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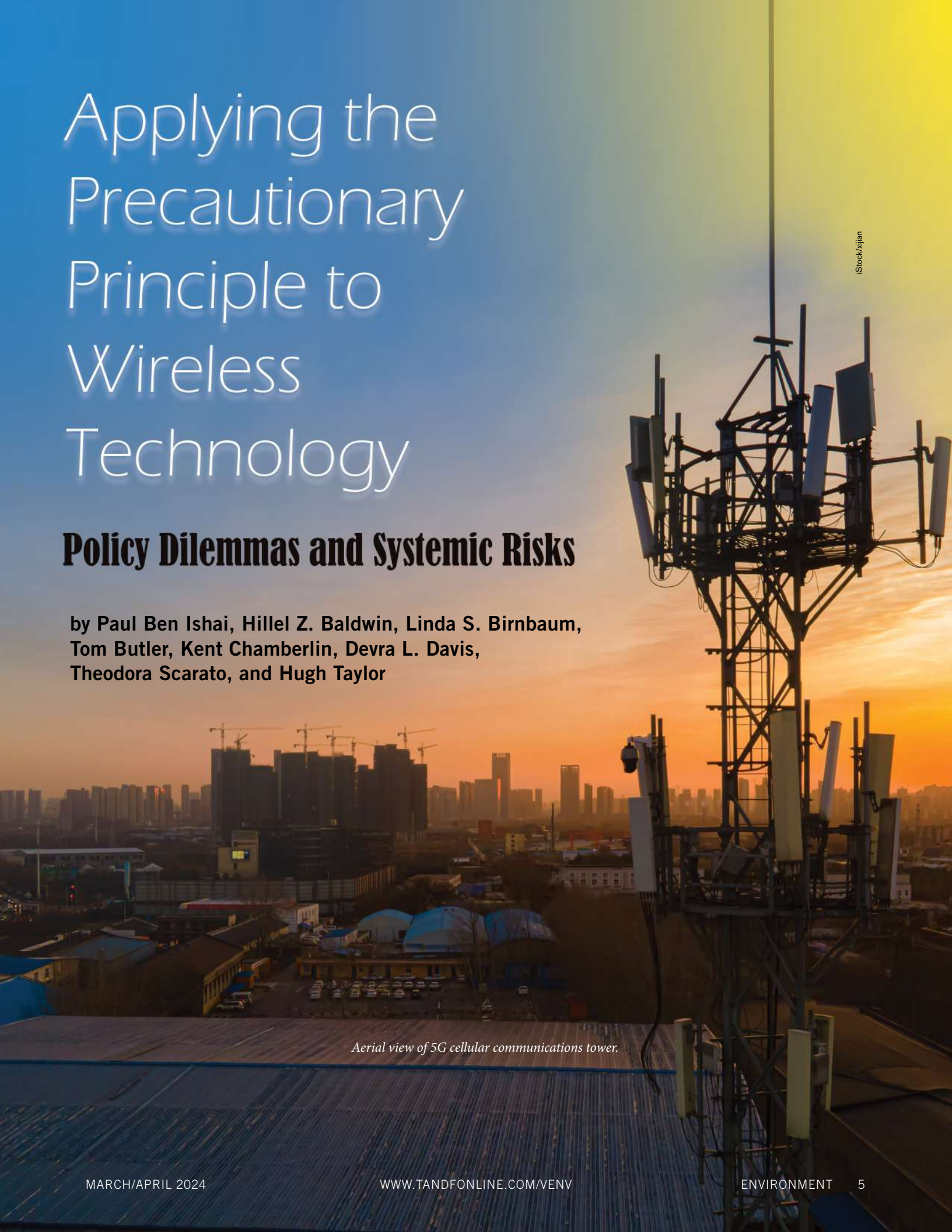
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Applying the Precautionary Principle to Wireless Technology

Policy Dilemmas and Systemic Risks

by Paul Ben Ishai, Hillel Z. Baldwin, Linda S. Birnbaum, Tom Butler, Kent Chamberlin, Devra L. Davis, Theodora Scarato, and Hugh Taylor



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Aerial view of 5G cellular communications tower.

Current policies in the United States and Europe regarding wireless radiation rest on an outdated assumption that the sole adverse impact to be avoided is acute heating of biological tissues.[1] These policies ignore substantial evidence of chronic impacts that wireless radiofrequency radiation (RFR) can have on public health and the broader environmental consequences. In this article, we briefly review the early history of policy development on RFR, provide evidence of significant adverse nonthermal chronic impacts from exposures that are not considered in current standards, and make the case for implementing the precautionary principle to protect public health and the environment. As with most environmental health hazards, the consequences of RFR are especially important to the fetus and children, as they will incur a lifetime of exposures that is without precedent. We thus argue for the adoption of the precautionary principle to reduce chronic, societal-level risks from exposures.

History

The origins of exposure standards in the United States were concerns within the military about health impacts on technicians working with high-power radar systems.[2] The U.S. military formed the Tri-Services Commission in 1957 to coordinate academic and industrial research into the effects of exposure, although research had been ongoing since 1952.[2] This commission included teams from the U.S. Air Force, Army, and Navy, Bell Laboratories, and academic institutions. The prevailing assumption in the United States was that the only important interaction between microwaves and biological systems would be thermal,[2,3,4] although that assumption was not adopted elsewhere in the world.[5] Initially a maximum permissible exposure (MPE) level to prevent tissue heating and burns from microwave or radiofrequency radiation was established. The MPE was calculated theoretically by Herman Schwan for the U.S. Navy in 1953[6] as 100 W/m^2 (watts per square meter). By 1957, General Electric, somewhat arbitrarily, had suggested that this level be reduced to 10 W/m^2 (or 1 mW/cm^2 in milliwatts per square centimeter),[2] a level recognizable in today's power density standards.[6]

In 1960 the task was delegated to the American Standards Association, who began the Radiation Hazards Standards Project, with the participation of the precursor of the Institute of Electrical and Electronics Engineers (IEEE).[7] This project spearheaded by leaders of the military and industry led to the development of the ANSI C95.1-1966 standard. This thermal threshold for ambient and skin surface exposure informed subsequent IEEE standard setting until 1982, when it was redefined using the specific absorption rate (SAR) approach,[8] which estimates the absorption of microwave radiofrequency energy and resultant tissue heating in the human body.[9]

As Nicolas Steneck's seminal history revealed, denial of nonthermal effects was already a well-established practice in the U.S. scientific and medical communities in the 1930s following the rise of diathermy (deep heating) for therapeutic medical purposes.[10] Diathermy is the application of ultrasound or microwave radiation to heat tissues. No other biological effects were assumed to exist, even though practical evidence and research at the University of Iowa in the 1940s[2] indicated otherwise. Steneck illustrates how ingrained assumptions and values led to the discounting of emerging scientific evidence of nonthermal effects surrounding diathermy.

This culture of denial extended into the military, as the manufacturing and widespread use of radar technologies during and after World War II exposed servicemen, researchers, and manufacturers to occupational exposures with increasing cases of adverse biological effects being reported. Again, the military, industrial, and scientific research communities failed to investigate chronic impacts. To this day in the United States, industry engineers and policymakers recognize no biological risks other than heating or thermal effects on humans considered by the IEEE and its International Committee on Electromagnetic Safety (ICES), which is responsible for industry safety standards. The points of reference for safety standards and guidelines that most policymakers and regulators outside the United States (including the European Union, the United Kingdom, Australia, Japan, and others) rely on are indistinguishable from those used in the United States.[11] These international standards were published by the self-appointed International Commission on Non-ionizing Radiation Protection (ICNIRP). Significantly, both ICNRIP and the IEEE/ICES, are mired in controversy[12] due to claims of industry bias, conflicts of interest, and, in the opinion of many independent scientists and clinicians, a failure to protect public health and the environment.

Assumption That Only Thermal Effects Are to Be Avoided Dominate Standards

"It seems reasonable to conclude that the main restraint against greater conservatism [in protecting public health] is a desire to maximize opportunities to expand the use of RF technology. What community has the greatest interest in expanding the use of RF technology? The military and industry, whose values are most strongly represented in C95.1-1982 and other similar policy decisions. At heart C95.1-1982 is a military-industry standard." —Nicholas Steneck, The Microwave Debate 1987[8]

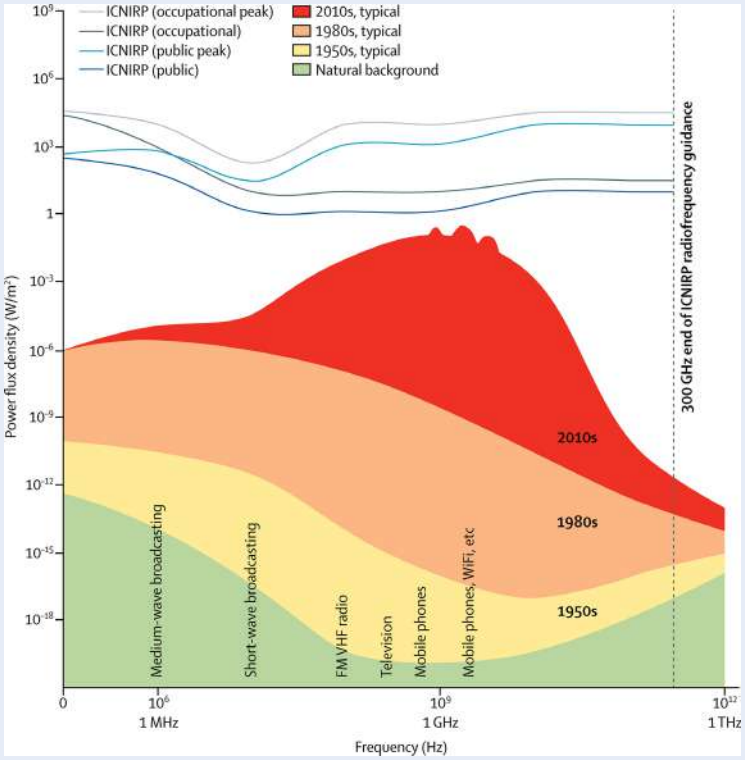
Figure 1. Up to 40,000 SpaceX Starlink sofa-size satellites will orbit the globe.



Wikimedia Commons/Botnet Sky

The IEEE engineers who developed the standards[13] could not have foreseen how ubiquitous wireless technologies became after the 1990s, with growing numbers of infants and toddlers exposed to wireless radiating devices. The built environment of homes, offices, schools, hospitals, and all commercial public and private spaces are now exposed to strong radiofrequency radiation (RFR) (in some cases exceeding a field strength of 7 V/m) from 2.4G, 5G, and 6G Wi-Fi and Bluetooth devices,[14,15] including the Internet of Things (IoT). Companies like Space X and Amazon intend to envelope the Earth with satellites transmitting 5G services (Figure 1). Smartphones, smartwatches, fitness and medical devices, tablets, and laptops also can provide particularly intense exposures because of their close proximity to the body.[16,17] All of these wireless sources expose humans and the environment 24/7 to human-made, modulated, pulsed, polarized, and biologically active microwave radiofrequency radiation. Figure 2 indicates that in the relevant band for cellphone communications, there has been an increase from a barely noticeable ambient exposure of 10^{-18} W/m^2

Figure 2. The ambient exposure to electromagnetic power density as a function of frequency. The different colored sections trace the exponential growth of exposure from the 1950s to 2010s.



Source: Reproduced from reference 18, courtesy of Elsevier.

As of 2023, SpaceX has 4,500 satellites out of a planned 40,000 Starlink low-earth-orbiting (LEO) satellites in operation providing high-bandwidth Internet connectivity in the band 10–50 GHz (gigahertz, a unit of frequency), which includes frequencies used by 5G technologies. Communication signals radiated at frequencies above 30 GHz are sometimes referred to as millimeter waves, while all wireless communication signals fall into the general category of radiofrequency radiation (RFR). In addition to RFR from space, urban and rural areas are now densely covered by high-level, terrestrial RFR sources in the 2–5G bands.[19]

(0.000000000000000001 W/m^2) in 1950 to almost 10^{-2} W/m^2 (0.01 W/m^2) 60 years later.[18] The ubiquity of wireless devices in the past 10 years has created unprecedented exposures to RFR that will increase in the future.

Policymakers and regulators in the United States, the United Kingdom, the European Union (EU), and beyond look to risk assessments, safety standards, and guidelines that have increased, rather than decreased,[20] maximum exposure limits producing thermal effects.[21,22] Furthermore, new ICNIRP Guidelines that accommodate 5G technologies make no distinction between prenatal embryos or fetuses, infants, toddlers, children, adolescents, and adults in terms of thermal or nonthermal exposure. In fact, despite the growing scientific evidence indicating significant risks to human health[23] from nonthermal effects, the explicit assumption of governments, the technology industry, and its engineers is that manmade microwave radiation has no negative consequences for overall human health or the environment. Instead, the focus of most policies is on maximizing potential applications of wireless radiation for economic growth.[24] As one UK senior civil servant put it to a concerned UK scientist: "The bodies will have to pile up in the NHS before the government will do anything."[25]

What Is the Evidence of Adverse Nonthermal Effects From RFR Exposure?

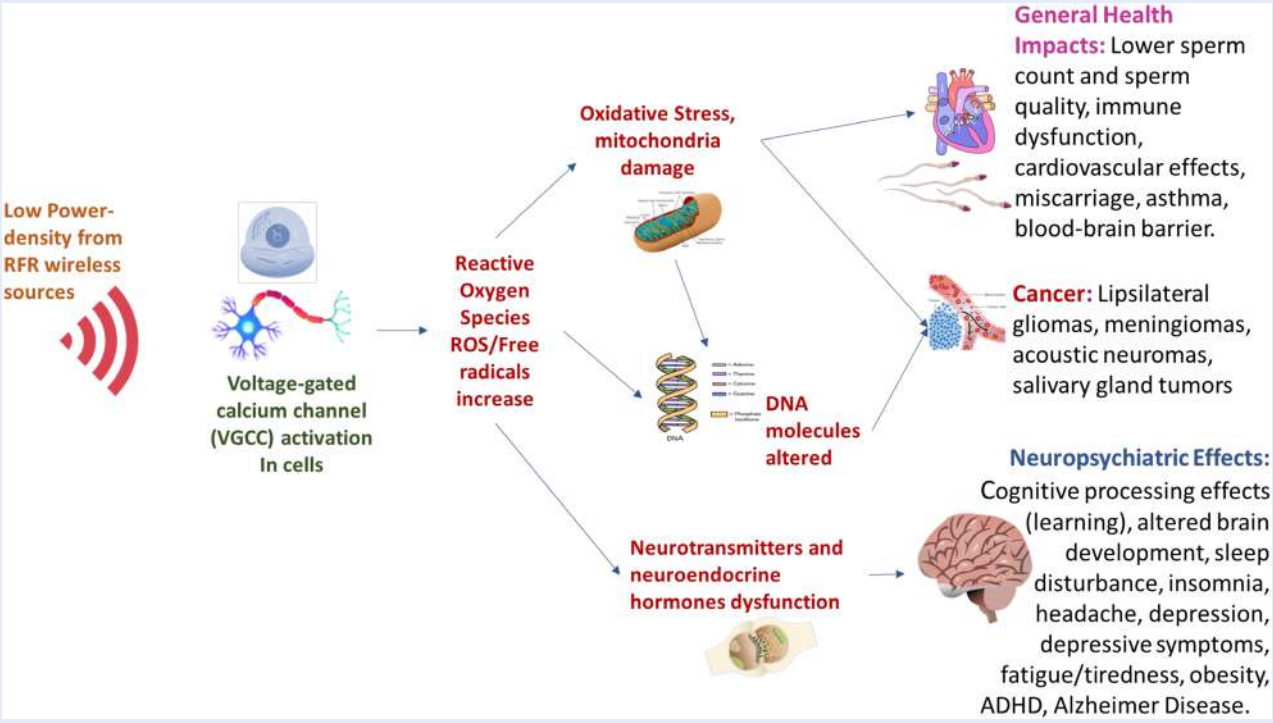
Three distinct types of evidence indicate the existence of adverse nonthermal effects of RFR: (1) experimental studies in human and animal tissues (in vitro studies); (2) studies of experimental animals (in vivo studies); and (3) epidemiological or clinical observations of humans. Based on evidence up to 2011, The World Health Organization (WHO) International Agency for Research on Cancer (IARC) classified microwave RFR as a *possible* carcinogen.[27] One IEEE member and former ICNIRP commissioner, James C. Lin, concluded in 2022 that "there are consistent indications from epidemiological studies and animal investigations that RFR exposure is probably carcinogenic to humans. The principle of ALARA—as low as reasonably achievable—ought to be adopted as a strategy for RFR health and safety protection."[28] Growing numbers of scientists are also of this opinion following the "clear evidence" of carcinogenicity and DNA and heart damage in animals due to RFR exposure in studies by the U.S. National Institute of Environmental Health Sciences National Toxicology Program (NTP)[29] and Ramazzini Institute.[30]

The final report of the NTP's comprehensive multi-million-dollar study confirmed that microwave RFR from 2G and 3G cell phones caused cancer and other serious health impacts in animals. That study refutes the long-held industry position that RFR cannot cause cancers or lead to other significant effects on health and well-being. Policymakers ignored the findings of these extensively peer-reviewed scientific studies, which were also challenged by ICNIRP and IEEE. Normally, the U.S. government would have carried out a formal risk assessment based on the NTP findings, as has been done with most of the 2800 evaluations it has carried out in the past four decades. That assessment would then have been employed by relevant regulatory agencies to set standards. Despite an unprecedented number of distinct peer reviews supporting the NTP study, no such evaluation has yet been conducted, nor is any anticipated. In fact, the Food and Drug Administration (FDA), the agency that formally requested, reviewed, and helped to fund the NTP study of RFR, rejected the NTP results in an anonymously authored note that lacked the rigor typically accorded such assessments.[31,32]

As of 2023, the International Agency for Research on Cancer (IARC) is reviewing its current classification as a matter of priority.

The cumulative body of evidence has recently been reviewed by several groups[11,33,34,35,36,37] that have found nonthermal effects of exposure in all three evidence categories, including epidemiological evidence, for RFR as a probable human carcinogen.[25,38] While the NTP and Ramazzini Institute provide state-of-the-art studies, other reports are of mixed rigor.[39] The existence of conflicting results has led some to conclude that evidence regarding biological impacts remains equivocal.[40] This scientific uncertainty has been manufactured in several instances[41] and is used by industry as an argument for inaction in a manner reminiscent of the Tobacco Industry campaign that denied the cancer-causing effects of cigarettes and the Fossil Fuel Industry campaign that denied the reality of climate change. Simply not undertaking necessary research can support scientific uncertainty. Take, for example, the reliance for reassuring statements by numerous agencies on the poverty of research on high-frequency 5G RFR where "the same poor quality scientific evidence is being used by the WHO, ICNIRP, IEEE-ICES, and numerous governmental agencies, like BfS (Bundesamt für Strahlenschutz, The Federal Office for Radiation Protection, Germany) or ARPANSA (Australian

Figure 3. A summary of the causality indicated by extant research.



Source: All figure components Wikimedia Commons, see endnote 26.

Radiation Protection and Nuclear Safety Agency), to assure users of the safety of the current guidelines."[42]

The first category of extant research, in vitro experiments, provides substantial evidence that RFR disrupts normal functioning of living cells (cellular homeostasis).[43] Figure 3 summarizes this research in a cursory web search.[44,45] While there is still debate on the molecular mechanisms at play, many agree that two intermediate endpoints are an increase in cellular reactive oxygen species (ROS) (which can have deleterious effects on aging and cause genetic mutations) and associated cellular oxidative stress (which can be associated with a variety of serious medical conditions.

Other studies have noted the special vulnerability of children to RFR exposure, as they face a lifetime of using radiofrequency-radiating emitting technologies that did not exist a decade previously.[46] Figure 4 illustrates just how pervasive wireless technology has become in the modern classroom setting. Similarly, fetal exposure is another

Figure 4. Children exposed to near-field WiFi. Some children hold and use the WiFi tablets at less than the 20 cm (8 inch) minimum distance recommended by the FCC and often carry other RF devices close to their bodies.



Wikimedia Commons/BarbaraLN

The Swiss expert group on electromagnetic fields and nonionizing radiation (BERENIS) advisory group to the Swiss government reviewed all relevant experimental studies up to 2021 and found compelling evidence of an increase in ROS by exposure to RFR of the same frequency bands as those used in 2–5G cellular telephony, Wi-Fi, and Bluetooth.[48,49] For example, a recent study of populations living within 80 m of an active 3G and 4G mobile base station found heightened levels of cellular ROS as compared to populations living over 300 m away.[50] It is acknowledged that ROS are biological markers for increased risk of cancer and degenerative diseases and other serious health conditions.[51]

major concern. Early development is a particularly vulnerable time where small insults can alter development and lead to permanent changes in developmental programming. Fetal exposure to cell-phone radiation has been reported to lead to lifelong behavioral changes, as well as to alterations in the quantity and quality of the hippocampus—a brain component critical to long-term memory, balance, and synthesis of abstract reasoning. Mice exposed solely as fetuses had persistent and permanent changes in memory and behavior throughout their lives.[47]

Analyses of studies across all three categories of research by independent researchers are indicative of the weight of scientific evidence for serious risks to human health. A study of the database on the biological effects of electromagnetic fields of the Oceania Radiofrequency Scientific Advisory Association Inc. (ORSAA) found that "There are 3 times more biological 'Effect' than 'No Effect' papers; nearly a third of papers provide no funding statement; industry-funded studies more often than not find 'No Effect', while institutional funding commonly reveal 'Effects.'"[52] Of these, 68% of peer-reviewed scientific research studies found physical and biological nonthermal effects, while 32% of studies reported no evidence of effects.



Wikimedia Commons/Esme Vos

Mobile phone dealers clustered in a mall in Kochi, India.

If the weight of scientific evidence was not enough to convince one of the biological effects, the use of electromagnetic fields in medicine constitutes prima facie evidence that microwave radiofrequency radiation has impacts on biological entities. In addition to physical therapy applications of heat using in diathermy,[54,55] other uses of electromagnetic fields in medicine include the treatment of various forms of cancer.[56,57,58] Two companies, Novocure and Therabionic, have already reached commercialization with products that inhibit the proliferation of cancer cells using pulsed electromagnetic fields (EMF). Both treatment regimens disrupt the correct formation and function of the mitotic spindle (which is the subcellular structure responsible for separating the chromosomes during division of the cellular nucleus).[45,59,60]

Another analysis of the ORSAA database found that 89% of papers showed an association between low-level exposure to RFR and oxidative stress. These findings were confirmed in yet another comprehensive review of 1,778 research papers.[53] Of these 79% or 1,106 papers on experiments using real-world RFR signals reported biological effects and 66% of 251 epidemiological studies reported biological effects. While the quality of some of these studies may be questioned, the weight of scientific evidence consistently finds significant risks to human health—these risks are magnified where children are concerned.

Shallow penetration does not equate to limited or no impact on humans. There are profound immunological effects in humans from very limited skin absorption of nonionizing radiation. A notable example of this is the capacity of UVA and UVB nonionizing radiation to ultimately lead to cancerous melanomas that can extend well below the upper dermis.[68] Preliminary studies have shown that helical structures of human sweat ducts in the epidermis lead to heightened radiation absorption with the frequencies[69] anticipated to be used in 5G,[70] which are not common in the environment and pose novel exposures with poorly studied outcomes. Shallow penetration in humans could have significant immunological and other biological effects.

Environmental Implications

Data collected about pollinators call for rethinking the approach to wireless radiation based on findings of harm not only to human health but also to the environment.[23] Studies conducted on beehives indicate that current transmission levels of RFR can disturb vital functions[61,62,63] and that microwave radiofrequency radiation should be seriously considered as yet another driver of the global decline in pollinating insects, in association with, or magnifying the effects of, agricultural intensification, pesticides, invasive species, and climate change. A research review published in *Science of the Total Environment* found "sufficient evidence" of effects on insects, including impacts on flight, foraging and feeding, short-term memory, and mortality.[64] Research has also documented disturbances in behavior after electromagnetic radiation exposure, including causing worker honeybees to produce specific sounds (piping), decreased egg-laying rate, and reduced colony strength.[49,65] In 2020, Thielens et al. produced computer simulations of honeybees with their model of bee structures and also carried out RFR measurements near hives.[66] Employing five different computer models, they found that shifting frequencies to above 3 GHz, as can occur with 5G, will result in a substantial increase in absorbed power, more than fivefold, compared to frequencies below 3 GHz. Recently, Lai and Levitt commented on these findings, noting the following: "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."[67]

Wherefore the Precautionary Principle in Using Wireless Technologies?

In the 2017 special issue of *Environment*, Rupert Read and Tim O'Riordan illustrated how the precautionary principle is under attack,[71,72,73] even among those who purport to advocate or are obliged to apply the principle as a matter of policy. Read and O'Riordan point out that such is its importance that it was "Principle 15 of the Rio Declaration on Environment and Development agreed by all UN nations in 1992."[74] Researchers argue that it is morally and ethically impossible to leave decisions to the commercial or growth imperative of corporations without considering the precautionary principle and consequences or externalities to people and the planet.[75] We argue that the time is long overdue to consider this principle's application to wireless technologies in society, since cell phones first became commercially available in 1984.[76] Steneck's *The Microwave Debate* reopened the contentious debate during the 1990s, with personal injury litigation in U.S. courts, but also the U.S. Telecommunications Act of 1996, limited the capacity of local authorities to object to actions by granting leeway to the telecommunications industry.[77]

In the face of growing concerns about the safety of the RFR emitted by cellphones, and in response to litigation and public fears and other controversies,[78] the Cellular Telecommunications Industry Association (CTIA), a Washington, DC-based lobbyist for the wireless telecommunications sector, recruited the services

Why the Precautionary Principle?

"The precautionary principle carries great significance for 'sustainability science.' It provides a powerful framework for improving the quality, decency and reliability of decisions over technology, science, ecological and human health, and improved regulation of risk-burdened human affairs. It asks us to pause and to review before leaping headlong into innovations that might prove disastrous. Such a call does not sit well with a 'deregulatory' (i.e., environmentally nonprotecting) policy setting, nor with the expectation by corporations of maintaining profit in an economic climate where competition is yelping and recession is barking at the door." —Rupert Read and Tim O'Riordan, "The Precautionary Principle Under Fire," *Environment,* 2017

of George Carlo to help counter negative media coverage and science. Thus, in 1995, he headed up the Wireless Technology Research (WTR) project with $28.5 million in funding.[79] Carlo was seen as a "safe pair of hands," as he had previously helped the paper and chlorine industries fight measures to regulate dioxins, which are highly toxic.[80] Among other things, the purpose of this initiative was to counter the EPA's findings, debunk the growing body of research conducted by independent scientists, and manage the negative media publicity linking cell phones with brain cancer.

The WTR research program did not turn out as expected: Carlo alleges that the program's studies uncovered evidence of the risk of adverse health effects to humans from RFR and that these findings were rejected by industry. After Carlo's contract was terminated, he and investigative journalist Martin Schram published *Cell Phones: Invisible Hazards in the Wireless Age: An Insider's Alarming Discoveries about Cancer and Genetic Damage*.[81] A letter from Carlo to C. Michael Armstrong, Chairman and Chief Executive Officer, AT&T Corporation, summarized the WTR findings (see box below). Carlo's findings (and in some instances their own earlier findings) were dismissed by scientists associated with regulatory bodies, the cell phone industry, and the IEEE C95.1 1991 and ICNIRP 1998 Guidelines, which promoted a thermal-effects-only view.[82]

More recently, several groups have provided detailed criticisms of the scientific failures and limitations of the ICNIRP, including the newly formed International Commission on the Biological Effects of Electromagnetic fields (ICBE-EMF) and researchers working with Swedish scientist Lennart Hardell.[83,84] The ICBE-EMF has produced several analyses of the selective evidence on which ICNIRP bases their standards and guidelines. ICNIRP continues to dismiss and discredit evidence of nonthermal impacts, including the $30 million, state-of-the-art National Toxicology Program (NTP) findings of carcinogenicity from current levels of cellphone radiation, and parallel findings in the Ramazzini Institute investigation of base-station radiation.

There are huge financial incentives for industry to adhere to the current thermal-only exposure guidelines. Complying with nonthermal guidelines would likely result in higher costs associated with cell tower siting and equipment redesign. In addition, as a practical matter, acute thermal effects can be measured and modeled precisely and reliably. In contrast, finding chronic long-term effects requires estimating public health risks by carrying out quantitative assessments based on clinical studies and epidemiology findings that involve long-term monitoring and measurements. Recent evaluation of the ICNIRP's review on 5G concluded that the group relied extensively on its own commissioners' and affiliates' publications and therefore reinforced its own previous positions. As a consequence, the ICNIRP review affirmed the notion that the only impact to be avoided from 5G and all other forms of RFR is thermal.[85]

Figure 5 presents the SAR thresholds established by ICNIRP for whole-body and partial-body exposures. Transmitters in wireless devices are designed to comply with this. However, today's wireless devices, including routers, laptops, and tablets, have multiple antennas or radio units, which will have 2,4 and 5G units.[86] A smartphone can have 2–5G antennas or radio units, but typically today will have either 4G or 5G radio units in data mode. That is in addition to Wi-Fi, Bluetooth, and near-field communication radio units. Many children and adults now also have smartwatches and Bluetooth earbuds, yielding significant exposures that have never been tested for their potential combined effects. This exposure tends to increase in an office environment with multiple overlapping

Letter from Dr. George Carlo to Mr. C. Michael Armstrong, Chairman, and Chief Executive Officer, AT&T Corporation

The rate of death from brain cancer among handheld phone users was higher than the rate of brain cancer death among those who used non-handheld phones that were away from their head;

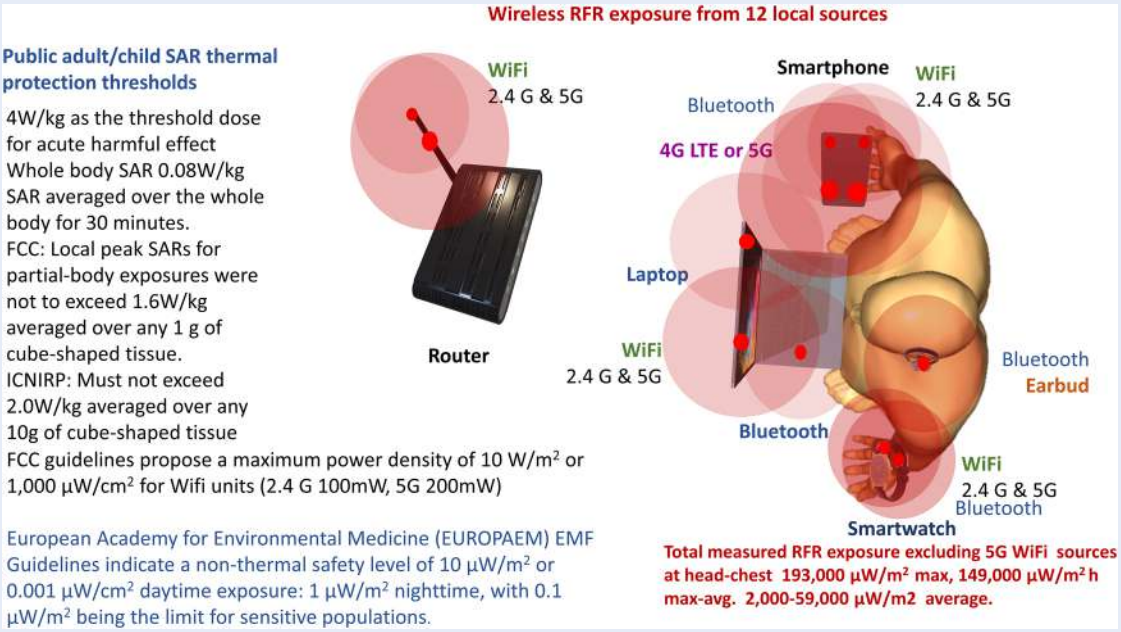
The risk of acoustic neuroma, a benign tumour of the auditory nerve that is well in range of the radiation coming from a phone's antenna system, was fifty percent higher in people who reported using cell phones for six years or more, moreover, that relationship between the amount of cell phone use and this tumour appeared to follow a dose-response curve;

The risk of rare neuro epithelial tumours on the outside of the brain was more than doubled, a statistically significant risk increase, in cell phone users as compared to people who did not use cell phones;

There appeared to be some correlation between brain tumours occurring on the right side of the head and the use of the phone on the right side of the head;

Laboratory studies looking at the ability of radiation from a phone's antenna system to cause functional genetic damage were definitively positive and were following a dose-responsive relationship.

Figure 5. A typical example of an adult home worker's exposure to multiple personal sources of microwave RFR.



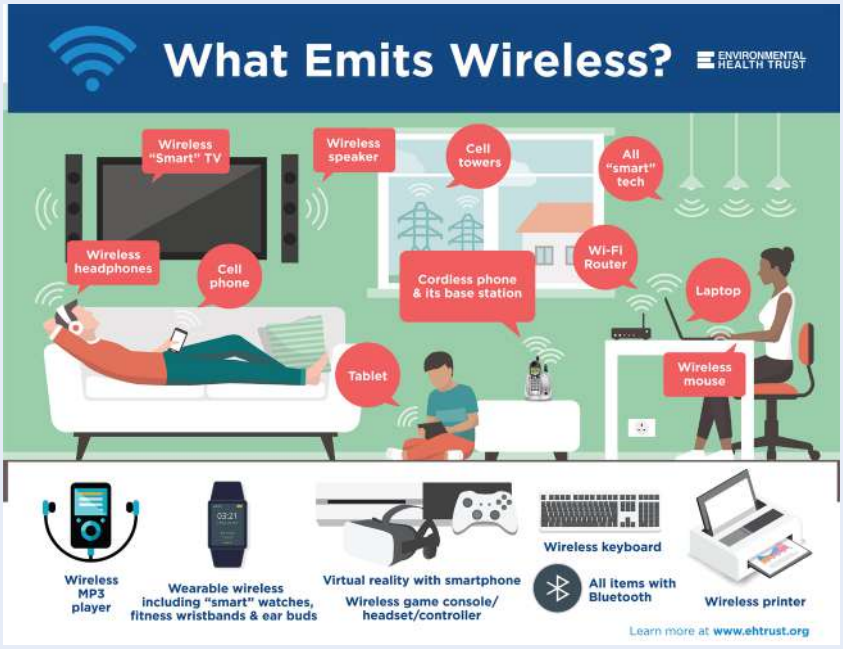
sources. Figure 6 indicates the multiple devices in the home today. Also, exposure from nearby cell towers can be significant if they are less than 500 m away. The exposure for the worker in Figure 5 is well in excess of even the outdated EUROPAEM (European Academy for Environmental Medicine) guidelines.[87]

A key point in this article is that the current, thermal-only standards are completely inadequate in protecting people and the environment from the long-term harms of wireless radiation exposure. However, even if those standards were adequate, they are not being applied appropriately in some cases, such as the certification process for cellphone radiation described briefly in the following, and also described in detail in the endnotes.[88]

The bottom line is that current procedures for evaluating the "safeness" of cellphones are insufficient at 4G and may be even less sufficient at 5G. There are other issues that come into play at the higher 5G frequencies, such as the fact already alluded to that the 3.5-mm-radius ear canal has the potential to act as an imperfect cylindrical waveguide at frequencies above 25 GHz, which could effectively channel cellphone 5G high-frequency radiation inside the ear.

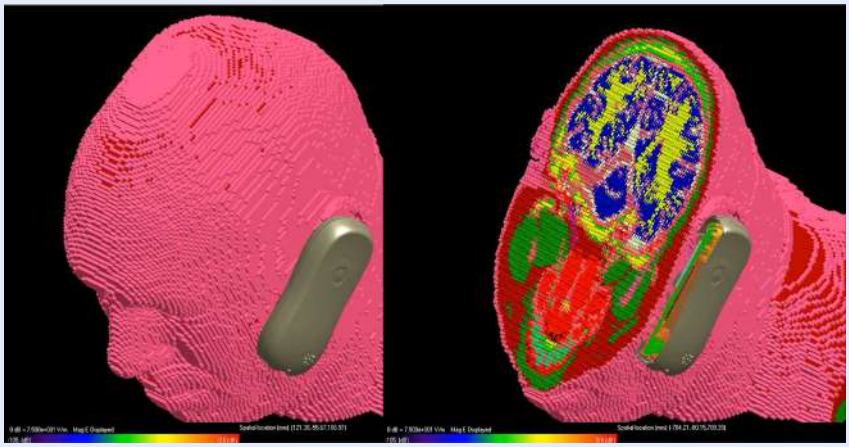
The process in use for certifying that a cellphone's radiation complies with standards currently employs a plastic head mannequin filled with a gel that is a uniform liquid electrical insulator, a simplification compared to the

Figure 6. Ubiquity of wireless devices and RFR sources.



Source: Courtesy of Environmental Health Trust, 2023.

Figure 7. FDTD model of human head impacted by radiation from a cellphone. The image on the left shows the modeled head before the cellphone is turned on and the figure on the right shows the modeled electric field inside the head resulting from the use of the cell phone.



Source: https://doi.org/10.1109/5.662875, see endnotes 88,89. Original simulation image generated using the model described in the source reference.

electrical properties of the various organs within the skull. For head estimations, the radiation source being tested, such as a cellphone, is not held up to the head, but is placed up to 2.5 cm (about an inch) from the surface of the mannequin's head. Figure 7 shows computer simulation of field exposure to the head that includes much more realistic electromagnetic properties of different tissue types obtained from the FDA-approved Visible Human Project.[89]

Discussion

In an ideal world, experimental evidence of significant risk of harm from ambient levels of nonionizing radiation from wireless devices would suffice to drive policies to reduce exposures. Whether the risks are posed by tobacco, asbestos, diagnostic radiation, or certain pesticides, policies to reduce exposures have been implemented in the United States and often elsewhere only after definitive proof of human harm has been well established. Early warnings of serious risk from these exposures based on experiments or reports of human harm have been routinely discounted by industries that object to the institution of preventive measures.[90] This means effectively that the first generations of people to be exposed to a given risk are compelled to provide proof of harm through the accumulation of sickness or deaths. Only after that evidence has accumulated have steps been taken to prevent its continuing occurrence in subsequent generations.[91]

With wireless devices and sources of human-made polarized, modulated, pulsed radiofrequency radiation ubiquitous, the steady accumulation of both experimental and human evidence of nonthermal biological and adverse health effects should have prompted a regulatory re-think. Yet this has not occurred, and the exposure safety levels are little changed from those fixed by the Tri-Services Commission in 1957 and Schwan in 1953. This article has demonstrated that there is substantial evidence that an unhealthy relationship exists between the highly profitable telecommunications and information technology industries and their regulatory body, the FCC[92,93] in the United States. Further, there is evidence that ICNIRP and the IEEE constitute essentially military–industrial standards bodies that have not kept pace with relevant scientific findings regarding chronic health and environmental impacts.

On September 12, 2023, France banned the sale of Apple iPhone 12 found to emit 5.4 W/kg of radiation when tested directly on the body. Within two weeks of getting the notice from the French that they were out of compliance with the Apple iPhone 12, Apple was able to come up with a software modification that dealt with this lack of compliance. An important lesson from this episode was that there is no regular routine testing of phones once they're on the market. The French tests averaged exposures within a homogenous 10-gram volume of human tissue. If such estimates were to apply to the US test system (which relies on a 1-gram volume), the excess radiation would have been well over twice as high—about 11 W/kg. The U.S. limit is 1.6 W/kg, while the French limit is 2.0 W/kg. Current US tests do not reflect normal use of keeping phones in the pocket or bra, they allow phones to be tested up to an inch off the body or allowing a 'spacer' for the ear that is up to 10 mm, with only one antenna operating at a time. The current test system is basically designed to produce passable results. In testing phones directly on the body as they are used, the French have provided a wake-up call to the world. As noted in the Harvard University Report,[97] by insisting that their phones pass outdated tests, the telecommunications industry is using the same playbook to stall regulatory reform as have other industries, including Big Tobacco.

At this juncture, various accessible and economical technological solutions are available to mitigate the impact of contemporary exposures to RFR with minimal or no increase in costs.[94] Héroux et al., for example, recently detailed several practical ways to achieve lower radiation from phones without compromising functionality or quality.[95] These involve software and hardware modifications, specifically the use of antennas that could reduce power absorbed in the head and body and increase power radiated for communications. Additionally, automated protocol-based reductions of the number of RFR emissions, their duration, or integrated dose could also be instituted. Yet mitigation of RFR exposures to users does not appear as a priority with most cellphone or wireless device manufacturers, even though the telecommunications industry is the most profitable industry in the world today. They do not acknowledge the chronic harms of RFR, and they use their political and economic influence to ensure that the risks of exposure are not considered in the regulatory process. It is for this reason that, given that "there are consistent indications from epidemiological studies and animal investigations that RFR exposure is, at least, probably carcinogenic to humans," "The principle of ALARA—as low as reasonably achievable—ought to be adopted as a strategy for RFR health and safety protection."[96]

Conclusion

Today, we are with RFR from wireless devices where we were with asbestos and tobacco in the 1970s. Sufficient scientific evidence has accumulated to demonstrate the risk of adverse health effects to humans from exposure to RFR at permitted levels of exposure. Children and fetuses are especially at risk, as are insect species in the environment. It is time to act now to reduce exposure, rather than insisting on more proof of human or environmental harm. Indeed, emerging studies of children and wireless devices are providing evidence of serious behavioral and cognitive consequences that may well be tied with both physiological and psychological consequences of exposures.

Based on the evidence to date, we believe that the case for precaution concerning wireless radiation rests on solid scientific foundations. Human health and the health of the physical environment are both at risk from current and planned expansions of exposure. Experimental evidence demonstrates risks to development that can occur from ambient levels of exposure to wireless radiation that affect the functioning of human cells, mitochondria, and DNA

"A brilliant and courageous tour de force by one of our nation's leading environmental health experts. Davis provides a detailed exposé that forces us all to take a good, hard look at what we know and what we don't know about cell phones."

—Ronald B. Herberman, M.D., Founding Director Emeritus, University of Pittsburgh Cancer Institute

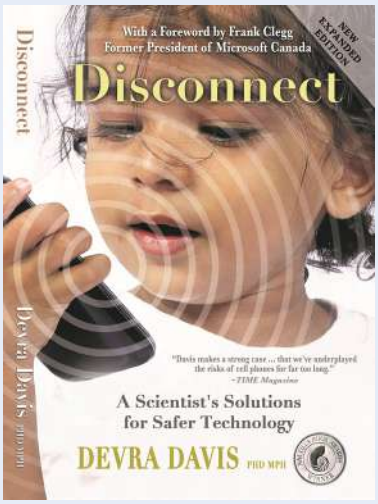
"From tobacco smoke to chemical pollutants to climate change and acid rain, Dr. Devra Davis has been in the Vanguard of the environmental health frontier. Her experience shedding light on . . . preventable environmental hazards makes the 2023 expanded edition all the more compelling since her original warnings on the biological and environmental effects of cellular radiation, are finally raising the alarms that they warrant."

—Mikhail Kogan, M.D., Medical Director, George Washington University Center for Integrative Medicine

"Devra Davis presents a range of recent and long-suppressed research in this timely bombshell. Cell phone radiation is a national emergency. Stunningly, the most popular gadget of our age has now been shown to damage DNA, break down the brain's defenses, and reduce sperm count while increasing memory loss, the risk of Alzheimer's disease, and even cancer. The growing brains of children make them especially vulnerable."

—Barnes & Noble

For more information: https://ehtrust.org/disconnect



via its ability to generate reactive oxygen species (ROS) and place cells into oxidative stress, creating a cascade of related adverse health impacts and disease endpoints. Although exposures are invisible and mostly undetectable, they can have permanent effects on our ability to reproduce and to live a good quality and healthy life. Therefore, we urge that a serious program of research and training must be established and independently funded so that additional research can be developed to clarify the public health and environmental impacts of wireless radiation. In the meantime, actions must be taken to reduce exposures based on the implementation of the precautionary principle. In essence: It is better to be safe than to be sorry. Or as Benjamin Franklin quipped centuries ago, "An ounce of prevention is worth a pound of cure."

Disclosure Statement

The authors declare that they have no conflict of interest.

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86. Operating at 100-mW and 200-mW outputs.

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88. The current, 27-year-old approach for certifying that a cellphone's radiation complies with standards tests a single phone provided by the manufacturer and directly estimates SAR within the human head. The Specific Anthropomorphic Mannequin (SAM) used for this certification constitutes a plastic model of a skull that originally weighed about 12 pounds—based on the dimensions gathered from the U.S. military of recruits from the top 10%. A homogeneous dielectric liquid (a liquid electrical insulator) is assumed to mimic the heterogeneous dielectric properties of the various organs within the cranium skull. SAR measurements are separately made for the head and the body. For head estimations, the radiation source being tested, such as a cellphone, is placed up to 2.5 cm (about an inch) from the surface of the mannequin's head, and an automated probe measures the field strength inside the gel-filled head at a specified distance from the inside surface of the head. The radiation source transmits a continuous signal, and the SAR is calculated based on computer-measured temperatures using a well-established formula. Clearly, the mannequin skull model, filled with a homogeneous gel, bears little resemblance to the complex structures within the head, as we and a number of other researchers have pointed out. Realistic simulations find significant inhomogeneous exposures within the skull that cannot be evident in a model like SAM that assumes homogeneity. Not only is the homogeneity assumption clearly in error, but this type of measurement does not account for factors such as the thinner skull and more absorptive and rapidly developing neural tissues of children. See also C. C. Gordon, T. Churchill, C. E. Clauser, et al., "Anthropometric Survey of U.S. Army Personnel: Summary Statistics, Interim Report for 1988," 1989; A. Drossos, V. Santomaa, and N. Kuster, "The Dependence of Electromagnetic Energy Absorption Upon Human Head Tissue Composition in the Frequency Range of 300–3000 MHz," *IEEE Transactions on Microwave Theory and Techniques* 48, no. 11 (2000): 1988–95. https://doi.org/10.1109/22.884187; A.-K. Lee, S.-E. Hong, J.-H. Kwon, and H.-D. Choi, "SAR Comparison of SAM Phantom and Anatomical Head Models for a Typical Bar-Type Phone Model," *IEEE Transactions on Electromagnetic Compatibility* 57, no. 5 (2015): 1281–84. https://doi.org/10.1109/TEMC.2015.2433314; A.-K. Lee, S.-E. Hong, J.-H. Kwon, and H.-D. Choi, "Is the SAM Phantom Conservative for SAR Evaluation of All Phone Designs?," *ETRI Journal* 41, no. 3 (2019): 337–47. https://doi.org/10.4218/etrij.2018-0231

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