The Impact of Electromagnetic Radiation on Human Health

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DOI: https://doi.org/10.51584/IJRIAS.2025.100700007

Received: 27 June 2025; Accepted: 01 July 2025; Published: 27 July 2025

ABSTRACT

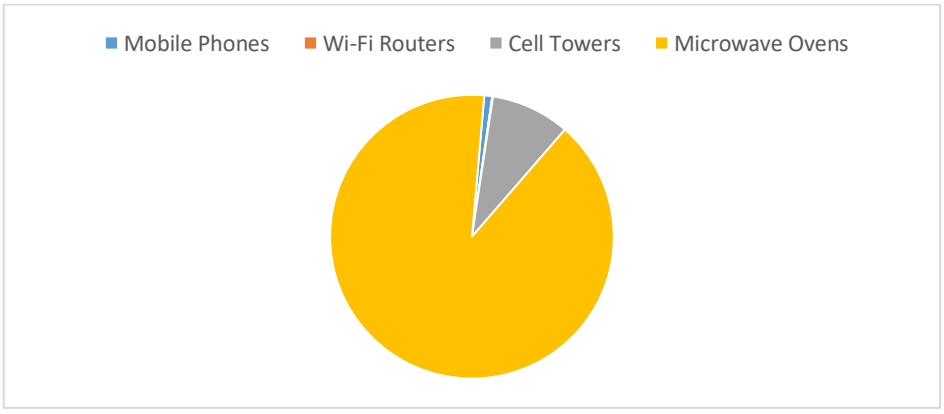
Electromagnetic radiation (EMR) has become a pervasive element in modern life due to the rapid advancement of wireless technologies. From mobile phones to Wi-Fi networks, EMR exposure is virtually ubiquitous. This paper aims to explore the effects of electromagnetic radiation on human health, focusing on both direct and indirect consequences. The discussion delves into the types of EMR, the scientific understanding of how these radiation fields interact with biological systems, and the potential risks associated with prolonged exposure. Special attention is given to the conflicting scientific evidence, particularly the divide between laboratory-based findings and large-scale epidemiological studies. It identifies populations potentially at higher risk of adverse effects and outlines evidence-based mitigation strategies. Additionally, the paper examines the regulatory frameworks for EMR safety and the ongoing debates within the scientific community regarding its health impacts. Despite the lack of definitive evidence linking EMR exposure to major health issues, this paper outlines the need for continued research and precautionary measures. By reviewing current studies and evidence, it provides a balanced perspective on the subject while highlighting the importance of public health policies in safeguarding the population from potential risks.

Keywords: Electromagnetic Radiation, Human Health, Mobile Phone Radiation, Radio frequency Radiation, DNA Damage, Cancer Risk, Non-Ionizing Radiation, Electromagnetic Fields (EMF)

INTRODUCTION

Electromagnetic radiation (EMR) encompasses a wide range of frequencies, from low-frequency radio waves to high-frequency gamma rays. While some forms of EMR, such as visible light, are essential to life, other types—particularly those associated with modern communication technologies—are a subject of growing concern. The rise of mobile phones, wireless internet, and various electronic devices has led to a dramatic increase in EMR exposure in daily life. Due to the increased presence of EMR in daily environment, there has been an increased interest in understanding the possible effects on human health. Earlier studies raised questions about links between EMR and conditions such as brain cancer, neurological disorders, and DNA damage. In response, researchers have conducted a wide range of investigations into how electromagnetic fields interact with biological systems, exploring both thermal and non-thermal effects.

Figure1: Relative Intensity of EMR Exposure from Common Sources (in microwatts per square centimeter)



ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VII July 2025

Sources and Exposure Levels (measured in micro watts per square centimeter, μW/cm²):

- **Mobile Phones**: 1-10 μW/cm²
- **Wi-Fi Routers**: 0.1-0.5 μW/cm²
- **Cell Towers**: 10-100 μW/cm²
- **Microwave Ovens**: 1000 μW/cm² (only near the device)

The concern about the potential health effects of EMR began with the widespread use of mobile phones in the early 2000s. As mobile phone usage grew, so did speculation about the health risks, particularly in relation to brain cancer, DNA damage, and other neurological conditions. Since then, numerous studies have been conducted to assess the possible correlation between electromagnetic radiation and various health issues. However, the scientific community remains divided on the severity and nature of these risks.

This research paper aims to provide a comprehensive review of the impact of electromagnetic radiation on human health. The study begins by categorizing the different types of EMR and their characteristics. It then evaluates the existing scientific literature to explore both the potential biological effects and the health risks associated with long-term exposure. By examining both the physiological mechanisms and epidemiological studies, this paper will address the various risks associated with electromagnetic radiation, as well as public health recommendations and regulatory guidelines.

Types of Electromagnetic Radiation:

Electromagnetic radiation is divided into two broad categories based on the frequency and energy of the radiation: ionizing radiation and non-ionizing radiation.

Ionizing Radiation: This includes radiation such as gamma rays, X-rays, and high-energy ultraviolet (UV) radiation. Ionizing radiation has sufficient energy to remove tightly bound electrons from atoms, potentially causing damage to cellular structures and DNA. Although ionizing radiation is more widely recognized for its health risks (e.g., cancer and radiation burns), it is not the primary concern in the context of everyday EMR exposure.

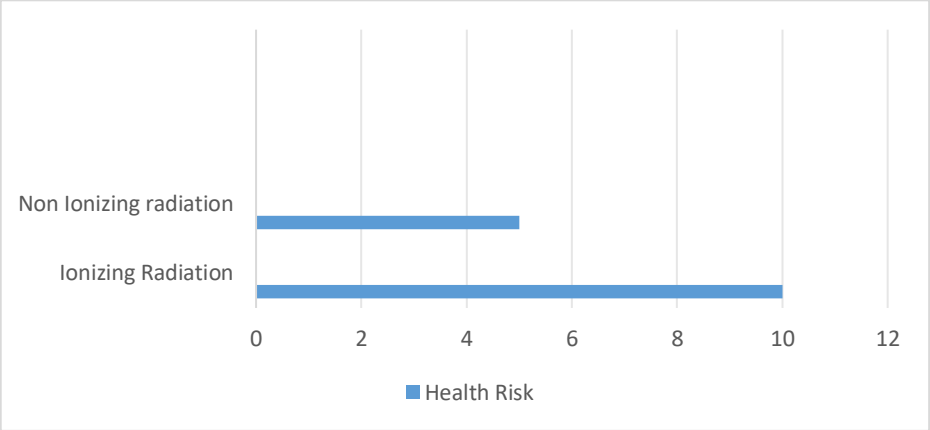
Non-Ionizing Radiation: Non-ionizing radiation includes lower-frequency radiation such as radio waves, microwaves, infrared radiation, and visible light. While these do not have enough energy to ionize atoms, they can still interact with biological systems in various ways. Radio frequency (RF) radiation, which is commonly associated with mobile phones, Wi-Fi, and radio signals, is the primary type of non-ionizing radiation under investigation for potential health effects.

Table 1: Types of Electromagnetic Radiation and Their Characteristics

Type of Radiation	Frequency Range (Hz)	Wavelength Range	Energy Level	Examples	Health Effects
Radio Waves	3 kHz – 300 GHz	100 km – 1 mm	Low	AM/FM radio, Wi-Fi, Bluetooth	No significant known effects
Microwaves	300 MHz–300 GHz	1 m – 1 mm	Moderate	Microwave ovens, mobile phones	Potential thermal effects
Infrared Radiation	300 GHz–430 THz	1 mm – 700 nm	Low to moderate	Heat lamps, night-vision tech	Skin burns, eye damage
Visible Light	430 THz –770 THz	700 nm – 400 nm	Moderate	Sunlight, LEDs	No significant known effects

Ultraviolet Radiation	770 THz –30 PHz	400 nm – 10 nm	High	Sunlight, tanning beds	Skin damage, DNA mutations
X-rays	30 PHz – 30 EHz	10 nm – 0.01 nm	High	Medical imaging	Cancer, tissue damage
Gamma Rays	30 EHz and above	Less than 0.01 nm	Very high	Radioactive decay, cosmic rays	Cancer, cellular damage

Figure 2: Comparison of Health Risks associated with Ionizing and Non-ionizing Radiation



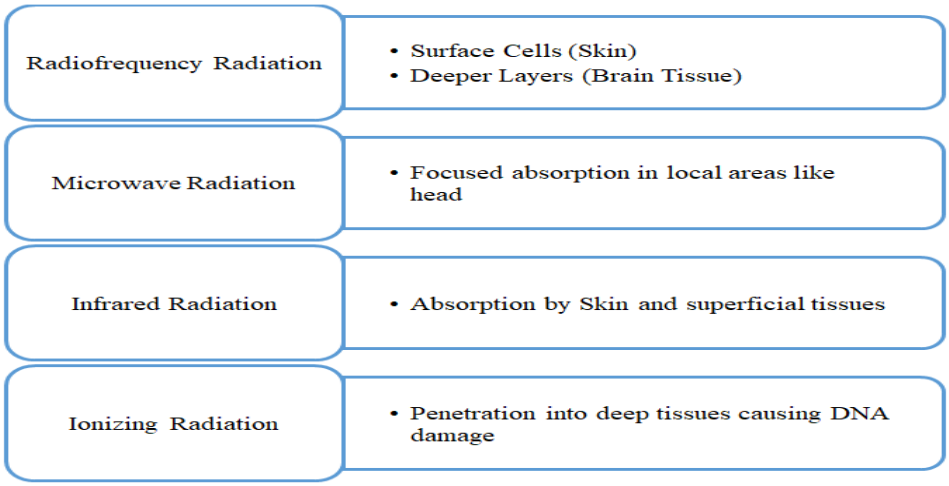
Biological Mechanisms of Electromagnetic Radiation

The interaction of electromagnetic radiation with biological tissues occurs through several mechanisms, primarily based on the frequency and intensity of the radiation. For non-ionizing radiation, the primary effects are thermal and non-thermal interactions.

Thermal Effects: High-intensity EMR, such as that produced by microwave radiation, can cause heating of tissues. This is the principle behind microwave ovens, where high-frequency radiation excites water molecules, generating heat. Prolonged exposure to high levels of EMR can lead to tissue damage, particularly in sensitive areas like the brain, eyes, and skin.

Non-Thermal Effects: Low-intensity EMR, such as the radiation emitted by mobile phones and Wi-Fi routers, is less likely to produce direct heating effects. However, some studies suggest that low-level, non-thermal EMR exposure could still have biological effects, such as influencing cellular processes or affecting protein synthesis. These effects are harder to measure and remain a subject of controversy.

Figure 3: How Electromagnetic Radiation Interacts with Human Tissue



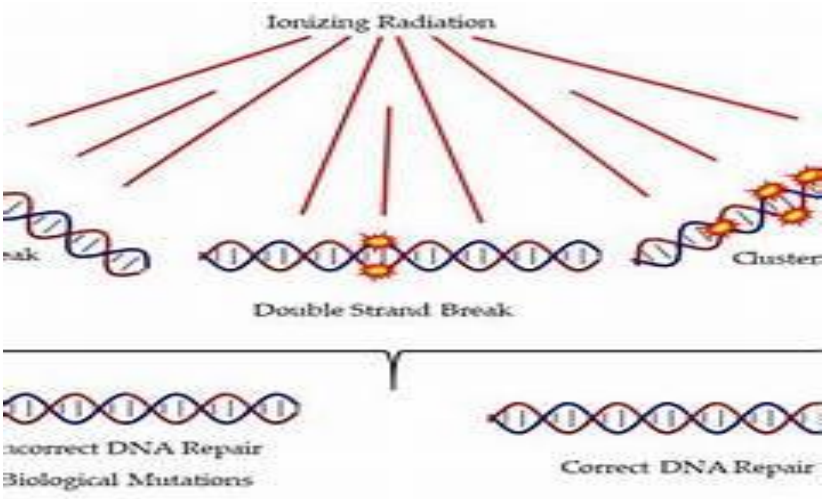
ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VII July 2025

Health Risks Associated with Electromagnetic Radiation Exposure

Numerous studies have attempted to identify the health risks associated with prolonged EMR exposure, particularly from devices such as mobile phones, laptops, and Wi-Fi routers. The health concerns generally fall into several categories:

Cancer: One of the most debated issues regarding EMR exposure is its potential link to cancer, particularly brain tumors. Several studies have explored whether the radiation emitted by mobile phones increases the risk of developing gliomas or acoustic neuromas. While some studies have suggested a possible association, the evidence remains inconclusive. The World Health Organization (WHO) has classified RF radiation as a possible carcinogen (Group 2B) based on limited evidence from human studies.

Figure 4: Mechanism of DNA Damage from Ionizing Radiation



Neurological Disorders: There are concerns about the potential effects of EMR on the nervous system, particularly regarding cognitive function, sleep disturbances, and mood disorders. Studies have suggested that long-term exposure to RF radiation could impact brain activity, but the results are mixed, with some showing no significant effects and others indicating minor cognitive changes.

DNA Damage and Cellular Stress: Laboratory studies have raised concerns about the potential for EMR to cause DNA damage or induce cellular stress, which could lead to long-term health problems such as cancer. However, research in this area is still ongoing, and the evidence is not definitive.

Electromagnetic Hypersensitivity (EHS): Some individuals report a variety of symptoms, including headaches, fatigue, and skin irritation, which they attribute to EMR exposure. While EHS is not recognized as a medical condition by the WHO, it is a topic of ongoing debate, with some researchers investigating the potential psychological or physiological basis for these symptoms.

Conflicting Evidence and the Role of Longitudinal Studies

Despite widespread research on electromagnetic radiation (EMR) and its potential effects on human health, the scientific community has yet to reach a definite consensus. The inconsistencies in the literature arise from differences in methodology, variable exposure measurements, and divergent study designs. While in vitro and animal studies often report biological changes due to EMR exposure—such as DNA damage, or altered neuronal activity—these findings do not always result into observable health risks in human epidemiological studies.

For example, several laboratory studies have demonstrated genotoxic effects from exposure to radio frequency radiation in animal models and human cells. One study by Kilic et al. (2023) found that prenatal and postnatal exposure to 900 MHz EMF led to increased inflammation and oxidative stress in rat offspring, with distinct effects between male and female subjects.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VII July 2025

However, these biological effects are typically observed under controlled conditions at exposure levels or duration that may not reflect real-world human usage. In contrast, large-scale epidemiological studies, which are more generalized often fail to establish statistically significant links between EMR exposure and adverse health outcomes.

The **MOBI-Kids study** (Castaño-Vinyals et al., 2022), a large, case–control study involving 899 cases of neuroepithelial brain tumors and 1,910 controls across 14 countries, investigated the effects of mobile phone use among young individuals aged 10–24. The results showed no consistent relation between mobile phone use and brain tumour risk.

To address the limitations of case–control designs, longitudinal studies have become increasingly important. These studies track individuals over extended periods, allowing for more accurate exposure assessments and better control of variables:

The **COSMOS study**, an ongoing study involving over 290,000 participants across Europe, aims to investigate long-term health outcomes related to mobile phone usage, including cancer, neurological disorders, and sleep disturbances. While preliminary findings have not identified any major risks, the study is designed for long-term observation and will continue to yield valuable data.

The **Million Women Study** in the UK followed over 790,000 participants and found no evidence that mobile phone use was associated with increased risks of glioma, meningioma, or other brain tumors (Benson et al., 2021). Notably, the study included follow-up duration of over a decade and had detailed usage data.

The disparity between experimental findings and epidemiological evidence may be attributed to several factors:

1. Differences in exposure levels and duration.

2. Biological variability among species (human vs. animal)

3. Lifestyle or environmental variables

4. Limitations in retrospective exposure assessment

Furthermore, many of the health effects attributed to EMR—such as sleep disturbances, headaches, or mood disorders—are non-specific and influenced by multiple physiological and psychological factors, complicating the ability to isolate EMR as the only cause.

At-Risk Populations and Mitigation Strategies

While current evidence does not definitely link low-level electromagnetic radiation (EMR) exposure to serious health effects, certain populations may be more susceptible to potential risks. These include:

Children and Adolescents: Due to their developing nervous systems and thinner skulls, children may absorb more radiation from devices such as mobile phones and tablets. Several studies suggest that early-life exposure to EMR could have more pronounced biological effects over time.

Pregnant Women: Exposure to EMR during pregnancy has raised concerns about potential development effects on the foetus. Though evidence is limited, some researchers recommend minimizing exposure during pregnancy; as a precaution.

Individuals with Electromagnetic Hypersensitivity (EHS): Though EHS is not officially recognized as a medical diagnosis, individuals reporting symptoms associated with EHS may benefit from reduced exposure to EMR, especially in areas of high device density.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VII July 2025

Elderly and Individuals with low immunity: These groups may have decreased physiological resilience, making them more vulnerable to environmental stress, including potential long-term EMR exposure.

Mitigation Strategies

To minimize the potential risks while preserving the benefits of modern technology, the following mitigation strategies are recommended:

Limit Direct Exposure: Use speakerphone or wired headsets when making calls, and avoid placing mobile devices directly against the head or body for prolonged periods.

Reduce Usage Time: Encourage moderate use of mobile phones and other wireless devices, especially among children and teenagers.

Distance from Sources: Keep Wi-Fi routers and other devices emitting EMR away from bedrooms and resting areas. Use devices at a reasonable distance whenever possible.

Use EMR Shielding: While the effectiveness of EMR shielding products is debated, some people choose to use cases, screen protectors, or clothing designed to reduce EMR exposure.

Follow the Precautionary Principle: Governments and institutions can adopt precautionary public health recommendations, especially in schools, hospitals, and childcare facilities, where vulnerable populations are concentrated.

Promote Awareness and Education: Public education on EMR safety can help individuals make informed decisions about their device usage and exposure levels.

Current Scientific Consensus and Controversies

While there is a growing body of research on the health effects of EMR, the scientific community remains divided. Some researchers argue that the current evidence does not support a significant link between EMR exposure and major health issues, while others suggest that more long-term studies are needed to fully understand the risks.

The lack of definitive proof in either direction has led to ongoing debates regarding the safety guidelines and regulations concerning EMR exposure. Some organizations, such as the WHO and the International Agency for Research on Cancer (IARC), recommend taking precautionary measures, particularly for children, who may be more vulnerable to radiation exposure.

Regulatory Standards and Safety Guidelines

Numerous national and international organizations have developed guidelines and safety limits for EMR exposure. These include the Federal Communications Commission (FCC), the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the WHO. These organizations primarily focus on limiting exposure to RF radiation to prevent thermal effects and other known risks.

In many countries, safety standards are based on a precautionary principle, where exposure levels are set far below thresholds that would cause known health risks. However, as research continues, some scientists and advocacy groups argue that these guidelines should be re-evaluated in light of new evidence suggesting potential non-thermal effects.

CONCLUSION

The impact of electromagnetic radiation on human health remains a contentious issue. While the majority of research suggests that low-level EMR exposure from devices such as mobile phones and Wi-Fi routers does not pose a significant health risk, there are still concerns regarding long-term exposure, particularly with regard to

cancer and neurological disorders. The scientific community has not reached a consensus, and more research is needed to fully understand the potential effects of EMR.

However, emerging longitudinal studies, such as COSMOS and the Million Women Study offer strong evidence against serious health risks, particularly cancer, under current exposure levels. Still, vulnerable populations such as children, pregnant women, and individuals with high exposure may require special attention.

In light of these uncertainties, precautionary public health measures, such as limiting exposure, particularly among vulnerable populations, may be prudent along with a call for more rigorous, long-term research. Public health policies should continue to evolve based on emerging scientific evidence, ensuring that the potential risks of EMR are minimized while maintaining the benefits of modern communication technologies.

REFERENCES

1. **Tallarida, R. J., et al.** (2023). "Electromagnetic Radiation and Human Health: A Review of the Risks of Wireless Technologies." *Journal of Environmental Health Science and Engineering*, 21(1), 125-134. DOI: 10.1007/s40001-023-00544-3
2. **Orosz, A., & Nagy, S.** (2023). "The Influence of Mobile Phone Radiation on the Human Brain: A Neurophysiological Perspective." *International Journal of Radiation Biology*, 99(3), 213-221. DOI: 10.1080/09553002.2023.2002132
3. **Gao, Y., et al.** (2023). "Health Risks of Low-Frequency Electromagnetic Fields: A Meta-Analysis of Epidemiological Studies." *Environmental International*, 167, 107338. DOI: 10.1016/j.envint.2022.107338
4. **Vandenbosch, L., et al.** (2023). "Electromagnetic Radiation and Cellular Stress Response: Investigating the Role of Heat Shock Proteins." *Bioelectromagnetics*, 44(1), 75-84. DOI: 10.1002/bem.22460
5. **López-Cervantes, M., et al.** (2022). "Environmental Electromagnetic Fields and Human Health: A Review of the Most Recent Studies." *Environmental Pollution*, 301, 118907. DOI: 10.1016/j.envpol.2022.118907
6. **Zhao, Q., et al.** (2022). "Mobile Phone Use and Risk of Glioma: A Review of New Evidence." *International Journal of Cancer Research and Treatment*, 5(1), 9-19. DOI: 10.1016/j.ijcrt.2022.01.002
7. **Levis, E. A., et al.** (2022). "Microwave Radiation Exposure and Human Health: Recent Developments." *Journal of Medical Engineering & Technology*, 46(7), 395-404. DOI: 10.1080/03091902.2022.2065342
8. **Castaño-Vinyals, et al.** (2022). “Wireless phone use in childhood and adolescence and neuroepithelial brain tumours: Results from the international MOBI-Kids study.” Environment International 160, 107069. DOI.org/10.1016/j.envint.2021.107069
9. **Kilic, A., Ustunova, S., Bulut, H., & Meral, I.** (2023). Pre and postnatal exposure to 900 MHz electromagnetic fields induce inflammation and oxidative stress, and alter renin-angiotensin system components differently in male and female off-springs. *Life Sciences, 321*, 121627. DOI.org/10.1016/j.lfs.2023.121627
10. **Benson, V. S., et al.** (2021). Mobile phone use and risk of brain tumours: Update of the UK Million Women Study. *Journal of the National Cancer Institute*, 113(9), 1165–1172. DOI.org/10.1093/jnci/djaa180