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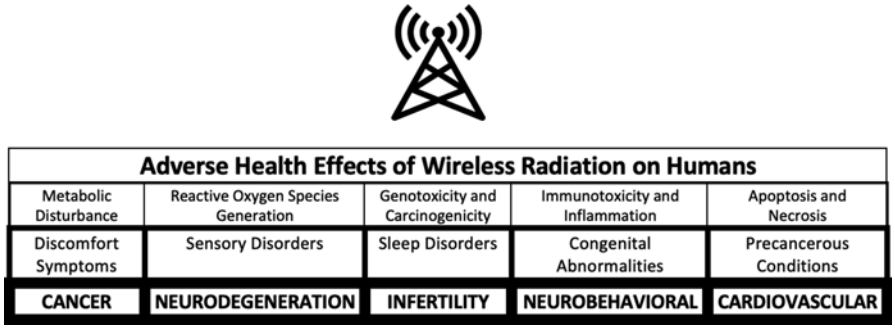
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Adverse health effects of 5G mobile networking technology under real-life conditions

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GRAPHICAL ABSTRACT



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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

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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

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Article

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

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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

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Letter

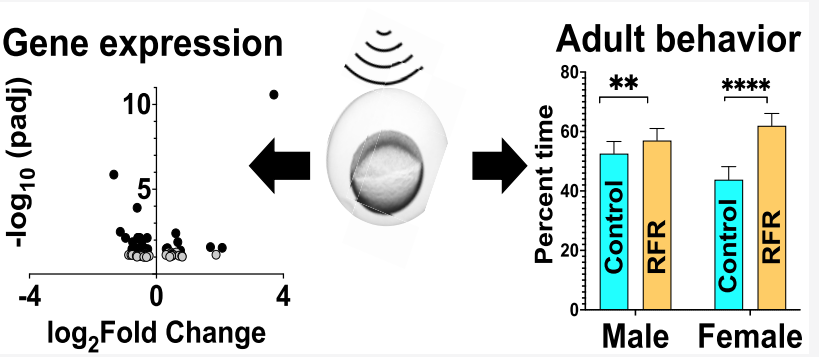
Transcriptomic and Long-Term Behavioral Deficits Associated with Developmental 3.5 GHz Radiofrequency Radiation Exposures in Zebrafish

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

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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.

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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-

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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

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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

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Article

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

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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

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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

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Problems in evaluating the health impacts of radio frequency radiation

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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

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

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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.

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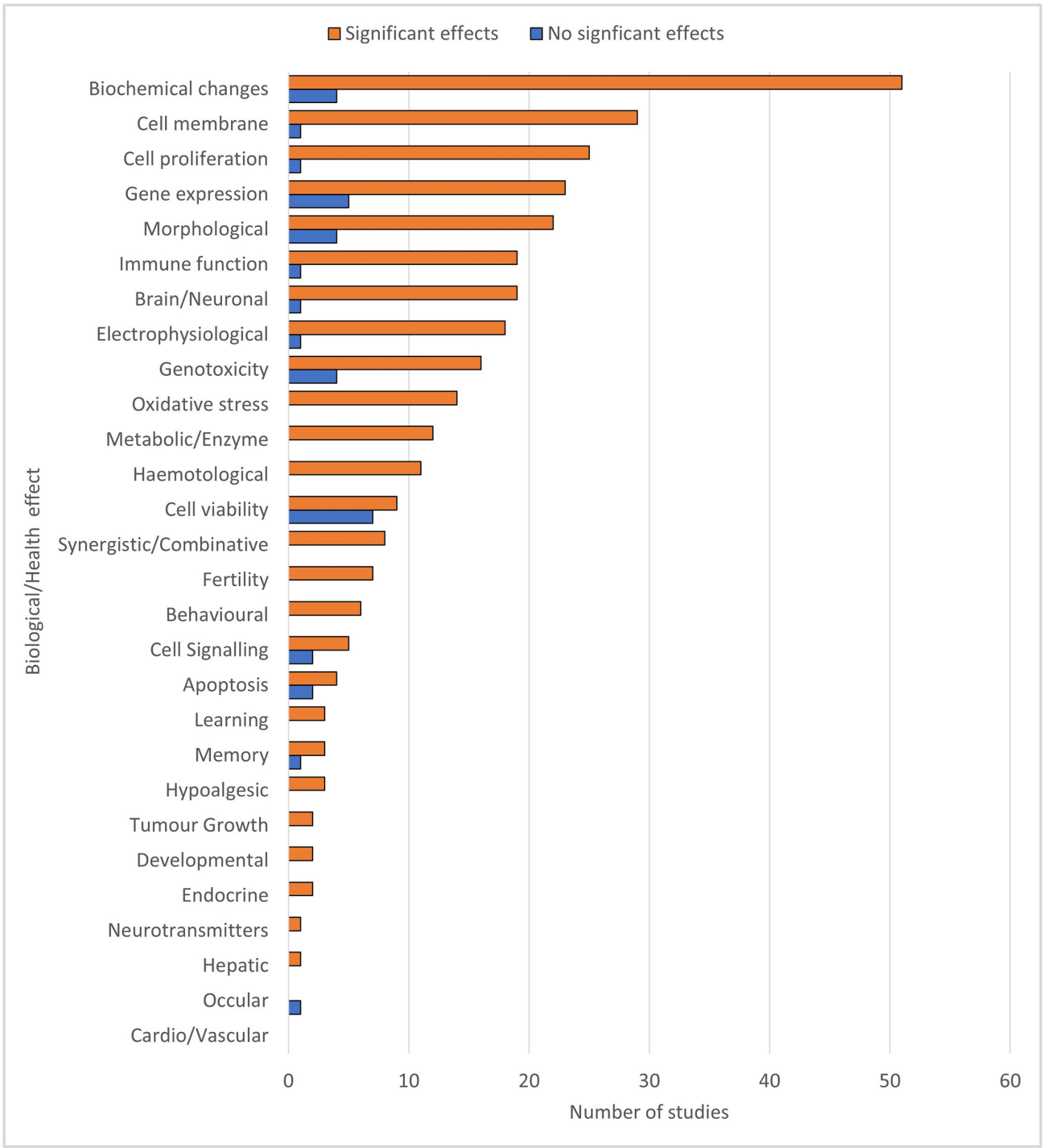


FIGURE 1
The main biological and health categories present in the mmWave experimental (i.e., *in vitro* and *in vivo*) literature base, and within each category, the number of papers producing effects vs. the number of papers resulting in no significant effects. The total number of studies is greater 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 insufficient 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 Sufficient 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 sufficient 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)].

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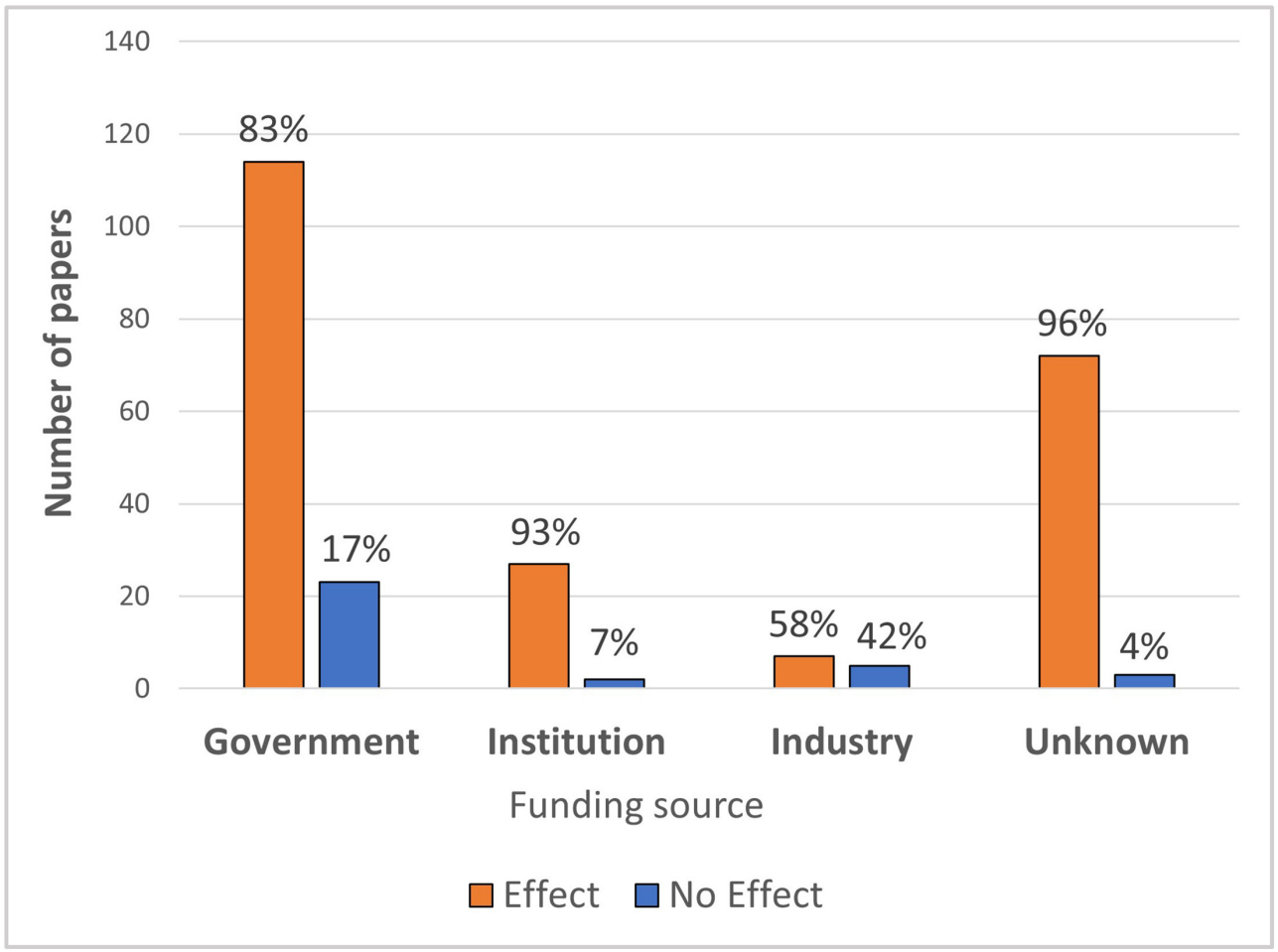


FIGURE 2
The relative proportion of "Effects" and "No Effects" outcomes from studies according to the funding source.

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.

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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.

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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?

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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

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Case Report

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

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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

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

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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 office 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 office one maximum (peak) RFR during one minute varied from 463 to 1,180,000 μW/m^2, in office two from 6,230 to 501,000 and in office 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 office for other offices 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

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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

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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.

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

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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

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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.

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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

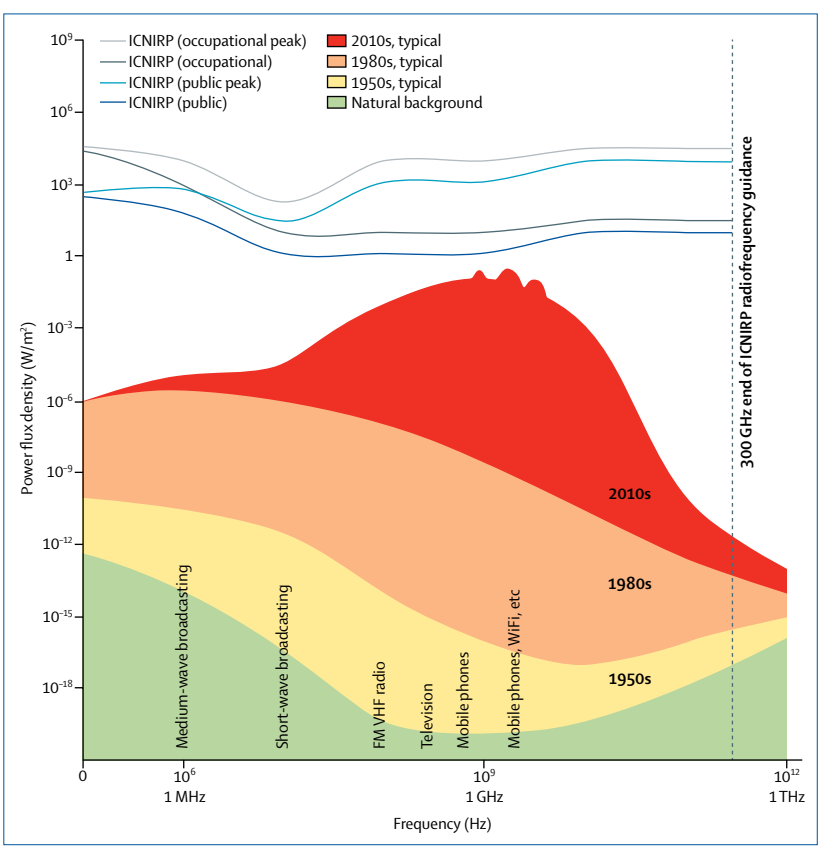


Figure: **Typical maximum daily exposure to radiofrequency electromagnetic radiation from man-made and natural power flux densities in comparison with International Commission on Non-Ionizing Radiation Protection safety guidelines[1]**

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.

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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.

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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.

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

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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.

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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,

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

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ABSTRACT

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

1. Introduction

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

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

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

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

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COMMENT

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

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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

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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

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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.

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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

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

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

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2. The WHO fact sheet
3. The WHO EMF project
4. WHO radio frequency fields: Environmental health criteria monograph
5. Human Health Effects of Non-Ionizing Radiation - Informal meeting at WHO March 3, 2017
6. Exposure to RF radiation within the WHO building in Geneva
7. Concluding remarks

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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

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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.

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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

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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.

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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

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REVIEW

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Genetic effects of non-ionizing electromagnetic fields

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ABSTRACT

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

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

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

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Commentary

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

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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

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

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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.

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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

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

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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

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

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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;

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

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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

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

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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].

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

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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

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REVIEW
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Effects of Radiofrequency Electromagnetic Radiation on Neurotransmitters in the Brain

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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

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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

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

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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.

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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

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Health impact of 5G

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

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

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

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

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

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

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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

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

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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;

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

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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.

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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.

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Case Report

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

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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.

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UNCORRECTED PROOF

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.

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ORIGINAL ARTICLE

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

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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

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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).

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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).

RIGHTSLINK

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.

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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.

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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.

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

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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.

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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

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[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.

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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

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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

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

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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*

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ORIGINAL ARTICLE

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

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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

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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

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RF Radiation–Induced Changes in the Prenatal Development of Mice

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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

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

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ABSTRACT

Exposure to low frequency and radiofrequency electromagnetic fields at low intensities poses a significant health hazard that has not been adequately addressed by national and international organizations such as the World Health Organization. There is strong evidence that excessive exposure to mobile phone-frequencies over long periods of time increases the risk of brain cancer both in humans and animals. The mechanism(s) responsible include induction of reactive oxygen species, gene expression alteration and DNA damage through both epigenetic and genetic processes. *In vivo* and *in vitro* studies demonstrate adverse effects on male and female reproduction, almost certainly due to generation of reactive oxygen species. There is increasing evidence the exposures can result in neurobehavioral decrements and that some individuals develop a syndrome of "electro-hypersensitivity" or "microwave illness", which is one of several syndromes commonly categorized as "idiopathic environmental intolerance". While the symptoms are non-specific, new biochemical indicators and imaging techniques allow diagnosis that excludes the symptoms as being only psychosomatic. Unfortunately standards set by most national and international bodies are not protective of human health. This is a particular concern in children, given the rapid expansion of use of wireless technologies, the greater susceptibility of the developing nervous system, the hyperconductivity of their brain tissue, the greater penetration of radiofrequency radiation relative to head size and their potential for a longer lifetime exposure.
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1. Introduction

Electromagnetic fields (EMFs) are packets of energy that have no mass. They vary in frequency and wavelength. At the high end of the electromagnetic spectrum there are cosmic and X-rays that have enough energy to cause ionization, and therefore are known as ionizing EMFs. Below in frequency and energy are ultraviolet, visible light and infrared EMFs. Excessive exposure to ultraviolet EMFs poses clear danger to human health, but life on earth would not be possible without visible light and infrared EMFs. Below these forms of EMF are those used for communications (radiofrequency or RF-EMFs, 30 kHz-300 GHz) and those generated by electricity (extremely low-frequency or ELF-EMFs, 3 Hz-3 kHz). These EMFs do not have sufficient energy to directly cause ionization, and are therefore known as non-ionizing radiation. RF-EMFs at sufficient intensity cause tissue heating, which is the basis of operation of the microwave oven. However the question to be addressed here is human health effects secondary to exposures to non-ionizing EMFs at low intensities that do not cause measureable heating.

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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

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'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

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

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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.

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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.

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Case Report

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

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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

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Physiological effects of millimeter-waves on skin and skin cells: an overview of the to-date published studies

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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.

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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

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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.

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Review Article

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

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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.

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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

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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

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***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.

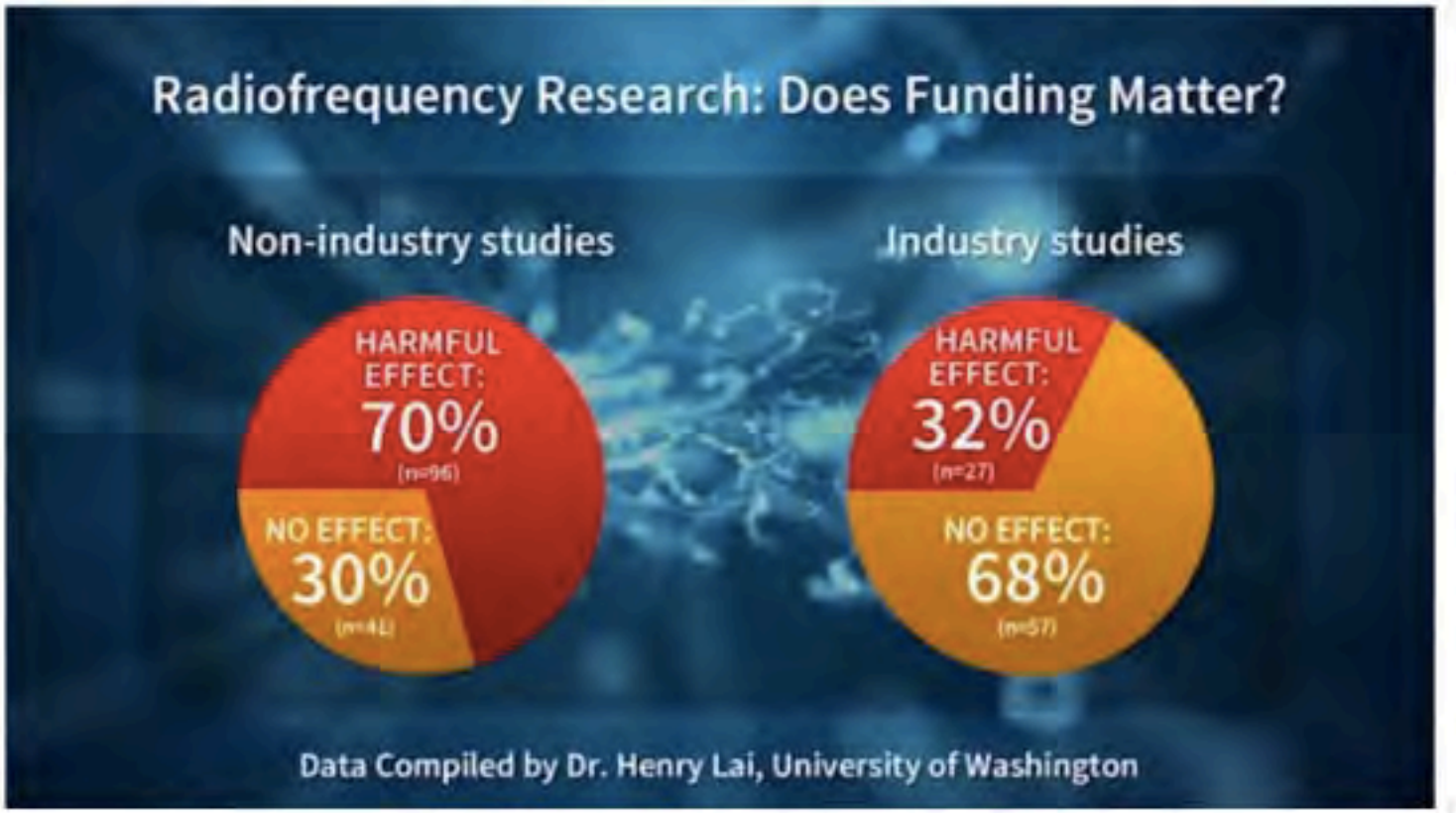
MmWave devices should be evaluated to comply with government exposure guidelines before they are introduced to the consumer market. At frequencies below 6 GHz for the Federal Communications Commission (FCC) or 10 GHz for the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the 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.

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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

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

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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

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Human-made electromagnetic fields: Ion forced-oscillation and voltage-gated ion channel dysfunction, oxidative stress and DNA damage (Review)

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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.

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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

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1. Introduction
2. Biophysical action of polarized/coherent EMFs resulting in voltage-gated ion channel (VGIC) dysfunction and disruption of cell electrochemical balance
3. Biochemical processes activated by irregular gating of VGICs, leading to DNA damage
4. Discussion

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

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

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ABSTRACT

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

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

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

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

1. Introduction

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

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

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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

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ARTICLE INFO

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RF
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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

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

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ABSTRACT

Radiofrequency radiations (RFRs) emitted by mobile phone base stations have raised concerns on its adverse impact on humans residing in the vicinity of mobile phone base stations. Therefore, the present study was envisaged to evaluate the effect of RFR on the DNA damage and antioxidant status in cultured human peripheral blood lymphocytes (HPBLs) of individuals residing in the 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.

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Antioxidants; genotoxicity; humans; micronucleus; power density

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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

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Exposure to RF EMF From Array Antennas in 5G Mobile Communication Equipment

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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,

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Mobile Phone Base Station Tower Settings Adjacent to School Buildings: Impact on Students' Cognitive Health

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Abstract

The use of mobile phones has remarkably increased and become a basic need of daily life. Increasing subscriptions of mobile phones boost the installation of mobile phone base station towers (MPBSTs) in crowded commercial and residential areas including near school buildings. This study investigated the impact of exposure to radiofrequency electromagnetic field (RF-EMF) radiation generated by MPBSTs on cognitive functions. Two hundred and seventeen volunteer male students aged between 13 and 16 registered from two different intermediate schools: 124 students were from School 1 and 93 students were from School 2. The MPBSTs were located within 200 m from the school buildings. In School 1, RF-EMF was 2.010 μW/cm^2 with a frequency of 925 MHz and in School 2, RF-EMF was 10.021 μW/cm^2 with a frequency of 925 MHz. Students were exposed to EMFR for 6 hr a day, 5 days a week for a total period of 2 years. The Narda Safety Test Solution device SRM-3006 was used to measure RF-EMF in both schools, and cognitive functions tasks were measured by the Cambridge Neuropsychological Test Automated Battery (CANTAB). Significant impairment in Motor Screening Task (MOT; $p = .03$) and Spatial Working Memory (SWM) task ($p = .04$) was identified among the group of students who were exposed to high RF-EMF produced by MPBSTs. High exposure to RF-EMF produced by MPBSTs was associated with delayed fine and gross motor skills, spatial working memory, and attention in school adolescents compared to students who were exposed to low RF-EMF.

Keywords

Electromagnetic Field Radiation, Mobile Phones Base Station Tower, Cognitive function

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In recent years, tremendous developments in mobile phones have revolutionized the telecom industry by making telecommunication faster, economical, and more convenient (D'Silva, Swer, Anbalagan, & Bhargavan, 2014). With the introduction of new applications and multifunctional technology in mobile phones, the telecom industry is appealing to both youth and adults. The usage of mobile phones has dramatically increased, which is considered as a basic tool in daily life (Al-Khlaiwi & Meo, 2004). Worldwide, the number of subscriptions of mobile phones is about 7.52 billion. This number is more than the worldwide population, as many users own more than one mobile phone (World Bank, 2018). The extensive usage of cellular phones has led to the growing installation of mobile phone base station towers (MPBSTs) in crowded commercial and residential areas, which raises community concerns (Buckus et al., 2017; Meo et al., 2015; Wiedemann, Freudenstein, F., Böhmert, Wiart, & Croft, 2017; Zhang et al., 2017; Figure 1).

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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.

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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
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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

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***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,

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Brain proteome response following whole body exposure of mice to mobile phone or wireless DECT base radiation

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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.

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Health Effects of Mobile Tower Radiation on Human — Case Study

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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

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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;

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RF Radiation–Induced Changes in the Prenatal Development of Mice

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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

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The human skin as a sub-THz receiver – Does 5G pose a danger to it or not?

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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

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INCREASED INCIDENCE OF CANCER NEAR A CELL-PHONE TRANSMITTER STATION.

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Running title: Cancer near a cell-phone transmitter station.

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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.

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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.

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Evaluation of the Genotoxicity of Cell Phone Radiofrequency Radiation in Male and Female Rats and Mice Following Subchronic Exposure

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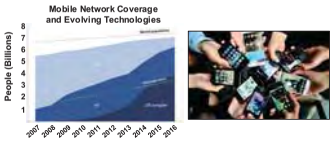
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Abstract

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)

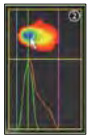
RFR Exposure Facility at Illinois Industrial Research Institute (ITRI)



- 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

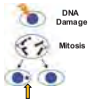
Frontal cortex, hippocampus, cerebellum, liver, and peripheral blood were analyzed in the comet assay. Single-cell suspensions were diluted in agarose and layered onto CometSlides™. Slides were incubated overnight in lysing solution at 4 °C, then treated with cold alkali solution for 20 min to allow 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

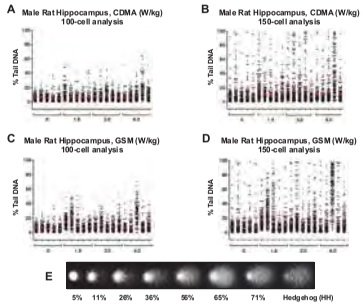


Fig. 1A, C: Comets were selected by a scorer (blind to treatment) for analysis *via* software to determine % Tail DNA. 100 cells were analyzed per animal/tissue and HH – identified by visual inspection – were tabulated but excluded from analysis. However, using this approach, % Tail DNA rarely exceeded 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

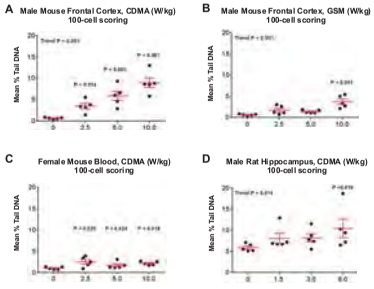
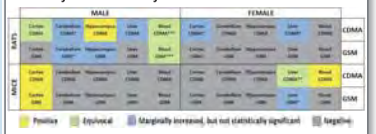


Fig. 2A-D: Of the 40 tissues examined (5 tissues, 2 species, 2 sexes, 2 modulations) using the 100-cell scoring approach, 4 showed positive results using the following criteria: significant trend test ($P < 0.025$) and at least one significant dose group ($P < 0.025$); or at least 2 significant dose 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.*