print]
125) Belyaev I, Dean A, Eger H, Hubmann G, Jandrisovits R, Johansson O, Kern M, Kundi M, Lercher P, Mosgöller W, Moshammer H, Müller K, Oberfeld G, Ohnsorge P, Pelzmann P, Scheingraber C, Thill R. 2016 EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. Rev. Environ. Health DOI 10.1515/reveh-2016-0011.
126) Pall ML. 2016 Electromagnetic fields act similarly in plants as in animals: Probable activation of calcium channels via their voltage sensor. Curr Chem Biol 10:74-82.
127) Medeiros LN, Sanchez TG. 2016 Tinnitus and cell phones: the role of electromagnetic radiofrequency radiation. Braz J Otorhinolaryngol. 2016 Jan-Feb;82(1):97-104.

128) Starkey SJ. 2016 Inaccurate official assessment of radiofrequency safety by the Advisory Group on Non-ionising Radiation. Rev Environ Health 31:493-503.
129) Hecht K. 2016 Health Implications of Long-term Exposure to Electrosmog: Effects of Wireless Communication Technologies, pp 1-64. Brochure 6 of A Brochure Series of the Competence Initiative for the Protection of Humanity, the Environment and Democracy E.V. URL: http://kompetenzinitiative.net/KIT/wp-content/uploads/2016/07/KI_Brochure-6_K_Hecht_web.pdf
130) Asghari A, Khaki AA, Rajabzadeh A, Khaki A. 2016 A review on electromagnetic fields (EMFs) and the reproductive system. Electron Physician. 2016 Jul 25;8(7):2655-62.
131) Houston BJ, Nixon B, King BV, De Iuliis GN, Aitken RJ. 2016 The effects of radiofrequency electromagnetic radiation on sperm function. Reproduction. 2016 Dec;152(6):R263-R276.
132) Halgamuge MN. 2017 Review: Weak radiofrequency radiation exposure from mobile phone radiation on plants. Electromagn Biol Med. 2017;36(2):213-235.
133) Bortkiewicz A, Gadzicka E, Szymczak W. 2017 Mobile phone use and risk for intracranial tumors and salivary gland tumors - A meta-analysis. Int J Occup Med Environ Health. 2017 Feb 21;30(1):27-43.
134) 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, Article ID 9218486, https://doi.org/10.1155/2017/9218486
135) Bielsa-Fernández P, Rodríguez-Martín B. 2017 [Association between radiation from mobile phones and tumour risk in adults]. Gac Sanit. 2017 Apr 12. pii: S0213-9111(17)30083-3. doi: 10.1016/j.gaceta.2016.10.014. [Epub ahead of print]
136) Alegría-Loyola MA, Galnares-Olalde JA, Mercado M. 2017 [Tumors of the central nervous system]. Rev Med Inst Mex Seguro Soc. 2017 May-Jun;55(3):330-340.
137) Miah T, Kamat D. 2017 Current Understanding of the Health Effects of Electromagnetic Fields. Pediatr Ann. 2017 Apr 1;46(4):e172-e174. doi: 10.3928/19382359-20170316-01.
138) Facchini G, Spinnato P, Guglielmi G, Albisinni U, Bazzocchi A. 2017 A comprehensive review of pulsed radiofrequency in the treatment of pain associated with different spinal conditions. Br J Radiol. 2017 May;90(1073):20150406. doi: 10.1259/bjr.20150406. Epub 2017 Feb 10.
139) Kim K, Jo D, Kim E. 2017 Pulsed Radiofrequency to the Dorsal Root Ganglion in Acute Herpes Zoster and Postherpetic Neuralgia. Pain Physician. 2017 Mar;20(3):E411-E418.
140) Prasad M, Kathuria P, Nair P, Kumar A, Prasad K. 2017 Mobile phone use and risk of brain tumours: a systematic review of association between study quality, source of funding, and research outcomes. Neurol Sci. 2017 Feb 17. doi: 10.1007/s10072-017-2850-8. [Epub ahead of print].
141) .Mishra SK, Chowdhary R, Kumari S, Rao SB. 2017 Effect of Cell Phone Radiations on Orofacial Structures: A Systematic Review. J Clin Diagn Res. 2017 May;11(5):ZE01-ZE05. doi: 10.7860/JCDR/2017/26547.9883. Epub 2017 May 1
142) Hardell L. 2017 World Health Organization, radiofrequency radiation and health – a hard nut to crack (Review). Int J Oncol 51:405-413.

Journal Pre-proof

Dosimetric assessment in the brain for downlink EMF exposure in Korean mobile communication networks

Ae-Kyoung Lee, Hyung-Do Choi

PII: S0013-9351(23)01346-4

DOI: https://doi.org/10.1016/j.envres.2023.116542

Reference: YENRS 116542

To appear in: *Environmental Research*

Received Date: 27 March 2023

Revised Date: 17 May 2023

Accepted Date: 1 July 2023

Please cite this article as: Lee, A.-K., Choi, H.-D., Dosimetric assessment in the brain for downlink EMF exposure in Korean mobile communication networks, *Environmental Research* (2023), doi: https://doi.org/10.1016/j.envres.2023.116542.

Ae-Kyoung Lee: Conceptualization; Formal analysis; Investigation; Methodology; Software; Visualization; Writing - original draft; Writing. **Hyung-Do Choi**: Project administration; Writing - review & editing

Dosimetric Assessment in the Brain for Downlink EMF Exposure in Korean Mobile Communication Networks

Ae-Kyoung Lee[1] and Hyung-Do Choi[1]

[1] Radio Technology Research Department, Electronics and Telecommunications Research Institute (ETRI), 218 Gajeong-ro, Yuseong-gu, Daejeon, 34129, Korea

E-mail: aklee@etri.re.kr

Abstract

Because the position and direction of the human body is not fixed in an actual environment, the incidence direction of the electromagnetic field (EMF) from mobile communication base stations, WiFi access points, broadcasting towers, and other far-field sources is arbitrary. To analyze the overall health effects of radio frequency EMF exposure, the dosimetric assessment for such environmental exposures created from an unspecified number of sources in daily life, along with exposures from specific EMF sources, must be quantified. This study is aimed at numerically evaluating the time-averaged specific absorption rate (SAR) of the human brain for environmental EMF exposure in the frequency range of 50–5800 MHz. Whole-body exposure to EMFs that are evenly incident spatially is considered. By comparing the results of several incidence directions and the number of polarizations, an optimal calculation condition has been derived. Finally, based on the results measured in Seoul at the end of 2021, the SAR and daily specific energy absorption (SA) in the brains of both a child and an adult for downlink exposures from 3G to 5G base stations are reported. Comparison results of the daily brain SA for exposure to DL EMF in all 3G to 5G mobile networks and exposure to a 10-min voice call (uplink EMF) using a mobile phone connected to a 4G network show that the SA from the downlinks is much higher than that from the uplinks.

Keywords: EMF exposure, mobile communication, downlink, base stations, numerical analysis, SAR, SA, Seoul

1. Introduction

Numerous epidemiological studies have looked for an association between brain tumors and exposure to radio frequency (RF) electromagnetic fields (EMFs) (Cardis et al., 2007; Aydin et al., 2011; Castaño–Vinyals et al., 2022). In Interphone and MOBI-Kids studies, the specific absorption rate (SAR) in the human brain was quantified for various types and frequencies of mobile phones, based upon which the EMF exposure of study subjects was evaluated. In other words, only an uplink (UL) EMF radiated from a mobile phone was considered in previous epidemiological studies.

In a mobile communication network, the term uplink refers to a transmission (access link) from user equipment such as a mobile phone (mobile station) to a base station (fixed station), whereas the term downlink indicates a transmission from a base station to user equipment.

Owing to the continuous development and changes in mobile communication technologies, downlink (DL) EMF radiation from base stations is becoming increasingly complex as networks from different generations of communication technologies (e.g., 3G through 5G) coexist in a single space. Such radiation is not a matter of individual choice and can be present at any time. Not all exposures to DL EMF are of the same frequency and intensity, and depending on the country or region, the mobile communication technologies serviced differ as do the start and end times of a specific service. Therefore, the long-term cumulative exposure of individuals living in different regions may be different. Lifestyle, such as location (e.g., outdoors, at home, or in a school or vehicle) and duration of stay also affect one's cumulative exposure.

The final goal of our study is to evaluate EMF absorption in the detailed brain structures of both a child and an adult for DL EMF exposure in an arbitrary real environment, along with UL EMF exposure owing to mobile phone use within the RF range. To do so, the following two databases (DBs) must be implemented: (1) a DB consisting of the normalized SAR distributions for far- and near-field exposures at the frequencies of interest in the brain at different ages and (2) a DB of the DL and UL exposure levels through large-scale measurements in a real environment. The first DB consists of SAR distributions, normalized to an electric field (E-field) of 1 V/m, as well as spatially uniform and SAR distributions, normalized to the maximum power of the mobile phone when held against the ear. The former SAR distributions are used for DL exposure evaluations, and the latter SAR distributions are used for UL exposure evaluations. The DL and UL exposures can be treated as far- and near-field exposures, respectively. The second DB consists of DL EMF levels and UL power levels measured for each technology. In addition, network and global positioning system (GPS) data at the measurement points are also provided in the DB. Therefore, if these two types of DBs are given, it becomes possible to derive and integrate detailed doses of the brain for real exposure to DL and UL EMFs at various frequencies.

The mobile phone types and SAR distributions related to UL exposure owing to the use of mobile phones, and the UL power level of mobile phones in a real environment have previously been reported (Lee et al., 2016; Lee et al., 2017; Lee et al., 2019; Lee et al., 2020; Lee et al., 2021). These previous studies generated the SAR distributions in the brain of 6- and 9- year-old children, a 15-year-old adolescent and a 22-year-old adult for mobile phone exposure and the SAR distributions become part of the first DB. The SAR level of the distributions corresponds to the values when the

output power of the mobile phone is at maximum, which has been determined for each type of commercial mobile phone model based on a statistical analysis of more than 1400 SAR test reports. Therefore, given the UL power level of a particular mobile phone in a real environment, the SAR of the detailed brain structure of the corresponding age can be obtained for the specific phone radiation (UL exposure).

To develop the second DB, the authors carried out drive test measurements evaluating the DL and UL EMF levels within the residential areas of Seoul, South Korea (conducted for a limited biennial period and in limited locations, i.e., mostly on side streets) (Lee et al, 2020; Lee et al., 2021). Various methods have been used to measure and statistically analyze the EMF levels radiated from sources such as FM and TV broadcast towers, WiFi access points, and base stations (Birks et al., 2018; Choi et al., 2018; Calvente et al., 2016; Zeleke et al, 2018; Aerts et al, 2018; Sagar et al., 2016). In this paper, the far-field EMF radiated from sources in a real environment is referred to as "environmental EMF" and treated as spatially uniform far-field radiation.

Because different frequencies generate different of dose levels in the human body, even when the same EMF levels at different frequencies outside the human body are given, it becomes necessary to provide them in a dose form for an exposure assessment, for instance, as an SAR value rather than as an EMF value.

To simulate EMF exposure, the first DB includes brain SAR distributions for UL EMF (near-field) exposure through mobile phone use and for the incidence (far-field exposure) of a spatially uniform E-field of 1 V/m. This paper focuses on the brain SAR for a far-field exposure. The same human head models that were considered numerically for UL exposure in previous studies (Han et al., 2018; Lee et al., 2019) were used in this research, allowing the integration of mobile phone and base station exposures. To simulate a whole-body exposure, each head model was combined with a body part below the neck appropriate for the corresponding age, which is discussed in Section 2.

The posture of a live human body continuously changes, and at the same time, various electromagnetic waves are present around the body. Therefore, a long-term averaged environmental EMF exposure can be regarded as exposure to multiple plane waves arriving from random directions at the corresponding frequency. Throughout this study, this is numerically considered by assuming plane waves uniformly incident to the human body. The number of incident directions and the number of E-field polarizations of plane waves incident from the outside surrounding the human body were analyzed (Section 3.1) to determine the most suitable combination of incident directions and polarizations for a dosimetric assessment of environmental EMF exposure.

Using the incidence configuration determined in Section 3.1, as the first step, the dose in the brain of both a 6-year-old child and an adult is calculated as the SAR for

environmental EMF exposures with an E-field strength of 1 V/m within the frequency range of 50 MHz to 5.8 GHz, at which FM and TV broadcasting towers, WiFi access points, base stations for mobile communications, and other RF sources radiate EMF. The SAR normalized to 1 V/m can be applied to estimate a specific absorption energy (SA) for the far-field radiation of an individual source or frequency using the corresponding E-field strength and exposure duration in a real environment. As the next step, the SA in the brain in a real DL environment of 3G–5G networks in Seoul is evaluated and compared to the SA of the exposure to the UL EMF of a mobile phone in Voice over Long Term Evolution (VoLTE) mode. These series of results are addressed in Section 3.

2. Material and methods

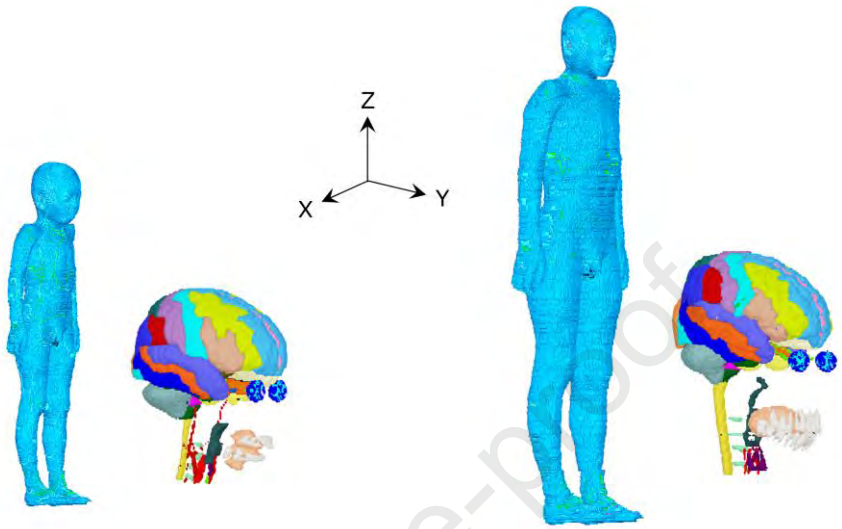
2.1. Implementation of whole-body voxel models

The anatomical morphology of the human head at different ages has been investigated using MRI data from hundreds of Koreans, including young children beginning their mobile phone use to adults (Han et al., 2018). Average head models with detailed brain structures based on the average morphology for the selected age groups of 6-, 9-, 15-, and 20–24-year-old Korean males have been implemented using a total of 70 head structures. The head models were labeled KR-6, KR-9, KR-15, and KR-22. Using these models, the age-dependency of brain exposure for mobile phone use was previously reported (Lee et al., 2020; Lee et al., 2019).

Dosimetric exposure levels should be quantified in the same head model to integrate exposure to the human brain for various environmental EMFs as well as EMFs from local sources such as mobile phones. Therefore, the KR-6 and KR-22 head models are employed in this study. The whole-body models for KR-6 and KR-22 had to be implemented because the exposure of plane waves to only a head model may yield a different brain SAR from that exposed to its whole-body model. Much earlier, the authors developed a whole-body model in a standing posture using magnetic resonance imaging (MRI) data of a 7-year-old child volunteer (Lee et al., 2009), and the 7-year-old model was nonlinearly reformed to produce models at other ages based on external dimensions of the body obtained from the Korean Anthropomorphic Survey (Lee and Choi, 2012).

To implement the whole-body models with KR-6 and KR-22, the following technique was employed in this study. First, the external dimensions of the body part below the neck of the 7-year-old model were non-linearly modified to fit the bodies of 6- and 22-year-old individuals. The heads of the modified models were then replaced with KR-6 and KR-22, respectively. The 6- and 22-year-old whole-body models were implemented using a voxel size of $1 \times 1 \times 1$ mm^3 or $2 \times 2 \times 2$ mm^3, hereafter referred to as KR-6-WB and KR-22-WB, respectively. From the left, KR-6-WB, the internal

structures of KR-6 and KR-22-WB, and the internal structures of KR-22 are shown in Fig. 1, respectively.



KR-6-WB KR-22-WB

Figure 1. Whole-body models KR-6-WB and KR-22-WB ($2 \times 2 \times 2$ mm^3) implemented with head models KR-6 and KR-22.

2.2. Numerical method

The finite-difference time-domain (FDTD) method was used to calculate the SAR of the whole-body models KR-6-WB and KR-22-WB in the frequency range of 50 MHz to 5.8 GHz. In the frequency ranges of 50 MHz to 3 GHz and 3 GHz to 5.8 GHz, uniform cell sizes of $2 \times 2 \times 2$ mm^3 and $1 \times 1 \times 1$ mm^3, respectively, were employed in the computational domain. A perfectly matched layer condition (Berenger, 1994) was employed for the absorbing boundary condition. A human voxel model was located at the center of the computational space for an isolated condition. In the authors' previous study (Lee and Choi, 2012), variations in the WBA SAR owing to changes in the dielectric properties based on age were checked for certain child models within the frequency range of the γ dispersion, and the differences were found to be marginal. Thus, in this study, the SAR was calculated using adult tissue properties according to a 4-Cole–Cole dispersion model (Gabriel, 1996).

As has been reported by many researchers, it is well known that a vertically polarized E-field incidence to the anterior region of the body brings about the highest whole-body average SAR (SAR_{wbody}) at most frequencies in comparison with other polarizations and incident directions. This is despite the fact that a horizontal polarization produces a higher WBA SAR in the region above 2 GHz (Dimbylow et al, 2010; Bakker et al., 2010; Hirata et al., 2010).

However, to evaluate the time-averaged SAR in the brain of a human body in unfixed postures and under exposure to a number of EMF sources surrounding it in a living environment, an infinite number of spatially uniform incident fields with different polarizations and incident directions should be considered at each frequency. Because it is impossible to conduct an infinite number of numerical simulations, an effective configuration with a finite number of plane wave incidences is required.

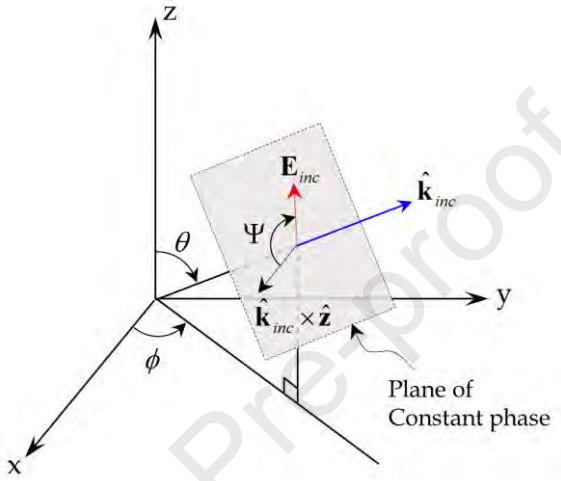


Fig. 2. Propagation direction and polarization of an incident wave (Taflove and Hagness, 2005).

Meanwhile, the method proposed in (Taflove and Hagness, 2005) was employed to define the propagation direction and polarization of an incident plane wave, as shown in Fig. 2. Using the spherical coordinates, the incident unit wave vector $\hat{\mathbf{k}}_{\text{inc}}$ is oriented with an angle θ relative to the +z-axis of the space lattice, where $0° < \theta < 180°$; in addition, with an angle ϕ relative to the +x-axis of the space lattice, where $0° \le \phi < 360°$ (Eq. (1)). To specify the incident-wave polarization, a reference direction $\hat{\mathbf{k}}_{\text{inc}} \times \hat{\mathbf{z}}$ is defined in the plane of the wavefront. An orientation angle Ψ for $\mathbf{E}_{\text{inc}}$ is specified relative to this direction, where $0° < \Psi < 360°$.

$$\hat{\mathbf{k}}_{\text{inc}} = \hat{\mathbf{x}}\sin\theta\cos\phi + \hat{\mathbf{y}}\sin\theta\sin\phi + \hat{\mathbf{z}}\cos\theta \tag{1}$$

For a spatially uniform field incidence, the distances between neighboring field incident points on a virtual spherical surface should be the same. Incidences from the vertices of regular polyhedrons, such as tetrahedron, octahedron, and icosahedron, meet this requirement. There can be a number of combinations of incident directions and polarizations for constructing a spatially uniform incidence of the plane waves. In this study, the vertices of regular octahedron and icosahedron structures are employed as incident directions. The SAR of KR-6-WB was calculated and compared for three

configurations of plane waves incident from the vertices. Details of the three configurations and a comparison of the results are described in Section 3, through which the optimal configuration was selected.

Using the selected incident wave configuration, the SAR_{wbody}, whole-brain average SAR (SAR_{wbrain}), and SAR averaged over 1 g of a brain are calculated as the ratio of the power dissipated in all voxels consisting of tissues of the corresponding body part divided by its total mass. The psSAR is defined as the maximum SAR averaged within a local region based on a specific averaging mass, e.g., any 1 or 10 g of tissue (IEC 2005). Hereafter, the psSAR averaged over a mass of 1 and 10 g is referred to as $psSAR_{1g}$ and $psSAR_{10g}$, respectively. In this paper, the $psSAR_{1g}$ of the brain was calculated according to IEC/IEEE 662704-1 (IEC/IEEE, 2017).

2.3. SAR and SA estimation for real exposure

The total brain exposure to DL and UL EMFs is derived within mobile communication networks in this paper. Using the 1-V/m normalized SAR distribution of a brain calculated according to the method described Section 2.2, the SAR for each mobile communication technology and the integrated SAR are estimated for DL EMFs in real 3G, 4G, and 5G networks.

The DL E-field strengths applied to the SAR estimation for real networks are from the results measured in 2021 using a previously reported method (Lee et al., 2020; Lee et al., 2021). Because this paper focuses on SAR and SA estimations for DL EMF, the measurement approach applied is only briefly summarized. As the measurement equipment used to evaluate the DL EMF for each individual network, an RF scanning receiver (PCTel Hbflex, 10 MHz to 6 GHz) was employed. The received E-field samples from a total of 18 frequency bands related to 3G through 5G networks were recorded along with the GPS data and time information. Meanwhile, an OPTis-M(II) system (Innowireless Co., Ltd.) consisting of a device and control software was used to collect UL power samples provided by the chipset of each mobile phone. Several mobile phones were connected to the measurement system, and UL power samples were recorded during voice calls using 3G and 4G networks and during the uploading and downloading of files in 5G NR networks. Power and field samples provided by the mobile phones and the scanning receiver, respectively, were collected every second while driving along the side streets in residential areas for a longer than 40-min period. The measurements were conducted over approximately a 3-month span, and 0.7×10^6 to 1.0×10^6 samples were collected for each link of each network in Seoul, South Korea.

The second database mentioned in Section 1 consists of the above measurement results for UL and DL exposures. The normalized SAR distributions for the UL exposure of various types of mobile phones were largely derived in previous studies, as mentioned in Section 1. Therefore, given the normalized SAR distributions for the

DL exposure covered in this paper, actual doses from UL and DL exposures in networks used in Seoul can be integrated. The daily accumulated energy or SA for 24-h exposure to DL EMFs is compared with that of exposure to UL EMF, assuming a total of 10 min of voice calls on a mobile phone per day. The SAR and SA results estimated for real mobile networks are described in Section 3.

3. Results

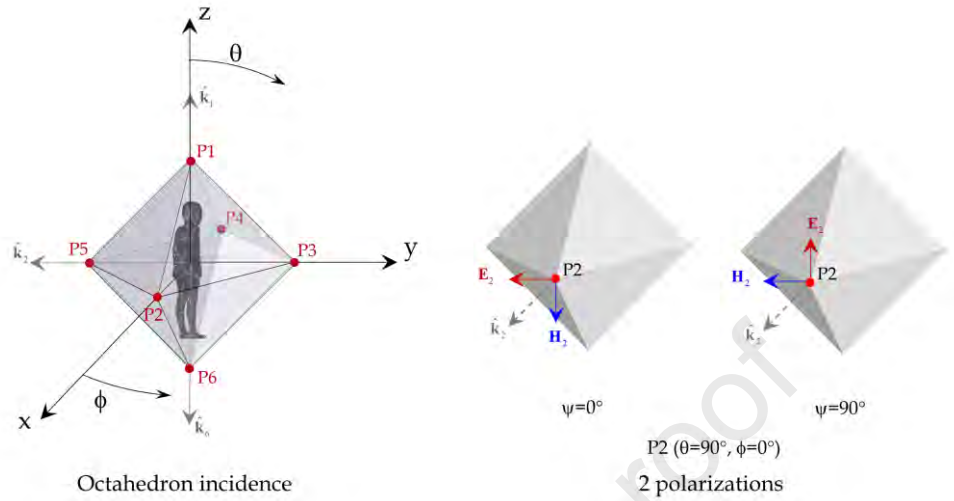
3.1 Comparison of three incident wave configurations

As mentioned in Section 2.2, to simulate a spatially uniform plane wave incidence, the SAR was calculated and compared for three configurations with different incident directions and polarizations. The three configurations shown in Fig. 3 (a), (b), and (c) are applied to KR-6-WB and compared at 900, 1850, 2650, and 3000 MHz, which are the main frequencies related to the mobile communication technologies.

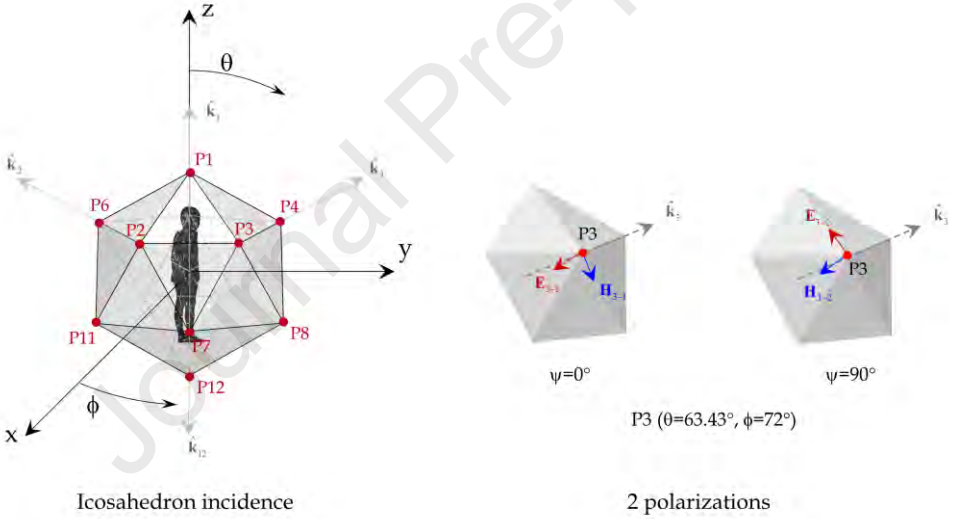
(A) With the Octa-2pol configuration, the incidence directions are from the origin toward six vertices of the octahedron (where the origin of the octahedron coincides with the origin of the coordinate system) surrounding the whole body and in each incidence direction, and two plane waves propagate respectively with mutually orthogonal polarizations (Fig. 3 (a)). The 12 SAR values obtained at each voxel of the body model for a total of 12 plane wave incidences (= 6 directions × 2 polarizations) are averaged.

(B) With the Icosa-2pol configuration, the incidence directions are toward 12 vertices of the icosahedron (where the origin of the icosahedron coincides with the origin of the coordinate system), and in each incidence direction, two plane waves with mutually orthogonal polarizations are respectively considered (Fig. 3 (b)). The 24 SAR values obtained for a total of 24 plane wave incidences (= 12 directions × 2 polarizations) are averaged at each voxel.

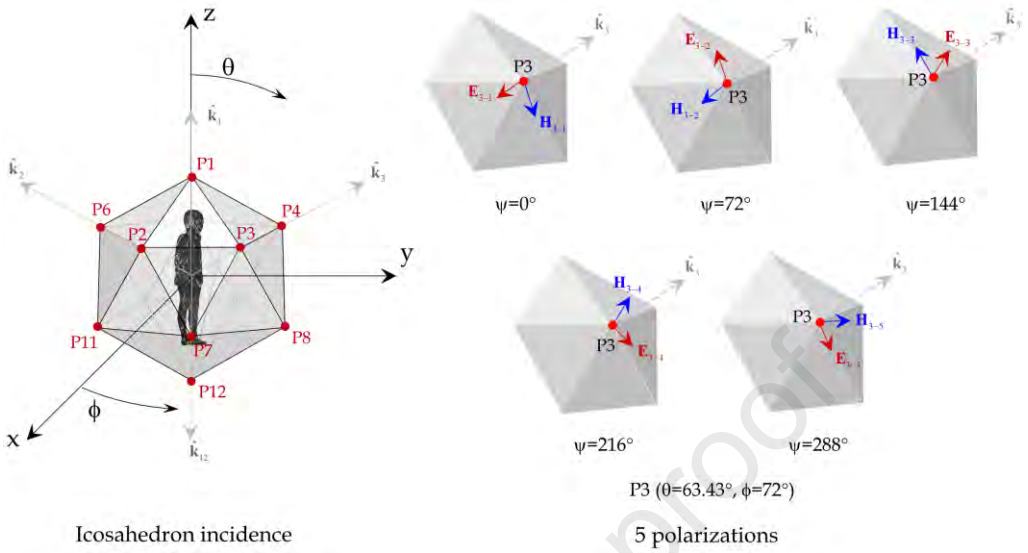
(C) With the Icosa-5pol configuration, the incidence directions are from the origin toward 12 vertices of the icosahedron, and in each incidence direction, five plane waves with linear polarizations at 72° intervals are considered (Fig. 3 (c)). The 60 SAR values obtained for a total of 60 plane wave incidences (= 12 directions × 5 polarizations) are averaged at each voxel.



(a) Octa-2-pol



(b) Icosa-2-pol



(c) Icosa-5-pol

Fig. 3. Three configurations used to numerically simulate spatially uniform EMF incidence.

Configuration (A) has been used for an SAR evaluation of animals exposed to EMF in a reverberation chamber (Gong et al, 2017). It was also recently employed for a far-field exposure assessment of a human body (Liorni et al, 2020). However, the effects on the number of incidence directions and/or polarizations have yet to be reported. Table 1 compares the calculation results on the SAR_{wbody} and whole-brain average SAR (SAR_{wbrain}) of KR-6-WB for the three configurations. It can be seen that the difference in the SAR between the Octa-2pol and Icosa-2pol configurations clearly increases with an increase in frequency. The Icosa-2pol and Icosa-5pol configurations provide higher results than the Octa-2pol configuration in most cases, and the difference between the Icosa-2pol and Icosa-5pol configurations is insignificant (< 0.2%). Based on these results, the SARs of a child and an adult (KR-6-WB and KR-22-WB) in the 50 MHz to 5.8 GHz band were calculated using the Icosa-2pol configuration.

3.2. Normalized SAR_{wbody} and SAR_{wbrain} (50 MHz to 5.8 GHz)

This section reports the SAR_{wbody} and SAR_{wbrain} of child and adult models (KR-6-WB and KR-22-WB, respectively), normalized to 1 V/m within a wide frequency range of 50 MHz to 5.8 GHz, and then compares them with those for a single wave incidence.

The resonant frequency depends on the outer shape of the body viewed from the direction in which the plane wave travels. Figure 4 shows SAR_{wbody} values generated by 24 incident waves according to the Octa-2pol configuration. When the direction (or polarization) of an E-field vector is projected onto the body, the path of the plane

wave along $\hat{\mathbf{k}}$ coincides with the longitudinal direction of the body, and the corresponding plane wave yields the highest SAR_{wbody} within the frequency range of 100–110 MHz, where the 1.144-m height of KR-6-WB corresponds to approximately 0.4-times the wavelength, as reported in previous studies (Lee and Choi, 2012; Dimbylow, 2002). As shown in Fig. 4, this corresponds to the plane waves polarized at $\psi = 90°$ for incident directions $\hat{\mathbf{k}}_2$ through $\hat{\mathbf{k}}_{11}$. Because the electrical length of the body viewed from the incident direction is shortened and diversified, all waves with $\psi = 0°$, including those incidences from the soles of the body ($\hat{\mathbf{k}}_1$) and the top of the head ($\hat{\mathbf{k}}_{12}$), produced a relatively gentle resonance over a wider and higher frequency band.

Figures 5 and 6 show the SAR_{wbody} and SAR_{wbrain} of KR-6-WB and KR-22-WB, respectively, exposed to environmental EMF. They were obtained by averaging the SAR values at each voxel for the 24 individual wave incidences, as stated in Section 2, and then calculating the SAR of the whole body and the entire brain.

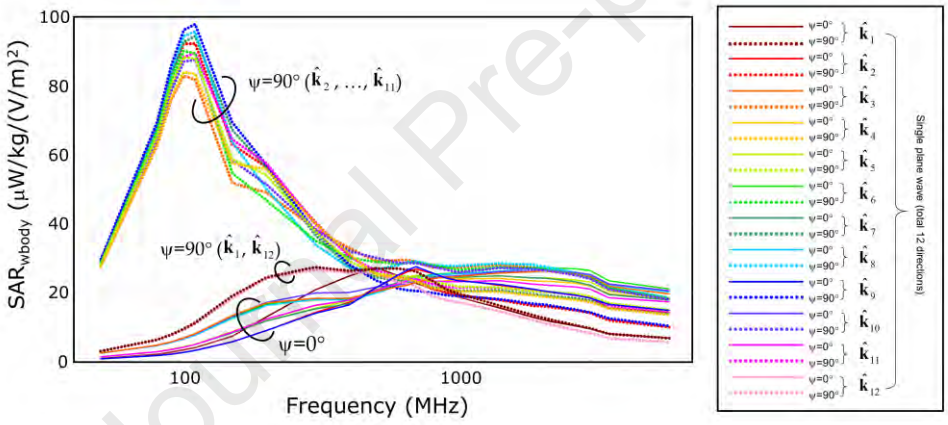


Figure 4. SAR_{wbody} of KR-6-WB for 24 single plane wave exposures. It was normalized to an incident E-field strength of 1 V/m at each frequency.

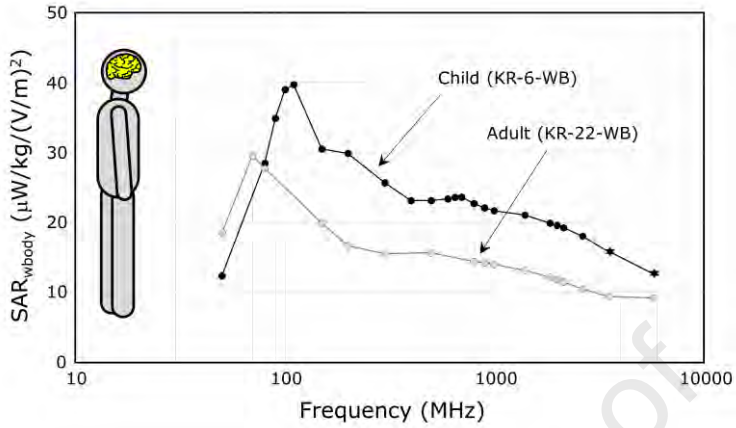


Figure 5. SAR$_{wbody}$ of the child and adult models (KR-6-WB and KR-22-WB) for environmental EMF exposure. At 3.5 and 5.8 GHz, a voxel size of 1 × 1 × 1 mm^3 was used for KR-6-WB, whereas a voxel size of 2 × 2 × 2 mm^3 was used for KR-22-WB owing to an excessive computation time.

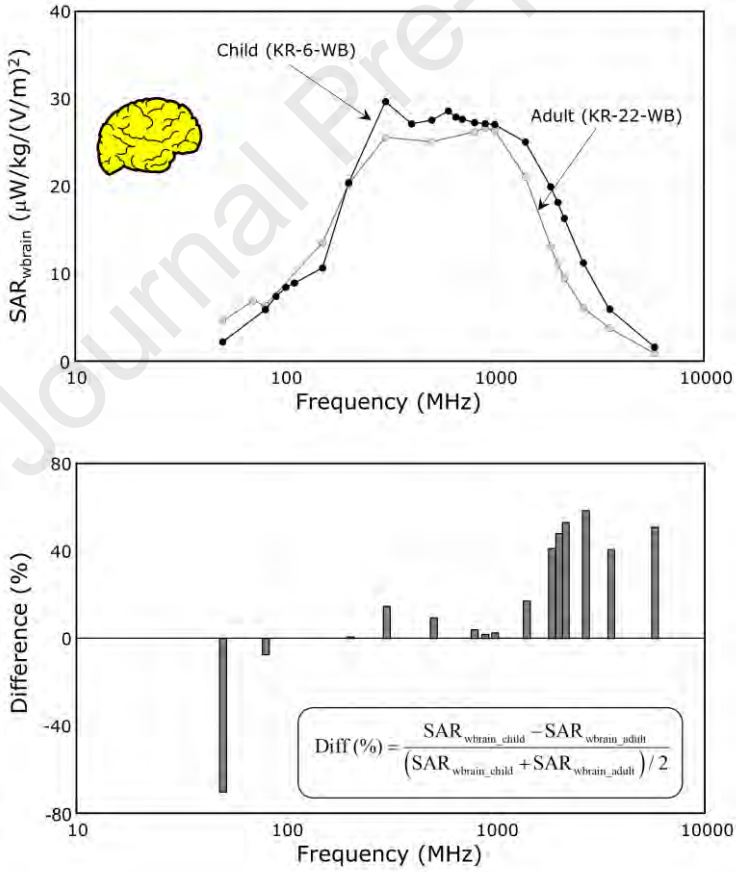


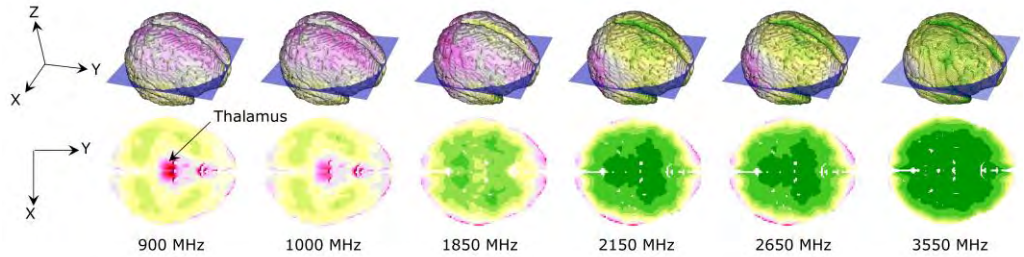
Figure 6. SAR$_{wbrain}$ of the child and adult models for environmental EMF exposure.

The whole-body resonance frequency of KR-6-WB (Fig. 5) is consistent with those of single waves polarized at ψ = 90° for incident directions $\hat{\mathbf{k}}_2$ through $\hat{\mathbf{k}}_{11}$ (Fig. 4); however, the resonance amplitude (Fig. 5) is much lower than that for the single plane wave, i.e., 39.7 μW/kg/(V/m)^2 at 110 MHz for KR-6-WB and 29.5 μW/kg/(V/m)^2 at 70 MHz for KR-22-WB.

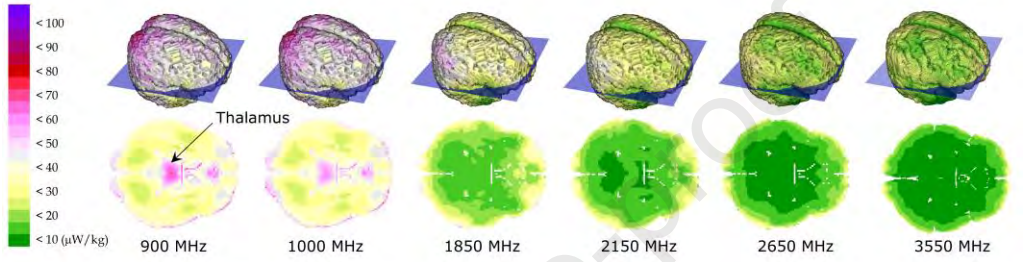
Figure 6 shows the frequency characteristics of the SAR_{wbrain} of the child and adult models. As reported by Lee et al. (2019), KR-6 and KR-22 showed only a 4% difference in brain (white matter and gray matter) volume, i.e., 1219 mm^3 (KR-6) and 1270 mm^3 (KR-22), respectively. Because the shape of the brain is not long in any particular direction, the brain resonance occurred in a relatively wider frequency range than that of the whole body, i.e., in the frequency range of 300–1000 MHz, with a mean of 27.8 and standard deviation (SD) of 0.86 dB for KR-6-WB and a mean of 26.0 and SD of 0.64 dB for KR-22-WB. In addition, as the frequency exited this frequency band (lower and higher frequencies), a larger SAR difference in SAR_{wbrain} between the child and the adult was observed. For example, in the range of 300–1000 MHz, the SAR_{wbrain} levels were similar to each other; however, at 2 GHz, SAR_{wbrain} of the child was approximately 50% higher than that of the adult. A similar tendency in the psSAR was reported for mobile phone exposure at 835 and 1850 MHz (Lee et al., 2019). This similar tendency occurred because the distance from the head surface to the peripheral region of the child brain is closer compared to that of the adult brain, and the penetration becomes shallower than at a higher frequency. At low frequencies of less than 300 MHz, SAR_{wbrain} of the adult was higher than that of the child owing to the resonance of the adult body, and SAR_{wbrain} for both the child and adult models increases sharply over a relatively narrow frequency range.

3.3. DL exposure dose in the brain within a real environment (Seoul, 2021)

Figure 7 shows the SAR distributions on the surface of the whole brain and a cross-section at the mid-height of the brain of KR-6-WB and KR-22-WB for the incidence of a 1-V/m E-field at the six representative frequencies related to a DL used for mobile communication. It is notable that the SAR distributions at low and high frequencies are extremely different. At 900 and 1000 MHz within the resonance frequency region, a high absorption of electromagnetic energy can be observed in deep areas of the brain, such as the midbrain and thalamus. When the frequency exits the resonant region, the absorbed energy is gradually attenuated from the surface of the brain to the inside, resulting in an extremely low absorption at the center. The higher the frequency, the faster the attenuation that is observed.



(a) Child (KR-6-WB)



(b) Adult (KR-22-WB)

Figure 7. Brain SAR distributions of KR-6-WB and KR-22-WB at frequencies related with mobile communication systems. The E-field strength is 1 V/m at each frequency.

As described in Section 2.3, the authors measured the power of DL channels radiated from base stations. In this section, based on the above SAR results, the SAR in the brain of the child and adult models is estimated and presented for a real DL EMF exposure. Table 2 shows the mean E-field strengths for all DL channels operating in 3G–5G networks in 2021. They were obtained by analyzing the channel power samples collected while driving along the side streets in residential areas of Seoul, as previously reported (Lee et al., 2020; Lee et al., 2021). The E-field strength for each frequency band is labeled as $E_{f,n}$, where the subscripts f and n represent the frequency (MHz) and its serial number, respectively, as shown in the second column from the right. Among the six frequencies (Fig. 7) where the SAR was calculated, the frequency is that closest to the channel frequency.

The SAR distributions at the six frequencies shown in Fig. 7 were used for an integrative dosimetric evaluation in the brain of KR-6-WB and KR-22-WB for 3G–5G DL exposures, i.e., the SAR at 900 MHz for 4G B5 DL, the SAR at 1850 MHz for 4G B3 DL, the SAR at 2150 MHz for UMTS2100 and 4G B1 DL, the SAR at 2650 MHz for 4G B7 DL, and the SAR at 3550 MHz for 5G DL. The following integrative SAR distribution was obtained:

$$\begin{aligned} \mathrm{SAR}_{\mathrm{integrative}}(x,y,z) = {} & \hat{\mathrm{SAR}}_{900}(x,y,z)\cdot\sum_{n=1}^{2}\mathrm{E}_{900,n}^{2} + \hat{\mathrm{SAR}}_{1000}(x,y,z)\cdot\sum_{n=1}^{1}\mathrm{E}_{1000,n}^{2} + \\ & \hat{\mathrm{SAR}}_{1850}(x,y,z)\cdot\sum_{n=1}^{3}\mathrm{E}_{1850,n}^{2} + \hat{\mathrm{SAR}}_{2150}(x,y,z)\cdot\sum_{n=1}^{6}\mathrm{E}_{2150,n}^{2} + \\ & \hat{\mathrm{SAR}}_{2650}(x,y,z)\cdot\sum_{n=1}^{3}\mathrm{E}_{2650,n}^{2} + \hat{\mathrm{SAR}}_{3550}(x,y,z)\cdot\sum_{n=1}^{3}\mathrm{E}_{3550,n}^{2} \end{aligned} \quad (2)$$

where $\hat{\mathrm{SAR}}_f(x, y, z)$ is a normalized value for an E-field strength of 1 V/m at a three-dimensional point (x, y, z) in biological tissue, of which the present authors focused on brain tissue. The subscripts f and n represent the SAR-calculated frequency (MHz) and the serial number of the sub-frequency regions for the DL within a frequency f of ±5%, respectively. For instance, when f is 1850, there are total three sub-frequency bands (n = 1, 2, and 3) within 1850 MHz ±5%, as shown in Table 2.

Liorni et al. (2020) described the concept of integrative exposure for multiple RF sources based on normalized SAR results for various human body models. The evaluation method, which overlaps the SAR distributions at different frequencies, as shown in Eq. (2), was also reported in IEC/IEEE 62209-1528 (2020) to be the most accurate method for evaluating the combined SAR under situations in which the human body is simultaneously exposed to different sources.

Figure 8 shows the SAR distributions of child and adult brains in the DL EMF environment of each technology and the environment where the DL EMFs for all 3G, 4G, and 5G NR network technologies are integrated. The mean E-field strength in Table 2 was applied to Eq. (2). The integrative SAR distribution on the far-right side of Fig. 8 is extremely similar to the SAR distribution of only 4G networks. The DL exposure within the mobile communication environment of Seoul in 2021 was primarily contributed to by the LTE networks rather than the others.

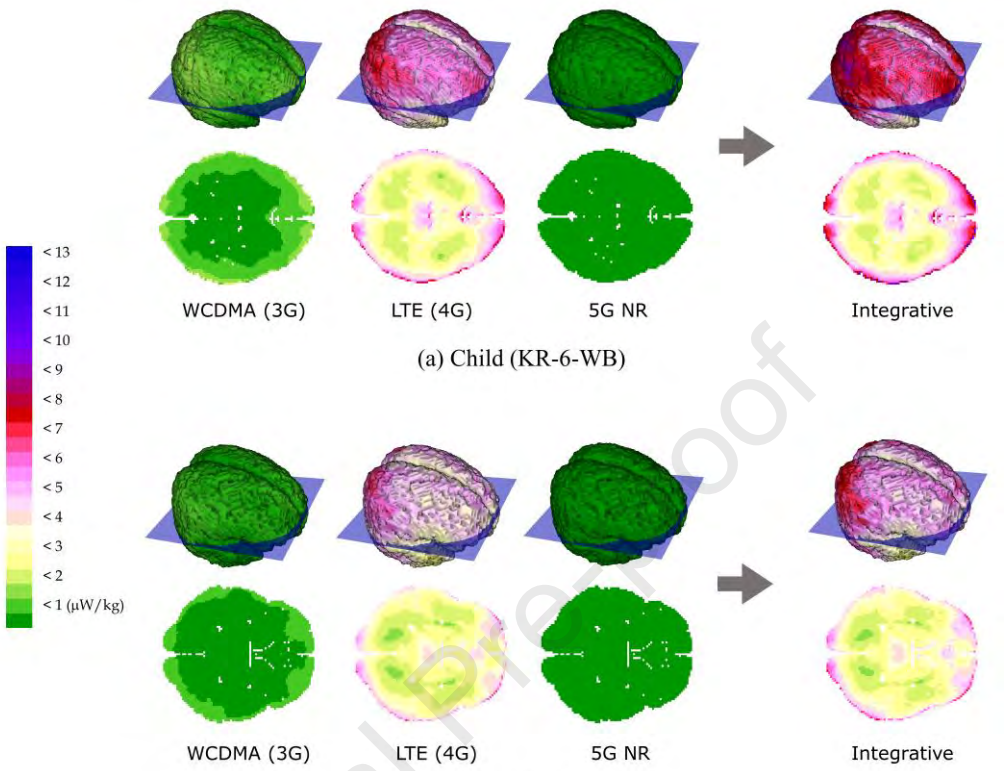


Figure 8. Brain SAR distributions for DL exposure in 3G, 4G, and 5G NR networks (Seoul, 2021).

As can be observed visually in Fig. 8, the brain SAR of KR-6-WB was approximately 25% higher than that of KR-22-WB, i.e., the SAR_{wbrain} was 3.45 and 2.69 μW/kg for KR-6-WB and KR-22-WB, respectively. The head part of these models was segmented into a total of 69 structures, and in particular, the grey matter of the cerebral cortex was subdivided into 27 gyri (Han et al, 2018; Lee et al., 2019). Figure 9 compares the SAR values for detailed structures of the brain between KR-6-WB and KR-22-WB for the above DL environment (integrated). Excluding the uncus of the limbic lobe, the brain structure-averaged SAR ($SAR_{structure-avg}$) of KR-6-WB was 27.4% higher on average compared to that of KR-22-WB in 40 of the 41 structures considered (see Fig. 9).

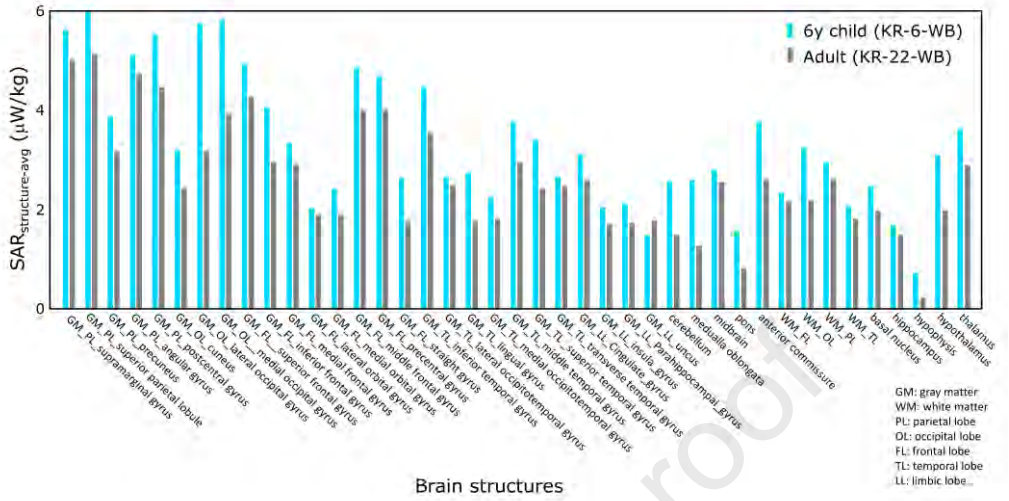


Figure 9. SAR averaged over each structure consisting of a brain for exposure to the mean E-field strengths (DL) measured in 3G, 4G, and 5G NR networks (Seoul, 2021).

3.4. Dose comparison and integration of DL and UL exposures

The SAR_{wbrain} and brain $psSAR_{1g}$ for UL and DL exposures are shown in Fig. 10. The SAR results for UL exposure are for voice calls when using a mobile phone connected to the 4G network of operator O_A, which has the largest number of mobile subscribers in South Korea as of 2021. The SAR was evaluated using the same approach applied by Lee et al. (2020), where the brain SAR for EMF exposure was caused by user voice calls on mobile phones, i.e., UL EMF exposure was assessed under all available mobile communication networks of the corresponding operator in Seoul.

As mentioned in Section 1, exposure to UL EMF alone has been considered in many previous epidemiological studies seeking out an association between brain tumors and RF EMF. It has been confirmed that DL exposure cannot be overlooked in the evaluation of EMF exposure in mobile communication networks through a comparison of the brain dose (SAR and SA) levels for UL and DL exposures, as shown in Fig. 10. The brain $psSAR_{1g}$ for UL exposure is much higher than that for DL exposure, whereas SAR_{wbrain} shows similar levels for both exposures. The considered UL exposure is the most probable case; that is, the transmitting antenna of the mobile phone was located at the bottom, and when calculating the SAR, the measured connection ratios among the LTE frequency bands of O_A were applied as weights (Lee et al., 2020). The mean of the measured UL power samples of a mobile phone was used, which was within the range of approximately 0.1–0.25 mW for the LTE bands of B1, B3, and B5. The UL frequency bands allocated for B1, B3, and B5 are 1940–1950, 1715–1735, and 829–839 MHz, respectively. In addition, it was assumed that the user makes a call by placing the mobile phone on the right side of the head.

Therefore, the SAR of the right temporal and frontal lobes of the brain was dominantly high, as shown in the SAR distribution of KR-6-WB in Fig. 10.

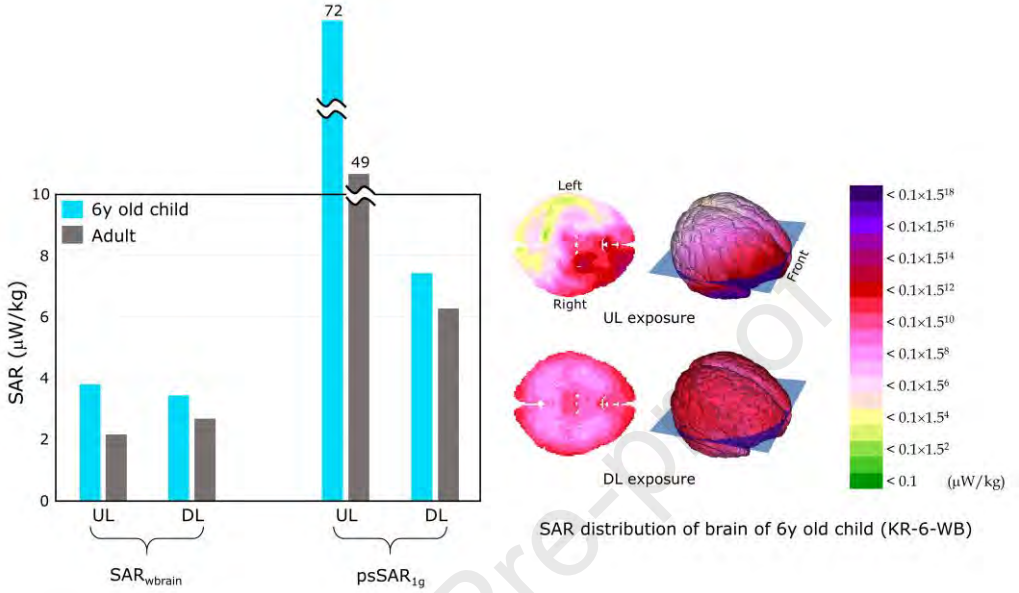


Figure 10. Brain SAR of the child and adult models (KR-6-WB and KR-22-WB) in real networks (Seoul, 2021).

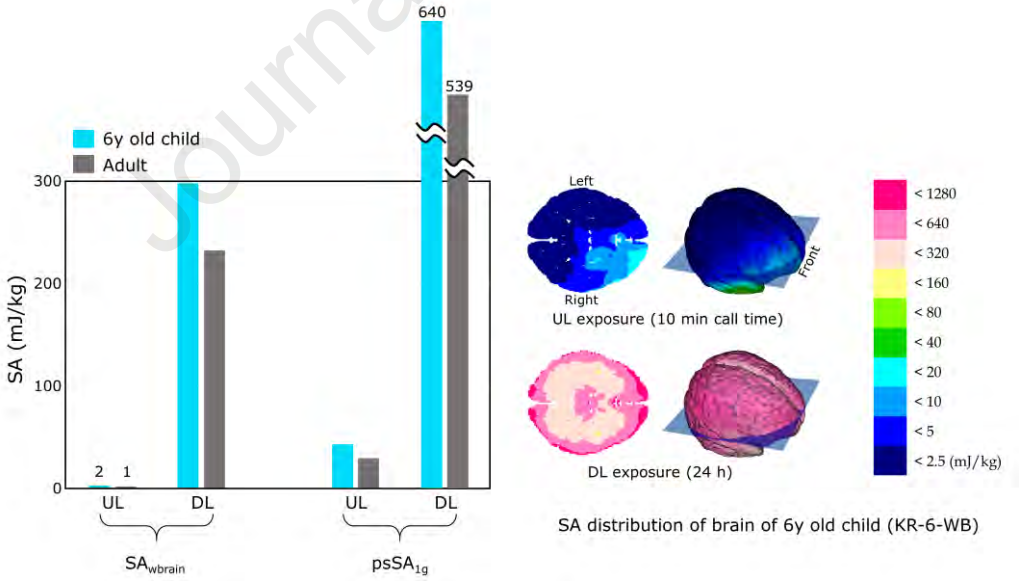


Figure 11. Daily brain SA of the child and adult models (KR-6-WB and KR-22-WB) in real networks (Seoul, 2021). Differences of more than 10 fold are shown in the SA between the EMF exposures of UL and DL.

The assessment of the health effects of RF EMF in many studies (Cardis et al., 2011; Castaño–Vinyals et al., 2022; Calderón et al., 2022) has been tried on a cumulative dosimetric quantity over time, which is likely related to EMF exposure. The time-cumulative physical quantity of SAR (W/kg) is often expressed as SA (J/kg). The daily SA averaged over the whole brain (SA_{wbrain}) and the peak spatial-averaged SA over 1 g of tissue ($psSA_{1g}$) in the brain are shown in Fig. 11.

The SA for DL exposure was obtained by multiplying the above DL SAR by 86,400 s (3600 s/h × 24 h) because the human body is in general continuously exposed to DL EMF regardless of the will of the person being exposed. However, for the SA of UL exposure, as an example comparison with the dose from DL EMF, the UL SAR was multiplied by 600 s for both KR-6-WB and KR-22-WB, assuming a total call time of 10 min per day. In Castaño-Vinyals et al. (2022), the median total call durations reported in age groups of 10–14 and 20–24 years were 53 and 655 h, respectively. It was estimated that the 20–24-year-old age group spent approximately 10.7 min on voice calls per day, assuming they have used a mobile phone during the past 10 years. In the case of a 6-year-old child, although the duration of the call might be much shorter than that of an adult, the 10-min call time was applied to both the child and adult models. Contrary to the SAR results shown in Fig. 10, it can be seen that the daily cumulative energy in the brain is much higher for DL than for UL.

Although the mean E-field strengths for DL EMFs across the Seoul area were applied to the exposure assessment in this study, in the future, it will be necessary to differentiate the frequencies and E-field strengths when considering individual life patterns and small-scale differences in regional networks.

4. Summary and discussion

In this paper, evaluating the energy absorption of the human brain in an EMF environment radiated from the base stations, a spatially uniform exposure consisting of 24 incident plane waves was applied to numerically simulate environmental EMF exposure within the frequency range of 50 MHz to 5.8 GHz. This approach was determined by comparing the results of a few configurations of plane wave incidences (see Section 3.1). The SARs for whole-body models (KR-6-WB and KR-22-WB) of a 6-year-old child and an adult were calculated, and SAR_{wbody} and SAR_{wbrain} normalized to 1 V/m were reported. The brain SAR was converted to that in a real exposure environment using the results of large-scale DL EMF measurements conducted in Seoul in 2021. Finally, the brain SA for 24-h exposure to the DL environment was obtained and the results were compared with those for a 10-min exposure to the UL

power level of a mobile phone. The UL data were collected for voice calls in an LTE network during the same time period as the DL EMF measurement.

The main findings and issues obtained from these processes are as follows.

- *Frequency and SAR for environmental EMF exposure (see Section 3.2)*
  For the evaluation of a long-term exposure to far-field EMFs in real life, the environmental exposure was assumed to be a spatially uniform plane wave exposure. The whole-body resonance frequency was consistent with those of single waves vertically polarized when the whole-body models of a child and an adult were exposed to spatially uniform plane waves. The resonance frequency was approximately 110 and 70 MHz for KR-6-WB and KR-22-WB, respectively. However, the resonance amplitude of SAR_{wbody} was much lower than that for a single plane wave because the SAR results were averaged for exposures to plane waves of all polarizations and incident directions. The whole-brain resonance occurred within a relatively wider frequency range than that of the whole body because the shape of the brain is not long in one particular direction. The standard deviation was less than 1 dB in SAR_{wbrain} for each brain was shown in the frequency range of 300–1000 MHz.

- *Age difference in brain SAR (see Sections 3.2 and 3.3)*
  In the frequency range of 300–1000 MHz, the SAR_{wbrain} levels of the child and adult models were extremely similar to each other; in other words, the frequency did not affect their SAR_{wbrain}. However, at the higher frequencies outside this frequency range, the SAR_{wbrain} of the child model gradually increased compared to that of the adult model because the distance from the head surface to the peripheral region of the child brain is shorter in comparison to that of the adult brain, and the penetration becomes shallower at a higher frequency. At frequencies lower than 300 MHz, SAR_{wbrain} of the adult was higher, which seems to be influenced by the whole-body resonance of the adult. The $SAR_{structure\text{-}avg}$ of the child in most brain structures and the SAR_{wbrain} of the child were approximately 27% and 25% higher, respectively, compared to the adult in a real DL EMF environment of Seoul (2021), where WCDMA, LTE, and 5G NR were being serviced.

- *Difference in doses between UL and DL exposures (see Sections 3.4)*
  Although this paper is mainly focused on DL exposure calculations, the brain dose (SAR and SA) levels for UL and DL exposures were compared. The brain $psSAR_{1g}$ for UL exposure is much higher than that for DL exposure at the mean Tx (UL) power of a mobile phone in VoLTE mode; however, the SAR_{wbrain} shows similar levels for both exposures. The energy in the brain from an UL signal from

a mobile phone when assuming a 10-min call time per day showed a much lower contribution to the integrated cumulative energy (SA) of all EMFs in the mobile communication networks, in comparison to that from DL signals (24-h exposure). Thus, it was confirmed that DL exposure cannot be ignored in the exposure evaluation for the studies seeking the association between chronic brain diseases and EMF exposure related to mobile communication services.

5. Conclusion

Many studies have investigated and reported the environmental EMF radiated from various far-field sources, such as broadcasting stations and mobile communication base stations. The authors previously implemented virtual head models with a statistically average structure for children, adolescents, and adults of various ages, and calculated and reported the brain SAR for various mobile phone exposures. In addition, to quantify the total exposure to UL and DL EMFs in real mobile communication networks, the UL and DL exposure levels in all networks operating in Seoul have been evaluated every other year since 2015. The relationship between an EMF outside the body and the corresponding dose of a specific organ inside the body is not simple.

In this paper, the optimal configuration of the incident waves simulating human exposure to an environmental EMF, such as DL fields radiated from base stations was derived and applied to the SAR calculation for virtual whole-body models of both a child and an adult. By combining the calculated UL and DL SAR distributions with the UL and DL EMF levels measured in Seoul in 2021, it was shown that the cumulative dose for each detailed structure of the brain can be derived for the exposure of a specific person living in the corresponding environment.

Comparison of the cumulative doses from UL and DL EMF exposures showed that the DL exposure must be included in the comprehensive evaluation of the RF exposure. With the recent emergence of 5G NR, the resulting EMF exposure environment is becoming more complex than in the past, and it is therefore necessary to evaluate the rapidly changing environmental EMF in more detail in terms of time and space.

Acknowledgements

This work was supported by Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (MSIT) (2019-0-00102, A Study on Public Health and Safety in a Complex EMF Environment).

References

572 Aerts, S., Wiart J., Martens, L., Joseph, W., 2018. Assessment of long-term spatio-temporal
573 radiofrequency electromagnetic field exposure. Environ. Res. 161, 136–143. DOI:
574 10.1016/j.envres.2017.11.003
575 Aydin, D., Feychting, M., Schüz, J., Tynes, T., Andersen, T.V. et al., 2011. Mobile phone use
576 and brain tumors in children and adolescents: a multicenter case-control study. J. Natl
577 Cancer. Inst. 103(16), 1264–1276. DOI: 10.1093/jnci/djr244
578 Bakker, J. F., Paulides, M. M., Christ, A., Kuster, N., van Rhoon, G. C., 2010. Assessment of
579 induced SAR in children exposed to electromagnetic plane waves between 10 MHz and
580 5.6 GHz. Phys. Med. Biol. 55, 3115–3130. DOI: 10.1088/0031-9155/55/11/009
581 Berenger J., 1994. A perfectly matched layer for the absorption of electromagnetic waves. J.
582 Comput. Phys. 114 185–200. DOI: 10.1006/jcph.1994.1159
583 Birks, L.E., Struchen, B., Eeftens, M., van Wel L., Huss, A. et al., 2018. Spatial and temporal
584 variability of personal environmental exposure to radio frequency electromagnetic fields in
585 children in Europe. Environ. Int. 117, 204-214. DOI: 10.1016/j.envint.2018.04.026
586 Calderón, C., Castaño–Vinyals, G., Maslanyj, M., Wiart, J., Lee, A-K., Taki, M., Wake, K.,
587 Abert, A., Badia, F., Hadjem, A., Kromhout, H., de Llobet, P., Varsier, N., Conil, E., Choi,
588 H-D., Sim, M. R., Cardis, E., 2022. Estimation of RF and ELF dose by anatomical location
589 in the brain from wireless phones in the MOBI-Kids study. Environ. Int. 163 107189.
590 DOI: 10.1016/j.envint.2022.107189
591 Calvente, I., Pérez-Lobato, R., Núñez, M-I., Ramos, R., Guxens, M., et al., 2016. Does
592 exposure to environmental radiofrequency electromagnetic fields cause cognitive and
593 behavioral effects in 10-year-old boys? Bioelectromagnetics 37, 25–36. DOI:
594 10.1002/bem.21951
595 Cardis, E., Richardson, L., Armstrong, B., Feychting, M., Johansen, C. et al., 2007. The
596 INTERPHONE study: design, epidemiological methods, and description of the study
597 population. Eur. J. Epidemiol. 22, 647–664. DOI: 10.1007/s10654-007-9152-z
598 Cardis, E., Varsier, N., Bowman J.D., Deltour, I., Figuerola, J., Mann, S., Moissonnier, M.,
599 Taki, M., Vecchia, P., Villegas, R., Vrijheid, M., Wake, K., Wiart, J., 2011. Estimation of
600 RF energy absorbed in the brain from mobile phones in the Interphone Study. Occup.
601 Environ. Med. 68 686–693. DOI:10.1136/oemed-2011-100065
602 Castaño-Vinyals, G., Sadetzki, S., Vermeulen, R., Momoli, F., Kundi, M., Merletti, F.,
603 Maslanyj, Calderón, C., Wiart, J., Lee, A-K., Taki, M., Sim, M., Armstrong, B., Benke,
604 G., Schattner, R., Hutter, H.-P., Krewski, D., Mohipp, C., Ritvo, P., Spinelli, J., Lacour,
605 B., Remen, T., Radon, K., Weinmann, T., Petridou, E.T., Moschovi, M., Pourtsidis, A.,
606 Oikonomou, K., Kanavidis, P., Bouka, E., Dikshit, R., Nagrani, R., Chetrit, A., Bruchim,
607 R., Maule, M., Migliore, E., Filippini, G., Miligi, L., Mattioli, S., Kojimahara, N.,
608 Yamaguchi, N., Ha, M., Choi, K., Kromhout, H., Goedhart, G., 't Mannetje, A., Eng, A.,
609 Langer, C.E., Alguacil, J., Aragonés, N., Morales-Suárez-Varela, M., Badia, F., Albert, A.,
610 Carretero, G., Cardis, E., 2022. Wireless phone use in childhood and adolescence and
611 neuroepithelial brain tumours: Results from the international MOBI-Kids study. Environ.
612 Int. 160, 107069. DOI: 10.1016/j.envint.2021.107069
613 Choi, J., Hwang, J-H., Lim, H., Joo, H., Yang, H-S., et al., 2018. Assessment of radiofrequency
614 electromagnetic field exposure from personal measurements considering the body
615 shadowing effect in Korean children and parents. Science of the Total Environment 627,
616 1544–1551. DOI: 10.1016/j.scitotenv.2018.01.318
617 Dimbylow, P. J., 2002. Fine resolution calculations of SAR in the human body for frequencies
618 up to 3 GHz. Phys. Med. Biol. 47, 2835–2846. DOI: 10.1088/0031-9155/47/16/301

Dimbylow, P., Bolch, W., Lee, C., 2010. SAR calculations from 20 MHz to 6 GHz in the University of Florida newborn voxel phantom and their implications for dosimetry. Phys. Med. Biol. 55, 1519-1530. DOI: 10.1088/0031-9155/55/5/017

Gabriel, S., Lau R.W., Gabriel, C., 1996. The dielectric properties of biological tissues: III. Parametric models for the dielectric spectrum of tissues. Phys. Med. Biol. 41, 2271. DOI: 10.1088/0031-9155/41/11/003

Gong, Y., Capstick, M.H., Kuehn, S., Wilson, P.F., Ladbury, J.M., Koepke, G., McCormick, D.L., Melnick, R.L., Kuster, N., 2017. Life-time dosimetric assessment for mice and rats exposed in reverberation chambers for the two-year NTP cancer bioassay study on cell phone radiation. IEEE Trans. Electromagn. Compat. 59(6), 1798–1808. DOI: 10.1109/TEMC.2017.2665039

Han, M., Lee, A-K., Choi, H-D., Jung, Y.W., Park, J.S., 2018. Averaged head phantoms from magnetic resonance images of Korean children and young adults. Phys. Med. Biol. 63, 035003. DOI: 10.1088/1361-6560/aaa1c7

Hirata, A., Fujiwara, O., Nagaoka, T., Watanabe, S., 2010. Estimation of whole-body average SAR in human models due to plane-wave exposure at resonance frequency. IEEE Trans. Electromagn. Compat. 52(1), 41-48. DOI: 10.1109/TEMC.2009.2035613

IEC/IEEE 62704-1, 2017. Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz – Part 1: General requirements for using the finite-difference time-domain (FDTD) method for SAR calculations.

IEC/IEEE 62209-1528, 2020. Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Part 1528: Human models, instrumentation, and procedures (Frequency range of 4 MHz to 10 GHz)

Lee, A-K., Byun, J-K., Park, J.S., Choi, H-D., Yun, J., 2009. Development of 7-year-old Korean child model for computational dosimetry. ETRI J. 31, 237–239. DOI: 10.4218/etrij.09.0208.0342

Lee, A-K., Choi, H-D., 2012. Determining the influence of Korean population variation on whole-body average SAR. Phys. Med. Biol. 57, 2709–2925. DOI: 10.1088/0031-9155/57/9/2709

Lee, A-K., Choi, H-D., 2020. Brain EM exposure for voice calls of mobile phones in wireless communication environment of Seoul, Korea. IEEE Access 8, 163176–163185. DOI: 10.1109/ACCESS.2020.3020831

Lee, A-K., Hong, S-E., Kwon, J-H., Choi, H-D., Cardis, E., 2017. Mobile phone types and SAR characteristics of the human brain, Phys. Med. Biol. 62, 2741–2761. DOI: 10.1088/1361-6560/aa5c2d

Lee, A-K., Jeon, S-B., Choi, H-D., 2021. EMF levels in 5G new radio environment in Seoul, Korea. IEEE Access 9, 19716–19722. DOI: 0.1109/ACCESS.2021.3054363

Lee, A-K., Park, J. S., Hong, S-E., Taki, M., Wake, K., Wiart, J., Choi, H-D., 2019. Brain SAR of average male Korean child to adult models for mobile phone exposure assessment, Phys. Med. Biol. 64, 045004. DOI: 10.1088/1361-6560/aafcdc

Lee, A-K., Yoon, Y., Lee, S., Lee, B., Hong, S-E., Choi, H-D., Cardis, E., 2016. Numerical implementation of representative mobile phone models for epidemiological studies, J. Electromagn. Eng. Sci. 16(2), 87–99. DOI: 10.5515/JKIEES.2016.16.2.87

Liorni, I., Capstick, M., van Wel, L., Wiart, J., Joseph, W., Cardis, E., Guxens, M., Vermeulen, R., Thielens, A., 2020. Evaluation of specific absorption rate in the far-field, near-to-far field and near-fields regions for integrative radiofrequency exposure assessment. Radiat. Prot. Dosimetry 190(4), 459-472. DOI: 10.1093/rpd/ncaa127

668 Sagar, S., Struchen, B., Finta, V., Eeftens, M., Roosli, M., 2016. Use of portable exposimeters
669 to monitor radiofrequency electromagnetic field exposure in the everyday environment,
670 Environ. Res. 150, 289–298. DOI: 10.1016/j.envres.2016.06.020
671 Taflove, A., Hagness, S.C., 2005 "Incident wave source conditions," in Computational
672 Electrodynamics, the Finite-Difference Time-Domain Method. 3rd ed. Boston: Artech
673 House, ch. 5 sec. 5.8, 204–205.
674 Zeleke, B.M., Brzozek, C., Bhatt, C. R., Abramson, M. J., Croft, R.J., Freudenstein, F.,
675 Wiedemann, P., Benke, G., 2018. Personal exposure to radio frequency electromagnetic
676 fields among Australian adults. Int. J. Environ. Res. Public Health 15(10), 2234. DOI:
677 10.3390/ijerph15102234
678

679 Table 1. SAR comparison between the configurations for uniform EMF incidence (KR-6-WB). The
680 incident E-field strength is 1 V/m.

681 (a) SAR_{wbody}

682 SAR unit: (μW/kg)

Frequency (MHz)	Octa-2pol (A)	Icosa-2pol (B)	Icosa-5pol (C)	Difference (%)	
				(B) – (A)[1)]	(B) – (C)
900	22.137	22.053	22.021	–0.38	+0.18
1850	18.941	19.867	19.862	+4.78	+0.06
2650	16.684	17.982	17.967	+7.48	+0.08
3000	15.683	17.063	17.043	+8.43	+0.12

683 [1)] $\text{Diff}(\%) = \dfrac{(B)-(A)}{\left(\dfrac{(B)+(A)}{2}\right)} \cdot 100$

684

685 (b) SAR_{wbrain}

686 SAR unit: (μW/kg)

Frequency (MHz)	Octa-2pol (A)	Icosa-2pol (B)	Icosa-5pol (C)	Difference (%)	
				(B) – (A)	(B) – (C)
900	27.672	27.215	27.168	–1.67	+0.17
1850	19.675	19.971	19.970	+1.49	0.00
2650	10.908	11.255	11.255	+3.13	0.00
3000	8.331	8.681	8.681	+4.12	0.00

687

688 Table 2. Mean E-field levels for DL channels of 3G, 4G, and 5G networks (Seoul, 2021).

Technology	Operator	Allocated freq. (DL) (MHz)	Band name[1)]	Channel no.[1)]	E-field strength (linear mean) (mV/m)	
3G (WCDMA)	O_A	2145-2150	UMTS 2100	10737	$E_{2150,1}$	105
	O_B	2160-2170	UMTS 2100	10812	$E_{2150,2}$	52
				10836	$E_{2150,3}$	99
4G (LTE-FDD)	O_A	2130-2145	B1	275	$E_{2150,4}$	106
		1810-1830	B3	1350	$E_{1850,1}$	130
		874-884	B5	2500	$E_{900,1}$	116
		2620-2640	B7	2850	$E_{2650,1}$	84
		2660-2670	B7	3200	$E_{2650,2}$	52
	O_B	2150-2160	B1	450	$E_{2150,5}$	70
		1830-1850	B3	1550	$E_{1850,2}$	117
		1850-1860	B3	1694	$E_{1850,3}$	99
		950-960	B8	3743	$E_{1000,1}$	165
	O_C	2110-2130	B1	100	$E_{2150,6}$	112
		884-894	B5	2600	$E_{900,2}$	132
		2640-2660	B7	3050	$E_{2650,3}$	76
5G NR[2)] (TDD)	O_A	3600-3700	n78	640001-646666	$E_{3550,1}$	23
	O_B	3500-3600	n78	633334-640000	$E_{3550,2}$	25
	O_C	3420-3500	n78	628000-633333	$E_{3550,3}$	68

689 [1)] It indicates UARFCN† for WCDMA, EARFCN†† for LTE, and NR-ARFCN††† for 5G NR.
690 [2)] Time-averaged SSB radiation. The sum of the SS-RSRPs of all SSB beams of O_C was used to calculate
691 the time-average SSB power of O_C.
692 † UMTS Absolute radio-frequency channel number
693 †† EUTRA Absolute radio-frequency channel number
694 ††† NR-Absolute radio-frequency channel number

695

Highlights

- EMFs radiated from base stations of 3G through 5G coexist in a single space.
- Dose in brain structures of a child and an adult for DL EMF exposure is evaluated.
- Doses between typical DL and UL EMF exposures in Seoul are compared.
- A daily SA from DL EMFs is much higher than that from UL EMF (a 10-min call time).

Declaration of interests

☒ 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.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

EUR. J. ONCOL.; Vol. 20, n. 3/4, pp. 180-182, 2015

International Appeal: Scientists call for protection from non-ionizing electromagnetic field exposure

An introduction to the International EMF Scientist Appeal

The current issue of the European Journal of Oncology contains a document the "International EMF Scientist Appeal" (EMFscientist.org) that addresses the concerns of 215 scientists from 40 nations about the adverse health effects on the human population exposed to non-ionizing electromagnetic fields (EMF) from extremely-low frequency to radiofrequency. The Appeal has been submitted to the United Nations, to two of its sub-agencies, the World Health Organization (WHO) and the United Nations Environmental Programme (UNEP), and to all UN Member Nations.

We note that the overall weight of evidence reported in peer-reviewed, scientific studies strongly supports greater precautionary measures be taken to reduce or eliminate EMF exposure.

Coordinating and Advisory Committee for the "International EMF Scientist Appeal" (Martin Blank, Magda Havas, Elizabeth Kelley, Henry Lai, and Joel Moskowitz). We can be reached through Elizabeth Kelley at info@EMFscientist.org.

To: His Excellency Ban Ki-moon, Secretary-General of the United Nations;
Honorable Dr. Margaret Chan, Director-General of the World Health Organization; Honorable Achim Steiner, Executive Director of the U.N. Environmental Programme; U.N. Member Nations

Summary. We are scientists engaged in the study of biological and health effects of non-ionizing electromagnetic fields (EMF). Based upon peer-reviewed, published research, we have serious concerns regarding the ubiquitous and increasing exposure to EMF generated by electric and wireless devices. These include–but are not limited to–radiofrequency radiation (RFR) emitting devices, such as cellular and cordless phones and their base stations, Wi-Fi, broadcast antennas, smart meters, and baby monitors as well as electric devices and infra-structures used in the delivery of electricity that generate extremely-low frequency electromagnetic field (ELF EMF).

Scientific basis for our common concerns

Numerous recent scientific publications have shown that EMF 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.

These findings justify our appeal to the United Nations (UN) and, all member States in the world, to encourage the World Health Organization (WHO) to exert strong leadership in fostering the development of more protective EMF guidelines, encouraging precautionary measures, and educating the public about health risks, particularly risk to children and fetal development. By not taking action, the WHO is failing to fulfill its role as the preeminent international public health agency.

Inadequate non-ionizing EMF international guidelines

The various agencies setting safety standards have failed to impose sufficient guidelines to protect the general public, particularly children who are more vulnerable to the effects of EMF.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) established in 1998 the "Guidelines For Limiting Exposure To Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)" (1). These guidelines are accepted by the WHO and numerous countries around the world. The WHO is calling for all nations to adopt the ICNIRP guidelines to encourage international harmonization of standards. In 2009, the ICNIRP released a statement saying that it was reaffirming its 1998 guidelines, as in their opinion, the scientific literature published since that time "has provided no evidence of any adverse effects below the basic restrictions and does not necessitate an immediate revision of its guidance on limiting exposure to high frequency electromagnetic fields (2). ICNIRP continues to the present day to make these assertions, in spite of growing scientific evidence to the contrary. It is our opinion that, because the ICNIRP guidelines do not cover long-term exposure and low-intensity effects, they are insufficient to protect public health.

The WHO adopted the International Agency for Research on Cancer (IARC) classification of extremely low frequency electromagnetic field (ELF EMF) in 2002 (3) and radiofrequency radiation (RFR) in 2011 (4). This classification states that EMF is a *possible human carcinogen (Group 2B)*. Despite both IARC findings, the WHO continues to maintain that there is insufficient evidence to justify lowering these quantitative exposure limits.

Since there is controversy about a rationale for setting standards to avoid adverse health effects, we recommend that the United Nations Environmental Programme (UNEP) convene and fund an independent multidisciplinary committee to explore the pros and cons of alternatives to current practices that could substantially lower human exposures to RF and ELF fields. The deliberations of this group should be conducted in a transparent and impartial way. Although it is essential that industry be involved and cooperate in this process, industry should not be allowed to bias its processes or conclusions. This group should provide their analysis to the UN and the WHO to guide precautionary action.

Collectively we also request that:

1. children and pregnant women be protected;
2. guidelines and regulatory standards be strengthened;
3. manufacturers be encouraged to develop safer technology;
4. utilities responsible for the generation, transmission, distribution, and monitoring of electricity maintain adequate power quality and ensure proper electrical wiring to minimize harmful ground current;
5. the public be fully informed about the potential health risks from electromagnetic energy and taught harm reduction strategies;
6. medical professionals be educated about the biological effects of electromagnetic energy and be provided training on treatment of patients with electromagnetic sensitivity;
7. governments fund training and research on electromagnetic fields and health that is independent of industry and mandate industry cooperation with researchers;

8. media disclose experts' financial relationships with industry when citing their opinions regarding health and safety aspects of EMF-emitting technologies; and
9. white-zones (radiation-free areas) be established.

The list of signatories and their affiliations is available at EMFscientist.org

References

1. http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf
2. http://www.icnirp.org/cms/upload/publications/ICNIRPStatementEMF.pdf
3. http://monographs.iarc.fr/ENG/Monographs/vol80
4. http://monographs.iarc.fr/ENG/Monographs/vol102/