

A Review Study On The Impact Of Electromagnetic Fields In The Development Of The Brain

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Abstract— The potential downside of rapid technological advancement has increased exposure to radiofrequency from wireless transmitting equipment and technologies. Because the radiation is nonionizing, it can disrupt your DNA, and also impact the water molecules or sugar molecules in your body. Normal mobile phone signals and even your Wi-Fi signal are in the microwave range, which means they utilize the same frequency as your microwave to cook food. Since the mobile phone emits a very high amount of radiation it will cause your skin or body to heat up somewhat, So you may actually experience your phone being hot in your hand when you use it too much now. Most human beings claim to be sensitive to the electromagnetic radiation emitted by modern digital devices and mobile phones, they describe symptoms such as headaches, nausea, skin responses, burning eyes, and weariness, nevertheless, these are only impacts claimed on a daily basis. A few studies have shown considerably more disturbing outcomes, such as probable links between the side of the brain used while people are using their phones and the emergence of brain tumors. So an intense review is necessary to look into this problem to get aware and take prevention accordingly.

Keywords— *Electromagnetic field, Nervous system, Brain development, Neurulation, Effects of electric-magnetic field, Controlling of EMF.*

I. INTRODUCTION

The widespread usage of cellular phones throughout the world demonstrates the influence of cellular phone EMF on human beings and other organisms. Using a cell phone closer to our ears and heads may cause Electromagnetic radiation exposure. Different parts of the electromagnetic spectrum correspond to different types of radiation, and many of them are completely harmless; however, radiation with very short wavelengths is harmless. These persons also experience issues with their central and peripheral nervous systems, which coordinate important processes. Whereas it affects the life cycle of nerve cells, regular sleep patterns, and headache frequency.

EMF exposure during pregnancy and lactation may cause neuronal cell damage and hinder the differentiation of stem cells into neurons. Human and animal model studies yielded notable results about issues impacting brain development. Neuronal cell death and the suppression of cell transformation into neurons in humans are the results of

EMF radiation exposure. The key objective is to investigate the consequence of the Electro Magnetic Field (EMF) on the Central Nervous System (CNS). As the CNS gets affected due to the EMF produced by cell phones, it happens due to the overuse of smart devices. Fig 1 shows the overall usage of the devices.

According to Fig. 1, the device that people use the most is the smartphone, and this device is the most health-threatening thing in the world when viewed from the perspective of an ordinary user. A thorough study is required for the various effects. Here sufficient information is provided regarding the preventive measures that must be undertaken to protect ourselves from harmful radiation. Maintaining the Integrity of the Specifications Since EMF from cellular phones causes drastic effects on human health, it is necessary to evaluate those effects and take preventive measures. The brain is the major controlling and coordinating part of the human body it is therefore essential to analyze the various effects of EMF on brain development. The brain can be affected in both pre-natal and post-natal life and we are liable to implement proper measures to maintain our health.

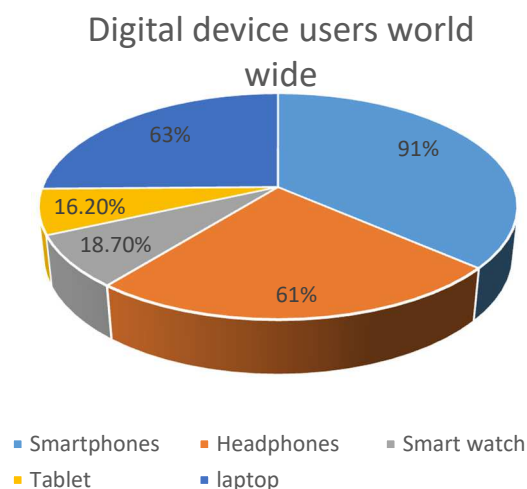


Fig 1. Smart devices used widely by people

II. EXISTING METHODOLOGY

The Effects of devices and long periods of EMF exposure on the human brain have been investigated by different methods. The impact of mobile phones on human brain morphology, as well as cerebral, stereological, and spectroscopic methods and neuropsychological assessments, are conducted by a student survey, in which the volunteers were divided into two groups and treated with either higher or lower levels of exposure to radiation. The students who were exposed to modest levels of radiation had no significant impacts on the human brain, but the students who were exposed to high levels of radiation had hazardous consequences on the morphology of the brain. [1] The study's shortcoming is that it only looked at morphological impacts on the hippocampus. There was no anatomical research.

The publication "Genotoxic and carcinogenic effects of non-ionizing radiation" performed research to analyze data on the carcinogenic and genotoxic effects of non-ionizing radiation. The findings from comparable investigations are inconclusive, making any thorough analysis impossible. Because epidemiological research undertaken here is a very limited sample size and a lack of prospective data[2]. Thermal properties and chemical effects are the two main effects of EMF on tissues. Long-term exposure to low-frequency EM waves induces tissue damage brought on by changes in the chemical micro-environment, as opposed to high-frequency EM waves, which predominantly cause thermal damage.

The electromagnetic spectrum includes a sizable section of non-ionizing EMF. EMF is produced by Radar, high-voltage lines, radio frequencies, power stations, and electrical appliances [3]. So far, the study has shown that EM and waves have a range of biological effects even at low potency and high degrees. Numerous findings were discovered as a result of experiments looking at the impacts of EMF on body weight, organ morphology and histology, biochemical parameters, hormones, the immune system, and blood electrolyte levels. Among these studies, some discovered that EMF hurts the body, while others discovered that they are beneficial and therapeutic [4]. According to animal studies, high-frequency EMFs may affect the nervous system. In their study, the hippocampus exposed to EMF during pregnancy exhibited significant cell death [5]. According to research prenatal EMF exposure causes significant granule cell loss during the postnatal period [6].

The many phases of brain development, such as the production of neural tubes, neural plates, neural folds, and neural crests, are discussed in [7]. The paper [8] explains the neurulation process. Neurotrophic factors produce a reduction in neural cells, which leads to neural death [9]. In early adolescence, the maximum entire cerebral volume is attained [10]. The brain grows and changes considerably during adolescence. During this time, there has been recorded rebuilding of neural networks, changes in nearly all brain regions, a rise in white matter, and a reduction in a grey matter [11]. MRI studies demonstrated an increase in the grey matter just before puberty, but afterward a decline. The general synthesis of axons and synapses in early adolescence and the fast synaptic paring down after puberty are the reasons for their cellular modification. The cumulative grey matter lasts until early and middle adolescence when it drops by a factor of 5 [12]. Boys, on the other hand, have more

volume in the left and right caudate, left Globus, and pallidus than girls. This change in hippocampus and amygdala volume might be connected to attention issues. Tourette syndrome and hyperactivity are neuro-psychiatric illnesses that, in their early stages, are similar to obsessive-compulsive disorder. Variation in synapsis is linked to knockoff, whereas changes in brain cells are correlated to mutation and stratification [13].

A. Descriptive case study

According to all of the above-mentioned studies, EMFs have a variety of effects on human health. because the brain is the primary control and coordinate organs of the human body. The impact of EMF includes cell loss in the cerebral cortex, abnormal sleep patterns, changes in synaptic plasticity, and so on. High-frequency EMF can cause serious brain tumors. Excessive EMF exposure can induce a change in hippocampus volume, resulting in cell death. Using a neurotransmitter prevents the transmission of nerve impulses because the nerve impulse is unidirectional[14].

EMFs have genotoxic consequences, such as changing gene expression. As a result, the structure of DNA changes, resulting in the process of mutation and as a result, genetic disorders. High EMF exposure also causes illnesses such as Parkinson's, Huntington's, Alzheimer's, and others. The effects of EMFs on individuals are mostly determined by their age factors that may have caused certain things to occur[15].

Our major objective is to define molecular and neuronal formations that are caused by EMFs and to know the impacts of EMF in our day-to-day life. Thorough research, as well as constant and well-experimented results, are required for this aim. The research defines EMF levels, experimental methods, the exact EMF sources, and prevention methods.

B. Electromagnetic Field

It is a physical field formed by electrons rotating within atoms and the core, which cause moving and electrically charged particles. Electromagnetic radiation consists of electromagnetic waves, which are synchronized oscillations of electric and magnetic fields traveling at the speed of light. EMF exists in whole units and is invisible to the naked eye, but sensitive devices can detect it. EMFs are broadly categorized into two types.

1. Very low frequency electric and magnetic field (ELF EMFs)
2. High Radiofrequency, electric and magnetic fields(RF EMFs)

Power lines, household electrical equipment, computers, and other sources of ELF EMFs are common. communications and broadcast, mobile phones and their base stations, and other sources of RF EMFs are the most common. Most energy is found in high-frequency waves.

EM waves have 2 effects

1. Thermal effect
2. Chemical effect

High-frequency electromagnetic waves are mostly responsible for heating problems (heat damage). Exposure to low-frequency EM radiation causes tissue damage due to chemical environmental changes. The quantity of EMFs

emitted by a variety of electrical systems such as radar, telecommunication, radio and television transmitters, power stations, electrical appliances, high voltage lines, and so on, has the greatest influence on human health, as seen in fig 2.

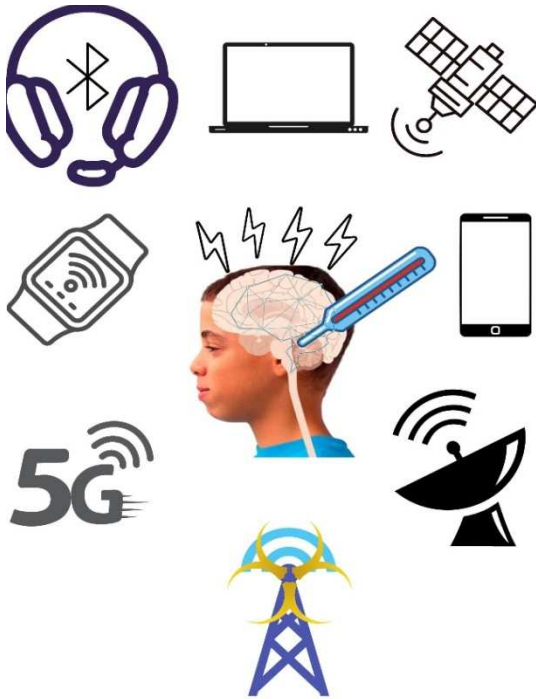


Fig 2. Radiation emitters

C. Nervous System

By sending and receiving signals to and from various bodily components, the nervous system is the component that coordinates its operations. It recognizes surrounding fluctuations and then cooperates with the endocrine system to react to them.

They are divided into two:

1. Central Nervous System (CNS)
2. Peripheral Nervous System (PNS)

Central Nervous System consists of :

1. Brain
2. Spinal cord

PNS consists of the main nerves :

1. Efferent or motor nerves
2. Afferent or sensory nerves
3. Mixed nerves

Neurons also known as nerve cells, send signals in the form of electrochemical waves.

The brain is divided into:-

1. Forebrain
2. Midbrain
3. Hindbrain

The forebrain consists of the cerebrum, thalamus, and hypothalamus. Midbrain consists of the tectum and tegmentum. The hindbrain holds the cerebellum, pons, and medulla oblongata. It has been shown that RF-EMF can cause RF-EMF acts as a stress source in living things, along with changes in CNS cells including neuronal cell death, changes in nerve myelin function, and changes in ion channel performance.

The ability to observe the impacts of Electromagnetic fields at several levels of organization within one experimental model demonstrates the intricacy of our study. Insects, which have been determined to be the ideal specimen in neurological investigations, provide us with this potential. There wouldn't be enough information on biological dangers or the biological effects of RF-EMF exposure to provide a conclusive answer to possible health issues for human beings.

D. Brain Development

The processes that develop, shape, and remodel the nervous system from the most rudimentary stages of embryogenesis through maturity are referred to as nervous system growth. The CNS develops from the embryo's ectoderm (outermost layer). During the third week of pregnancy, neuroectoderm develops and forms the neural plate along the embryo's dorsal side. An incision occurs along with the neural plate, and the neural tube is formed and filled with cerebrospinal fluid beginning in the fourth week. The neural tube generates vesicles throughout embryonic development, which subsequently change into the forebrain, midbrain, and hindbrain. Triencephalon diencephalon, mesencephalon, metencephalon, and myelencephalon are subdivided further. The telencephalon connects to the spinal cord. Neurons and ganglia are formed by neural stem cells. The newly formed neurons migrate to various sections of the growing brain, where they develop into axons and dendrites that will link with other neurons.

A neural plate, a flat layer of tissue, functions as the CNS's beginning point. The notochord and paraxial mesoderm stimulate the division of the ectoderm into neural plates. The neural plate gives way to neural folds, the NB neural tube, and the neural crest. The neural tube gives rise to the CNS. The formation of neural plates and neural tubes is known as neurulation, and it occurs at the start of the fourth week. The walls of the neural tube get thickened and create the brain and spinal cord. The medulla spinalis centralis and the brain's ventricular system make up the neural canals. When a notochord develops from a lumen, a canal quickly arises.

The prechordal plate, a slender cylinder-like endodermal cell positioned near the Ectoderm and the Endoderm, is where the Notochords attach. The notochord degenerates and vanishes as the neurocranium develops, but it is still present in the nucleus of each intervertebral disc and regulates the growth of the neural plate and embryonic ectoderm. Furthermore, it has been proven that 900 MHz EMFs have a detrimental effect on the brain-blood barrier's permeability.

E. Neurulation: -

Neurulation is an important stage in vertebrate evolution because it controls the formation of the CNS. This mechanism is the consequence of a tightly controlled

interplay between growth factors, local gradient concentration, and other variables. The neural plate enlarges and moves closer to the cranial oropharyngeal membranes as the notochord lengthens. The neural plate and the central axis introverts on the 18th day and forms a neural channel that runs longitudinally into the center line. The earliest signs of brain development are the fluffy neural folds on the cranial end of the embryo. The neuronal folds start to shut and merge around the end of the third week. The neural plate has transformed into a neural tube during the fourth week of neurulation. [Fig. 3]. Neural crest cells give rise to spinal ganglions and autonomous nervous system ganglions.

Furthermore, these cells form a peripheral nerve sheath that protects the brain and spinal cord. The neural tube then produces neural folds, which mature into basic vesicles. (i.e., forebrain, midbrain, and hindbrain).

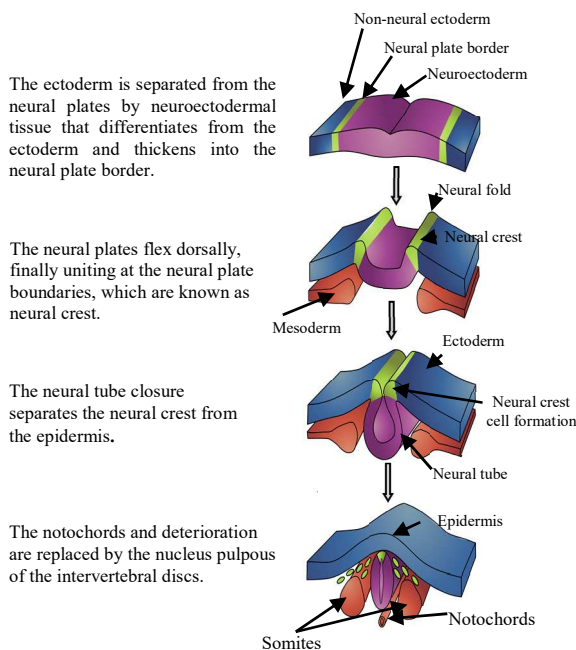


Fig 3. Neurulation

The forebrain is separated into two secondary vesicles, the telencephalon, and the diencephalon, at the start of the third week. The hindbrain has been separated into two primary regions by the fifth week; metencephalon and myelencephalon.

As a part of the research, the application of a weak 60 Hz magnetic flux can change the biochemistry of growing chicken embryos

It has also been shown that morphological aberration is associated with altered ODC activity, the amount among which is the same in control and magnetic coil embryos.

Because ODC is a critical enzyme in the process of economic growth, it is a good trait to postulate that there might be a link between magnetic field-induced changes in ODC activity during neurulation and magnetic dipole neural tube abnormalities reported later.

F. Specific Absorption Rate (Sar)

When subjected to a frequency modulated electromagnetic field, the human body absorbs energy at a rate known as SAR. It is measured in watts per kilogram (W/Kg) and described as the energy gained per given tissue. SAR is frequently estimated as a body-wide average or as a tiny sample volume. The phone is put against a depiction of a human head in a conversation posture for measuring SAR with a mobile phone. The SAR value is then determined at the appropriate place.

$$\text{Specific Absorption Rate (SAR)} = \frac{\sigma \times E^2}{m_d}$$

$$\text{Incident Power Density} = \frac{E^2}{377}$$

σ = Conductivity of Material

E = Electric Field (RMS)

m_d = Mass Density

TABLE I. RADIATION ABSORPTION RATE

Body part	RADIATION ABSORBED IN milli Watt/Kg		
Detail	5 YEAR OLD KIDS	10YEAR OLD KIDS	IN ADULTS
Head	33.12	19.77	7.84
Eye fluid	40.18	18.38	3.30
Eye lens	15.60	6.93	1.34
Connective tissue	19.69	9.8	1.77

SAR calculation in humans is extremely complex (and inaccurate), necessitating advanced mathematical modeling and computer simulations. When a certain imaging technique is selected, all widely viable MR machines have programs that anticipate SAR values and alert the controller if regulatory limits are liable to be violated. Yet, because each manufacturer uses a different proprietary approach, estimated SAR values might differ greatly across manufacturers. SAR estimate also necessitates the technician enter an appropriate patient weight.

G. Measuring methods of SAR Value

The National Electrical Manufacturers Association has developed criteria for assessing SAR generated by devices using phantoms, which have been incorporated into their standard MS 8-2016. Manufacturers utilize these approaches to compute SAR for their MRI equipment. Two fundamental approaches may be used:

a) The Pulse Energy Method

A coupler is used to monitor forward and reflected power, and an oscilloscope is often used to measure peak-to-peak voltages in the Pulse Energy Method.

b) The Calorimetric Method.

Employs an insulated loading phantom with direct temperature monitoring. The absorbed energy and SAR may be calculated as the temperature rises.

In addition, studies are being conducted to examine the existing radiation standards for the anticipated 5G high-frequency bands. The IEEE recently revised the C95.1 standard to use a specific absorption rate (SAR) below 6 GHz and absorbed power density (PD) above 6 GHz.

Despite the fact that the scientific community continues to argue the thermal and nonthermal consequences of absorbed radiation at specific SAR values. We suspect that such disparities are mostly related to extremely small amounts of absorption in living tissues. Setting such standards would then no longer be a point of contention. Finally, the influence of heat on physical, chemical, electrochemical, and biological processes is complicated and can manifest as favorable, unfavorable, or null effects in certain tissues or species. Temperature and period of exposure influence the rate of cell damage and death. The use of thermal graphs is gaining popularity.

III. EFFECTS OF ELECTROMAGNETIC FIELD ON BRAIN DEVELOPMENT

EMFs harm cells and impair their synthesis. It reduces the ability of antioxidant enzymes. The indices of oxidative stress are raised. During adolescence, EMFs affect brain progenitor cells. Long-term EMF exposure can lead to Alzheimer's disease by raising amyloid-beta levels, a leading cause of the illness, and inducing cell damage in the cerebral cortex and hippocampus. The most noticeable sign is oxidative stress (fig. 4).

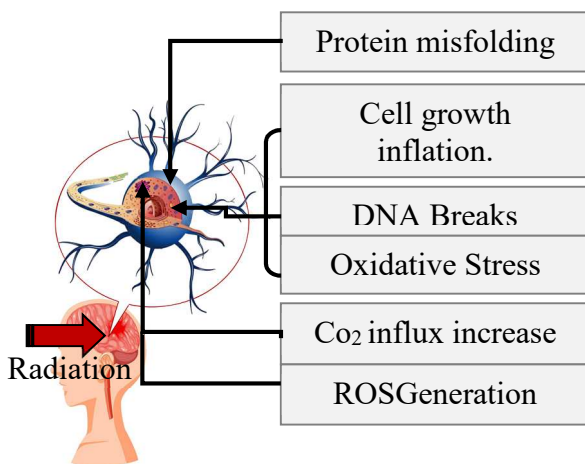


Fig 4. Emf effect on brain neurons

When cells are exposed to EMFs, free radicals form. This affects the structure of the proteins, membrane, and DNA, which are important components of the cell, and induces carcinogenesis via the Fenton reaction. Hydrogen peroxide and hydroxyl radicals are formed as a result of this reaction

(OH). The most powerful reactive oxygen species is the hydroxyl radical (ROS). As a result, the structure of proteins and DNA is disrupted, which may lead to gene mutation and, as a result, disease. As a result, the structure of proteins and DNA is changed, which can result in significant gene mutations and, eventually, cancer. EMFs from mobile phones induce headaches, dizziness, and an increase in the frequency of migraines. Mobile phone radiation affects gene-related levels in embryonic stem cells, greatly increasing the synthesis of the heat shock protein HSP 70. EMFs at 915 MHz cause cancer. According to the study, the more we use mobile phones, the more likely we are to acquire cancer (Figure 5).

It reduces the cognitive and memory capacity of a pregnant woman's future embryo. It increases oxidative stress in neurons by changing calcium levels. EMF causes brain cancer, significantly inhibits cerebral function, and lowers the number of neurons in children's CNS's hippocampus. Children's brain tumors are of embryonic or mesodermal origin, and the most prevalent kind is brain stem glioma. Adult malignancies form in epithelial tissues, particularly in the cerebral hemisphere.

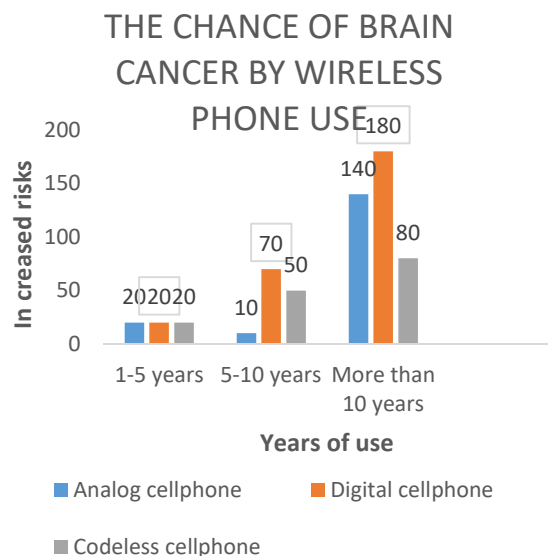


Fig 5. Chances of brain cancer due to wireless mobile

Parkinson's disease causes damage to dopaminergic neurons. Amyotrophic lateral sclerosis (ALS) is a fatal neurological illness that causes the slow degeneration of motor neurons in the spinal cord, motor cortex, and brainstem. Huntington's disease is a genetic disorder that causes energy deficiency and neural death. The skulls of young children are thin. As a result, as shown in table 5, absorption rates in children and adolescents are greater than in adults.

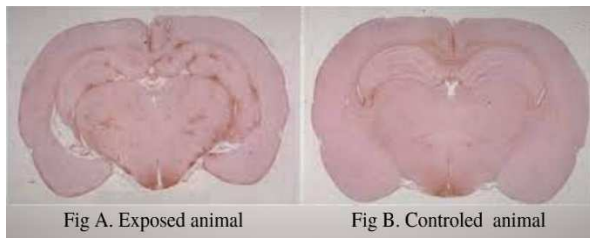


Fig 6. *Emf Controlled and Emf exposed brain*

Figure 6 shows the findings in the Cross-sections of the central nervous systems of (A) a rat subject to RF EMFs and discolored for albumin, which looks brown, and (B) an unexposed control rat. Albumin is located in the brain's central inferior lobes (the hypothalamus) in (B), which is a typical characteristic. Albumin is seen in many tiny foci in (A), indicating leakage from multiple arteries. Magnification of approximately three times.

IV. CONTROLLING INTERFERENCE WITH SHIELDING

Shields act as a physical barrier between a circuit and its surroundings. Most are board-mounted, that is, they are physically affixed to a printed circuit board (PCB). To avoid having to add shielding after the board or device has been finished and tested, it is better to integrate a strategy for shielding early in the design phases. Shields, like other manufactured components, take up space in the assembly and cost time and money to make and test, so planning early might save money later. To limit or lessen interference, metallic shields reflect or absorb waves.

The degree to which they succeed in this is referred to as shielding effectiveness or SE. The two most important components of SE are;

- How much electromagnetic radiation is reflected away from a circuit.
- How much electromagnetic radiation is absorbed by the shield?

The good news is that there are simple techniques to decrease your exposure to EMFs. These methods entail lowering both the intensity and duration of exposure.

- a) Turn off wireless functions:** Turning off the wireless devices after use to reduces radiation exposure.
- b) Use Wired Devices Rather Than Wireless Devices** which helps to reduce the radiation and heating from the wireless device.
- c) Make Good Use of Your Smartphone.** Check the SAR rating of the mobile brands before you purchase the phone.
- d) Maintain a safe distance between yourself and EMF sources.**
- e) Prioritize sleeping locations by keeping away electronic devices from your head or body.**

V. CONCLUSION

The electromagnetic fields (EMFs) emitted by widespread mobile communication affect brain development. The brains of fetuses and children are especially sensitive to electromagnetic radiation. EMF neurodegenerative sickness was discovered. Neuronal injury was revealed to be caused by 900MHz. As a result, extensive electromagnetic frequency, immunochemical, biochemical, and stereological research is necessary. In today's world of contemporary gadgets, it's difficult to escape EMF. Extreme caution should be maintained when using cell phones. Table 2 demonstrates that the influence of electromagnetic waves on humans has been a source of contention due to research yielding contradictory results. Antioxidant treatment may be an alternative strategy to minimize the adverse effects of addiction. The easiest method to decrease the impacts of EMR radiation is to avoid certain EMF-producing sources.

TABLE II. EMF IMPACT ON HUMAN

NEGATIVE IMPACT ON HUMAN HEALTH DUE TO EMF			
METABOLIC DISTURBANCE	GENO-TOXICITY	REACTIVE OXYGEN SPECIES GENERATION	IMMUNO TOXICITY
DISCOMFORT SYMPTOMS	SLEEPING DISORDER	SENSORY DISORDER	CONGENITAL DISORDERS
CANCER	INFERTILITY	NEURO DEGENERATION	NEURO BEHAVIOURAL

However, this is impractical, we may reduce our consumption. That is, only use equipment when necessary. This might contribute to the development of a healthy society in the future. The research will be utilized to examine the impacts of EMR on brain development. It has been shown that neuron death caused by EMF radiation might result in memory impairment and neurological diseases. It also interferes with sleep and causes headaches. Cancer is caused by prolonged exposure. EMF has a significant influence on brain development in several disorders such as Parkinson's disease, Huntington's disease, and Alzheimer's disease.

VI. REFERENCES

- [1] Omur Gulsum Deniz, Suleyman Kaplan, Mustafa Bekir Selçuk, Murat Terzi, Gamze Altun, Kıymet Kübra Yurt, Kerim Aslan, Devra Davis, Effects of short and long term electromagnetic fields exposure on the human hippocampus, *Journal of Microscopy and Ultrastructure*, Volume 5, Issue 4, 2017, Pages 191-197 <https://doi.org/10.1016/j.jmau.2017.07.001>
- [2] Kocaman.A, Altun.G, Kaplan.A.A, Deniz O.G, Yurt K.K, Kaplan S, "Genotoxic And carcinogenic Effects Of Non-Ionizing Electromagnetic Fields", *Elsevier Environmental Research* 168, 71-79, January 2018.
- [3] J. Wyszowska, M. Jankowska and M. Stankiewicz, "Comprehensive study of the effects of electromagnetic field exposure on nervous system using insect models," *2018 EMF-Med 1st World Conference on Biomedical Applications of Electromagnetic Fields (EMF-Med)*, 2018, pp. 1-2, doi: 10.23919/EMF-MED.2018.8526060.
- [4] Basset.C.A, 1993.Beneficial effects of EMFs.*J.Cell.Biochem.*51,387-393.
- [5] Bas.O, Odaci.E, Mollaoglu.H, Ucok.K, Kaplan.S, 2009.Chronic prenatal exposure to the 900MHz EMF induces pyramidal cell loss in the hippocampus of new born rats.*Toxicol.Ind.Health* 25.
- [6] Malka N Halgamuge, Lyn Mclean "Measurement and Analysis of Power Frequency Magnetic Fields In Residences: Results From A Pilot Study", *Elsevier Journal Of Measurement* 125(2018) 415-424.

- [7] Moore.K.L, Persuad T.V.N, Torchia.M.G.2013.The developing human: clinically oriented embryology.ninth ed.Elsevier / Saunders. Philadelphia, PA.
- [8] Stiles .J, Jernigan. T. L , 2010. The basics of brain development.Neuropsychol.Rev.20.327-348.
- [9] Tongiorgi.E.2008.Activity dependent expression of brain derived neurotrophic factor in dendrites: facts and open questions.Neurosci.Res.61.335-346.
- [10] GieddJ.N,Snell.J.W,Lange.N,RajapaksheJ.C,Casey.B.J,Kozuch.P.L,Vaituzis.A.C,Vaass.Y.C,Hamburger.S.D,Kaysen.D,Rapoport.J.L 1996,Quantitive MRI of human brain development ages 4-18,Cereb.Cortex6,551-560.
- [11] Benes. F. M 2003.Why does psychosis develop during adolescence and early adulthood? Curr.Opin.Psychiatry 16.372-390.
- [12] Lenroot.R,K ,Giedd.J.N 2006.Brain development in children and adolescents:insights from anatomical MRI.Neurosci.Biobehav.Rev.30.718-729.
- [13] Andersen S.L 2003.Trajectories of brain development: point of vulnerability or window of opportunity? Neurosci. Biobehav. REV 27.3-18.
- [14] Carubba.S, Marino.A.A, 2008.byThe effects of low-frequency environmental strength EMF on brain electrical activity:acriticalreviewofthe literature.Electromagn.Djol.Med.27,83-101.
- [15] Heidelb., pp. 613–22, 2010.8Hardell L, Sage.C, 2007. Biological effects from EMF exposure and public exposure standards, Biomed.Pharmacother.62.104-109.