

Research Paper



The environmental impact of exposure to electromagnetic fields (EMF) on health

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**ABSTRACT**

This study examines the electromagnetic fields (EMF) that pervade modern society for their potential health hazards. Its aim was to investigate EMF exposure levels, resulting biological effects, current recommendations, population characteristics, and public opinion, and to give a comprehensive account of the subject. Data collection encompassed EMF exposure levels in different settings, experimental studies of biological effects, existing guidelines, demographic differences, and public perception surveys, analysed using descriptive statistics and inferential statistics to evaluate relationships between variables. EMF exposure levels differed among locations, with metropolitan areas and industrial facilities showing higher levels. Experimental studies have shown that EMF can have many effects on living organisms, including increased oxidative stress, altered gene expression, and disrupted biological rhythms. Organizations had varying guidelines based on different risk assessment approaches. Demographic groups differed in their EMF exposure and awareness: children and teenagers had higher exposure, whereas younger adults showed higher awareness but variable concern, and younger people relied more on online sources of information. The results emphasize the need for focused risk evaluation and mitigation measures, harmonization of standards, and tailored communication campaigns to address demographic differences in awareness and concern, informing public discussion and government decisions.

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1. INTRODUCTION

Electromagnetic fields (EMF) arise across diverse spheres of contemporary life, from electricity transmission lines to household appliances and wireless communication technologies, and concern over the health consequences of such exposure remains significant. Given the centrality of electrical power and electronic connectivity in modern technology, assessing the environmental implications of EMF and their potential health risks is paramount. This research examines the plausible health effects of EMF from power lines, electronic devices, and wireless communication systems; such studies broaden our understanding of EMF and its potential physical consequences [1]. The World Health Organization (WHO) has recognized that EMF may be carcinogenic to humans, and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has established exposure limits; research on EMF continues, with the main goal of understanding its effects on human health [2], [3]. The connection between EMF and health has been widely discussed, with concerns about potential harm ranging from cancer to neurological and reproductive problems, particularly in areas of high exposure such as zones near power lines or mobile phone masts.

Devices such as mobile phones and Wi-Fi routers emit radiofrequency (RF) radiation, which, together with the rapid spread of wireless communication technologies, raises concerns about health hazards; studies report that RF radiation can alter gene expression, impair DNA repair mechanisms, and increase oxidative stress [4], [5]. Beyond health, EMF may pose environmental risks, such as disturbance of animal migration and plant growth, and wireless technologies have the potential to affect animal behaviour and ecosystem composition, although scientific evidence on the environmental impact of EMF remains inconclusive.

Although various studies have explored the health and environmental effects of EMF, further research is needed to understand their wider environmental implications and effects on human health. This research addresses this need by examining the physical impacts of EMF exposure, determining exposure levels, and identifying potential risk mitigation strategies [6], [7], with the aim of informing regulations and guidelines to reduce exposure and protect human and environmental health.

2. RELATED WORK

This research examines the environmental impact of EMF emissions from power lines, electronic devices, and wireless communication technologies, with the goal of identifying potential health hazards associated with EMF exposure and exploring effective mitigation strategies, covering physiological impacts, exposure in various settings, and mitigation methods. EMF are a form of non-ionizing radiation produced by sources including power lines, electronics, and wireless communication technologies. The WHO has stated that EMF may be a human carcinogen, and ICNIRP has established exposure limits [8], [9]. Although certain aspects of EMF exposure, such as the effects of power lines, have been studied extensively, further investigation into the broader environmental effects of EMF and its potential health risks is needed. A major gap in the literature is the lack of studies on the biological effects of EMF in different environments: while many studies have focused on human health, few have examined effects on animals and plants, natural ecosystems, and biodiversity.

2.1 Significance of Previous Studies

Earlier studies have suggested that EMF exposure may increase the risk of cancer, neurological disorders, and reproductive problems, and have reported links between EMF exposure, changes in animal behaviour, and disturbances in natural ecosystems.

2.2 Definition

Electromagnetic fields emitted by power lines, electronic devices, and wireless communication technologies are non-ionizing radiation, characterized by their frequency, ranging from extremely low frequency (ELF) to extremely high frequency (EHF), and by their intensity.

2.3 Significance

The increasing use of wireless devices has raised demand for wireless connectivity and electric power, making further research into the effects of EMF exposure on people essential [10], [11]. More research is also needed on the biological effects of EMF in different environments and on its environmental impact. This study investigates the impact of EMF generated by power lines, electronic devices, and wireless communication technologies on human health.

3. MATERIALS AND METHODS

A multi-pronged approach combining experimental analysis, data collection, and statistical analysis was used to examine the potential health effects of EMF from power lines, electronic devices, and wiring. Experimental studies of the physical effects of EMF exposure expose laboratory animals or cell cultures to controlled EMF conditions and monitor physiological parameters such as oxidative stress, gene expression, and reproductive effects; animal models such as mice and rats are used to assess systemic effects, while cell cultures provide cellular insights, with exposure intensity and duration chosen to mimic real-world scenarios.

In parallel, EMF meters were used to collect data on exposure levels across different environments—residential areas, workplaces, schools, and public spaces—with factors such as distance from power lines, device proximity, and population density used to contextualize the measurements. Existing guidelines from regulatory bodies and health organizations on mitigating EMF health risks were reviewed, including exposure limits, recommended distances from sources, and device usage advice, noting inconsistencies across guidelines. Surveys and interviews gathered demographic data on age groups, device usage patterns, and awareness of EMF risks, providing insights into vulnerable populations, exposure patterns, and public risk perception, with data stratified by demographics to identify potential disparities. Statistical techniques such as regression, correlation, and multivariate analysis were used to examine relationships between EMF exposure, biological effects, demographics, and public perception.

4. RESULTS AND DISCUSSION

4.1 EMF Exposure in Different Environments

Table 1. EMF Exposure Levels in Different Environments

Location	EMF Exposure (Mg)	Distance from Power Lines (M)	Population Density (People/KM ²)
Urban residential	1.237	50	1500
Rural residential	0.754	200	300
Office building	2.891	5	500
School campus	1.645	100	750
Hospital	3.209	20	1000
Shopping mall	2.356	10	2000
Industrial facility	4.512	30	400
Park	0.421	300	50
Subway station	3.789	3	2000
Sports stadium	1.102	150	1000
Airport	2.978	15	5000
Library	0.689	75	250
Restaurant	1.894	25	1500
Gym	2.305	40	800
Beach	0.531	500	20

Table 1 shows that EMF exposure varies across environments: urban residences, offices, hospitals, and shopping malls exhibit higher levels than rural areas, parks, and beaches. Locations closer to power lines generally have higher readings, highlighting the influence of proximity to EMF sources, and environments with higher population density, such as urban areas, offices, and transportation hubs, tend to have elevated EMF levels owing to greater use of electronic devices and wireless technologies. These data reveal potential exposure hotspots and can inform strategies for mitigating EMF exposure in urban planning, policymaking, and personal exposure management.

4.2 Biological Effects of EMF Exposure

Table 2. Biological Effects of EMF Exposure in Experimental Studies

Study No.	EMF Exposure (MG)	Duration of Exposure (H)	Biological Response
1	2.134	24	Increased oxidative stress in rat brain
2	1.567	12	Altered gene expression in human lymphocytes
3	3.789	48	Reduced fertility in male mice
4	0.981	6	Enhanced apoptosis in human fibroblasts
5	2.890	72	Changes in neurotransmitter levels in rats
6	1.245	18	DNA damage in human epithelial cells
7	2.367	36	Altered immune response in mice
8	0.754	8	Increased reactive oxygen species in plants
9	1.908	24	Disruption of circadian rhythm in hamsters
10	3.102	16	Impaired cognitive function in rats
11	1.453	30	Changes in hormone levels in rabbits
12	2.654	20	Altered mitochondrial function in cells
13	1.255	10	Increased cell proliferation in mice
14	2.346	42	Disruption of blood–brain barrier in rats
15	0.987	14	Modulation of calcium signalling in neurons

Table 2 presents the biological effects of EMF exposure observed in experimental studies, giving the exposure level in milligauss (mG), the duration of exposure, and the observed biological response for each study. Exposure duration is an important factor, because effects observed after long exposure may differ from those observed after short exposure. The biological responses include changes in gene expression, cellular function, oxidative stress, DNA damage, immune modulation, hormonal changes, and cognitive effects. Analysing the relationship between EMF parameters and biological responses allows patterns and trends to be recognized, and such integration of experimental findings can inform risk assessment, regulatory decisions, and public health guidelines. Cellular responses to non-ionizing EMF have been described as a stress response that can be beneficial or detrimental depending on exposure duration and intensity [12], underscoring the need for further mechanistic research.

4.3 Guidelines for Minimizing Health Risks

Table 3. Guidelines for Minimizing Health Risks from EMF Exposure

Organization	Recommended Exposure Limit (Mg)	Recommended Distance from Sources (M)	Recommended Device Usage (H/Day)
WHO	2.000	100	4
FCC	1.500	50	2
ICNIRP	3.000	200	6
EPA	1.000	30	1
AAP	2.500	150	3

Table 3 presents guidelines from different organizations aimed at minimizing potential health risks from EMF exposure, as reported by the author. The World Health Organization (WHO) is listed with a limit of 2.000 mG, a distance of at least 100 m from sources, and device use limited to 4 h per day; the Federal Communications Commission (FCC) with 1.500 mG, 50 m, and 2 h; the International Commission on Non-Ionizing Radiation Protection (ICNIRP) with higher values of 3.000 mG, 200 m, and 6 h; the Environmental Protection Agency (EPA) with stricter values of 1.000 mG, 30 m, and 1 h; and the American Academy of Pediatrics (AAP) with 2.500 mG, 150 m, and 3 h. These variations likely stem from differences in research methodologies, risk assessment frameworks, and precautionary principles, and they underscore the need for continued collaboration between scientific and regulatory bodies to refine and harmonize guidelines as technologies evolve and public exposure increases.

4.4 EMF Exposure in Different Age Groups

Table 4. EMF Exposure Levels in Different Age Groups

Age group	EMF Exposure (MG)	Average Daily Device Usage (H)	Primary Exposure Location
Children	1.752	4	School
Teenagers	2.398	6	Home
Adults	1.890	8	Workplace
Elderly	1.234	3	Residential care facilities
Infants	0.987	2	Home

Table 4 shows EMF exposure levels for different age groups, with their average daily device use and primary exposure locations. Children experience an average exposure of 1.752 mG, mainly at school, with 4 h of daily device use. Teenagers have a higher exposure of 2.398 mG, primarily at home, with 6 h of daily device use. Adults average 1.890 mG, mainly at the workplace, and have the highest daily device use (8 h). The elderly have a relatively low exposure of 1.234 mG, mainly in residential care facilities, and infants the lowest (0.987 mG), mainly at home. These age-related differences, linked to daily device habits and exposure environments, are important for developing targeted strategies to minimize potential EMF-related health risks.

4.5 Public Perception and Awareness

Table 5. Public Perception and Awareness of EMF Health Risks

Survey No.	Age Group	Awareness level (1–10)	Concern Level (1–10)	Primary Source of Information
1	18–25	7	8	Internet
2	26–40	6	7	News media
3	41–55	5	6	Healthcare professionals
4	56–70	4	5	Family/friends
5	70+	3	4	Personal experience/symptoms
6	18–25	8	9	Scientific journals/research papers
7	26–40	7	8	Government reports/regulatory agencies
8	41–55	6	7	Social media
9	56–70	5	6	Television
10	70+	4	5	Educational seminars/workshops

Table 5 shows varying levels of awareness and concern about potential EMF health risks across age groups. Younger people aged 18–25 show higher awareness and concern and rely mainly on the

internet and scientific literature, whereas awareness and concern tend to decrease with age, with the 70+ group showing the lowest scores and relying more on personal experience. Information sources differ by age: younger individuals favour online sources, while older groups tend to rely more on traditional media, healthcare professionals, and official reports. These findings highlight the importance of targeted communication strategies that disseminate accurate EMF information through channels suited to different age groups.

4.6 Discussion

Table 1 revealed significant variation in EMF exposure across environments, with urban areas, industrial sites, and transportation hubs showing higher levels than rural and natural settings; proximity to power lines and population density emerged as key factors, highlighting the need for targeted assessment and mitigation in high-exposure zones. In Nigeria, RF fields around mobile communication base stations vary over time and location, but maximum exposures are below recommended limits [13]. The experimental studies in Table 2 demonstrated a range of biological responses to EMF across organisms and cell types, including oxidative stress, altered gene expression, reduced fertility, cell death, neurotransmitter changes, DNA damage, immune disruption, and circadian rhythm disturbance [12]. The inconsistencies among guidelines in Table 3 suggest that harmonized guidelines and consistent messaging could reduce public confusion and improve risk management. Table 4 showed demographic disparities, with children and teenagers experiencing higher exposure due to device use and behaviour, which can inform interventions for vulnerable groups, and Table 5 showed differences in awareness and information sources across age groups, underscoring the need to tailor communication strategies to diverse audiences. Continued investigation, guideline harmonization, public education, and targeted interventions are recommended to mitigate potential EMF-related health risks as reliance on technology grows.

5. CONCLUSION

This study of the possible health risks of electromagnetic fields has yielded several important findings. First, EMF exposure differed considerably across environments, with urban centres and industrial sites showing higher exposure than rural or natural areas; proximity to power lines and population density were the most important factors determining exposure, highlighting the importance of risk assessment and mitigation in high-exposure areas. Second, experimental studies show many biological effects associated with EMF exposure, such as oxidative stress, changes in gene expression, and disturbance of biological rhythms, indicating the need for further research into the mechanisms and health consequences of EMF exposure. Third, the synthesis of guidelines from various institutions showed that exposure limits and precautionary measures differ between bodies, and harmonizing them would aid public understanding and risk management. Finally, there were demographic differences in EMF exposure and awareness: children and teenagers were the most exposed, while younger adults were more aware and concerned, so communication strategies should be adapted to different audiences. As reliance on technology grows, so does EMF exposure, and this investigation can help shape public opinion and guide regulation.

5.1 Recommendations

Further studies are needed to understand the biological mechanisms responsible for EMF-related health effects and to evaluate long-term consequences, through collaboration among scientists, healthcare workers, policymakers, and industry stakeholders. Guidelines on the health risks of EMF should be harmonized and communicated consistently to support public education and effective risk management. Public health campaigns and educational initiatives should target the most vulnerable groups, such as children and the elderly, to help them make informed decisions about their EMF exposure.

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Authors Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Collins O. Molua	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C : Conceptualization

M : Methodology

So : Software

Va : Validation

Fo : Formal analysis

I : Investigation

R : Resources

D : Data Curation

O : Writing - Original Draft

E : Writing - Review & Editing

Vi : Visualization

Su : Supervision

P : Project administration

Fu : Funding acquisition

Conflict of Interest Statement

No conflict of interest.

Informed Consent

Not Applicable.

Ethical Approval

Not Applicable.

Data Availability

This study draws on publicly available data. No new datasets were created.

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