

Effect of Exposure of High Frequency Electromagnetic Field on Human Health: A Review

Nitin.S. Thakare, Akshay S. Utane

Abstract—This paper highlights the various effect of exposure of Electromagnetic fields on human body and surrounding. Electromagnetic fields (EMF) have various chemical effects, imbalance in ionic equilibrium, biological systems reactions, stress, and oxidative stress in many tissues of the body, physiological and psychological effects on human health. In society human now using different types of devices that expose the radiation such as mobile phones, oven etc. Electromagnetic fields are emitted by many natural and man-made sources that plays vital roles in daily life. More than 3 billion people across the world are exposed to EMF every day.

Index Terms— EMF, Free Radical, Frequency, Neuro Endocrine, Specific Absorption Rate (SAR), Tissue.

I. INTRODUCTION

A wide spectrum of electromagnetic waves are today emitted by radar, communication equipment, mobile phone base stations, high voltage lines, radio and television transmitters, substations, and electrical equipment at home and work, in addition to many electrical systems in the environment. The Global System for Mobile Communications (GSM, 850–900 MHz and 1850–1990 MHz) is currently the most extensive system for mobile telecommunications worldwide. The mobile phone models (1800 MHz –2200 MHz), laptops (1000 MHz–3600 MHz) and wireless networks in use today function with high frequency (2.45 GHz) microwave radiation. In parallel to technological developments in this century, technological devices are becoming ever more important in daily life. However, despite making life easier, they may also cause a number of health problems. In particular, the average age of beginning mobile phone use has decreased rapidly to elementary school age, and durations of exposure to EMF are also increasing. Several studies have reported findings such as stress, headache, tiredness, anxiety, decreased learning potential, impairment in cognitive functions and poor concentration in case of exposure to microwave radiation emitted from mobile phones. EMFs influence metabolic processes in the human body and exert various biological effects on cells through a range of mechanisms. EMF disrupts the chemical structures of tissue since a high degree electromagnetic energy absorption can

change the electric current in the body. As a result of this exposure, the functions of organs are affected. Electric fields exert an oscillatory force on every free ion on the both sides of the plasma membrane and cause them to cross it. This movement of ions causes deterioration in the ion channels on the membrane, biochemical changes in the membrane and consequently impairment of all cellular functions. Exposure to EMFs can damage biological tissues by inducing changes, which can be explained in terms of thermal or non-thermal mechanisms. Thermal effects can occur with the conversion and absorption of heat by the body's electromagnetic energy. Increased body temperature is stabilized and alleviated by blood circulation. Although non-thermal effects do not raise the body temperature sufficiently to impair the structure of tissues, their effects can still be seen as an increase in free radical production in tissues. EMFs, no matter where they occur in the frequency spectrum, are reported to causes a rise in levels of oxygen free radicals in an experimental environment in plants and humans [3]

II. EFFECT OF EMF ON BIOLOGICAL SYSTEM

Exposure to EMF is known to increase free radical concentrations and traceability and can affect the radical couple recombination which impact of oxidative stress on antioxidant systems and does harmful effects on the biological system [2]. The increasing use of mobile phones may have a number of physiological and psychological effects on human health. Many animal and human studies have reported various effects on the central nervous system and cognitive performance from of exposure to electromagnetic fields (EMF) emitted by mobile phones. The aim of the present study was to evaluate the effects of mobile phones on the morphology of the human brain and on cognitive performance using stereological and spectroscopic methods and neuro cognitive tests [3]. Non-thermal microwave/lower frequency electromagnetic fields (EMFs) act via voltage-gated calcium channel (VGCC) activation. Calcium channel blockers block EMF effects and several types of additional evidence confirm this mechanism. Low intensity microwave EMFs have been proposed to produce neuropsychiatric effects, sometimes called microwave syndrome, and the focus of this review is whether these are indeed well documented and consistent with the known mechanism of action of such EMFs. VGCCs occur in very high densities throughout the nervous system and have near universal roles in release of neurotransmitters and neuron endocrine hormones. Soviet and Western literature shows that much of the impact of non-thermal microwave exposures

Nitin S. Thakare, Department of Electronics and Telecommunication Engineering. P.R.M.I.T. &R. Badnera, Amravati, India. (e-mail: nit.thakare12@gamil.com).

Akshay S. Utane, Department of Electronics and Telecommunication Engineering. P.R.M.I.T. & R. Badnera, Amravati, India. (e-mail: akshay.utane11@gamil.com).

in experimental animals occurs in the brain and peripheral nervous system, such that nervous system histology and function show diverse and substantial changes[4]. The use of mobile phones has become widespread in recent years. Although beneficial from the communication viewpoint, the electromagnetic fields generated by mobile phones may cause unwanted biological changes in the human body. Given the rapid introduction of mobile phones and other portable wireless devices into society, and the increased possibility of young children using or being exposed to electromagnetic (EM) fields, a study of specific absorption rate (SAR) in the head of young children is becoming increasingly relevant. Electromagnetic fields (EMF) have a major impact on biological systems including human health. Some studies were showed to confirm the effects of electromagnetic radiation (EMR) on functions of cell [5].

III. EFFECT OF EMF ON TISSUE AND SKIN

The skin and other superficial tissues usually absorb the non-thermal radiations emitted by mobile phones; this causes the insignificant increase of temperature of the brain or other organs in the body. Non-thermal mechanisms are those that are not directly associated with this temperature change but rather to some other changes in the tissues in association with the amount of energy absorbed. A significant part of many studies concerning EMF have investigated the “non-thermal” effects of RF on biological tissues. Exposure to EMF has been observed to cause increased free radical production in the cellular environment. Living organisms have anti-oxidative mechanisms, such as glutathione (GSH), glutathione peroxidase (GPx), catalase (CAT), and superoxide dismutase (SOD), in order to alleviate the damage caused by ROS and their products. Studies in recent years have reported that free radicals play a major role in the mechanism behind many diseases, such as diabetes and cancer [3].

IV. EFFECT OF EMF ON BACTERIAL GROWTH

The two gram-positive and one-gram negative bacteria used here were exposed to 900 and 1800 MHz, with growth rates being determined following exposure for 2 h. With the exception of a significant decrease after 12 h exposure to 900 MHz, no significant effects on the growth of *S. aureus* were seen following exposure to 900 and 1800 MHz, similarly, no significant differences in the growth of *S. epidermidis* was seen following such exposure. In contrast, the growth of *P. aeruginosa* was significantly reduced following exposure for 10 and 12 h to 900 MHz while, no significant reduction in growth followed exposure to 1800 MHz. Mobile phones, which operate at frequencies of 1.8–2.2 giga-hertz (GHz) for digital systems and 400–900 MHz for analogue systems, are currently very widely used. Intensive use of mobile phones among adolescents is leading to concern regarding common physical and emotional problems, ranging from insomnia to problems with concentration. During mobile phone use, the human brain can be exposed to a high specific absorption rate (SAR) because of its close proximity to sources of radiofrequency electromagnetic fields (RF-EMF) source. Exposure to mobile phones is generally associated with the

emit-tered RF power. Various parameters, including the properties of the absorbing tissue, the antenna position and the magnetic field frequency, must be considered in evaluating the side-effects of RF-EMF exposure on human health. In that context, Hardell et al. suggested that long-term exposure to RF-EMF emitted by mobile phones may increase the risk of brain tumours, such as glioma and neuroma [6]. The morphological and biochemical alterations caused by RF-EMF exposures have been investigated in animal studies. At this point, prenatal exposure results in smaller litter size, lower birth weight and offspring with significant impairment of the hippocampus, pyramidal cell and glial cells. Neuronal damage in the central nervous system has been reported due to both prenatal and early adult exposures to electromagnetic radiation [2].

V. EMF-RELATED OXIDATIVE STRESS AND EFFECTS ON TISSUES

Free radicals are reactive molecules produced during the con-version of foods into energy through oxygen. The formation of free radicals is an oxidation reaction that occurs on an oxygen basis. Since oxygen is essential for survival, the formation of free radicals cannot be avoided. However, factors including ionizing and non-ionizing radiation alter the transcription and translation of genes such as JUN, HSP 70 and MYC, via the epidermal growth factor receptor EGFR-ras, leading to the generation of ROS and resulting in the overproduction of ROS in tissues. The Fenton reaction is a catalytic process that converts hydrogen peroxide, a product of mitochondrial oxidative respiration, into a highly toxic hydroxyl free radical. Some studies have suggested that EMF is another mechanism through the Fenton reaction, suggesting that it promotes free radical activity in cells. Although some researchers have reported that ROS perform beneficial function, a high degree of ROS production may cause cellular damage, resulting in a range of diseases. These radicals react with various bio molecules, including DNA. Namely, the energy of free radicals is not enough, and for this reason they behave like robbers who seize energy from other cells and rob a person to satisfy themselves. Kazemi et al. investigated the effect of exposure to 900-MHz on the induction of oxidative stress and the level of intracellular ROS in human mononuclear cells. Excessive elevation in ROS levels is an important cause of oxidative damage in lipids and proteins and nucleic acids. It therefore causes changes in enzyme activity and gene expression, eventually leading to various diseases, including sleep disorder, atherosclerosis, and loss of appetite, diabetes, dizziness, rheumatoid arthritis, cardiovascular disease, nausea and stroke. Some studies have reported that low frequency (0–300 Hz) and RF (10 MHz–300 GHz) EMF damages DNA and blood–brain barrier disruption is connected, and that autism spectrum conditions are associated with EMF exposure. At the same time, men carrying phones in their pocket or on their belt and therefore, most of adverse effects of the EMF are seen in reproductive organs. Sepehrmanesh et al. showed that exposure to RF-EMF produces increases in testicular proteins in adults that are related to carcinogenic risk and reproductive damage. Neuro endocrine changes caused by EMFs are a key factor in changing hormone functions. Ero glu et al. stated that exposure to cell phone radiation reduces the motility and changes the morphology of isolated sperm cells. They also discussed the effects of EMF

son female infertility. Goldhaber et al. reported a significant increase in fetal abnormalities and spontaneous abortions in pregnant women exposed to EMF. Studies on the effects of EMF on tissues discussed here are set out in Tables 1 [3].

VI. EXPERIMENTAL STUDIES ON THE OXIDATIVE EFFECTS OF EMF

Reference	Biological endpoint	Results
Ghodbane et al.	Kidney	In the study investigated that whether Static magnetic fields induces oxidative stress and apoptosis in rat tissues and to evaluate the possible protector effect of selenium (Se) and vitamin E (vit E) supplementation. In the results have been shown exposure to SMF induced oxidative stress in kidney that will be able prevented by treatment with Se or vit E.
Meral et al.	Brain	890-915-MHz EMF emitted by cellular phones may generate oxidative stress. MDA levels increased and GSH level and CAT enzyme activity decreased, while vitamin A, E and D3 levels remained unchanged in the brain tissue of guinea pigs
Misa-Agustino et al.	Thymus	The thymus tissue exhibited several morphological changes, including increased distribution of blood vessels along with the appearance of red blood cells and hemorrhagic reticuloepithelial cells
Balcı et al.	Cornea and lens	To investigate the adverse effects of mobile-phone on the antioxidant balance in corneal and lens tissues and to observe any protective effects of vitamin C in this setting. The results of this study suggest that mobile telephone radiation leads to oxidative stress in corneal and lens tissues and that antioxidants such as vitamin C can help to prevent these effects.
Bodera et al.	Antioxidant capacity of blood	EMF exposure at 1800 MHz significantly reduced antioxidant capacity in both healthy
		animals and those with paw inflammation O
Ozorak et al.	Kidney and testis	In the present study was investigated that the effects of both Wi-Fi and 900 and 1800 MHz EMF on oxidative stress and trace element levels in the kidney and testis of growing rats from pregnancy to 6 weeks of age. It has been observed Wi-Fi and mobile phone-induced EMR may cause precocious puberty and oxidative kidney and testis injury in growing rats.
Ozorak et al.	Liver and kidney	RF exposure is reported to induce lipid peroxidation, accompanied by decreased activity of superoxide dismutase (SOD), myeloperoxidase (MPO) and glutathione peroxidase (GSH-Px), in various organs, such as guinea pig liver and rat kidney
İkinci et al.	Spinal cord	The aim of this study was therefore to investigate changes in the spinal cords of male rat pups exposed to the effect of 900 MHz EMF. The study results showed that MDA and GSH levels in EMFG increased significantly while CAT and SOD levels decreased following application of 900-MHz EMF pathological changes may occur in the spinal cords of male rats following exposure to 900 MHz.
Gurler et al.	Brain	In the study has been investigated that the oxidative damage and protective effect of garlic on rats exposed to low level of EMF at 2.45 GHz MWR. It may be concluded that EMF increases the DNA damage in both brain tissues and plasma of the rats whereas it increases protein oxidation only in plasma. It may also be argued that the use of garlic decreases these effects.
Türedi et al.	Bladder	In the study investigated

		the effect on male rat bladder tissues of exposure to 900 MHz EMF applied on postnatal days 22-59, inclusive. In bladder tissue, degeneration in the transitional epithelium and stromal irregularity and an increase in cells tending to apoptosis were observed in EMFG.			oxidative stress may be one underlying causes of the behavioral deficits seen in rats after RF exposure
			Hanci	Spleen and thymus	900 MHz EMF applied to spleen and thymus tissue caused significant histopathological changes at the TEM and LM levels
Yan et al.	Sperm	Rats exposed to 6 hours of daily cellular phone emissions for 18 weeks exhibited a significantly higher incidence of sperm cell death than control group rats.	VII. CONCLUSION		
Rajkovic et al.	Thyroid gland	After significant morphophysiological changes caused by ELF-EMF exposure, the thyroid gland recovered morphologically, but not physiologically, during the investigated repair period.	This paper highlight the effect of Electromagnetic Field exposure on Human Health. Thus itbecomes mandatory everyone should pay attention on this a wide variety of issues. Some ofthese effects of EM fields on different biological systems have been investigated. Although the majority of studies have found no evidence of genetically effects still there are a few positive findings that should be followed up. Some of the studies provide evidence that gene expression is affected by EMF exposure. This paper highlight the effect of EMF exposure on Human Health.		
Deniz et al.	Kidney	In the results was observed the 900-MHz EMR cause to kidney damage and FA may exhibit a protective effect against the adverse effects of EMR exposure in terms of the total number of glomeruli.	REFERENCES		
Wang et al.	Blood-testicle Barrier	In the study investigated the effect of electromagnetic pulse (EMP) exposure on cerebral micro vascular permeability in rats. It has been shown that exposure to 200 and 400 pulses (1 Hz) of EMP at 200 kV/m can increase the permeability of the blood-testicle barrier in mice	[1] Saleh H. Salmen, Sulaiman A. Alharbi, Asmaa A. Faden, M. Wainwright, Saudi Journal of Biological Sciences(2017), "Evaluation of effect of high frequency electromagnetic field on growth and antibiotic sensitivity of bacteria".		
Avendano et al.	Sperm	Four-hour EMF exposure ex vivo to a wireless internet-connected laptop caused a significant decrease in progressive sperm motility and an increase in sperm DNA fragmentation	[2] Omur Gulsum Deniz, Suleyman Kaplan, Mustafa Bekir Selc, uk, 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 5 (2017) 191–197.		
Narayanan et al.	Human semen	RF exposure for one month induced oxidative stress in the rat brain, but the magnitude differed in the various regions studied, and RF-induced	[3] Elfide Gizem Kıvrak*, Kıymet Kubra Yurt, Arife Ahsen Kaplan, İsınsu Alkan, Gamze Altun, "Effects of electromagnetic fields exposure on the antioxidant defense system", Journal of Microscopy and Ultrastructure 5 (2017) 167–176.		

VII. CONCLUSION

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Nitin S. Thakare, ME Digital Electronics, working as Assistant Professor at Electronics and Telecommunication Engineering Department, Prof. Ram Meghe Institute of Technology and Research Badnera Amravati. Maharashtra India.

Akshay S. Utane, M.Tech. Electronics and Telecommunication Engg. working as Assistant Professor at Electronics and Telecommunication Engineering Department, Prof. Ram Meghe Institute of Technology and Research Badnera Amravati. Maharashtra India.