Increasing exposure to non-ionizing electromagnetic fields: The case for a robust federal oversight program to ensure workers are safeguarded across various occupations.

American Public Health Association: Occupational Health and Safety Section

Theodora Scarato, *Environmental Health Sciences*

BACKGROUND

Non-ionizing electromagnetic fields (EMFs) from electrical equipment and wireless technologies are an occupational exposure across many industries. EMFs are invisible energy forces characterized by their frequency, measured in hertz (Hz) or cycles per second.

EMFs span a wide frequency range from 0 Hz up to 300 GHz. Types of EMFs at workplaces include:

- **Static fields** (0 Hz) from permanent magnets and direct current sources (e.g., MRI systems, maglev trains and electric vehicles).
- **Extremely low-frequency (ELF) and low-frequency** (1 Hz – 100 kHz) **and magnetic fields**: Time-varying electric and magnetic fields are present wherever electricity exists. Sources include high voltage power lines, transformers, electrical substations, appliances, powered machinery, welding equipment, induction heaters, motors and electric charging stations.
- **Radiofrequency (RF) radiation or RFR** (100 kHz – 300 GHz) emitted by wireless antennas on cell towers, radar and satellite systems, AM/FM broadcasting towers, cell phones, Wi-Fi systems, microwave ovens, and industrial RF sealers.

In many workplaces, employees are exposed to multiple frequencies of EMF simultaneously, contributing to cumulative exposure. While some types of non-ionizing EMF exist naturally (e.g. sun, lightning, and the Earth's magnetic field), artificially created EMFs from electricity and wireless communication are relatively new to the Earth and they are considered more bioactive than naturally occurring EMFs.[1–6]

Workers are exposed at work and at home. Exposure is now constant, multilayered, and begins before birth. Today's wireless devices emit a complex mix of frequencies and modulations that were not present when current standards were established.[7]

While some groups assert that non-ionizing electromagnetic fields (EMFs) are a weak and non harmful exposure, a substantial body of peer-reviewed research now reports biological effects at exposure levels far below FCC limits, including cancer[4,8–11], DNA and genetic damage[12–14], endocrine disruption[15–17], and impacts to the reproductive system[17–23] and brain development[24,25]. Chronic exposure has also been linked to cellular stress responses and increased oxidative stress which can contribute to chronic disease.[26–28] Long-term animal studies from the U.S. National Toxicology Program[29,30] and the Ramazzini Institute[31] in Italy have reported increased rates of brain and heart tumors at exposure levels comparable to cell phones and cell towers. A review on people living near cell towers found the majority of studies found effects from cancer, to radiation sickness symptoms to biochemical changes.[32] A review of low intensity studies found that biological effects could occur at rates much lower than the FCC's limits.[33]

An European Parliament requested research report "Health Impact of 5G" released in July 2021 concluding 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.[34]

However, despite numerous scientific expert calls to update limits[4,10,11,35–41], the FCC and other transnational organizations that set safety limits maintain that such health effects have not been conclusively established.

METHODS

- Review of U.S. federal regulations and EMF-related activities, including OSHA and NIOSH guidance.
- Comparative analysis of international frameworks for occupational safety.

FINDINGS

I. EMFs Are A Growing Occupational Exposure

Occupational EMF exposure is expanding beyond traditional high-risk industries like telecom, utilities, and industrial work to modern workplaces, from healthcare, education, retail, service, and emergency response.[42,43] Workers face increasing chronic low-level exposure from cell phones, walkie-talkies, Wi-Fi, medical devices, vehicles and other wireless technologies as device use and network density rise.

Examples of traditionally high risk occupations include:

Telecommunications and Utilities
Wireless Industry: Cell tower climbers, wireless antenna technicians
Radio Station Workers: Engineers and technicians for AM/FM transmitters, studio-to-transmitter links, and antennas
Electric Industry: Power line workers, substation operators

Building Maintenance and Workers on Rooftops and Buildings
Any workers on rooftops, especially in an urban area with dense wireless networks, can be exposed to radiofrequency EMFs from nearby or rooftop-mounted wireless antennas. Wireless equipment may be painted or camouflaged, making them less visible and creating an unrecognized exposure.

- **HVAC Technicians:** Installing or maintaining rooftop units, ductwork, or antennas
- **Electrical Maintenance Workers:** Servicing rooftop equipment, solar panels
- **Painters, Construction, Building Maintenance Workers:** Working on coatings, framing, insulation, repairs, and equipment installation on rooftops or exterior of buildings

Industrial and Manufacturing
Induction heater operators: Metal parts are heated via an induction coil with rapidly changing magnetic fields for processes like metal forging, heat treating, soldering, and shrink fitting. Workers near the coil are exposed to both magnetic fields from the coil and electric fields if the equipment isn't fully shielded. Examples of how induction heaters are used include:

- **Automotive industry:** for hardening gears, shafts, and engine components
- **Aerospace manufacturing:** for bonding or heat-treating metal parts for aircraft
- **Metal fabrication shops**: for brazing, soldering, or annealing metal sheets and rods
- **Electronics manufacturing:** for joining components and connectors, such as those used in circuit boards

RF Sealers: In textiles and plastics manufacturing, RF sealers use radiofrequency radiation to heat, bond, and seal plastic/vinyl and synthetic materials.

Microwave Drying: RF frequencies are used in drying grains, plastics and ceramics. They're also used in wood processing and in the chemical and pharmaceutical industries. Even with proper shielding, maintenance, and monitoring, workers can still experience accidental exposures from damaged or improperly used microwave ovens and industrial dryers.

Transportation and Infrastructure

- **Aviation personnel:** Pilots, air traffic controllers, and ground staff near high-powered radar and communication systems
- **Maritime workers:** Radar operators and ship engineers exposed to marine radar systems and communication antennas
- **Rail and metro maintenance staff:** Exposure to power systems, signaling equipment, and communication networks

- **Electric vehicle (EV) and battery technicians**: Exposure to strong magnetic fields from high-current charging and inverter systems

Public Safety

- **Police, firefighters, paramedics:** Use body-worn radios, vehicle antennas, radar guns, and communication systems
- **Security staff:** Operate metal detectors, millimeter-wave scanners, and RFID security gates

Healthcare and Medical

- **MRI Technicians / Radiologists**: exposure to strong static and radiofrequency magnetic fields from MRI scanners used for diagnostic imaging.
- **Diathermy Operators: Diathermy is a therapeutic technique that uses electromagnetic energy such as radiofrequency and microwaves to warm body tissues and promote healing.**

Military

Military personnel are exposed to a wide range of EMF from radar systems, communication transmitters used by personnel and on the body (radio, satellite, HF/VHF/UHF systems), transmitters embedded in vehicles and aircraft, and electronic warfare equipment such as microwave and directed-energy systems, jammers, signal interceptors and more.

Cosmetic

Pulsed low frequency magnetic fields are used for skin rejuvenation and muscle building. Radiofrequency radiation is used for lipolysis, skin rejuvenation, and hair removal.

Overexposure Risks For Workers

In 2022, Rianne Stam (Netherlands' National Institute for Public Health and the Environment) found that workers in industries like plastic dielectric heating, security, and telecommunications could face EMF exposures above recommended limits and called for research on emerging technologies like 5G and wireless power transfer.[42] Stam later reviewed EMF exposure from cosmetic procedures[43] for workers and clients, finding some could exceed occupational limits and pose health risks, stating, "there is a potential for exceeding the occupational exposure limits in the European Union EMF Directive, which could lead to nerve or muscle stimulation, burns or overheating. There are also potential hazards for clients or workers wearing active or passive medical devices. The severity of reported adverse effects increases with EMF frequency."

Despite these findings, U.S. agencies currently have no ongoing research on the full range of worker EMF exposures.

Exposure in All Modern Workplaces

In modern workplaces, including education, healthcare, retail, service, emergency response, offices, hospitality, transportation, logistics, call centers, libraries, co-working spaces, and public facilities, workers are exposed to RFR from multiple sources including cell phones, walkie-talkies, cordless phones, Wi-Fi, tablets, laptops, smart meters, medical devices, RFID scanners, Bluetooth devices, security systems, and other wireless technologies.

Although these exposures are widespread and continuous, they are often overlooked in workplace safety assessments and rarely monitored compared to more traditional occupational hazards. Current regulations from the FCC, IEEE and ICNIRP primarily focus on short-term or acute effects, while long-term, low-level chronic exposures are largely dismissed, despite a substantial body of scientific evidence and expert evaluations recommending that overall EMF exposure be minimized whenever possible.[39,39,41,44–46]

II. Minimal Research, Guidance, Oversight or Enforcement Activities Related to Occupational Exposures

Federal occupational health agencies have minimal activities related to EMF.

Key regulatory gaps related to occupational health include:

- **Bioeffect Research:** No recent literature review or risk assessment.
- **Data Collection:** No site-specific national monitoring or exposure database.
- **Risk Mitigation & Guidance:** Existing NIOSH/OSHA recommendations are outdated and precautionary recommendations by NIOSH experts are not formalized.
- **Training & Education:** No mandatory worker training for all exposed occupations.
- **Medical Surveillance:** No requirement for monitoring exposed workers.
- **Oversight & Enforcement**: No routine checks. EMF compliance/inspections are rare; investigations occur *after* accidents.

Although federal oversight is minimal, healthcare and research facilities generally have stricter internal EMF oversight processes, whereas sectors like automotive, construction (rooftop), and general industry often have limited or no oversight. While OSHA can cite both employers and landlords, federal and state agencies lack active engagement in educating employers and workers leaving many unaware of potential risks or how to report them.

On July 1, 2015, William Perry, the Director of OSHA's Directorate of Standards and Guidance, when asked about the agencies related to the FCCs regulations, wrote[47] that "RF emissions are not on OSHA's active regulatory agenda, so we have not conducted a comprehensive literature review or risk assessment on RF hazards."

In 2013, FCC had reiterated OSHA's lack of oversight activities, stating, " We disagree with comments that we should defer to OSHA with regard to RF safety issues. First, OSHA does not

appear to have a particularized program in place to ensure worker safety with regard to RF exposure from the wide variety of RF transmitters regulated by the Commission. Second, although we do collaborate with OSHA staff regarding matters related to RF safety, and both agencies are members of an inter-agency RF working group, we are not aware that OSHA has adequate resources to ensure compliance with our limits for occupational/controlled exposure among our licensees and grantees."

Outdated EMF Guidance
As an example of the outdated resources on EMF, NIOSH has previously published materials such as "EMFs In The Workplace" (1996) and "Proceedings of the Scientific Workshop on the Health Effects of Electric and Magnetic Fields on Workers" (1991). However, there have been no recent updates or new guidance published for employees or employers specifically focused on non-ionizing EMFs.

III. Outdated and Inadequate Human Exposure Regulations

There are no federal limits for EMF or magnetic fields. Although the EPA and NIOSH used to have robust research programs, they were defunded and dismantled Employers often adopt the voluntary standards of American Conference of Governmental Industrial Hygienists, IEEE or the International Commission on Non-ionizing Radiation Protection (ICNIRP).

Limits Without Proper Review Since 1996: The FCC set exposure limits for RFR in 1996 allowing higher exposures for workers (called controlled/occupational) as compared to the general public.[48,49] The FCC states its occupational exposure limits apply to persons who: are exposed to RF radiation as a consequence of their employment, have been made aware of the possibility of exposure, and can exercise control over their exposure. This means many occupations would utilize the general public exposures if exposures were evaluated.

However, the FCC exposure limits are:

- Only designed to address tissue heating, ignoring low-level biological impacts.
- Not designed to protect against the effects of long-term exposure.
- Not designed to prevent cancer or impacts on the nervous, reproductive, endocrine, and immune systems.
- Without comprehensive scientific review by health or environmental agencies.

1999: NIOSH, OSHA, and federal experts identified major flaws in RFR exposure limits, such as weak biological basis, neglect of modulated and long-term exposures, and averaging methods that obscure peak levels. They urged a comprehensive scientific review and stronger, evidence-based standards to protect workers and the public.[50,51]

Today: FCC limits remain without a comprehensive scientific review, despite a 2021 federal court ruling (*EHT et al. v. FCC*) requiring the FCC to explain how its limits protect public health, specifically in regards to modern technology and long term exposure.[52] The FCC has not responded to the Court.

IV. Significant Science Indicates Exposure Limits Do Not Protect Health

A growing body of substantial science reports health impacts at levels of non-ionizing EMF exposure below regulatory thresholds. Numerous experts recommend updating limits to address biological effects of low intensity exposure.[4,11,39,41,53,54] Several countries have policies to reduce public exposure to levels 100x (for RFR) to over 1000x (for EMF) lower. China and Russia have limits for the public far more stringent than the USA.

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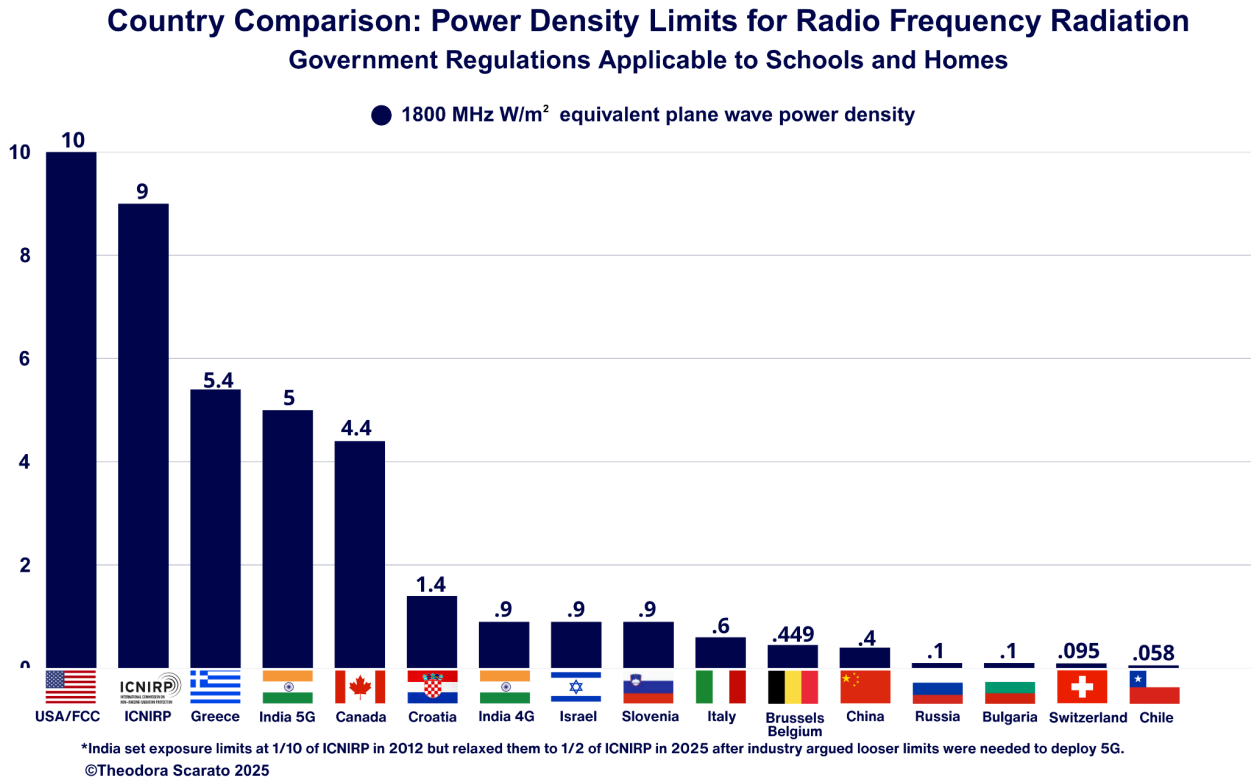

“Adverse effects observed at exposures below the assumed threshold SAR include non-thermal induction of reactive oxygen species, DNA damage, cardiomyopathy, carcinogenicity, sperm damage, and neurological effects, including electromagnetic hypersensitivity. Also, multiple human studies have found statistically significant associations between RFR exposure and increased brain and thyroid cancer risk.”

“FCC and ICNIRP exposure limits, which are based on false suppositions, do not adequately protect workers, children, hypersensitive individuals, and the general population from short-term or long-term RFR exposures.”
-International Commission on the Biological Effects of Electromagnetic Fields, *Environmental Health* 2022

Vulnerable Populations

- Pregnant workers[11,17,25,55,56]
- Workers with cardiac pacemakers, implanted medical devices and/or metal implants: static or ELF magnetic fields can interfere with devices, and metal can heighten exposure in the body[57–60]
- Workers with medical conditions and environmental sensitivities[6,61–65]

Telecom Climbers At Risk

The rapid growth of networks has outpaced existing safety frameworks and procedures, and workers have reported instances of overexposure. Despite this, federal safety efforts continue to focus primarily on falls and physical hazards, with little attention to RFR exposure.

Key issues for cell tower climbers and antenna technicians include:

- **OSHA & FCC provide minimal oversight and enforcement.** Subcontracting fragments accountability. RFR accidents and overexposure are not uncommon.
- **RFR overexposure incidents are underreported.** Many climbers report experiencing flu-like symptoms and headaches with overexposure. Symptoms of RFR overexposure include warmth, sweating, fatigue, nausea, headache, and/or a metallic taste in the mouth.
- **Inadequate training and education.** No oversight to ensure adequate RFR training and no standardization of curriculum.
- **Inability to mitigate exposure.** Even when workers are properly trained (which is not often the case), they may be unable to fully control their RFR exposures in dense wireless environments, such as on rooftops with multiple antennas and transmitters.

2020 Case Report on Overexposed Cell Tower Climber
[66]

A telecom engineer was accidentally overexposed for two hours to high-powered antennas. He was burned, but early MRI did not show brain lesions. Seven years later, he developed demyelinating brain lesions and kidney and lung masses, which his doctors believe were a delayed RFR injury, mimicking Multiple Sclerosis (MS).

2023 Case Report on Workers in Office Near Cell Towers
Nilsson and Hardell. 2023 *Annals of Clinical Case Reports*

Two men working in offices directly below rooftop 5G antennas developed microwave syndrome symptoms, fatigue, headaches, tinnitus, dizziness, concentration issues, and balance problems. Symptoms resolved after moving to lower-exposure offices.[61]

V. Frameworks Exist to Address Several Oversight and Training Gaps

IEEE Standard for Electromagnetic Energy Safety Programs, 0 Hz to 300 GHz[67]

Provides guidance addressing RFR risks in the workplace and specifies key elements of a safety program including: hazard identification, exposure assessment, control measures (engineering, administrative, signage, restricted zones), training of personnel, and periodic evaluation of program effectiveness. It recommends defining oversight roles and conducting regular audits.

While larger organizations like universities, MRI centers, and research institutions are more likely to adopt these measures, many workplaces leave employees exposed to non-ionizing EMF without oversight.

Notably, medical and health surveillance is optional under the standard, though it is a critical component for protecting workers in high RFR exposure settings.

EU 2013 Directive on Worker Exposure to Electromagnetic Fields[68]

The European Union's Directive on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) establishes minimum occupational health and safety requirements for worker exposure to EMF. The Directive includes risk assessments and preventive measures, with special protections for pregnant workers and individuals with medical implants. However, the Directive currently "only addresses short-term effects and does not concern possible long term effects."

The EU Commission has published a non-binding guide to support employers with advice on carrying out risk assessments and implementing preventive measures related to risks arising from electromagnetic fields. It includes a Practical Guide that explains how to assess EMF exposure, apply limits, and protect at-risk workers (e.g., pregnant or with medical implants). The Case Studies volume presents twelve real-world worksite examples, from offices to rooftop antennas, illustrating assessments and controls. There is also a guide that offers simplified steps for smaller workplaces.

Risk Mitigation Guidance Was Never Formalized

Historical Recommendations To Reduce Exposure

1995: Robert A. Curtis, then Director of OSHA's Health Response Team, recommended a Comprehensive Federal RF Protection Program, but it was never implemented.[69]

Summary of 1995 OSHA Presentation on Proposed Elements of a Comprehensive RF Protection Program by Robert A. Curtis, Director US DOL/OSHA Health Response Team, from his presentation on April 12, 1995, at the National Association of Broadcasters Broadcast Engineering Conference in Las Vegas, NV:

1.Utilization of RFR source equipment which meet applicable RFR and other safety standards when new and during the time of use, including after any modifications.
2. RFR hazard identification and periodic surveillance by a competent person who can effectively assess RFR exposures.
3. Identification and Control of RFR Hazard Areas.
4. Implementation of controls to reduce RFR exposures to levels in compliance with applicable guidelines (e.g., ANSI, ICNIRP), including the establishment of safe work practice procedures.
5. RFR safety and health training to ensure that all employees understand the RFR hazards to which they may be exposed and the means by which the hazards are controlled.
6. Employee involvement in the structure and operation of the program and in decisions that affect their safety and health, to make full use of their insight and to encourage their understanding and commitment to the safe work practices established.
7. Implementation of an appropriate medical surveillance program.
8. Periodic (e.g., annual) reviews of the effectiveness of the program so that deficiencies can be identified and resolved.
9. Assignment of responsibilities, including the necessary authority and resources to implement and enforce all aspects of the RFR protection program.

NIOSH experts have recommended and developed precautionary measures to minimize exposure in industrial occupations, but they have never been formalized.

1979: NIOSH/OSHA joint publication recommended precautionary measures to reduce exposures from RF sealers and heaters.[70]

"To protect workers from unwarranted exposure to RF energy, both NIOSH and OSHA recommend the use of properly designed and installed shielding material, the limitation of access to RF sealers and heaters to properly trained personnel, the posting of warning signs, the development of medical monitoring for exposure to RF energy, and the regular measurement of RF energy levels in the workplace."

The 1979 NIOSH/OSHA Report also noted the existence of non-thermal impacts, stating:

> "…absorption of RF energy may also result in 'nonthermal' effects on cells or tissue, which may occur without a measurable increase in tissue or body temperature.

> ‘Nonthermal’effects have been reported to occur at exposure levels lower than those that cause thermal effects. While scientists are not in complete agreement regarding the significance of reports of ’nonthermal’ effects observed in laboratory animals, NIOSH believes there is sufficient evidence of such effects to cause concern about human exposures. NIOSH and OSHA recommend that precautionary measures be instituted to minimize the risk to workers from unwarranted exposure to RF energy.”

1996: NIOSH’s EMFs in the Workplace Factsheet suggested simple steps to reduce occupational exposure, despite inconclusive evidence on health risks. Recommendations include informing workers and employers, reducing exposure time/duration, increasing distance from EMF sources, and implementing low-EMF equipment and workplace designs.

2003: NIOSH published a webpage online regarding a Safety Checklist Program for Schools that addresses RFR and covers regulations issued by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA). The webpage asks “have warning signs been posted in and around equipment that emits nonionizing radiation?”, “have all possible sources of nonionizing radiation in or near the classroom or work environment been identified?” and if sources had been evaluated by a qualified person. However, NIOSH has no current oversight in place regarding occupational RFR exposures in schools.

2012: NIOSH employees authored a publication in the *American Journal of Industrial Medicine* concluding that even modest reductions in EMF exposure could yield significant public health and economic benefits.[71] The authors' conclusions emphasized that magnetic fields from AC electricity are classified as a “Possible Human Carcinogen,” based on limited epidemiological evidence—yet workplace exposure limits remain largely unchanged.

2016: Joseph D. Bowman, PhD, then of the Engineering and Physical Hazards Branch at NIOSH, presented[72] on “Precautionary Strategies to Reduce Worker Exposures to Extremely Low Frequency (ELF) Magnetic Fields, a Possible Carcinogen.” However, no protective policies were ever formally issued by the agency to disseminate to employers nationwide. Bowman has since retired from NIOSH.

NIOSH and OSHA Experts Called For Updated Limits Decades Ago

In March 1994, OSHA wrote the FCC highlighting the need for an up-to-date research review for two standards (NCRP 1986 Report and IEEE/ANSI 1991). These were ultimately used by the FCC to develop its 1996 exposure guidelines, which have not been updated since. The agency also questioned the heavy focus on the FCC’s exposure limits to the exclusion of “other RF protection elements which must be considered in developing a comprehensive safety and health program. It is recommended that FCC require its applicants to implement a written RF protection program which appropriately addresses traditional safety and health program elements

including training, medical monitoring, protective procedures and engineering controls, signs, hazard assessments, employee involvement, and designated responsibilities for program implementation. Exposure criteria may be useful in determining when certain elements of an RF program must be implemented."

OSHA also stated that, "the possible implication that employees may be subjected to a higher level of risk because "they are aware of the potential for exposure as a concomitant of employment" is unacceptable to OSHA. Rather, it is suggested that the FCC adopt the uncontrolled environment criteria as an "action limit" which determines when an RF protection program is required." This recommendation was never incorporated into the regulations despite years of subsequent requests.

In 1999 and 2003, NIOSH and OSHA experts, along with other members of the Federal Radiofrequency Interagency Work Group (FDA, FCC, EPA, DoE, NTIA, NIEHS, CDC, and HHS) sent letters to the IEEE committee focused on RFR human exposure limits, characterizing federal limits as "outdated and insufficiently protective," highlighting 17 critical issues with the limits including the lack of biological basis, inadequate dosimetric modeling, failure to address modulated exposures, flaws in the two-tier occupational/public system, insufficient attention to long-term health effects and problems with how averaging over time and tissue volume can mask peak exposures.[50,51] RFIAWG called for a comprehensive scientific review and stricter, science-based standards to better protect public and worker health.

They again raised critical questions regarding the two-tiered limits and again recommended the adoption of OSHA's approach which used public levels as action levels requiring safety assessments and control measures. These recommendations were never implemented and the limits remain unchanged since 1996.

Conclusion

Establishing a comprehensive occupational health program is essential to ensure that EMF exposures are controlled and mitigated, protecting workers' health over both the short and long term.

Recommended measures include:

- Reinvigorate a coordinated federal bioeffects research program across relevant agencies, including OSHA and NIOSH.
- Revise exposure limits to account for long-term cumulative effects.
- Characterize and monitor exposure levels in a broad range of exposed occupations, from telecom, plastic industry, utilities, healthcare, military, to retail and education.
- Establish standardized medical surveillance with mandatory recordkeeping and reporting to track worker health and exposure incidents, including overexposures.

- Initiate R&D and innovation programs that prioritize low-EMF design and emission reduction in industrial and workplace technologies, focusing on minimizing unnecessary EMF exposures through improved engineering and manufacturing practices.
- Require machinery and equipment to incorporate engineered EMF controls, shielding, and design features that minimize worker exposure, with verified performance and routine maintenance checks.
- Issue comprehensive, site-specific guidance to minimize EMF exposure and mitigate risk, with special provisions for accommodating pregnant workers, medically vulnerable individuals, and persons with implants.
- Ensure employer/worker training and education.

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