WILDLIFE AND WIRELESS: POLICY NEEDED TO PROTECT FLORA AND FAUNA

Escalating levels of wireless RF* radiation from the proliferation of 4G and 5G telecommunication antennas pose serious risks to wildlife and the natural world. Accumulating research studies have found numerous adverse effects at levels much lower than the Federal Communication Commission (FCC) legal limits for cell tower emissions.

No Safety Standards

The FCC's federal exposure limits were designed for humans, not wildlife. "Safe" levels of RF exposure for wildlife and plants have never been developed by any scientific or government entity.

Serious Regulatory Gaps

There is no federal agency measuring or monitoring the current levels of RF in the environment, monitoring the scientific research or gathering data on wildlife impacts from wireless infrastructure.

No Environmental Review

There has been no review of the environmental impact of the 5G infrastructure buildout which the FCC states will require 800,000 new wireless "small" cells.

Higher Exposures

Birds, insects and other airborne species fly, nest and perch close to transmitting antennas. "Small" cells & cell towers emit plumes of RF radiation which are hundreds to thousands of times higher than government limits extending 10 to 30 feet or more away from the antennas. Yet these emissions are "legal" because telecom compliance tests *only consider areas inhabited by people.*

Pollinators at Risk

5G networks will include higher frequencies — submillimeter and millimeter waves — which studies have found to uniquely absorb at higher intensities into the bodies of bees and insects. Studies on bees have long linked cell tower frequencies to increased stress, decreased honey production and altered pupal development.

Damage to Tree Canopy

Trees are being cut down, aggressively trimmed and their roots disturbed to build "small" cell infrastructure. A ten year field study found damage to trees after years of RF exposure from cell antennas.

The need for regulatory action is urgent. Immediate steps to reduce environmental levels of RF and develop safety standards must be taken to ensure wildlife and their habitat are protected now and in the future.

**RF = radiofrequency*

"In addition to its impact on humans, radiofrequency radiation poses harmful effects to flora and fauna."

— Natural Resources Defense Council Amicus Brief in EHT et al. v the FCC

PEER REVIEWED SCIENCE ON FLORA, FAUNA, WIRELESS AND NON-IONIZING RADIATION

Adequate Science To Trigger Regulatory Action To Protect Wildlife

A research review by U.S experts of over 1,200 studies on the effects of non ionizing radiation to wildlife entitled "Effects of non-ionizing electromagnetic fields on flora and fauna" published in *Reviews on Environmental Health* found adverse effects at even very low intensities including impacts to orientation and migration, reproduction, mating, nest, den building and survivorship. (Levitt et al., 2021)

"A review of the ecological effects of RF-EMF" published in *Environment International* found RF had a significant effect on birds, insects, other vertebrates, other organisms, and plants in 70% of the studies. Development and reproduction in birds and insects were strongly affected. (Cucurachi et al., 2013)

The research review "Electromagnetic radiation as an emerging driver factor for the decline of insects" published in *Science of the Total Environment* found "sufficient evidence" of effects to insects including impacts to flight, foraging and feeding, short-term memory and mortality. (Balmori 2021)

A 2022 Oregon State University study investigated the long-term behavioral effects to zebrafish from short term exposures to 5G's midband 3.5 GHz. The researchers found "subtle but significant abnormal responses...that suggest potential long-term behavioral effects." and they concluded, "Overall, our study suggests the impacts of RFRs on the developing brain, behavior, and the metabolome should be further explored." (Dasgupta et al 2022)

US RF Exposure Limits Unchanged Since 1996

The US has the most lenient rules regarding allowable emissions from cell towers. Many countries such as Italy, Switzerland, Israel, China, Russia, and India have environmental RF limits 10 to 100 times lower (more stringent).

India dropped their RF limits by 1/10th of US limits after an Inter-Ministerial Committee set up by the Ministry of Environment and Forests reviewed the research on birds, bees, plants and animals and found the majority of studies showed impacts.

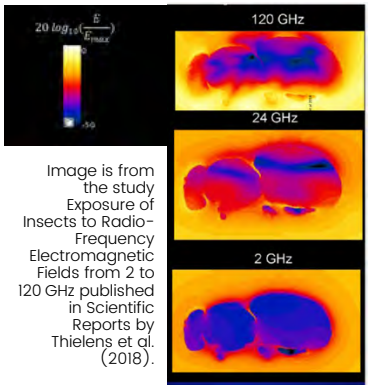


Image is from the study Exposure of Insects to Radio-Frequency Electromagnetic Fields from 2 to 120 GHz published in Scientific Reports by Thielens et al. (2018).

This is an image of the normalized electric field strength (dB) into a Western Honey Bee at various wireless frequencies. It shows that as the wavelengths are higher (as will be used in 5G) the absorption in the bodies of insects also increases, even when the power is the same.

Norway Maple Tree, Damaged by Cell Antennas

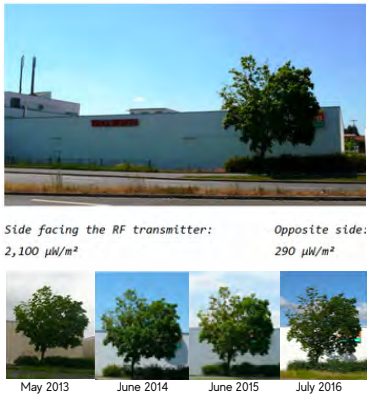


Image: Tree Observation Guide by Helmut Breunig 2017 .

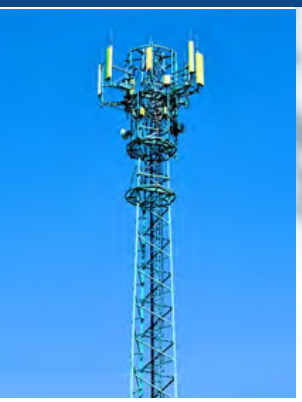
"The electromagnetic radiation standards used by the Federal Communications Commission (FCC) continue to be based on thermal heating, a criterion now nearly 30 years out of date and inapplicable today."

— U.S. Department of the Interior letter that details studies showing impacts to birds from cell tower radiation.

"The Federal Communications Commission also completely failed even to acknowledge, let alone respond to, comments concerning the impact of RF radiation on the environment."

— U.S. Court of Appeals for the D.C. Circuit Ruling in EHT et. al. v FCC

CHILDREN'S VULNERABILITY TO WIRELESS RADIOFREQUENCY (RF) RADIATION



The American Academy of Pediatrics states:

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

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

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

–American Academy of Pediatrics
HealthyChildren.org

Cell towers and cell phones emit wireless radiofrequency (RF) radiation.

Children are more vulnerable to RF radiation, just as they are to other environmental exposures. They have proportionately more exposures to RF compared to adults. More importantly, even very low exposures to children can have serious impacts later in life because their nervous and immune systems are still in development.

Children absorb higher levels of RF radiation deeper into their brains and bodies because they have:

- Thinner skulls allow RF radiation to move easier into the brain.
- Higher water content in brain tissue which is more conductive to electricity.
- Smaller heads result in a shorter distance for the RF to travel from the skull to critical brain regions important for learning and memory.

Children are more sensitive to RF impacts because:

- Their brains are still developing.
- Children have more active stem cells- a type of cell scientifically found to be uniquely impacted by RF.
- Children will have a longer lifetime of higher exposures, starting from before they are born.

CELL TOWER RF RADIATION AND CANCER

International Agency for Research on Cancer

World Health Organization

PRESS RELEASE
N° 208

31 May 2011

IARC CLASSIFIES RADIOFREQUENCY ELECTROMAGNETIC FIELDS AS POSSIBLY CARCINOGENIC TO HUMANS

Lyon, France, May 31, 2011 – The WHO/International Agency for Research on Cancer (IARC) has classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B), based on an increased risk for glioma, a malignant type of brain cancer[1], associated with wireless phone use.

The World Health Organization International Agency for Research on Cancer Classified Radiofrequency Radiation as a "Possible" Carcinogen in 2011

In 2011, radiofrequency electromagnetic fields (RF-EMF) were classified as a Group 2B possible carcinogen by the World Health Organization's International Agency for Research on Cancer (WHO/IARC).

The WHO/IARC scientists clarified that this determination was for RF-EMF from any source be it cell phones, wireless devices, cell towers or any other type of wireless equipment.

Since 2011, the published peer-reviewed scientific evidence associating RF-EMF (also known as RF-EMR and RFR) to cancer and other adverse effects has significantly increased.

A large-scale animal study published in Environmental Research found rats exposed to RF levels comparable to cell tower emissions had elevated cancers, the very same cancers also found in the US National Toxicology Program animal study of cell phone level RF that found "clear evidence" of cancer in carefully controlled conditions (Falcioni 2018).

In 2019, the WHO/IARC advisory committee recommended that radiofrequency radiation be re-evaluated as a "high" priority in light of the new research. The date of the re-evaluation has not been set.

Currently, several scientists conclude that the weight of currently available, peer-reviewed evidence supports the conclusion that radiofrequency radiation is a proven human carcinogen (Hardell and Carlberg 2017, Peleg et al. 2022, Miller et al. 2018).

SCIENTIFIC RESEARCH STUDIES

European Parliament requested a research report "**Health Impact of 5G**" which was released in July 2021 and concluded that commonly used RFR frequencies (450 to 6000 MHz) are probably carcinogenic for humans and clearly affect male fertility with possible adverse effects on the development of embryos, fetuses and newborns.

A review entitled "**Evidence for a health risk by RF on humans living around mobile phone base stations: From radiofrequency sickness to cancer**" reviewed the existing scientific literature and found radiofrequency sickness, cancer and changes in biochemical parameters (**Balmori 2022**).

A **study** published in Electromagnetic Biology and Medicine found changes in blood considered biomarkers predictive of cancer in people living closer to cell antenna arrays (**Zothansiama 2017**).

A **study** published in the International Journal of Environmental Research and Public Health found higher exposure to cell network arrays linked to higher mortality from all cancer and specifically lung and breast cancer (**Rodrigues 2021**).

A 10-year **study** published in Science of the Total Environment on cell phone network antennas by the local Municipal Health Department and several universities in Brazil found a clearly elevated relative risk of cancer mortality at residential distances of 500 meters or less from cell phone towers (**Dode 2011**).

A **study** commissioned by the Government of Styria, Austria found a significant cancer incidence in the area around the RF transmitter as well as significant exposure-effect relationships between radiofrequency radiation exposure and the incidence of breast cancers and brain tumors (**Oberfeld 2008**).

A **review** published in Experimental Oncology found "alarming epidemiological and experimental data on possible carcinogenic effects of long term exposure to low intensity microwave (MW) radiation." A year of operation of a powerful base transmitting station for mobile communication reportedly resulted in a dramatic increase of cancer incidence among the population living nearby (**Yakymenko 2011**).

NEW HAMPSHIRE STATE COMMISSION

2020 REPORT: 5G HEALTH AND ENVIRONMENT

In 2020, the New Hampshire State Commission issued a Final Report with 15 recommendations to "to protect people, wildlife, and the environment from harmful levels of radiation" after a year-long investigation with numerous meetings and expert testimony.


State of New Hampshire

MEMORANDUM

"A likely explanation as to why regulatory agencies have opted to ignore the body of scientific evidence demonstrating the negative impact of cellphone radiation is that those agencies are "captured."

Recommendations To Update RF Exposure Regulations With New Science

- A resolution to U.S. Congress to require the FCC to commission an independent health study and review of safety limits.
- New measurement protocols needed to evaluate high data rate, signal characteristics associated with biological effects and summative effects of multiple radiation sources.

Recommendations To Address Impacts to Wildlife And Environment

- Engage agencies with ecological knowledge to develop RF-radiation safety limits that will protect the trees, plants, birds, insects and pollinators.
- Under the National Environmental Policy Act, FCC should do an environmental impact statement as to the effect on New Hampshire and the country as a whole from 5G and the expansion of RF wireless technologies.

Recommendations To Reduce Public Exposure

- Require setbacks of 1,640 feet for new wireless antennas from residences, businesses and schools.
- Cell phones and wireless devices should be equipped with updated software that stops cell phones from radiating when positioned against the body.
- Establish RF radiation-free zones in commercial and public buildings.
- New Hampshire health agencies should educate the public on minimizing RF exposure with public service announcements on radio, television, print.

Recommendations To Utilize Safer Alternatives

- New Hampshire schools and libraries should replace Wi-Fi with hardwired connections.
- Support statewide deployment of fiber optic cable connectivity with wired connections inside homes.

Recommendations To Increase Transparency

- State should measure RFR and post maps with RF measurements..
- Require 5G structures to be labeled for RFR at eye level and readable from nine feet away.
- RFR signal strength measurements for cell sites should be done by independent contractors.
- NH professional licensure to offer RF measurement education for home inspectors.
- Warning signs posted in commercial and public buildings.

THE NEED FOR ACCOUNTABILITY ON WIRELESS SAFETY

EXPERT VOICES

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

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

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

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

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

THE URGENT NEED FOR SAFER TECHNOLOGY

EXPERT VOICES

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

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

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

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

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

5G, CELL TOWERS AND WIRELESS

LEGAL & LIABILITY ISSUES

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

An Uninsurable Risk?

- Insurers rank wireless, cell tower, and 5G RFR non-ionizing electromagnetic field (EMF) radiation as a "high" risk, comparing the issue to lead and asbestos.
- Most insurance plans have "electromagnetic field exclusions" and do not insure for long-term RFR damages.
- Additionally, some insurance plans will not provide a defense for any supervision instruction or recommendation given *"or which should have been given"* in connection to EMFs.
- Wireless RFR and non-ionizing electromagnetic radiation are defined as a type of "pollution" by wireless companies themselves.
- U.S. mobile operators have been unable to get insurance to cover liabilities related to damages from long-term RFR exposure.
- Wireless companies warn their shareholders of RFR risk but do not warn users of their products, nor do the companies warn the people exposed to emissions from their infrastructure.

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

ENVIRONMENTAL HEALTH TRUST

T-Mobile on 5G: Possible Changes to FCC Human Exposure Limits for RF Could Impact Cash Flow

T-Mobile advertises to the public about going "live" but omits the warnings they give to shareholders regarding 5G, regulatory changes and risk perception.

T-Mobile

T-Mobile 10-K Report 2/2023

"Negative public perception of, and regulations regarding, the perceived health risks relating to 5G networks could undermine market acceptance of our 5G services" (page 13)

"We, along with equipment manufacturers and other carriers, are subject to current and potential future lawsuits **alleging adverse health effects arising from the use of wireless handsets or from wireless transmission equipment such as cell towers."**

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


Mobile Telecommunications and Health

Review of the Current Scientific Research in view of Precautionary Health Protection

A 2000 Ecolog Institute Report commissioned by T-Mobile and DeTeMobil Deutsche Telekom MobilNet recommended an exposure limit 1000x lower than the FCC's current power density limit after reviewing the research on biological effects, including impacts to the immune system, central nervous system, hormones, cancer, neurotransmitters and fertility.

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

ENVIRONMENTAL HEALTH TRUST

Cell Tower Companies Warn Shareholders of Risk From Cell Tower Radiation

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

Verizon 10-K Report

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

Crown Castle 10-K Report

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

AT&T 10-K Report

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

T- MOBILE 10-K Report

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

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

Cell Tower Companies Warn Shareholders of Risk From Cell Tower Radiation

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

American Tower 10-K

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

Nokia 10-K

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

Qualcomm 10-K

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

Ericsson Annual Report

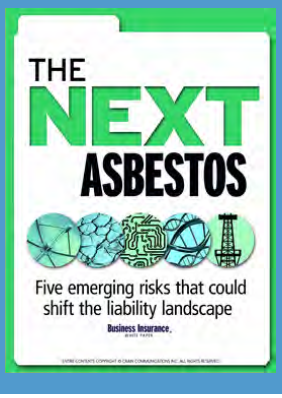
"Any perceived risk or new scientific findings of adverse health effects from mobile communication devices and equipment could adversely affect us through a reduction in sales or through liability claims."

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

ENVIRONMENTAL HEALTH TRUST

5G, CELL TOWERS AND WIRELESS

LEGAL & LIABILITY ISSUES SHAREHOLDER WARNINGS



"Some research has shown biological effects from lower -level "non thermal" exposure and people exposed at lower levels have reported headaches, dizziness, nausea, mood disorders, mental slowing and memory loss."
Business Insurance White Paper, The Next Asbestos: Five Emerging Risks That Could Shift the Liability Landscape

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

"Exclusions: This insurance does not apply to: Bodily injury, personal injury, advertising injury, or property damage arising directly or indirectly out of, resulting from, caused or contributed to by electromagnetic radiation, provided that such loss, cost or expense results from or is contributed to by the hazardous properties of electromagnetic radiation.
— Portland Oregon Public School Insurance (page 30)

Insurance Plans Not Only Exclude EMF Damages, But Some Even Exclude Defending Decision Makers From Their Actions in Regards to Their Actions on EMFS

"This policy does not apply to and we will not provide a defense for: a. bodily injury... arising out of ... exposure to or contact with electromagnetic radiation... b. costs of abatement .. of EMF" or c. any supervision, instruction, recommendation, warning or advice given or which should have been given in connection with a or b. above."- City of Ann Arbor Michigan Insurance Policy page 14.

Insurance Authorities Rate 5G as "High Risk."
5G mobile networks are classified as a "high," "off-the-leash" risk. "Existing concerns regarding potential negative health effects from electromagnetic fields (EMF) are only likely to increase. An uptick in liability claims could be a potential long-term consequence" and "[a]s the biological effects of EMF in general and 5G in particular are still being debated, potential claims for health impairments may come with a long latency."
— Swiss Re Institute (2019)

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

Wireless Companies Warn Shareholder About Risk But Not People Living Near Their Wireless Infrastructure

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

Wireless Companies Define Pollution in Their Own Policies as Including EMFs, Microwaves and Non-ionizing Radiation.

Verizons Total Mobile Protection Plan says: "Pollution" is defined as "any solid, liquid, gaseous, or thermal irritant or contaminant including smoke, vapor, soot, fumes, acid, alkalis, chemicals, artificially produced electric fields, magnetic field, electromagnetic field, sound waves, microwaves, and all artificially produced ionizing or non-ionizing radiation and/or waste."

ENVIRONMENTAL HEALTH TRUST

Example of an EMF Exclusion in an Insurance Plan

THIS ENDORSEMENT CHANGES THE POLICY. PLEASE READ IT CAREFULLY.

ELECTROMAGNETIC RADIATION EXCLUSION

This endorsement modifies insurance provided under the following:

GENERAL LIABILITY COVERAGE PART
PUBLIC RISK GENERAL LIABILITY RETAINED LIMIT COVERAGE FORM
LAW ENFORCEMENT COVERAGE PART
LAW ENFORCEMENT LIABILITY RETAINED LIMIT COVERAGE FORM
PUBLIC OFFICIALS COVERAGE PART
PUBLIC OFFICIALS LIABILITY RETAINED LIMIT COVERAGE FORM
EMPLOYMENT PRACTICES LIABILITY COVERAGE PART
EMPLOYMENT PRACTICES LIABILITY RETAINED LIMIT COVERAGE FORM

The following **Exclusion** is added:

This policy does not apply to and we will not provide a defense for:

a. "Bodily injury," "property damage", "personal and advertising injury", "employee benefits wrongful acts", "personal injury", "law enforcement wrongful acts", "public officiels wrongful acts", "educator's legel wrongful acts", or "employment practices wrongful acts" arising out of, or which result in, the actual, alleged, threatened, perceived, latent, sudden and accidental or incidental exposure to or contact with electromegnetic radiation in any form, from any source.

b. The costs of abatement or mitigation of:

(1) Electromagnetic radiation; or

(2) Exposure to electromagnetic rediation.

c. Any supervision, instruction, recommendation, waming or advice given or which should have been given in connection with **a.** or **b.** above.

Electromagnetic radiation includes but is not limited to, magnetic energy, waves, fields or forces generated, produced, transmitted or maintained by the charges, currents, frequencies, energy or forces of electricity that is generated, flowing or otherwise transmitted through or via the medium, methods and equipment designed to generate, produce, distribute, trensport or transmit the electrical charges, currents, frequencies, energy or forces.

Verizon Total Mobile Protection Plan

16. Pollution

The discharge, dispersal, seepage, migration or escape of pollutants. Pollutants means any solid, liquid, gaseous, or thermal irritant or contaminant including smoke, vapor, soot, fumes, acid, alkalis, chemicals, artificially produced electric fields, magnetic field, electromagnetic field, sound waves, microwaves, and all artificially produced ionizing or non-ionizing radiation and/or waste. Waste includes materials to be recycled, reconditioned or reclaimed.

A REGULATORY GAP
No Federal Agency Ensuring Cell Tower Wireless Safety

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

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

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

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

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

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

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

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

Blue text *is hyperlinked to source.*

5G, Small Cells & Cell Towers Can Drop Property Values

Would you buy a home with cell antennas outside the bedroom window?

Legal filings by cities and municipalities to the FCC highlight how small cell deployment could impact aesthetics and property values.

"many deployments of small cells could affect property values, with significant potential effect…"

— Reply Comments of Smart Communities Siting Coalition (local governments and associations representing 1,854 communities) 4/7/2017,Docket No. 16-421, April 7, 2017

"Considering that the Smart Communities' prior filings show that the addition of facilities of this size diminish property values, it is strange for the Commission to assume that approval can be granted in the regulatory blink of an eye…."

"…allowing poles to go up in areas where poles have been taken down has significant impacts on aesthetics (not to mention property values)."

— *Ex Parte* Submission of Smart Communities Letter to Ms. Marlene H. Dortch, Secretary, Federal Communications Commission, September 19, 2018

FACTSHEET: ENVIRONMENTAL HEALTH TRUST ET AL. V. FCC

COURT RULING ON FCC'S LACK OF ADEQUATE REVIEW FOR WIRELESS EXPOSURE LIMITS

LANDMARK FEDERAL COURT RULING AGAINST THE FCC

On August 13, 2021 the U.S. Court of Appeals for the D.C. Circuit ruled the Federal Communications Commission (FCC) ignored scientific evidence and failed to provide a reasoned explanation for its determination that its 1996 regulations adequately protect the public against all the harmful effects of wireless radiation.

FCC'S REFUSAL TO UPDATE 1996 LIMITS

The legal case challenged the FCC's 2019 decision not to update its 1996 regulations regarding allowable radiofrequency radiation (RF) exposures from wireless technologies - including 5G, cell phones, cell towers, Wi-Fi, and wireless networks.

EVIDENCE OF HARMFUL EFFECTS BELOW FCC LIMITS

FCC limits are based on the belief that heating is the only proven harm from RF. Over 11,000 pages of evidence - 447 exhibits in 27 Volumes - was submitted to the Court documenting biological effects and illness from wireless radiation exposure below heating levels. Research has found brain damage, headaches, memory problems, reproduction damage, synergistic effects, nervous system impacts, brain cancer, genetic damage, as well as harm to trees, birds, bees, and wildlife.

THE COURT FINDINGS

The ruling stated that the FCC's "arbitrary and capricious" decision to maintain their 25 year old exposure limits did not address evidence indicating "non-cancer" harm such as:

- impacts to children
- testimony of persons injured by wireless radiation
- impacts to the developing brain
- impacts to the reproductive system
- impacts to wildlife and the environment

THE COURT ORDER

The Court ordered the FCC to provide a reasoned determination as to whether the evidence warrants a change to 1996 RF limits especially in regards to:

- children's vulnerability
- long-term exposure
- environmental impacts
- new technological developments and the ubiquity of wireless
- how FCC's cell phone tests only measure heat and allow a space between the phone and body

TIMELINE

1980s: EPA had robust research program and was tasked to develop RF safety limits by U.S. Science Advisory Board.

1995: EPA presents to FCC on the EPA timeline for its development of human exposure RF limits which would include both thermal effects and non thermal effects.

1996: EPA is fully defunded by Congress amid heavy lobbying for Telecom Act and halts all research on RF.

1996: The FCC adopts RF limits developed by industry-tied groups - based on short term heating - thermal- effects from high power exposures (based on studies of small animals exposed to high RF levels for under an hour).

1999: FDA requests the National Toxicology Program (NTP) study RF because of the lack of safety data on long-term exposure.

2008/2009 Congressional Hearings

2011: Wireless RF classified as a "possible" Class 2B Carcinogen by International Agency for Research on Cancer.

2012: GAO Report recommends rules be reassessed to reflect current use patterns and recent science.

2013-2019: FCC opens record on RF limits - gets over 1000 submissions.

2018: NTP/NIH releases $30M animal study concluding "clear evidence" of cancer. FDA rejects the findings.

2019: FCC closes record, decides not to update its 1996 wireless RF limits.

2020: Cases filed against FCC.

2021: U.S. Court of Appeals, D.C Circuit ruled that the FCC decision not to change human exposure limits and regulations was "arbitrary and capricious." FCC ordered to respond.

2021: No FCC response to Court, so EHT and others filed request to refresh record.

Timeline is hyperlinked to sources.

FCC'S LACK OF ADEQUATE REVIEW FOR WIRELESS RADIATION EXPOSURE LIMITS

FCC Compliance Does Not Ensure Safety

Most of the public assumes that current FCC safety limits for cell phones, cell towers, Wi-Fi, 5G, and wireless networks are based upon an up to date robust review of all relevant research. This assumption of safety is now clearly documented to be erroneous.

Lack of Oversight by Health and Environmental Agencies

The ruling reveals a lack of accountability with our federal health agencies regarding wireless radiation. The EPA, CDC, NIOSH, and NCI did not submit any reports to the Court, revealing that none of these agencies has reviewed the science on health effects to ensure safety for the public. The U.S. has no pre- market safety testing for health effects, no post-market surveillance, no environmental monitoring, and no meaningful interagency coordination.

FDA's Dismissal of Harm Deemed Insufficient

The Court states the FCC improperly relied on the FDA's conclusions that RF limits did not need an update. The FDA's submissions were described by the Court as "cursory" and "insufficient." Although the FDA later released a literature review, it was only focused on cell phones, not cell towers, Wi-Fi nor 5G technology. It also was only focused on cancer, further confirming the fact that U.S. agencies have failed to evaluate the myriad of effects documented in scientific studies, such as brain, immune, fertility and endocrine impacts. A U.S. government review of *the full body of recent science* has simply never been done.

"the Commission's failure to provide a reasoned or even relevant explanation of its position that RF radiation below the current limits does not cause health problems unrelated to cancer renders its explanation as to the effect of RF radiation on children arbitrary and capricious. "

— 2021 EHT et al. v. FCC

The Court Did Not Agree That "Cell Phones Do Not Cause Cancer"

Contrary to the wireless industry's recent claims, the Court *did not make a scientific determination regarding cancer*. The ruling simply stated that in regards to cancer- the FCC passed the minimum legal requirement for adequate review because it (at least) referenced why the FCC dismissed cancer evidence. The FCC cited the rejections of NIH studies by the FDA and of ICNIRP (a small group with no oversight and whose members have a long history of industry ties).

Children's Vulnerability and Effects of Long Term Exposure Ignored by the FCC

The Court states the FCC "dismissed" the American Academy of Pediatrics recommendations to strengthen regs and ensure children and pregnant women are protected. The Court found the FCC failed to explain why it ignored research indicating children's developing brains are more sensitive. Children will have a lifetime of exposure, yet the FCC was found to ignore the issue of impacts *from long term exposure*.

Wildlife Remains Unprotected

FCC's limits were designed in 1996 to protect only humans, not flora or fauna. The Court found that the FCC had "completely failed" to address the "substantive evidence of potential environmental harms" on the record, which included science showing serious impacts to birds, bees, trees, and plants.

PETITIONERS: Environmental Health Trust, Consumers for Safe Cell Phones, Elizabeth Barris, Theodora Scarato, Children's Health Defense, Michelle Hertz, Petra Brokken, Dr. David Carpenter, Dr. Toril Jelter, Dr. Paul Dart, Dr. Ann Lee, Virginia Farver, Jennifer Baran, Paul Stanley M.Ed.

KEY RESOURCES: Court Ruling 8/13/2021, Evidence (11,000 pages), EHT Press Conference

Amicus Briefs

- Amicus of NRDC: Natural Resources Defense Council
- Amicus of Attorney Joe Sandri including declaration of Dr. Linda Birnbaum, former Director of the National Institute of Environmental Health Sciences
- Amicus of Catherine Kleiber
- Amicus of the Building Biology Institute

EHTrust.org for more.

frontiers in Public Health

REVIEW
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Risks to Health and Well-Being From Radio-Frequency Radiation Emitted by Cell Phones and Other Wireless Devices

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Radiation exposure has long been a concern for the public, policy makers, and health researchers. Beginning with radar during World War II, human exposure to radio-frequency radiation[1] (RFR) technologies has grown substantially over time. In 2011, the *International Agency for Research on Cancer* (IARC) reviewed the published literature and categorized RFR as a "possible" (Group 2B) human carcinogen. A broad range of adverse human health effects associated with RFR have been reported since the IARC review. In addition, three large-scale carcinogenicity studies in rodents exposed to levels of RFR that mimic lifetime human exposures have shown significantly increased rates of Schwannomas and malignant gliomas, as well as chromosomal DNA damage. Of particular concern are the effects of RFR exposure on the developing brain in children. Compared with an adult male, a cell phone held against the head of a child exposes deeper brain structures to greater radiation doses per unit volume, and the young, thin skull's bone marrow absorbs a roughly 10-fold higher local dose. Experimental and observational studies also suggest that men who keep cell phones in their trouser pockets have significantly lower sperm counts and significantly impaired sperm motility and morphology, including mitochondrial DNA damage. Based on the accumulated evidence, we recommend that IARC re-evaluate its 2011 classification of the human carcinogenicity of RFR, and that WHO complete a systematic review of multiple other health effects such as sperm damage. In the interim, current knowledge provides justification for governments, public health authorities, and physicians/allied health professionals to warn the population that having a cell phone next to the body is harmful, and to support measures to reduce all exposures to RFR.

Keywords: brain cancer, electromagnetic hypersensitivity, glioma, non-cancer outcomes, policy recommendations, radiofrequency fields, child development, acoustic neuroma

[1] Per IEEE C95.1-1991, the radio-frequency radiation frequency range is from 3 kHz to 300 GHz and is non-ionizing.

INTRODUCTION

We live in a generation that relies heavily on technology. Whether for personal use or work, wireless devices, such as cell phones, are commonly used around the world, and exposure to radio-frequency radiation (RFR) is widespread, including in public spaces (1, 2).

In this review, we address the current scientific evidence on health risks from exposure to RFR, which is in the non-ionizing frequency range. We focus here on human health effects, but also note evidence that RFR can cause physiological and/or morphological effects on bees, plants and trees (3–5).

We recognize a diversity of opinions on the potential adverse effects of RFR exposure from cell or mobile phones and other wireless transmitting devices (WTDs) including cordless phones and Wi-Fi. The paradigmatic approach in cancer epidemiology, which considers the body of epidemiological, toxicological, and mechanistic/cellular evidence when assessing causality, is applied.

CARCINOGENICITY

Since 1998, the *International Commission on Non-Ionizing Radiation Protection* (ICNIRP) has maintained that no evidence of adverse biological effects of RFR exist, other than tissue heating at exposures above prescribed thresholds (6).

In contrast, in 2011, an expert working group of the *International Agency for Research on Cancer* (IARC) categorized RFR emitted by cell phones and other WTDs as a Group 2B ("possible") human carcinogen (7).

Since the IARC categorization, analyses of the large international Interphone study, a series of studies by the Hardell group in Sweden, and the French CERENAT case-control studies, signal increased risks of brain tumors, particularly with ipsilateral use (8). The largest case-control studies on cell phone exposure and glioma and acoustic neuroma demonstrated significantly elevated risks that tended to increase with increasing latency, increasing cumulative duration of use, ipsilateral phone use, and earlier age at first exposure (8).

Pooled analyses by the Hardell group that examined risk of glioma and acoustic neuroma stratified by age at first exposure to cell phones found the highest odds ratios among those first exposed before age 20 years (9–11). For glioma, first use of cell phones before age 20 years resulted in an odds ratio (OR) of 1.8 (95% confidence interval [CI] 1.2–2.8). For ipsilateral use, the OR was 2.3 (CI 1.3-4.2); contralateral use was 1.9 (CI 0.9-3.7). Use of cordless phone before age 20 yielded OR 2.3 (CI 1.4–3.9), ipsilateral OR 3.1 (CI 1.6–6.3) and contralateral use OR 1.5 (CI 0.6–3.8) (9).

Although Karipidis et al. (12) and Nilsson et al. (13) found no evidence of an increased incidence of gliomas in recent years in Australia and Sweden, respectively, Karipidis et al. (12) only reported on brain tumor data for ages 20–59 and Nilsson et al. (13) failed to include data for high grade glioma. In contrast, others have reported evidence that increases in specific types of brain tumors seen in laboratory studies are occurring in Britain and the US:

- The incidence of neuro-epithelial brain cancers has significantly increased in all children, adolescent, and young adult age groupings from birth to 24 years in the United States (14, 15).
- A sustained and statistically significant rise in glioblastoma multiforme across all ages has been described in the UK (16).

The incidence of several brain tumors are increasing at statistically significant rates, according to the 2010–2017 *Central Brain Tumor Registry of the U.S.* (CBTRUS) dataset (17).

- There was a significant increase in incidence of radiographically diagnosed tumors of the pituitary from 2006 to 2012 (APC = 7.3% [95% CI: 4.1%, 10.5%]), with no significant change in incidence from 2012 to 2015 (18).
- Meningioma rates have increased in all age groups from 15 through 85+ years.
- Nerve sheath tumor (Schwannoma) rates have increased in all age groups from age 20 through 84 years.
- Vestibular Schwannoma rates, as a percentage of nerve sheath tumors, have also increased from 58% in 2004 to 95% in 2010-2014.

Epidemiological evidence was subsequently reviewed and incorporated in a meta-analysis by Röösli et al. (19). They concluded that overall, epidemiological evidence does not suggest increased brain or salivary gland tumor risk with mobile phone (MP) use, although the authors admitted that some uncertainty remains regarding long latency periods (>15 years), rare brain tumor subtypes, and MP usage during childhood. Of concern is that these analyses included cohort studies with poor exposure classification (20).

In epidemiological studies, recall bias can play a substantial role in the attenuation of odds ratios toward the null hypothesis. An analysis of data from one large multicenter case-control study of RFR exposure, did not find that recall bias was an issue (21). In another multi-country study it was found that young people can recall phone use moderately well, with recall depending on the amount of phone use and participants' characteristics (22). With less rigorous querying of exposure, prospective cohort studies are unfortunately vulnerable to exposure misclassification and imprecision in identifying risk from rare events, to the point that negative results from such studies are misleading (8, 23).

Another example of disparate results from studies of different design focuses on prognosis for patients with gliomas, depending upon cell phone use. A Swedish study on glioma found lower survival in patients with glioblastoma associated with long term use of wireless phones (24). Ollson et al. (25), however, reported no indication of reduced survival among glioblastoma patients in Denmark, Finland and Sweden with a history of mobile phone use (ever regular use, time since start of regular use, cumulative call time overall or in the last 12 months) relative to no or non-regular use. Notably, Olsson et al. (25) differed from Carlberg and Hardell (24) in that the study did not include use of cordless phones, used shorter latency time and excluded patients older than 69 years. Furthermore, a major shortcoming was that patients with the worst prognosis were excluded, as in Finland

inoperable cases were excluded, all of which would bias the risk estimate toward unity.

In the interim, three large-scale toxicological (animal carcinogenicity) studies support the human evidence, as do modeling, cellular and DNA studies identifying vulnerable subgroups of the population.

The *U.S. National Toxicology Program* (NTP) (National Toxicology Program (26, 27) has reported significantly increased incidence of glioma and malignant Schwannoma (mostly on the nerves on the heart, but also additional organs) in large animal carcinogenicity studies with exposure to levels of RFR that did not significantly heat tissue. Multiple organs (e.g., brain, heart) also had evidence of DNA damage. Although these findings have been dismissed by the ICNIRP (28), one of the key originators of the NTP study has refuted the criticisms (29).

A study by Italy's Ramazzini Institute has evaluated lifespan environmental exposure of rodents to RFR, as generated by 1.8 GHz GSM antennae of cell phone radio base stations. Although the exposures were 60 to 6,000 times lower than those in the NTP study, statistically significant increases in Schwannomas of the heart in male rodents exposed to the highest dose, and Schwann-cell hyperplasia in the heart in male and female rodents were observed (30). A non-statistically significant increase in malignant glial tumors in female rodents also was detected. These findings with far field exposure to RFR are consistent with and reinforce the results of the NTP study on near field exposure. Both reported an increase in the incidence of tumors of the brain and heart in RFR-exposed Sprague-Dawley rats, which are tumors of the same histological type as those observed in some epidemiological studies on cell phone users.

Further, in a 2015 animal carcinogenicity study, tumor promotion by exposure of mice to RFR at levels below exposure limits for humans was demonstrated (31). Co-carcinogenicity of RFR was also demonstrated by Soffritti and Giuliani (32) who examined both power-line frequency magnetic fields as well as 1.8 GHz modulated RFR. They found that exposure to Sinusoidal-50 Hz Magnetic Field (S-50 Hz MF) combined with acute exposure to gamma radiation or to chronic administration of formaldehyde in drinking water induced a significantly increased incidence of malignant tumors in male and female Sprague Dawley rats. In the same report, preliminary results indicate higher incidence of malignant Schwannoma of the heart after exposure to RFR in male rats. Given the ubiquity of many of these co-carcinogens, this provides further evidence to support the recommendation to reduce the public's exposure to RFR to as low as is reasonably achievable.

Finally, a case series highlights potential cancer risk from cell phones carried close to the body. West et al. (33) reported four "extraordinary" multifocal breast cancers that arose directly under the antennae of the cell phones habitually carried within the bra, on the sternal side of the breast (the opposite of the norm). We note that case reports can point to major unrecognized hazards and avenues for further investigation, although they do not usually provide direct causal evidence.

In a study of four groups of men, of which one group did not use mobile phones, it was found that DNA damage indicators in hair follicle cells in the ear canal were higher in the RFR exposure groups than in the control subjects. In addition, DNA damage increased with the daily duration of exposure (34).

Many profess that RFR cannot be carcinogenic as it has insufficient energy to cause direct DNA damage. In a review, Vijayalaxmi and Prihoda (35) found some studies suggested significantly increased damage in cells exposed to RF energy compared to unexposed and/or sham-exposed control cells, others did not. Unfortunately, however, in grading the evidence, these authors failed to consider baseline DNA status or the fact that genotoxicity has been poorly predicted using tissue culture studies (36). As well funding, a strong source of bias in this field of enquiry, was not considered (37).

CHILDREN AND REPRODUCTION

As a result of rapid growth rates and the greater vulnerability of developing nervous systems, the long-term risks to children from RFR exposure from cell phones and other WTDs are expected to be greater than those to adults (38). By analogy with other carcinogens, longer opportunities for exposure due to earlier use of cell phones and other WTDs could be associated with greater cancer risks in later life.

Modeling of energy absorption can be an indicator of potential exposure to RFR. A study modeling the exposure of children 3–14 years of age to RFR has indicated that a cell phone held against the head of a child exposes deeper brain structures to roughly double the radiation doses (including fluctuating electrical and magnetic fields) per unit volume than in adults, and also that the marrow in the young, thin skull absorbs a roughly 10-fold higher local dose than in the skull of an adult male (39). Thus, pediatric populations are among the most vulnerable to RFR exposure.

The increasing use of cell phones in children, which can be regarded as a form of addictive behavior (40), has been shown to be associated with emotional and behavioral disorders. Divan et al. (41) studied 13,000 mothers and children and found that prenatal exposure to cell phones was associated with behavioral problems and hyperactivity in children. A subsequent Danish study of 24,499 children found a 23% increased odds of emotional and behavioral difficulties at age 11 years among children whose mothers reported any cell phone use at age 7 years, compared to children whose mothers reported no use at age 7 years (42). A cross-sectional study of 4,524 US children aged 8–11 years from 20 study sites indicated that shorter screen time and longer sleep periods independently improved child cognition, with maximum benefits achieved with low screen time and age-appropriate sleep times (43). Similarly, a cohort study of Swiss adolescents suggested a potential adverse effect of RFR on cognitive functions that involve brain regions mostly exposed during mobile phone use (44). Sage and Burgio et al. (45) posit that epigenetic drivers and DNA damage underlie adverse effects of wireless devices on childhood development.

RFR exposure occurs in the context of other exposures, both beneficial (e.g., nutrition) and adverse (e.g., toxicants or stress). Two studies identified that RFR potentiated adverse effects of lead on neurodevelopment, with higher maternal use of mobile phones during pregnancy [1,198 mother-child pairs, (46)] and

Attention Deficit Hyper-activity Disorder (ADHD) with higher cell phone use and higher blood lead levels, in 2,422 elementary school children (47).

A study of Mobile Phone Base Station Tower settings adjacent to school buildings has found that high exposure of male students to RFR from these towers was associated with delayed fine and gross motor skills, spatial working memory, and attention in adolescent students, compared with students who were exposed to low RFR (48). A recent prospective cohort study showed a potential adverse effect of RFR brain dose on adolescents' cognitive functions including spatial memory that involve brain regions exposed during cell phone use (44).

In a review, Pall (49) concluded that various non-thermal microwave EMF exposures produce diverse neuropsychiatric effects. Both animal research (50–52) and human studies of brain imaging research (53–56) indicate potential roles of RFR in these outcomes.

Male fertility has been addressed in cross-sectional studies in men. Associations between keeping cell phones in trouser pockets and lower sperm quantity and quality have been reported (57). Both *in vivo* and *in vitro* studies with human sperm confirm adverse effects of RFR on the testicular proteome and other indicators of male reproductive health (57, 58), including infertility (59). Rago et al. (60) found significantly altered sperm DNA fragmentation in subjects who use mobile phones for more than 4 h/day and in particular those who place the device in the trousers pocket. In a cohort study, Zhang et al. (61) found that cell phone use may negatively affect sperm quality in men by decreasing the semen volume, sperm concentration, or sperm count, thus impairing male fertility. Gautam et al. (62) studied the effect of 3G (1.8–2.5 GHz) mobile phone radiation on the reproductive system of male Wistar rats. They found that exposure to mobile phone radiation induces oxidative stress in the rats which may lead to alteration in sperm parameters affecting their fertility.

RELATED OBSERVATIONS, IMPLICATIONS AND STRENGTHS OF CURRENT EVIDENCE

An extensive review of numerous published studies confirms non-thermally induced biological effects or damage (e.g., oxidative stress, damaged DNA, gene and protein expression, breakdown of the blood-brain barrier) from exposure to RFR (63), as well as adverse (chronic) health effects from long-term exposure (64). Biological effects of typical population exposures to RFR are largely attributed to fluctuating electrical and magnetic fields (65–67).

Indeed, an increasing number of people have developed constellations of symptoms attributed to exposure to RFR (e.g., headaches, fatigue, appetite loss, insomnia), a syndrome termed *Microwave Sickness* or *Electro-Hyper-Sensitivity* (EHS) (68–70).

Causal inference is supported by consistency between epidemiological studies of the effects of RFR on induction of human cancer, especially glioma and vestibular Schwannomas, and evidence from animal studies (8). The combined weight of the evidence linking RFR to public health risks includes a broad array of findings: experimental biological evidence of non-thermal effects of RFR; concordance of evidence regarding carcinogenicity of RFR; human evidence of male reproductive damage; human and animal evidence of developmental harms; and limited human and animal evidence of potentiation of effects from chemical toxicants. Thus, diverse, independent evidence of a potentially troubling and escalating problem warrants policy intervention.

CHALLENGES TO RESEARCH, FROM RAPID TECHNOLOGICAL ADVANCES

Advances in RFR-related technologies have been and continue to be rapid. Changes in carrier frequencies and the growing complexity of modulation technologies can quickly render "yesterdays" technologies obsolete. This rapid obsolescence restricts the amount of data on human RFR exposure to particular frequencies, modulations and related health outcomes that can be collected during the lifespan of the technology in question.

Epidemiological studies with adequate statistical power must be based upon large numbers of participants with sufficient latency and intensity of exposure to specific technologies. Therefore, a lack of epidemiological evidence does not necessarily indicate an absence of effect, but rather an inability to study an exposure for the length of time necessary, with an adequate sample size and unexposed comparators, to draw clear conclusions. For example, no case-control study has been published on fourth generation (4G; 2–8 GHz) Long-term Evolution (LTE) modulation, even though the modulation was introduced in 2010 and achieved a 39% market share worldwide by 2018 (71).

With this absence of human evidence, governments must require large-scale animal studies (or other appropriate studies of indicators of carcinogenicity and other adverse health effects) to determine whether the newest modulation technologies incur risks, prior to release into the marketplace. Governments should also investigate short-term impacts such as insomnia, memory, reaction time, hearing and vision, especially those that can occur in children and adolescents, whose use of wireless devices has grown exponentially within the past few years.

The Telecom industry's fifth generation (5G) wireless service will require the placement of many times more small antennae/cell towers close to all recipients of the service, because solid structures, rain and foliage block the associated millimeter wave RFR (72). Frequency bands for 5G are separated into two different frequency ranges. Frequency Range 1 (FR1) includes sub-6 GHz frequency bands, some of which are bands traditionally used by previous standards, but has been extended to cover potential new spectrum offerings from 410 to 7,125 MHz. Frequency Range 2 (FR2) includes higher frequency bands from 24.25 to 52.6 GHz. Bands in FR2 are largely of millimeter wave length, these have a shorter range but a higher available bandwidth than bands in the FR1. 5G technology is being developed as it is also being deployed, with large arrays

of directional, steerable, beam-forming antennae, operating at higher power than previous technologies. 5G is not stand-alone—it will operate and interface with other (including 3G and 4G) frequencies and modulations to enable diverse devices under continual development for the "internet of things," driverless vehicles and more (72).

Novel 5G technology is being rolled out in several densely populated cities, although potential chronic health or environmental impacts have not been evaluated and are not being followed. Higher frequency (shorter wavelength) radiation associated with 5G does not penetrate the body as deeply as frequencies from older technologies although its effects may be systemic (73, 74). The range and magnitude of potential impacts of 5G technologies are under-researched, although important biological outcomes have been reported with millimeter wavelength exposure. These include oxidative stress and altered gene expression, effects on skin and systemic effects such as on immune function (74). *In vivo* studies reporting resonance with human sweat ducts (73), acceleration of bacterial and viral replication, and other endpoints indicate the potential for novel as well as more commonly recognized biological impacts from this range of frequencies, and highlight the need for research before population-wide continuous exposures.

GAPS IN APPLYING CURRENT EVIDENCE

Current exposure limits are based on an assumption that the only adverse health effect from RFR is heating from short-term (acute), time-averaged exposures (75). Unfortunately, in some countries, notably the US, scientific evidence of the potential hazards of RFR has been largely dismissed (76). Findings of carcinogenicity, infertility and cell damage occurring at daily exposure levels—within current limits—indicate that existing exposure standards are not sufficiently protective of public health. Evidence of carcinogenicity alone, such as that from the NTP study, should be sufficient to recognize that current exposure limits are inadequate.

Public health authorities in many jurisdictions have not yet incorporated the latest science from the U.S. NTP or other groups. Many cite 28-year old guidelines by the *Institute of Electrical and Electronic Engineers* which claimed that "Research on the effects of chronic exposure and speculations on the biological significance of non-thermal interactions have not yet resulted in any meaningful basis for alteration of the standard" (77)[2].

Conversely, some authorities have taken specific actions to reduce exposure to their citizens (78), including testing and recalling phones that exceed current exposure limits.

While we do not know how risks to individuals from using cell phones may be offset by the benefits to public health of being able to summon timely health, fire and police emergency services, the findings reported above underscore the importance of evaluating potential adverse health effects from RFR exposure, and taking pragmatic, practical actions to minimize exposure.

We propose the following considerations to address gaps in the current body of evidence:

- As many claim that we should by now be seeing an increase in the incidence of brain tumors if RFR causes them, ignoring the increases in brain tumors summarized above, a detailed evaluation of age-specific, location-specific trends in the incidence of gliomas in many countries is warranted.
- Studies should be designed to yield the strongest evidence, most efficiently:
  - ➢ Population-based case-control designs can be more statistically powerful to determine relationships with rare outcomes such as glioma, than cohort studies. Such studies should explore the relationship between energy absorption (SAR[3]), duration of exposure, and adverse outcomes, especially brain cancer, cardiomyopathies and abnormal cardiac rythms, hematologic malignancies, thyroid cancer.
  - ➢ Cohort studies are inefficient in the study of rare outcomes with long latencies, such as glioma, because of cost-considerations relating to the follow-up required of very large cohorts needed for the study of rare outcomes. In addition, without continual resource-consuming follow-up at frequent intervals, it is not possible to ascertain ongoing information about changing technologies, uses (e.g., phoning vs. texting or accessing the Internet) and/or exposures.
  - ➢ Cross-sectional studies comparing high-, medium-, and low-exposure persons may yield hypothesis-generating information about a range of outcomes relating to memory, vision, hearing, reaction-time, pain, fertility, and sleep patterns.
- Exposure assessment is poor in this field, with very little fine-grained detail as to frequencies and modulations, doses and dose rates, and peak exposures, particularly over the long-term. Solutions such as wearable meters and phone apps have not yet been incorporated in large-scale research.
- Systematic reviews on the topic could use existing databases of research reports, such as the one created by *Oceania Radiofrequency Science Advisory Association* (79) or EMF Portal (80), to facilitate literature searches.
- Studies should be conducted to determine appropriate locations for installation of antennae and other broadcasting systems; these studies should include examination of biomarkers of inflammation, genotoxicity, and other health indicators in persons who live at different radiuses around these installations. This is difficult to study in the general population because many people's greatest exposure arises from their personal devices.
- Further work should be undertaken to determine the distance that wireless technology antennae should be kept away from humans to ensure acceptable levels of safety, distinguishing among a broad range of sources (e.g., from commercial transmitters to Bluetooth devices), recognizing that exposures fall with the inverse of the square of the distance

[2]The FCC adopted the IEEE C95.1 1991 standard in 1996.

[3]When necessary, SAR values should be adjusted for age of child in W/kg.

(The inverse-square law specifies that intensity is inversely proportional to the square of the distance from the source of radiation). The effective radiated power from cell towers needs to be regularly measured and monitored.

POLICY RECOMMENDATIONS BASED ON THE EVIDENCE TO DATE

At the time of writing, a total of 32 countries or governmental bodies within these countries[4] have issued policies and health recommendations concerning exposure to RFR (78). Three U.S. states have issued advisories to limit exposure to RFR (81–83) and the *Worcester Massachusetts Public Schools* (84) voted to post precautionary guidelines on Wi-Fi radiation on its website. In France, Wi-Fi has been removed from pre-schools and ordered to be shut off in elementary schools when not in use, and children aged 16 years or under are banned from bringing cell phones to school (85). Because the national test agency found 9 out of 10 phones exceeded permissible radiation limits, France is also recalling several million phones.

We therefore recommend the following:

1. Governmental and institutional support of data collection and analysis to monitor potential links between RFR associated with wireless technology and cancers, sperm, the heart, the nervous system, sleep, vision and hearing, and effects on children.
2. Further dissemination of information regarding potential health risk information that is in wireless devices and manuals is necessary to respect users' *Right To Know*. Cautionary statements and protective measures should be posted on packaging and at points of sale. Governments should follow the practice of France, Israel and Belgium and mandate labeling, as for tobacco and alcohol.
3. Regulations should require that any WTD that could be used or carried directly against the skin (e.g., a cell phone) or in close proximity (e.g., a device being used on the lap of a small child) be tested appropriately as used, and that this information be prominently displayed at point of sale, on packaging, and both on the exterior and within the device.
4. IARC should convene a new working group to update the categorization of RFR, including current scientific findings that highlight, in particular, risks to youngsters of subsequent cancers. We note that an IARC Advisory Group has recently recommended that RFR should be re-evaluated by the IARC Monographs program with high priority.
5. The World Health Organization (WHO) should complete its long-standing RFR systematic review project, using strong modern scientific methods. National and regional public health authorities similarly need to update their understanding and to provide adequate precautionary guidance for the public to minimize potential health risks.
6. Emerging human evidence is confirming animal evidence of developmental problems with RFR exposure during pregnancy. RFR sources should be avoided and distanced from expectant mothers, as recommended by physicians and scientists (babysafeproject.org).
7. Other countries should follow France, limiting RFR exposure in children under 16 years of age.
8. Cell towers should be distanced from homes, daycare centers, schools, and places frequented by pregnant women, men who wish to father healthy children, and the young.

Specific examples of how the health policy recommendations above, invoking the Precautionary Principle, might be practically applied to protect public health, are provided in the **Annex**.

[4]Argentina, Australia, Austria, Belgium, Canada, Chile, Cyprus, Denmark, European Environmental Agency, European Parliament, Finland, France, French Polynesia, Germany, Greece, Italy, India, Ireland, Israel, Namibia, New Zealand, Poland, Romania, Russia, Singapore, Spain, Switzerland, Taiwan, Tanzania, Turkey, United Kingdom, United States.

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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ANNEX: EXAMPLES OF ACTIONS FOR REDUCING RFR EXPOSURE

1. Focus actions for reducing exposure to RFR on pregnant women, infants, children and adolescents, as well as males who might wish to become fathers.
2. Reduce, as much as possible, the extent to which infants and young children are exposed to RFR from Wi-Fi-enabled devices such as baby monitors, wearable devices, cell phones, tablets, etc.
3. Avoid placing cell towers and small cell antennae close to schools and homes pending further research and revision of the existing exposure limits. In schools, homes and the workplace, cable or optical fiber connections to the Internet are preferred. Wi-Fi routers in schools and daycares/kindergartens should be strongly discouraged and programs instituted to provide Internet access via cable or fiber.
4. Ensure that WTDs minimize radiation by transmitting only when necessary, and as infrequently as is feasible. Examples include transmitting only in response to a signal (e.g., accessing a router or querying a device, a cordless phone handset being turned on, or voice or motion activation). Prominent, visible power switches are needed to ensure that WTDs can be easily turned on only when needed, and off when not required (e.g., Wi-Fi when sleeping).
5. Lower permitted power densities in close proximity to fixed-site antennae, from "occupational" limits to exposure limits for the general public.
6. Update current exposure limits to be protective against the non-thermal effects of RFR. Such action should be taken by all heath ministries and public health agencies, as well as industry regulatory bodies. Exposure limits should be based on measurements of RFR levels related to biological effects (2).
7. Ensure that advisories relating to cell phone use are placed in such a way that purchasers can find them easily, similar to the Berkeley Cell Phone "Right to Know" Ordinance (86).
8. Advise the public that texting and speaker mode are preferable to holding cell phones to the ear. Alternatively, use hands-free accessories for cell phones, including air tube headsets that interrupt the transmission of RFR.
9. When possible, keep cell phones away from the body (e.g., on a nearby desk, in a purse or bag, or on a mounted hands-free accessory in motor vehicles).
10. Delay the widespread implementation of 5G (and any other new technology) until studies can be conducted to assess safety. This includes a wide range of household and community-wide infrastructure WTDs and self-driving vehicles, as well as the building of 5G minicells.
11. Fiber-optic connections for the Internet should be made available to every home, office, school, warehouse and factory, when and where possible.

GLOSSARY

ALARA	As Low a level As Reasonably Achievable
CBTRUS	Central Brain Tumor Registry of the United States
CI	Confidence Interval
EMR	Electro Magnetic Radiation
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
INEP	International Network for Epidemiology in Policy
LTE	Long-Term Evolution modulation
NTP	U.S. National Toxicology Program
OR	Odds Ratio
RFR	Radio-Frequency Radiation
SAR	Specific Absorption Rate
WTD	Wireless Transmitting Device

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Low-level EMF effects on wildlife and plants: What research tells us about an ecosystem approach

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There is enough evidence to indicate we may be damaging non-human species at ecosystem and biosphere levels across all taxa from rising background levels of anthropogenic non-ionizing electromagnetic fields (EMF) from 0 Hz to 300 GHz. The focus of this Perspective paper is on the unique physiology of non-human species, their extraordinary sensitivity to both natural and anthropogenic EMF, and the likelihood that artificial EMF in the static, extremely low frequency (ELF) and radiofrequency (RF) ranges of the non-ionizing electromagnetic spectrum are capable at very low intensities of adversely affecting both fauna and flora in all species studied. Any existing exposure standards are for humans only; wildlife is unprotected, including within the safety margins of existing guidelines, which are inappropriate for trans-species sensitivities and different non-human physiology. Mechanistic, genotoxic, and potential ecosystem effects are discussed.

KEYWORDS

non-ionizing electromagnetic fields, static/extremely-low frequency electromagnetic fields, radiofrequency radiation, wildlife, electro/magnetoreception, DNA, cryptochromes

Introduction

Contrary to popular opinion, we know a great deal about how non-ionizing electromagnetic fields (EMF) affect non-human species because we have been using animal and plant models in research going back at least to the 1930's (1). Such research may have been conducted with humans in mind but can also be extrapolated to non-human species protection if we choose to apply it that way.

Mice and rats have been the primary animal species used in research, but also rabbits, dogs, cats, chickens, pigs, non-human primates, amphibians, insects, nematodes, various microbes, yeast cells, plants, and others. Effects have been seen in all taxa, in various frequencies, intensities, and exposure parameters. To non-human species, these are highly biologically active exposures, often functioning as stressors. This includes non-ionizing EMF in the static, extremely low frequency (ELF; 0–300 Hz) through the radiofrequency (RF) ranges used in all modern technology between 3 kHz and 300 GHz.

Extrapolations to wildlife from carefully controlled laboratory conditions, however, are difficult to quantify due to myriad variables such as: genetic variation and mobility, weather/climate change, site/region-specific environmental aspects, duration of exposure and variations in movements across habitats, species specialized physical characteristics, animal size, and orientation toward the field source—all of which can confound precise data assessment. Sometimes controlled studies correlate with patterns seen in wildlife, e.g., genetic, behavioral, reproductive, and other effects. Where this is the case, more confidence is possible. But often effects to wildlife manifest in the negative—species simply disappear. Nevertheless, increasing evidence has found effects to different species near communication structures in studies where extrapolations to field exposure have been made (2–9).

In addition, there have been extensive EMF wildlife reviews published between 2003 and 2021 (10–22). Recently, Levitt et al. (23–25) extrapolated to broad ecosystem level effects for the first time, including extensive tables that match rising ambient levels to effects seen at vanishingly low intensities now common in the environment as chronic exposures, and offer policy recommendations based on existing environmental laws.

The measured rising EMF levels in ambient environments (23) certainly elevate concerns, especially with 5G on the horizon using higher frequencies and novel signal characteristics/waveforms that are capable of affecting insects in particular with implications for the entire biome as discussed below. 5G is now increasing as a network platform in many places even as we are trying to figure out how to measure and distinguish its wideband signals from the larger scheme of 3–4G LTE networks with which it interacts. Already some of the unusual aspects of 5G (e.g., significantly higher peak emissions), are distinguishable from the background of other exposures as an environmental factor (26).

Functioning misconceptions and terminology

There are two prevalent misconceptions today about how low-level non-ionzing EMF couples with and affects non-human species: (1) There is no need for environmental concern since exposures as currently regulated are too low to cause effects; and (2) Existing exposure standards for humans are sufficient to cover non-human species too. Neither supposition is accurate.

No radiofrequency (RFR) emission guidelines today take non-human species into consideration, despite constant measured rising background levels in urban, suburban, and rural areas [see Supplement 1 in reference (23)] that are capable of affecting wildlife and plants [see Supplement 3 and 4 in reference (24)]. This includes guideline allowances for RFR (100 kHz-300 GHz) created by the International Commission on Non-ionizing Radiation Protection (ICNIRP) (27), as well as a member organization of the American National Standards Institute (ANSI) called the International Electronics and Electrical Engineers (IEEE) that has written exposure guidelines for frequencies between 0 Hz and 300 GHz (28). Once countries or regulatory agencies, such as the U.S. Federal Communications Commission (FCC) (29), adopt such guidelines, they can become enforceable standards if those entities choose to do so within their statutory authority. The FCC can, and sometimes does, enforce RFR emission standards based partially on IEEE guidelines (For the purposes of this paper, we will refer to recommendations as exposure guidelines as applied to the environment). In addition, ICNIRP and IEEE/FCC only control for short-term acute exposures capable of heating tissue, not the long-term low-level chronic exposures common today for which they say there is not enough evidence to warrant change in recommendations (These authors disagree). They also fail to include important signaling characteristics (29), like modulation with significant biological effects particular to different transmission features (30). Many European countries, as well as Canada and Australia, have traditionally adopted ICNIRP guidelines (sometimes with slight variations) while others, like Switzerland, have adopted more stringent levels (25).

One complexity (among many) regarding writing EMF safety guidelines in general—but especially with wildlife in mind—involves the semantic difference between "emissions" (characteristics of the field at the transmission source) and "exposures" (the characteristics of the field absorbed by an object). ICNIRP/IEEE/FCC have guideline components for both emissions (expressed as a value of radiant energy in space for far-field encounters at some distance from the generating source) and exposures [expressed as a specific absorption rate (SAR) that is also pertinent to near-field exposures such as from cell phones held against the human head]. Emissions, of course, result in exposures; it is just a question of degree. Depending on species and environment, wildlife is capable of experiencing both near- and far-field exposures like humans. Once emissions leave the transmitting source, they are capable of creating broad exposures and becoming a chronic source of pollution. For the purposes of this paper, we will use "emissions" to denote transmission values and "exposures" to denote uncontrolled, unregulated ambient exposures.

There are many things in the environment that can affect how non-ionizing electromagnetic energy is absorbed, including atmospheric moisture and/or particulate content, soil composition, natural and/or artificial obstacles (trees/buildings), and the presence of other waveforms which can augment and/or diminish exposures, among others. Such complexities should not be used as an excuse to do nothing. Writing guidelines for all species is clearly a yeoman's task that will take far more than simply turning the power down; it may take significant electrical and RF re-engineering, alterations in frequency allocation, and societal change too (30).

A current effort to include non-human species in emission guidelines

There is a current effort by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), which uses the ICNIRP standards, to investigate broad information regarding effects to wildlife (31). ARPANSA, like ICNIRP/IEEE/FCC, has traditionally focused on human exposures with no recognized guidelines specifically addressed to the protection of plants and animals (31). The ARPANSA inquiry's emphasis thus far is on study design, i.e., how to sort research according to predefined inclusion/exclusion criteria, then incorporate the knowledge into "systematic maps" to see if the current human exposure criteria are sufficient to cover wildlife.

While this is a significant undertaking heretofore overlooked by guidelines-setting groups, the described approach may prove little more than a formula to verify the status quo. The defined exclusion criteria will likely eliminate from review most of the salient research on non-human sensitivity to the lowest intensity exposure levels to which many species are exquisitely sensitive at, or near, natural background levels that are clearly far below current guidelines. The resulting data will inevitably be skewed since the lowest level exposure research will be mixed in with controls and essentially disappear into the proposed analysis as a non-exposure, or it may be eliminated from review altogether. Example: the elimination criterion defines study controls as: "Sham exposure, no exposure beyond the background exposure level (which can be assumed to be negligibly low), or exposure at a lower level" (31). Since "lower level" is not defined and many ambient background levels are now artificially high [see Supplement 1 in reference (23)], this may not be the best methodology to quantify real-world field exposures to non-human species, let alone match it to relevant studies. Any true inquiry into EMF wildlife effects must begin from environmental/biological realities, not pre-existing dosimetry perspectives.

Different frequency ranges may adversely affect one species but have no impact on another. ICNIRP/IEEE/FCC's singular focus on heating effects may be particularly insupportable regarding insects, which can reach resonant matches with higher frequencies such as those used in the top ranges of 5G (>6 GHZ) due to insect's reduced size (32, 33). Insects do not dissipate heat and can suffer extreme effects within short periods of exposure even in much lower ranges (<3 GHZ), leading to reproductive problems and death (1). Existing exposure standards may prevent humans from heating effects due to thermo-regulatory mechanisms but not with other species such as insects, small amphibians and reptiles.

Wildlife exposures today are just a question of degree. Many wildlife species constantly traverse varying artificial fields in all environments with many flying species—such as birds, bats, and insects—reaching extremely close proximity to transmission sources to which humans are rarely, if ever, exposed. Some of the highest power density areas, e.g., near broadcast antenna farms, are specifically located away from human populations with the assumption that if wildlife were impacted, they would abandon such sites for more favorable ones. But because of complex avian magnetoreception, RFR-generating infrastructure may be functioning as an attractant instead. Many such exposures may simply damage wildlife and go unnoticed, likely from near-field thermal effects as well as far-field non-thermal effects, among other causes (34–36).

Research on anthropogenic EMF has found non-linear effects that function differently from classic linear dose-response toxicology models. EMF effects may be fundamentally different than thermal effects, possibly working *via* different mechanisms (37). Effects may be more damaging to some species at lower intensities—the exact opposite of how emission guidelines that can become exposure standards are currently written and a primary reason to include the lowest level exposures in new research efforts. Even once pristine wilderness regions are now RFR-exposed environments from ground-based cell networks rimming national parks and wilderness areas, and from the exponential increase in satellites delivering internet connectivity to anywhere on Earth (23).

The true trans-species biological realities of today's exposures are enormously difficult to quantify, given the inherent variables of species differences, macro and microclimate adaptations, mating/migration patterns, and vastly different environments—e.g., aerial, ground-based, and aquatic—all with unique species-specific adaptions and electromagnetic receptor mechanisms. New methodological approaches that take the lowest exposures at ecosystem levels into consideration are needed.

Natural sensitivities vs. manmade EMF

Many non-human species have highly specific vulnerabilities to anthropogenic EMF due to unique physiology that depend upon, and constantly use, the Earth's static geomagnetic fields for seasonal migration/orientation, nest/den building, mating, reproduction, offspring care, food finding, territorial defense, simple daily/seasonal circadian rhythms, and even longevity and survivorship. Electromagnetic perceptual factors include multi-system environmental species-specific mechanisms. Many species have specialized electroreceptor cells and/or magnetoreception abilities pertinent to their environments that far surpass human sensitivity. For instance, many species can sense natural DC magnetic fields in diverse ways including: migratory bird species (38, 39); numerous insect species including honey bees (40, 41); fish (42–47); mammals (48);

bats (49); mollusks (50), and bacteria (51, 52). Some bird species may actually 'see' the Earth's magnetic fields *via* complex magnetoception capabilities (53) located in their eye and beak areas.

As noted in Panagopoulos et al. (54), natural and manmade EMF are significantly and fundamentally different. Unlike natural EMF, all anthropogenic EMF is polarized, meaning it is more biologically active *via* the ability to amplify intensities (called constructive interference) as well as alter cellular charged/polar molecule oscillations into parallel planes in phase with the applied field. This can result in irregular gating in cell membrane ion channels and thereby disrupt the normal cellular electrochemical balance. In other words, manmade EMF can capture, entrain, and manipulate living cells' basic functioning architecture unlike natural EMF with which most living things have evolved. In addition, anthropogenic EMF typically functions at higher intensities for longer durations thereby increasing exposures in frequency ranges that are minimal in the natural environment, introducing signaling characteristics (modulation, phasing, pulsing etc.) that simply do not exist in nature but are now greatly amplified as a novel exposure due to technology. All these factors may account for the myriad biological effects seen in the literature over the last several decades.

Magnetoreception: Mechanisms

There are three primary mechanisms involved with magnetoreception in non-human species:

- An induction process in which weak electrical signals are induced by magnetic stimulation in specialized sensory receptors (55).
- A magnetomechanical method in which localized deposits of single-domain magnetite crystals create signal information interactions (56, 57).
- A specialized-cell model in which radical-pair photoreceptor molecules create dedicated information pathways—an area getting significant research attention today (19, 30, 58–73).

In the induction model, according to Tenforde (57), specialized organs are involved with electrodynamic interactions with weak electromagnetic fields. In aquatic species this is seen in sharks, rays, and skates (elasmobranch fish) with heads that contain jelly-filled canals that have high electrical conductivity called Ampullae of Lorenzini. Small voltage gradients are induced in these canals *via* DC electric fields as low as 0.5 μV/m as these fish swim through the Earth's geomagnetic flux lines. Directional information is provided by the polarity of the induced field in relation to Earth's geomagnetic field. This may be an aqueous environment/species-specific factor as such organs have not been found in birds, insects, or land-based animals (58) although other physiological mechanisms may function in a similar capacity in some land-based species.

Many animals have evolved other special receptor organs. For example, the duck-billed platypus (*Ornithorhynchus anatinus*), a semi-aquatic egg-laying mammal, has thousands of electric sensors on its bill skin that allow for vital information processing in the somatosensory cortex (74). A platypus can detect an electric field of 20 μV/cm (equivalent to that produced by the muscles of a shrimp) *via* these electroreceptors interacting with a mechanoreceptor. Such electroreception is also seen in two aquatic species of monotremes: the long-bill (*Zaglossus bruijni*) and short-bill (*Tachyglossus aculeatus*) echidna. Other electric fish (including elasmobranchs) emit their own electric fields extending several centimeters for location/orientation, food-finding, and defense (75, 76). This unique ability allows electric fish to distinguish subtle differences in electrical properties within its immediate vicinity, including the electric fields of other fish, *via* electroreceptors capable of detecting a field of 5 nV/cm. While such evolutionary perceptual adaptations are extremely efficient and sensitive, they also render such species exceptionally vulnerable to unnatural anthropogenic fields. Some researchers postulate that electro-receptors in fish are a form of alternate touch and communication (77). The primary concern for aquatic species is from AC-ELF exposures from underwater cabling and other technologies, not RF which is of more concern for ground-based and aerial species (24).

The magnetomechanical model involves the naturally occurring iron-based crystal called magnetite (78–80) that has been found in most species studied, often in very different physiological areas. Magnetite-based orientation/interactions are patterned according to the geomagnetic field. Magnetite is highly reactive to external electromagnetic fields—a million times more strongly than any other known magnetic material. The abdominal areas of honey bees, for instance, contain magnetite with complex nerve endings feeding into it and can detect static magnetic field fluctuations as weak as 26 nT against background earth-strength magnetic fields that are much higher (79). They can also sense weak alternating fields at frequencies of 10 and 60 Hz (79). Bees are also affected by RFR as discussed below.

The third mechanistic model involves a complex conversion of electrons (singlet-triplet inter-conversion) and a free-radical-pair reaction in a group of proteins called cryptochromes.

As reviewed in Levitt et al. (24), cryptochromes have been found in the retinas of nocturnal migratory songbirds indicating intricate communication between avian eye and brain for orientation when relying on magnetoreception (38, 39). Cryptochromes were also found to be a critical magnetoreception component in fruit flies (*Drosophila melanogaster*) (81). Some other animals are also known to have retinal cryptochromes (38). Radiofrequency radiation (82) and

oscillating magnetic fields have been reported to disrupt the migratory compass orientation in migratory birds (83). There are also reports of cryptochromes in plants which may account for the effect of EMF on plant growth (66). Cryptochromes are also known to be involved with circadian rhythms (72). Ritz et al. (63) published a review on the theories, plausibility, and complexities of cryptochrome/radical pairs.

Some species rely on combinations of mechanisms, e.g., two mechanisms exist side-by-side in some birds that mediate, as needed, different types of magnetic information. That is what facilitates flight on sunny vs. cloudy days and/or nocturnal flights. Both mechanisms can be easily disrupted (63, 84–86). It is thought that birds can co-process natural DC magnetic information with visual information and are able to distinguish them from each other (87, 88). According to Wiltschko and Wiltschko (88) and Wiltschko et al. (89), the likely mechanism occurs in the higher brain area and eyes *via* radical pair and light-dependent information processing (blue light absorbing photopigment cryptochromes have been found in avian retinas). The avian magnetic compass—an inclination compass—reacts to more than natural magnetic fields. RFR fields in the Larmor frequencies near 1.33 MHz were found to disrupt birds' orientation in an extremely sensitive resonance relationship (24). Radiofrequency radiation in particular may interfere with magnetoreception and be able to disable the avian compass while the exposures remain (4, 84). There are many uncertainties with this area in need of clarification.

Radiofrequency radiation may also affect natural "natal homing behavior"—the astounding ability of some species like sea turtles (90); eels (91); and salmon (42–44), among others—to return to their original birth location to reproduce. The underlying mechanism, though imperfectly understood, involves such species being "imprinted" with the exact location of their birth, likely through geomagnetic configurations, then "remembering" it at reproduction time even when thousands of kilometers away. The local geomagnetic field intensity and inclination angle are somehow impressed on newborns—information later used to return at breeding time. Landler et al. (92) found multiple effects of EMF in turtles that reproduce on land too, e.g., that RFR can alter natural orientation, establish its own orientation, and completely reverse natural orientation. This bellwether study is reason to protect sensitive breeding/nesting grounds from cell towers/transmitters being located nearby.

Different aspects of EMF and molecular mechanisms are likely used in many species and possibly more subtle stimuli as yet defined. The intensity and/or inclination of a stimulus, when combined with the vector of the geomagnetic field, may afford directional information. Avian behavioral studies (93) found birds used both cryptochrome and magnetite in response to a short intense pulsed magnetic field. It was also found that avian orientation was light-dependent and easily disrupted by high-frequency magnetic fields in the MHz range (83) suggesting that along with electrophysiological and histological studies, avian eyes have a radical pair mechanism providing compass-like directional information while magnetite in the upper beak senses magnetic intensity, thus providing positional information. The authors (83), however, pointed out that the songbird magnetic compass can be disrupted by an oscillating 1.403-MHz magnetic field of 2–3 nT—a level that cannot be explained by the radical-pair mechanism.

In 2014, Engles et al. (3) found magnetic noise between 2 kHz and 9 MHz disrupted the magnetic compass orientation of the migratory European Robin (*Erithacus rubecula*) at a vanishingly low level of 0.01 V/m, or 0.0000265 $\mu W/cm^2$ (That frequency range is within AM radio transmission). Similar RFR magnetoreception interference has also been reported in the same species, with broadband being the most detrimental (8), as well as in other species (4).

Another long-distance migratory species—the iconic Monarch butterfly (*Danaus plexippus*) in the U.S.—is known to have magnetite in their antennae (94, 95) and to contain cryptochromes (96, 97). A 1982 study (98) found the head and thorax areas of monarchs contained magnetic materials and a 2014 study (99) found that monarchs' longest fall migration from Canada to wintering grounds in Mexico is assisted by a magnetic compass.

The above information indicates potential adverse effects at ecosystem levels to some avian, aquatic, and insect species from RFR at current ambient levels [see Supplement 1 in reference (23)].

Genetic effects and EMF effects on insects

Despite classic assumptions that non-ionizing radiation cannot directly damage DNA, genotoxic effects have been seen in land-based, aerial, aquatic, and plant species at very low intensity RFR exposures far below ICNIRP/IEEE/FCC guidelines. There are at least 48 papers showing DNA damage after exposure to RFR at <0.4 W/kg [see Supplement 1 in reference (24)]. Genotoxic effects are also seen in animal and plant species that are found exceptionally sensitive to both natural and man-made EMF [also see Supplement 2 in reference (24)]. Insects are of special concern as populations are being decimated globally (24).

At 1.2 MHz range—known as the Larmor frequency—insects demonstrated the strongest effects (100). The Larmor frequency is also related to radical pair resonance and superoxide formation. This indicates that RFR effects are frequency-dependent. 5G and broadband include this range. Extremely low frequency EMF was also found by Shepherd et al. (101) to disrupt the directional sense of honey bees *(Anthophila)*.

Depending on insect type and exposure duration, Michaelson and Lin (1) back in 1987 noted sequential insect reactions to RFR (at high intensities): insects first tried to escape,

followed by motor disturbance and coordination problems, including stiffening, immobility, rigidity, and eventually death. At the same field intensity, *D. melanogaster*, for instance, survived longer than 30 min, whereas some tropical insects lived only a few seconds. Also seen were metabolic concentration changes and embryogenesis effects with gastrulation and larval growth being accelerated (102) (Embryogenesis is the period needed for a butterfly to complete metamorphosis). In 1961—in one of the earliest studies to find that pulsing alone is a biologically active exposure—Heller and Mickey (103) discovered that pulsed RFR between 30–60 MHz caused a 10-fold rise in sex-linked recessive mutations. In later studies using *D. melanogaster* models, Panagopoulos et al. (104) found severe effects in early and mid- stage oogenesis when flies were exposed *in vivo* to either GSM 900-MHz or DCS 1,800-MHz radiation from common digital cell phones, at non-thermal intensities for a few minutes per day during the first 6 days of adult life. The decrease in oviposition—as also previously reported by Panagopoulos et al. (105–107)—was hypothesized as due to degeneration of large numbers of egg chambers after DNA fragmentation of constituent cells. This was induced by both GSM and DCS mobile phone radiation. For the first time, induced cell death was documented in all cell types that constitute an egg chamber—including follicle cells, nurse cells, and the oocyte—and in all stages of early and mid-oogenesis from germarium to stage 10, during which programmed cell death does not physiologically occur (The most sensitive developmental stages to electromagnetic stress induced by the GSM and DCS fields were found to be germarium and stages 7–8). These papers, taken collectively, signify serious potential effects from cell phones/infrastructure and WiFi devices to all similar size insect species. Panagopoulos (108) further discussed the subject in an extensive review on genetic effects in 2019.

Ants also react adversely to RFR (109–111). Cammaerts et al. (111) found that memory and association between food sites and visual/olfactory cues in ants (*Myrmica sabuleti*) was significantly inhibited, with memory eventually wiped out altogether, from exposures to GSM-900 MHz signal at 0.0795 $\mu W/cm^2$. A cumulative effect was seen even at very low intensity with subsequent exposure. The exposed colonies' overall condition eventually resembled that of honeybee (*Apis mellifera*) colony collapse disorder. The researchers concluded that exposures common to cell phones/towers and other transmission sources are capable of disastrous effects on a wide range of insects that rely on olfactory and/or visual memory, including bees.

For nearly 100 years, researchers have known that bees have an acute sense of the Earth's DC magnetic fields (40, 112–115) and rely on that perception for survival. Because of bees' outsize pollinator significance to human food supplies, and their current significant population declines, they are a much-studied model for ELF EMF and RFR effects (see below). Early studies were conducted in the ELF ranges (24) and are ongoing. For an excellent review of ELF/RFR-EMF effects to insects, including bees, see Balmori (16) and a recent article by Li et al. (114) for ELF-EMF exposure/developmental defects.

Some RFR effects seen in bees include: significant inhibitory effects on sensory olfactory excitability and short term memory impairment after 24-h WiFi-router exposure (116); induced worker piping—the sound that initiates swarming behavior in colonies, or as a warning/distress signal—that demonstrated 900-MHz GSM is a stressor to bees (117); reduced motor activity and changes in biomolecules in the body (118); reduction of worker bees and reduced egg laying by queens exposed to cell phone radiation (119); reduced hatching and altered pupal development after cell phone radiation exposure (120); decrease in comb weight and delayed return or hive abandonment after exposure to DECT phone radiation (121, 122); changes in carbohydrate, lipid, and protein concentrations in the body with cell phone radiation exposure (123, 124); and increased mortality with exposure to HF (13.56 MHz) and UHF (868 MHz) RFR (125). RFR has also been implicated in colony collapse disorder (117, 126, 127). Most of the above studies were conducted in non-thermal ranges and non-linear effects were often seen, with the lower exposures causing the greater effects.

Insect size, non-linear effects, waveform characteristics, frequencies, and RFR transmission direction/antenna tilt are critical concerns with 5G radiation today due to that technology's extremely complex near- and- far-field ambient exposures in all environments from ubiquitous macro- and micro-cells, as well as increased low Earth orbit satellite networks (23). The range of frequencies used for wireless telecommunication systems will increase up to 120 GHz for 5G from below 6 GHz for 3G, 4GLTE, and WiFi. The shorter wavelengths at such higher frequencies are a far better resonant match with small insects. Both heating and non-heating effects are likely to occur. Flora is also known to be adversely affected by RFR with implications for small cell placement on utility poles near trees [see Supplement 4 in reference (24)].

An alarming study by Thielens et al. (32) computer modeled (as a function of frequency alone) absorbed RFR from 2 GHz to 120 GHz in four different insect types. All insects indicated an increase in frequency-dependent absorbed RFR at and above 6 GHz compared to absorbed RFR below 6 GHz. Computer modeling demonstrated that an upward conversion to frequencies above 6 GHz at just 10% of the incident power density could lead to increased RFR absorption between 3-to-370%. This is a large differential indicating potentially serious consequences to numerous insect species and consequently the entire food web.

In 2020, Thielens et al. (33) investigated western honeybees (*A. mellifera*) with a combination of computer simulations and *in-situ* RFR exposure measurements near bee hives. Five models were exposed to frequencies already carved out for 5G—plane waves from 0.6 GHz to 120 GHz. Frequency simulations quantified averaged absorbed whole-body RFR. Depending on

the specimen, they found the average increased by factors of 16-to-121 when a fixed incident electric field strength increased from 0.6 GHz to 6 GHz. Measurements were also taken near five different locations at 10 beehive sites. Results estimated a realistic absorption rate between 0.1 and 0.7 nW from an average total incident RFR field strength of 0.06 V/m, from which they concluded that an assumed 10% incident power density shift to frequencies higher than 3 GHz would cause increased RFR honeybee absorption between 390 and 570%. 5G involves just such a frequency shift.

The Thielens et al. (32, 33) studies alone raise serious concerns about ambient environmental invertebrate effects at these higher frequency exposures. There is a broad presumption of safety at ICNIRP/IEEE/FCC due to 5G millimeter-waves superficial penetration ability to affect skin tissue in humans. But shallow penetration in humans can equal whole body penetration in insects. This one technology has the ability to create significant holes in the food web with implications throughout the biome, yet no significant environmental reviews have been conducted prior to buildout and to date most emissions criteria adopted in various countries are primarily guidelines without consequence for violation.

Discussion

It is clear that non-human species experience EMF as environmental stressors and biological effects can occur at anthropogenic levels in our present environment. This largely unrecognized variable can conceivably alter delicate ecosystems, arguably including the biosphere where all living organisms are located—and may, in fact, be doing so. Traditionally, other than in small localized situations, e.g., near powerline corridors or broadcast antennas, ELF/RFR-EMF environmental effects have not been of serious concern to regulating authorities. But this subject now requires immediate attention with 5G on the horizon, as well as a reexamination of chronic rising ambient levels across all non-ionizing electromagnetic frequency ranges today.

Investigators have known since the early 1970's how EMF and RF couples with most animal species (128, 129). Given our increasing ambient EMF levels, far more precise understanding of the molecular and cellular processes of electro- and magneto-reception in non-human species is suddenly critical. We may already be overwhelming some species' natural biological sensors that evolved over eons. Electroreception mechanisms, including magneto/electroreceptors, magnetite, and cryptochrome/radical-pairs, enable vast living organisms in all environments to detect the presence of, and immediate changes, in non-ionizing electromagnetic fields at very low intensities across a range of frequencies. Such heightened sensitivities function far beyond human perception and create unique vulnerabilities that can easily be disturbed by novel man-made fields. Since technology changes so fast, no evolutionary adaptation is possible.

Radiofrequency radiation is a form of energetic air pollution and should be regulated as such (25). U.S. law (130) [42 USC § 7602 (g)] defines air pollution as:

"The term "air pollutant" means any air pollution agent or combination of such agents, including any physical, chemical, biological, radioactive (including source material, special nuclear material, and byproduct material) substance or matter which is emitted into or otherwise enters the ambient air. Such term includes any precursors to the formation of any air pollutant, to the extent the Administrator has identified such precursor or precursors for the particular purpose for which the term "air pollutant" is used."

Unlike classic chemical toxicology pollutants in which a culprit can typically be identified and quantified, RFR may function as a "process" pollutant in the air not unlike how endocrine dysruptors function in food and water in which the stressor causes a cascade of unpredictable systemic effects. The stimulus in the RFR analogy would be physical/energetic rather than chemical.

Long-term chronic low-level EMF exposure guidelines, which do not now exist, should be set accordingly for wildlife; mitigation techniques where possible should be developed; full environmental reviews should be conducted prior to the licensing/buildout of major new technologies like 5G; and environmental laws/regulations should be strictly enforced (25). We have a long over-due obligation to consider potential consequences to other species from our current unchecked technophoria—an obligation we have thus far not considered before species go extinct. In the views of these authors, the evidence requiring action is clear.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Author contributions

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

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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