

by Priyanka Bandara; David O Carpenter



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 Protection¹ 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 Program⁹ 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 neurodevelopment¹⁴ 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

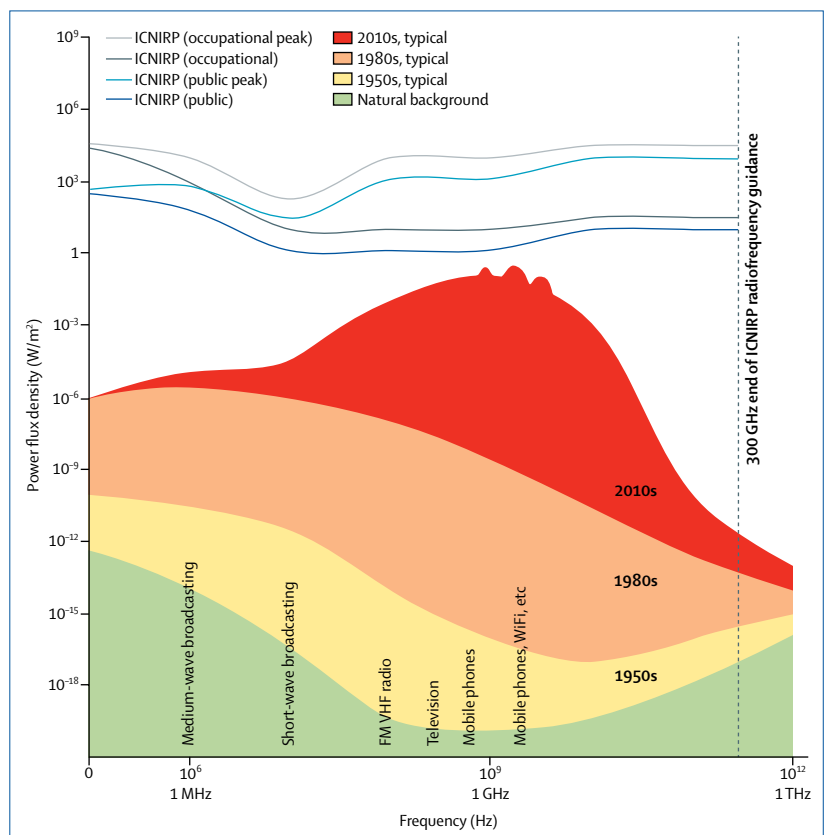


Figure: Typical maximum daily exposure to radiofrequency electromagnetic radiation from man-made and natural power flux densities in comparison with International Commission on Non-Ionizing Radiation Protection safety guidelines¹ Anthropogenic radiofrequency electromagnetic radiation levels are illustrated 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 Lamburn¹² with permission. Natural levels of radiofrequency electromagnetic radiation were based on the NASA review report CR-166661.¹³

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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.

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.

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.

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