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Exposure and Biological Impacts Assessment of Non-ionizing Electromagnetic Radiation

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Abstract

For many years, there has been increased interest in the effects of non-ionizing electromagnetic radiation exposure on the biological systems because of the possible health risks it poses. Numerous researchers studying radiation in the fields of biology, medical physics, medicine, and agriculture have been interested in these impacts of electromagnetic field (EMF) alterations on biological systems. The objective of this review is to examine the biological effects of non-ionizing electromagnetic fields (NIEMFs) on biological systems of the human body, plants, and animals based on past and new studies. The use of electrical equipment as an artificial source of NIEMFs in recent years has significantly increased the amount of exposure that people experience on a daily basis. The steady increase in the usage of mobile phones, electric power lines, and home appliances throughout the world over the past 20 years has spurred economic growth but also directly and indirectly caused significant harm to the environment, people, and animals. Non-ionizing electromagnetic radiation from mobile phones, radio-based stations, phone towers, and high-voltage power lines has been linked to a number of health effects, including an increased risk of cancer, chromosomal effects, infertility, and abortion in humans, as well as negative effects in animals, birds, and other species. Although the use of this radiation from mobile phones, power lines, and appliances has sharply increased, there is a dearth of accurate information regarding the risks. From this study, it is clear that the kind, intensity, and length of the field's exposure all have a direct bearing on the biological impacts of NIEMF. The review presents the research data based on multiple studies and any knowledge gaps that might exist. Additionally, the current study highlights the reports, studies, and literature that are accessible on this topic and will aid in the development of guidelines for the public's exposure limits. The biological impact of non-ionizing electromagnetic radiation is typically a major problem in the literature and a source of debate among scientists. In order to determine the effects of non-ionizing electromagnetic radiation, it was proposed that more follow-up studies with a larger number of samples be conducted. These outcomes can be both repairing and harmful.

Keywords: Non-ionzing Iadiation, Electromagnetic Fields and Biological Effects of NIEMFs

Introduction

The energy needed to sufficiently excite atoms or electrons, but not to expel them from their orbitals, is referred to as non-ionization. Precautionary actions have the potential to increase anxiety, amplify risk perceptions associated to EMFs, and erode confidence in the safety of the public health. Decisions about preventative measures should take into account such repercussions that question social presumptions. Non-ionizing radiation (NIR) is frequently utilized in the medical field for procedures including laser surgery, long-term UV light therapy, and transcranial magnetic stimulation, which are more recent developments for the treatment of depression. In-depth research is done on the many kinds of non-ionizing radiation in this paper. Human reproductive organs are seriously harmed by invisible cell phone radiation, which can result in infertility [1]. Although a molecule or an atom cannot be ionized by radiofrequency radiation, they can be excited to move into a higher energy state. Microwave ovens, mobile phones, and Wi-Fi are examples of devices that utilise radiofrequency non-ionizing ranges in daily life. These devices are used for communications, such as television and radio transmission (Figuer 1). NIEMFs come in a variety of spectra, and long waves or low energies Non-ionizing EMFs can affect how cells function and multiply.

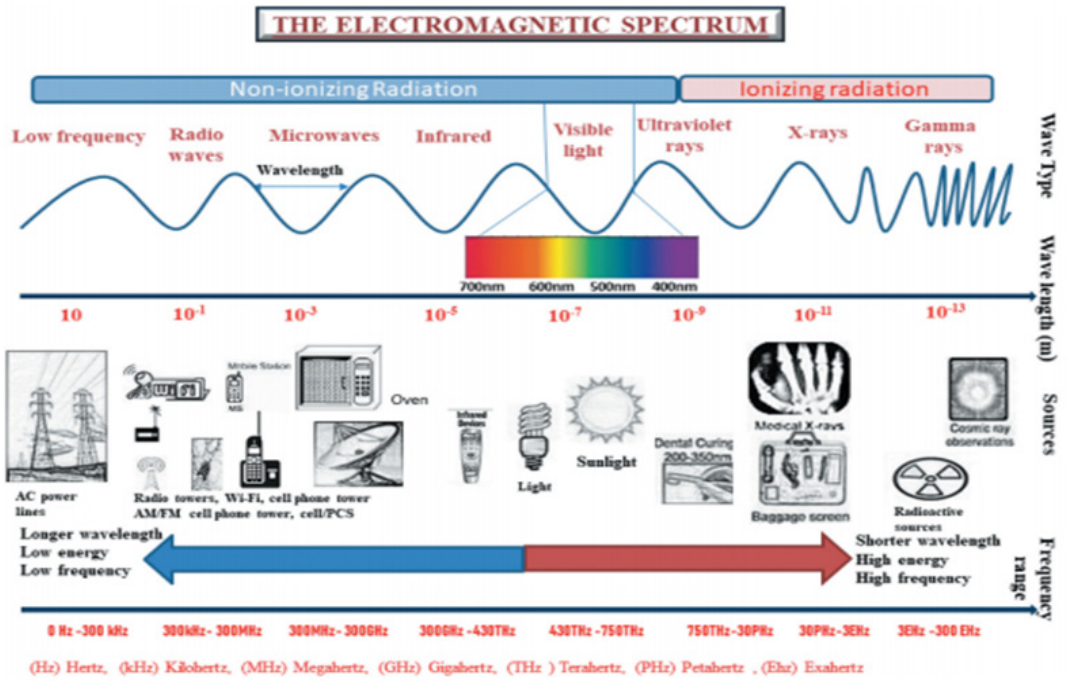

Figure 1: A graphical representation of electromagnetic spectrum (non-ionization & ionization radiation Types [2].

Infertility may result from exposure to EMR since it can stimulate oxidative stress, lower antioxidant levels, and promote lipid peroxidation, which points to an increase in free radicals [3-4]. People are becoming more motivated to learn about the consequences of electromagnetic fields with extremely low frequencies on public health. The likelihood of individuals being exposed to extremely low frequency (elf) electromagnetic fields on a more frequent and intense basis is rising as a result of industrialization and the gradual improvement in quality of life. As a result, individuals from a variety of social strata, especially scientists, have begun to make an effort to establish a link between exposure to NIEMFs and specific cancer types that are increasingly being diagnosed in both children and adults [5]. Depending on the frequency of the applied field, exposure to electromagnetic fields has different effects. Health risks may result from prolonged exposure to electromagnetic fields at high intensities [6]. By examining the electromagnetic field sizes measured in workstations and the general public, the level of exposure (both occupational and public) is ascertained. The electromagnetic field's action is experienced by the operators of the electric networks and other types of workers in the electric power industry during the exploitation activity. Additionally, residents of houses built close to overhead power lines may experience long-term effects from exposure to low-frequency electromagnetic fields.

Electromagnetic fields (EMF) are produced whenever power is produced, sent through a network, or used [7]. High voltage transmission (HVT) lines are widely used, which has led to a great deal of concern being about how exposure to HVT lines' electromagnetic fields (EMFs) may affect people's health, particularly in youngsters [8]. The result is that in several nations, building new HVT lines has encountered strong opposition . Since Wertheimer and Leeper's initial publication on the subject in 1979, there has been ongoing research in the potential link between EMF exposure from HVT lines and childhood cancer for the past thirty years [9]. Extremely low frequency electromagnetic fields (ELF-EMF) have been labeled as a potential carcinogen by the International Agency for Research on Cancer (IARC) in light of research on leukemia-stricken youngsters [10]. Studies looking into possible links between occupational exposure to ELF-EMF and poor health outcomes have mostly concentrated on childhood cancers or nervous system diseases, like amyotrophic lateral sclerosis, brain tumors, and Alzheimer's disease, from exposure [11-15]. There is a lack of research on the connection between children's neurobehavioral development and exposure to EMF from HVT lines. Acute cognitive effects from brief exposure to powerful EMF have been linked to studies in adults and animal models. The formulation of exposure guidelines requires the characterization of these consequences. Studies examining field-dependent effects in youngsters are unfortunately scarce [16]. Environmental pollutant exposure varies among children and is frequently significantly higher than it is for adults. Children's exposure variations are partly caused by variations in physiology, surface-to-volume ratio, and behavior. Due to their continued physiological and psychological growth, children are more sensitive to EMF than adults. Due to its bioelectric characteristics, the nervous system is particularly vulnerable to the effects of EMF [17].

Given how frequently electronic devices like microwaves, televisions, and mobile phones are used, there is growing worry about the potential health implications of prolonged exposure to the electromagnetic fields (EMF) that these devices create [18]. Some people have reported experiencing symptoms such as headaches, fatigue, increased stress, sleep disorders, skin-related sensations (such as burning, prickling, and itching), rashes, muscle pains and aches, and other health issues as a result of being exposed to the EMF produced by mobile phones and their base stations [19]. The phrase "idiopathic environmental intolerance attributable to electromagnetic fields" (IEI-EMF), which describes symptoms people experience after being exposed to EMFs, was created by the World Health Organization (WHO) [20]. With increasing frequency in a child's daily life, electromagnetic fields (EMFs), such as extremely low-frequency (ELF)

or power frequency fields, and radiofrequency radiation (RFR), emit biologically relevant signals at very low intensity levels. Nearly everyone in today's environment is subject to two different forms of EMFs: (a) ELF EMF from electrical and electronic appliances and power lines, and (b) RFR from wireless devices including cell phones and cordless phones, cellular antennae and towers, and broadcast transmission towers. ELF or RFR are used in this context to refer to the specific type of exposure, while the word EMF is used to refer to all EMF in general. This review article offers fresh information on potential health effects, including epigenetics as a potential contributor to neuro-developmental and neurobehavioral issues that are now frequently observed in children's growth, including abnormal states and functional alterations resembling autism and attention deficit hyperactivity disorder (ADHD), which can be brought on by exposure to EMF and RFR. The term "epigenetic" refers to heritable changes in gene expression that do not include changes to the underlying DNA sequence in response to environmental changes. Epigenetics has developed to offer a more precise and stable control of gene expression and genomic regulation. Today, epigenetic refers to any information that can be passed down during cell division that is not inherited through the DNA sequence. It offers ways for the environment and the genome to interact in addition to controlling how genes are expressed. The use of wireless technologies, such as mobile phones and Wi-Fi emissions at levels to which the fetus and young children may be exposed, has led to the synthesis of several new lines of scientific evidence that show how EMF and RFR present in wireless technologies can cause epigenetic changes that can adversely affect childhood development Unfavosrable effects on children's health and development, as well as their rising dependency on mobile devices, the incorporation of wireless educational technologies into curricula, and indications that these tools may actually work against rather than in favour of academic success.

In order to address the issue with non-ionizing electromagnetic fields, it is necessary to measure the magnetic field, electric field, specific absorption rate, and power density close to home appliances, GSM & Cell phones, and overhead power lines. The measures' results were compared to the international organizations' established limits [6].

Material and Method

Literature Search Strategy

According to the Preferred Reporting Items for Systematic Reviews and Mata-analysis, a literature search of the research findings that had been published was carried out utilizing the databases of Google Scholar, Research Gate, Academia, and PubMed. It was also not limited to a specific time period. The search phrases were created by combining different ways of characterizing the exposure features, such as "Biological consequences of Non-ionizing Electromagnetic Radiation," "Health implications of Magnetic and Electric Fields," and "Effects of Electromagnetic Fields." the additional synonyms for each main sentence. Before data extraction, two researchers (B.S and H.M) enhanced the data extraction table. These two researchers independently searched citation databases, such as Google Scholar, Research Gate, and other databases, before gathering data using prepared tables (table 1). Any contradictions were resolved by discussion with a third investigator (Y.M).

Inclusion Criteria

The search was limited to studies in which people, animals, and plants were exposed to EMFs. The databases' "related article" feature and the citations of relevant papers were both used to search for further articles. Only peer-reviewed works that were published in English were taken into account. According to the various exposure frequency ranges, the studies required to provide the exposure levels for magnetic field, electric field, specific absorption rate, and kilovoltage in indoor environments.

Data Extraction

B.Samaila extracted the data, Y. M Sagagi and H.M Tampul validated the findings. Information on the biological consequences of emfs, exposure time, frequency, power density, kilovoltage of power lines, and other factors was gathered. It was discovered that the health implications had negative short- and long-term effects. We analyzed studies on the adverse effects of NIEMFs that concentrated on either short-term or long-term impacts.

Results and Discussion

Over the past few decades, the use of electronic gadgets has increased exponentially. Due to this, people are now exposed to increasing electromagnetic fields (EMF). Magnetic fields are produced by the flow of electric current, whereas electric fields are produced by variations in voltage. EMF waves with higher frequencies have more energy than those with lower frequencies, making them generally more dangerous. DNA strand breakage and cellular stress response are both brought on by an EMF [21]. Effectively evaluating the relationships between EMF and children malignancies is hampered by numerous methodological issues. Numerous research have come to the conclusion that extremely low-frequency electromagnetic fields (EMFs) play no causative effect in children cancers, including brain tumors [22]. A recent investigation revealed a connection between EMF radiation and the growth of cancerous tumors in rats. The American Academy of Pediatrics released fresh guidelines to lessen the negative impacts of cell phone exposure on kids in response to that study. 200 separate papers were found in September 2022 through searches on Google Scholar, Research Gate, and other websites. Of the 200 studies, 100 were found via a literature search on Google Scholar, 70 were found on Research Gate, and 30 were found in other sources. After title, abstract, and full-text screening, 180 papers remained. 20 papers were added to the meta-analysis after duplicate studies were taken out. Studies that lacked sufficient data and ones that didn't fit the inclusion criteria had been eliminated. Out of the twenty (20) papers that were evaluated for this study, two of the included studies obtained a good quality rating, sixteen received a medium quality rating, and two had a moderate quality rating. Table 1 provides a summary of each study's characteristics.

Table 1: An overview outcomes of the Literatures

Parameters NIEMRs	Source of NIEMRs	Exposure time	Exposed subjects	Biological effects	Ref
900 MHz 1800 MHz 2100MHZ	-	2h/day for 6m	Rats	Oxidative damage, Induce increase in lipid per oxidation, and Increase in Oxidative DNA damage formation and DNA single-breaks	Mehmet et al., 2019
2400MHz	-	40-60 min	Mice	Behavioral Changes in mice such as anxiety and Cytoplasmic cell with shrunken morphology degenerative alteration in neuronal hippocampus In mice	Hasan et al., 2022
27GHz	-	10-60 min	Mytilus gallo-provincialis	Infertility: Sperm cell Motility reduced after 10 min and after ½ hour majority of Spermatozoa was motionless and not vital at all.	Pecoraro et al., 2022
-	Mobile phone	12h dark/light	Albino mice	Infertility: Ovary and Uterus damage were observed in albino mice.	Aburawi et al., 2021
50 Hz to 16 mG	EMFs	-	Human	Increase risk of abortion	Masumeh et al., 2021
50Hz	EMFs	varied time-periods	-	Increases mitochondrial permeability in exposed human amniotic epithelial cells	Rohit et al., 2020
65 µT Magnetic field	EMFs	24h/day/30days	-	The micronucleus test indicated that ELF-MF induced a slight genotoxic damage only after the maximum exposure time and that this effect faded away in the months following the end of exposure	Bhawan and Marg 2014 Pachuau and Pachuau 2014
380Kv 50Hz	EMFs	20 years	Human	structural chromosome aberrations and sister chromatic exchanges (SCE) in blood cells	
200kV 5–10 µT Magnetic field	EMfs	-	Human	Increased frequency in structural chromosome aberrations was found but not in SCEs or aneuploidy	
400kV	EMfs	-	-	Increased frequencies of chromosome aberrations	
400kV	EMfs	-	Human	The frequency of cells with chromosomal aberrations and micronuclei was significantly Increased but SCEs were not increased	

>100 µT Magnetic fields	Emfs		-	Showed a significant increase in the frequency of cells with chromo-some-type aberrations.	
132 kV	EMfs	2years	-	Increased DNA damage was found in the exposed subjects	
-	Computer monitor	-		Exposure to radiations from computer monitors induces oxidative stress in the corneal tissues with in-crease in malondialdehyde (MDA), catalase, glutathi-one peroxidase activity	Balci et al. 2009
1.15 µT Magnetic field	laptop com-puters	7hrs/day/ week		Dose dependent decrease in sperm count and mo-tility	(Mortazavi et al. 2010; McGill and Agarwal 2014; Brodić and Amelio 2015).
500 kV	HVT	-	Human	Negative impact on neu-robehavioral function in children	(Huang et al., 2013)
11 kV	Power lines	2-3 weeks	Human	Dermatological effects: redness, tingling, and burning sensations Vegetative effect: fatigue, tiredness, concentration difficulties, dizziness, nau-sea, heart palpitation, and digestive disturbances Neurasthenic	Quamruz-zaman et al., 2014
132kV	Power lines	2 years	Human	increased DNA damage was found in the exposed subjects	Tiwari et al. (2015)
2.104GHz	mobile phone	18hrs/day		Alterations in spermato-genesis with significant decrease in sperm cell, spermatogonia and leydig cells which effect the fer-tility for 28 days	Oh et al. 2018
900 MHz and SAR of 2.0 W/Kg	**mobile phone**	**Varying time**			**Falzone et al. 2011**

Table 2: International countries standards of Power Density from mobile phone and tower

Countries	Frequency	Power Density Standards	Ref
USA, Australia, Japan, Canada	900	4.5 W/m^2	Bhawan and Marg 2014, Rohit et al., 2020
	1800	9.0 W/m^2	
	2100	10.5 W/m^2	
India	900	0.45 W/m^2	
	1800	0.90 W/m^2	
	2100	1.05 W/m^2	

Table 3: Radiations effects from GSM tower

Power Density	NISEMfs effects	Ref
0.021W/m^2 in 50m away from tower	fatigue, nausea, dizziness and muscle pain	Pachuau and Pachuau 2014 Rohit et al., 2020
-	Neuropsychiatric conditions: Headache, memory changes, dizziness, tremors, depression, and sleep cycle disturbance	Abdel-Rassoul et al. 2007 Rohit et al., 2020
0.0122 W/m^2	depression, memory status, insomnia, and hair loss	Gulati et al. 2018

Table 4: Power density (µw/cm^2) emitted from mobile phone on different modes in different battery charging levels.

Battery Charge levels (%)	Power Density (calling mode) (µw/cm^2)	Power Density (called mode) (µw/cm^2)	Power Density (taking mode) (µw/cm^2)
1.0	38.08	35.05	25.95
5.0	7.34	32.31	34.61
10.0	6.09	33.98	29.96
15.0	6.83	27.10	19.01
20.0	6.75	29.19	25.66
30.0	5.14	25.06	19.38
50.0	5.83	25.15	17.36
60.0	6.27	30.16	18.03
70.0	5.04	25.09	16.80
80.0	4.85	26.91	30.23
100.0	19.44	29.46	19.61
Total	998	908	90
Source: Shiwangi et al., 2020			

Discussion

Oxidative stress, DNA damage and Neurobehavioral Change studied rats [23]. In this study, rats were exposed to the frequencies 900 MHz, 1800 MHz, and 2100 MHZ for two hours each day for six months (table 1). Indicators of DNA damage and oxidative stress were more prevalent in the non-ionizing electromagnetic radiation exposure groups than in the sham-control group, according to the study's findings. In the frontal lobe of the rat brain tissues, 900-, 1800-, and 2100-MHz RFR produced from mobile phones may generate increased lipid peroxidation, trigger oxidative DNA damage production, and cause oxidative damage. Furthermore, DNA single-strand breaks might develop as a result of 2100 MHz RFR.looked into the behavioral alterations brought on by a 40–60 minute exposure to 2400MHz in mice [24]. The results imply that 2400-MHz RF-EMR cell phone radiation affects the hippocampus' structural integrity, which would result in behavioral changes like anxiety. However, it warns us about the potential negative consequences of RF-EMR exposure over the long term. Mice also exhibited Cytoplasmic cells with shrunken morphology, a degenerative alteration in the neuronal hippocampus. According to, exposure to radiation from computer monitors causes oxidative stress in the corneal tissues and increases the activity of glutathione peroxidase, catalase, and malondialdehyde (MDA). After two years of exposure to 132 kV power lines, more DNA damage was discovered. A similar study was carried out by, and the results showed that exposure to 500 kV higher voltage transmission had a deleterious effect on children's neurobehavioral function [7]. However, more research is required to examine the effects of exposure to extremely low frequency EMF on neurobehavioral function and development in children due to variances in results, potential limitations, and the fact that only two out of four tests attained statistical significance. Exposure to 50Hz EMFs over a range of time periods was found to increase the permeability of the mitochondria in human amniotic epithelial cells [25]. Alkaline comet assay was performed by to look into DNA damage in cells from 132 kV substation personnel who had been exposed to ELF-EMFs for more than two years [26]. Analyses were done on blood samples from 151 non-exposed people and 142 exposed people. When compared to controls who were not exposed, the exposed participants showed a "tendency" toward more DNA damage, although statistical significance could not be determined. Epidemiological investigations display an accelerated danger of malignancy and leukemia in children provided to low recurrence electromagnetic field and past the 5.0 e kV/m and 0.4 T [27].

Infertility Effects due to Non-ionizing EMFs radiation

examined the effects of exposure to 27 GHz NIEMFs for 10 to 60 minutes on Mytilus galloprovincialis infertility (table 1) [28]. After 10, 20, 30, 40, and 60 min, a light microscope and an Eosin test were used to assess the impact of the exposure. Each time series underwent ten replications, and the t-test was used for statistical analysis. After 10 minutes of exposure, sperm

motility started to decline, and after 30 minutes, the majority of spermatozoa were stationary and not alive. This study offers helpful information on the high-band 5G's possible ecological effects on animal reproductive, the impact of which is now being studied. Similar research on the impact of NIEMFs on Albino infertility was done by [29]. The albino was exposed to a phone for 12 hours during light and dark. The findings demonstrated that albino mice had ovarian and uterus damage. Mobile phone radiation exposure has no impact on any central nervous systems function or behavior while exposure is occurring. Histologically, the ovary and uterus were harmed by this length of exposure. To maintain the health of the mind and body, it is advisable to restrict daily cell phone usage to a minimum. According to, exposure to laptop computers that emit [30]. 1.15 T magnetic fields led to a dose-dependent decrease in sperm count and motility after 7 hours per day/per week of exposure. 28 days of exposure for 18 hours per day at a distance of 3 cm resulted in changes to spermatogenesis, including a significant decline in sperm cells, spermatogonia, and leydig cells that affect fertility [31]. In an in vitro investigation, exposure of spermatozoa to 900 MHz radiation for one hour at a specific absorption rate (SAR) value of 2.0 W/Kg alters sperm morphometry and binding to hemizona, resulting in a reduction in sperm fertilization capacity [32]. Figure 2 below shows the causes of male infertility.

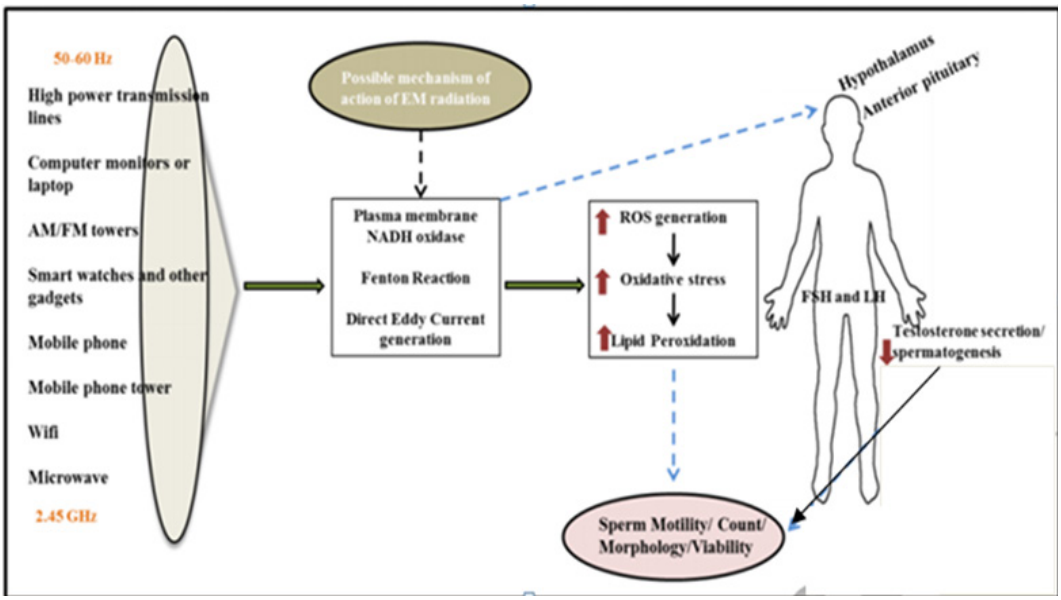

Figure 1: Diagrammatic illustration suggesting the consequence of EMR exposure on male reproductive system [25].

Miscarriage Impact of non-ionizing radiation

Abortion risk increases by 1.27 when exposed to NIEMFs above 50 Hz . It could be advisable to warn women away from this possibly serious environmental threat. Pregnant women should, in fact, receive personalized counseling.

Immediate effects of NIEMFs

NIEMFs with a power density of 0.021□W/m□^2 at a distance of 50 meters from the mobile tower have been linked to reports of weariness, nauseousness, dizziness, and muscle discomfort [33-25]. revealed that exposure to non-ionizing EMF radiation may cause neuropsychiatric problems such as headache, memory changes, dizziness, tremors, depression, and sleep cycle disturbance in a study that is comparable to that conducted by. According tosignificant causes of depression, memory impairment, sleeplessness, and hair loss were measured at 0.0122 □W/m□^2 power density (table 3) [3].

Dermatological effects of non-ionizing emf radiation

Human exposure to 11 kV Power lines was studied by [34]. In response to exposure to 11 kV power lines, people experienced dermatological effects (such as redness, tingling, and burning sensations), vegetative (such as exhaustion, fatigue, difficulties concentrating, nausea, dizziness, and digestive abnormalities), and neurotonic effects (table 1).

Chromosomal, Sister chromatic exchanges and Genotoxic effect of non-ionizing EMFs radiation

The effects of prolonged exposure to magnetic and electric fields on structural chromosomal abnormalities and sister chromatic swaps in participant blood cells have been the subject of numerous studies. According to, chromosome analysis was done on the lymphocytes of 32 workers who had spent more than 20 years working in 380 kV switchyards where they were exposed to 50 Hz alternating electric and magnetic fields [35]. The control group consisted of 22 workers who were of a similar age. Their employment did not coincide with ELF-EM exposure despite having a comparable line of work. In both groups, Sister chromatic exchanges (SCE) and chromosomal abnormalities were prevalent. Some publications have noted connections between EMF exposure and cancer, as genetic damage is frequently a hallmark of the disease.

Similar results were seen when electromagnetically treating human and plant cells, according to. For Allium cepa L. and human peripheral lymphocytes, for instance, electric fields with power densities (electric field intensity) of 1000, 1500, and 2000 V/m and magnetic field strengths of 0.25, 0.50, and 1 mT were established in order to study the effects of electromagnetic fields. Randomly amplified polymorphic DNA-polymerase was used to study the genetic impact of electromagnetic fields on DNA levels. Following the use of chain reaction (RAPD-PCR) techniques, it was discovered that electromagnetic fields had an impact on the mitotic index and increased chromosomal abnormalities in all treatment groups. A comparable investiga-

tion measured the magnetic field from a 380kV power line at 65 μT. The micronucleus test revealed that ELF-MF only slightly caused genotoxic damage during the maximal exposure time (of 30 days), and that this effect diminished in the months after exposure ended and P [33]. Sister chromatic exchanges (SCE) and structural chromosomal aberrations (CGA) in blood cells in the range of 5-10 T magnetic fields were seen in 20 years of human exposure to 200kV at 50Hz. Another study on power lines found that although SCEs did not increase, exposure to 400kV may increase the frequency of structural chromosomal abnormalities and micronuclei. Furthermore, cells with chromosome-type abnormalities are far more likely to occur when exposed to magnetic fields larger than 100 μT. [33]. Magnetic fields ranging from a few μT to more than 100 μT were applied to the drives. Again, chromosomal aberrations were investigated in peripheral lymphocytes. A pilot study of 18 engine drivers revealed a significant four times higher occurrence of cells with chromosomal abnormalities when compared to a control group of 16 office workers. In a follow-up investigation with 30 additional engine drivers and 30 more police officers, the number of cells with chromosome-type abnormalities considerably rose (used as controls).

[36]. studied the cytogenetic effects of exposure to ELF-EMF in railroad engine drivers (2010). In this work, structural chromosomal abnormalities and sister chromatid swaps were looked into. The exposure of the engine drivers to other (chemical) agents was thought to be modest and typically inconsequential, but their exposure to quite high magnetic field concentrations was assumed. This study refuted the idea that ELF-EMFs are genotoxic by not demonstrating any enhanced chromosomal damage in the person who had been exposed to them. 15 train guards and 15 railway engine drivers made up the study's exposed population and controls, respectively. With regard to age, habits, and socioeconomic circumstances, both groups were comparable. On 13 laboratory personnel who had been exposed to electromagnetic fields, a similar study was carried out. Seven of them were laboratory cable splicers for high voltage (up to 200 kV), and six of them were engineers who had been subjected to static, alternating, or pulsing electric and magnetic fields. The matched controls consisted of 20 people who were the same age, had the same job description (but no exposure), and smoked in the same ways. Although the alternating 50 Hz magnetic fields were normally 5-10 T, they were occasionally capable of reaching far higher levels (500 T for whole-body exposure; 10,000 T at the level of the hands). Chromosome aberrations, SCEs, and aneuploidy (numerical chromosome aberrations) in the subject's peripheral white blood cells were examined. In this study, structural chromosomal abnormalities were shown to be more common than SCEs or aneuploidy, but not both. Numerous cytogenetic biomonitoring studies on exposed workers were carried out.

Twenty switchyard workers at 400 kV substations had their peripheral blood lymphocytes analyzed for chromosomal abnormalities. These aberrations were more frequent than in the controls, according to the data. In a subsequent investigation, 38 workers from an electric power business were questioned; 19 of these workers repaired and maintained circuit breakers and disconnections in 400 kV substations. The 19 additional individuals served as controls and were only exposed to background electromagnetic radiation. The frequency of cells with micronuclei and chromosomal abnormalities was significantly higher than the rates in the control cells. There was no increase in SCEs. A research by [37]. included police officers, office workers, train dispatchers, and engine drivers (2001). In light of the findings of epidemiological studies, research on the genotoxic effects of EMF is gaining popularity. When the effects of 50 Hz 0.1 to 7.5 mT EMF on lymphocytes collected from adults and activated by mitotic activating chemicals are evaluated, it is discovered that EMF has no influence on either the frequency of chromosome mutations or chromosome breakage. In another investigation, cells were exposed to a 0.4 mT EMF, and it was shown that there was a statistically significant rise in chromosome breakage. The "pulsed" nature of the EMF used in this investigation [38].

When EMF is applied to lymphocytes that have had their mitosis activity stimulated for 24, 48, and 72 hours, it is found that the sister chromatic mutations in these cultures did not change significantly during the 24 and 48-hour trials, but a significant increase in the mutation frequency was observed during the 72-hour period. In a different investigation, adult male rats were subjected to microwave radiation at 9450 MHz with a power density of 2.65 mW/□cm□^2 for one hour each day for thirteen days. Standard studies of the chromosomes in the bone marrow were performed, and the experimental group was compared to the control group. According to the findings, rats' chromosomal mitotic index dropped and increased aberrant metaphase following a 13-day application when compared to normal [38]. The DNA is said to be badly impacted in a number of research on the effects of electrical and magnetic fields on biological structures. Numerous investigations on potential genetic impacts in individuals who were occupationally exposed to extremely low-frequency electromagnetic fields were conducted due to the relationship between genetic effects and cancer (at least in many cases). The majority of these investigations revealed increased DNA damage, making the overall conclusion somewhat worrisome. But these findings should be thoroughly scrutinized [38]. The chart below provides a summary of the impacts of EMFs, including clinical

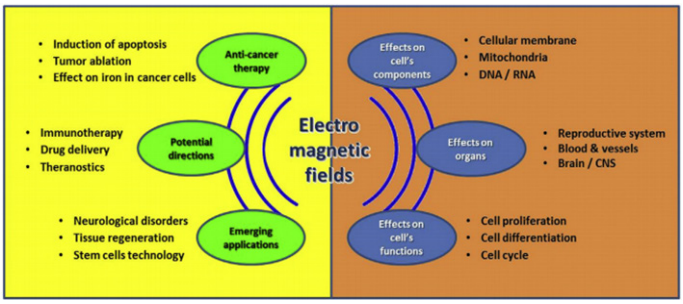

Figure 3: Biological effects caused by electromagnetic fields, and their potential therapeutic applications [39].

Impact of non-ionizing EMFs radiation from different charging levels of mobile phones

The use of mobile phones and cell phone towers has significantly increased in modern times, making them the most potent wireless communication devices ever. There are currently over 5.1 billion cell phone customers worldwide, and as data usage is expected to grow by about 4% annually, it is anticipated that this number will reach 5.7 billion by 2025. [2-40]. investigated the

impact of battery charging levels at the time of electromagnetic frequencies released from the mobile phones in light of the potential negative health effects of mobile phones as the main and dominant source of electromagnetic radiation and growing public interest in the radiations exerted from mobile phones depend on the different battery charging level [2]. In the investigation, they used an HTC One E9+ Li-Po model with 0.181 W/kg SAR and an internal battery, and they discovered that the power density was higher while chatting for 360 seconds (23.005 w/cm2) than it was while being called for 40 seconds (10.27 w/cm2). Table 4 displays the various power densities produced by mobile phones in various modes. The field strength was measured at various battery charge levels: 1%, 5%, 10%, 15%, 20%, 30%, 50%, 60%, 70%, 80%, and 100%. Power density was even higher when the phone was charging and the battery level was barely 1%. carried out research on the impact of mobile phone users' personal habits on sperm quality when conversing while the battery is charged [41]. People who converse on the phone while the battery is charging have an aberrant sperm ratio of 66%, which is much greater than the 35% ratio seen in healthy individuals, and is a contributing factor to low sperm production.

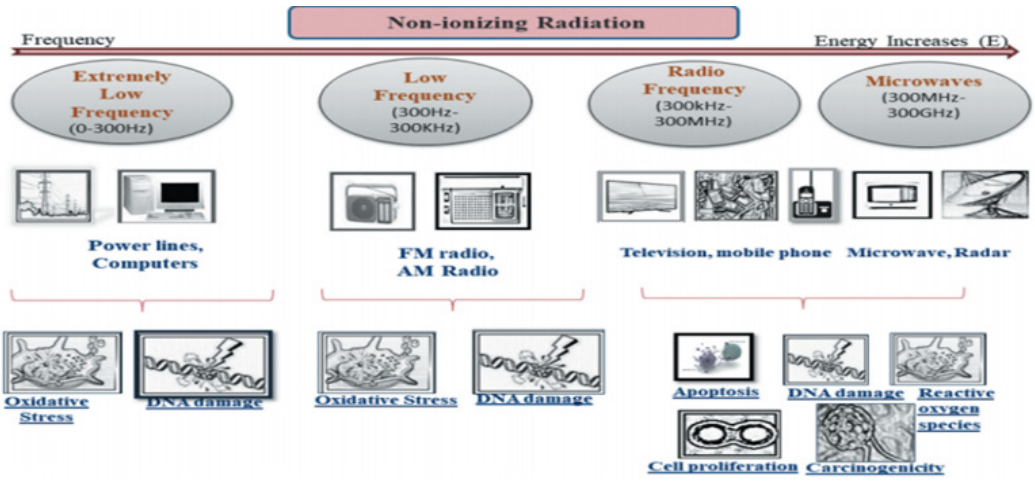

Figure 4: The possible effects of different frequency of non- ionizing radiation [2].

used an electrosmog meter in Iran to measure the electromagnetic waves emitted by mobile phones (Nokia, Sony Ericsson, and Samsung) at a distance of 5 to 21 cm from the antenna (TES-593) [42]. A statistically significant difference was found between the power densities of the mobile phones, which were tested in the taking mode at 17.57, 102.62, and 43.28 w/cm2. The power densities of mobile phones were 0 (standby), 50.14 (calling), and 65.72 mW/□cm□^2 (talking) modes, respectively, at the same time. Talking mode exhibited a greater rate than calling mode. The study also found that call speak reproduces a three times stronger field than listening on the phone. discovered no notable differences between the caller and the recipient [43]. Using a Nokia smartphone in ring mode, receiving-ring mode, and taking mode, assessed power densities [44]. The degree of radiation release in calling mode was found to be much higher than in chatting mode, according to a 2015 study by [45]. Precautions should be made with reputable mobile phone brands and having low SAR values, it is advised, in order to prevent the potential negative effects of RFR.

Conclusion

The frequency ranges of electronic equipment are continuously expanding today, concurrently with the escalating pace of technical advancement and the society's growing need for household electronics, mobile phones, and power lines. Human and animal bodies can absorb non-ionizing radiation that is emitted by electrical equipment. Children as well as adults are impacted by the increased time spent using phones and the use of them in close proximity to our bodies. Therefore, there is growing worry in society about the harmful biological impacts of EM waves released from phones and other electronic gadgets in homes, marketplaces, mosques, churches, and recreational facilities. According to the findings of the entire body of research examined in this study, no-ionizing EMF radiation may increase chromosomal abnormalities, cause abortion in pregnancy (in both human and or animals), damage DNA, impair fertility, and raise oxidative stress. Genetic damage is the cause of the illness known as cancer. Regulations regulating the use of electronic devices should be created in accordance with international standards taking into account these detrimental consequences, and society should be made aware of the dangers.

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Conflicts of interest

The authors do not have any conflicts of interest to disclose

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