



THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC FIELDS ON HUMAN AND EXPERIMENTAL ANIMALS

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ABSTRACT

Objectives: This study aim to review the sources of exposure to Electromagnetic fields (EMFs) and its effects on the human health, through out summarized the key findings and scientific issues regarding the electromagnetic sources and the biological effects of exposure to EMFs on human and experimental animals. Electromagnetic sources can be classified into natural electromagnetic sources [sun, some distant stars, atmospheric discharges like thunder, or human body] and unnatural or human made sources [printers, vacuum cleaners, cellular phones, hair dryers, refrigerators, washing machines, kettles microwaves, cables that carry electrical currents, television and computers, electrical home gadgets, radio and television base stations, mobile phone base stations and phone equipment], home wiring airport, and transformers. EMFs might produce a variety of adverse in vivo effects such as chronic fatigue, headaches, cataracts, heart problems, stress, nausea, chest pain, forgetfulness, influence the learning and memory, cardiovascular system and reproductive system, CNS, endocrine, immune systems, sleep disturbances. It have been implicated in adversely affecting multiple facets of human health such as leukemia, brain cancer, lung and breast tumors, Lou Gehrig's disease, genotoxicity and neurodegenerative disease, infertility, birth defects, increased risk of miscarriage, childhood morbidity, de novo mutations, amyotrophic lateral sclerosis, depression, reproduction anomalies, suicide, and Alzheimer's' disease. Also, there was a positive relationship between occupational monitor labor during pregnancy and the natural abortion rate. **Conclusion:** It can be concluded that exposure of

human and animals to EMFs have been a negative effects on cardiovascular system, CNS, endocrine, immune systems and reproductive system, the developing embryo/fetus, and cause a histopathological changes and disturbances in functions of different body organs.

KEYWORDS: Electromagnetic fields, EMF sources, Health effects of EMF, Physiological and histological effects of EMF.

INTRODUCTION

Power lines carrying high-voltage electricity are ubiquitous in the developed world and in urban areas of many developing countries. For example, as of 1999, Sweden had 220,000 km of power lines covering 450,000 km² while South Africa, the most developed African country, possessed 255,745 km of lines carrying electricity over 1,185,000 km² [1, 2].

Similar to every device that carries an electric current, power lines generate electric and magnetic fields that are collectively called electromagnetic fields [EMFs]. Electric fields are measured in kilovolts per meter [kV/m] and magnetic fields in microteslas [μ T]. Studies by Hydro-Québec, a Canadian power company, found that the ambient magnetic field produced by all electric currents flowing inside and outside a Canadian home ranges from 0.01 to 1 μ T, while household appliances alone ay generate magnetic fields of up to 4 μ T [2, 3]. The strength of the electric and magnetic fields depends upon the current intensity carried through a conductor and the distance of exposure from the source. Both fields are highest immediately around a power line and diminish rapidly with distance away from the source [2].

Electromagnetic fields exposure exists at home, workplaces as a result of all types of electrical equipment such as refrigerators, washing machines and kettles [2, 4], and building wiring as well as a result of nearby power lines. It represents one of the invisible environmental pollutant factors that affect animals and human health [5, 6]. Humans beings are unavoidably exposed to ambient electromagnetic fields generated from various electrical devices and from power transmission lines [7]. The increasing use of the electric technology, electromagnetic fields especially the extremely low frequency electromagnetic fields [ELF-EMF] have become a part of the modern life. These fields are produced by all electric devices, including high energy sources like power lines and microwaves, but also found in low energy devices such as cell phones [8]. Electromagnetic sources can be classified into natural electromagnetic sources (sun, some distant stars, atmospheric discharges like thunder, or human body) and unnatural or human made sources (printers, vacuum cleaners, cellular phones, hair dryers, microwaves [9, 10], cables that carry electrical currents, Television [TV]

and computers, electrical home gadgets, radio and TV base stations, mobile phone base stations and phone equipment) [11, 12], home wiring airport, and transformers [8]. High electric current, mobile phones and their bases station are an important source of ultrahigh frequency electromagnetic field and their utilization is increasing allover the world [13]. The Electromagnetic fields an be classified into static, extremely low frequency, intermediate frequency and radiofrequency fields. Among the previous types; the low frequency electromagnetic field is wide spread in human environment and has a considerable attention among scientific community. This field can originate from sources as trains for public transport, any device involved in the generation, distribution or use of electric power [14, 15]. Also, it can be produced by power lines and many kinds of electric appliances [15-18].

In recent years histological and physiological studies have increased in the evaluation of the effects of electromagnetic fields on human health [4, 6, 7, 19-23]. The safety of human exposure to an ever-increasing number and diversity of electromagnetic field sources both at work and at home has become a public health issue [24]. Electromagnetic field might produce a variety of adverse in vivo effects such as chronic fatigue, headaches, cataracts, heart problems, stress, nausea, chest pain, forgetfulness [25], influence the learning and memory, cardiovascular system and reproductive system [26, 27], CNS, endocrine, immune systems [15, 28], sleep disturbances, modifications of electroencephalographic activity as well as alterations of biological functions in human and animals [29, 30]. Electromagnetic fields have been implicated in adversely affecting multiple facets of human health, including increasing the risks of life-threatening illnesses such as leukemia [31-34], brain cancer [33, 34], lung and breast tumors [15, 28, 35], Lou Gehrig's disease [36], genotoxicity and neurodegenerative disease, infertility, birth defects, increased risk of miscarriage, childhood morbidity, de novo mutations [37, 38], amyotrophic lateral sclerosis, depression [39, 40], reproduction anomalies [41], suicide [42], and Alzheimer's' disease [43]. A great deal of research and controversy exists as to whether or not exposure to EMFs affects the cellular, endocrine, immune, and reproductive systems of vertebrates [2]. Exposure to extremely low-frequency electromagnetic fields reduces the pineal gland's nocturnal production of the hormone melatonin, thereby increasing susceptibility to sex hormone-related cancers such as breast cancer [35]. Also, EMF may interfere with memory performance as there is evidence suggesting impairing effects of stress- induced corticosterone release on object recognition in rats [4, 44], or may certainly increase the risk of both Alzheimer's disease and breast cancer [4, 45]. The key events arising from exposure to EMF may include alterations in cell membrane activity and effects on various enzyme systems [4, 46].

The effect of an electromagnetic field on the living organism is a complex phenomenon. Studies show that electromagnetic fields have a range of complicated effects on the vital molecules (DNA, ionic channels, and other body proteins) and activities of the nervous system and other organs [10, 47]. Various theories were described concerning the effect of EMF on living organisms through induction, resonance, and radical mechanisms [48-50] affecting cell signal transmission, structure of biological membranes and ion transport, processes of replication and transcription of nucleic acids and synthesis of proteins, and cell proliferation processes [48-50]. The initial mechanism is physico-chemical in nature; and afterwards biological effects develop. The physicochemical action of an electromagnetic field consists in electron, ion, dipolar, macrostructure and electrolytic polarization. Other factors may also play a role, such as molecular excitation, biochemical activation, generation of radicals, chemical bond weakening, hydration change, altered relaxation time of atom vibration, and altered spin of dipoles [51-54]. These physicochemical changes may affect the biochemical parameters of serum [54].

It was reported that extremely low frequency EMF induced tissue damage in different organs of the experimental animals [7, 20, 55]. Several studies on animal cells have also shown that EMFs influence a large variety of cellular functions [6, 56]. EMFs penetrate human body and act on all organs, altering the cell membrane potential and the distribution of ions and dipoles [6, 57]. Chemical and physical processes at the atomic level are the bases of reactions between biomolecules in an EMF, since the field can magnetically affect the chemical bonds between adjacent atoms with consequent production of free radicals [6, 57-58]. These alterations may influence biochemical processes in the cell, thus changing both biochemical parameters and enzyme activities of serum [6, 51].

Effects of EMF on Hematological parameters

Purushothaman *et al.*, [59] found that the adult male albino rats exposed to the magnetic field of 202 μ T showed significant increase in RBCs, WBCs, Hbs and platelet count as well as decrease in red blood cell indices values of MCV, MCH and MCHC as compared with controls. The hematological parameters were affected by the electromagnetic field exposure suggesting the possible induction of hazardous biological effects during the exposure to magnetic field. Hashem and El-Sharkawy [4] reported that Repeated exposure of mice to EMF of 2 mT intensity [4h /day] for 30 days induced an increase in the count of RBCs, platelets, Hb content, Ht values and leukocytosis with neutrophilia, lymphocytosis and monocytosis, compared to control unexposed mice. The

phagocytosis % and phagocytic index were significantly increased in mice exposed to EMF for 30 days. Also, an increase in Hb concentration, RBC, WBC and platelet numbers in rats following exposure to EMF for 1h/day during 30 consecutive days have demonstrated [60, 61]. Among the characteristic biological effects of EMF are the functional changes in immune systems [15, 28]. Also, Esfahani *et al.* [62] recorded that a significant increase in RBCs, PCV and Hb in rats exposed for one year to electromagnetic field. Exposure to EMF result in deterioration of RBCs function and metabolic activity, it was expected that, the increase of toxicity in specific organs was a result of the RBCs functional failure. Therefore, changes in antioxidants may be due to the deterioration in cellular membrane properties in the liver. In addition to increase toxicity in different organs [63].

Effects of EMF on Serum Glucose Level

Hashem and El-Sharkawy [4] reported that exposure to EMF increased significantly serum glucose level. The increase in the glucose level agrees well with previous findings with EMF with different strengths [64-66]. Also, Sedghi *et al.*, [67] reported that glucose level in the blood of experimental animals was increased after exposure to EMF. Khaki *et al.*, [10] reported that exposure of rats to EMF produced by an electromagnetic device, with a frequency of 50 Hz and intensity of 3 mT 4 h a day for 6 weeks led to the decrease of insulin blood concentration accompanied to the reduction of size of the pancreatic islets. Gorczynska and Wegrzynowicz [68] study point to suppressing effect of exposure to EMF on insulin secretion with a secondary increase in serum glucose concentration.

Effects of EMF on The Liver

Purushothaman *et al.*, [59] reported that the adult male albino rats exposed to the magnetic field of 202 μ T showed significant increase of AST and ALT levels in plasma indicating the involvement of MF on liver cell membranes. Liver enzymes were affected by the electromagnetic field exposure suggesting the possible induction of hazardous biological effects during the exposure to magnetic field.

Hashem and El-Sharkawy [4] found that exposure to EMF increased significantly transaminases activities. Serum transaminases have been widely utilized as biomarkers for hepatocellular injury [61]. Magnetic field induced structural changes in hepatocytes, primarily in mitochondria, and in turn significant increase in ALT activity, which indicates cytotoxic effect [60, 69-70].

EMFs were observed to influence enzyme action, signal transduction, protein synthesis and gene expression. These activities play an important role in regulating cell growth and processes important to promotion [6, 57, 71]. Furthermore, alterations may influence biochemical processes in the cell, thus changing both biochemical parameters and enzyme activities of the blood serum [6].

Effects of EMF on Serum Proteins

Hashem and El-Sharkawy [4] reported that the hyperproteinemia due to EMF exposure suggesting the change in protein metabolism of stressed mice or the increase in the globulin component. These results agree with similar reports [61, 72]. On contrary, a significant decrease in the levels of total protein, albumin and /or globulins were observed in steelworkers exposed to EMF [1.3 mT intensity and 50 Hz frequency, mean 6.8h /day] for 5days, and in rats exposed to EMF, 4-8hr daily, for 2months [73]. This discrepancy could be due to the difference of the intensity of the EMF and the exposure scenario and duration. The increased phagocytosis % and phagocytic index in mice with EMF exposure indicated that the role of electromagnetic field is prevalent in the formation of effects of the intensity and completeness of phagocytosis [74]. There is no generally accepted mechanism to explain how extremely low frequency fields might initiate bioeffects, if any, on immune system [75]. Factors, such as frequency and amplitude of EMF and the exposure time are crucial for the determination of the possible negative effects of EMF, including a low protein level in serum, disturbances in protein synthesis at chromosomal levels [12, 76].

Effects of EMF on The Kidney

Hashem and El-Sharkawy [4] found that exposure of mice to EMF increases serum creatinine and urea levels. Similarly, Tsuji *et al.*, [77] stated that mice exposed to SMFs [5 T] for 48 h increased blood urea nitrogen and creatinine levels. Exposure of mice to static magnetic field [SMF] increased the blood urea nitrogen, and creatinine [65]. This may be due to the renal dysfunction associated with contracted glomerular tufts of some glomeruli and focal leukocytic aggregation by pathologic examination. Oktem *et al.*, [76], Ozguner *et al.*, [78] and Hanafy *et al.*, [79] reported that renal impairment in animals exposed to mobile phone radiations are due to oxidative stress induced by EMFs and using of melatonin [as an antioxidant] may exhibit a protective effect against this impairment. Contrarily, SMF exposure had no effect on serum creatinine and urea levels in rats [60].

Gholampour *et al.*, [12] reported that rats exposed to a 50 Hz ELFEMF, 1 mT [emitted from solenoid] for 24 h daily during 135 days were showed plasma concentration of creatinine and urea nitrogen was increased [$p < 0.001$] which was accompanied by marked vascular congestion in the renal cortex and reduction in red blood cell count in glomerular capillaries but there were no changes in total protein, albumin and globulin levels.

Effects of EMF on The Heart function

The detected significant increase of both CK and LDH levels after 3 months of exposure to EMF are agreed with these of Zhang *et al.*, [80], who reported that, electromagnetic shield applied to volunteers showed a highly significant effect on serum level of creatinine phosphokinase. Moreover, Olson and David [81] reported an elevation in CK, LDH and GOT after exposure to radiofrequency. This may be due to that magnetic fields interact with moving charges in cells and change their velocities, [82]. However, Cell membranes have been identified as a primary site of interaction with the low frequency fields [83]. Therefore, the alterations in these charges and molecules consider the first step in the production of biological effects as magnetic field interact with moving charges and change enzymatic activity [84]. In addition, EMF may regulate the rate and the amount of product of biochemical reaction possibly through free radical mechanism including direct influence on enzyme action [85].

Effects of EMF on The Reproductive parameters

To date, many in vivo and in vitro studies have revealed that EMF exposure can alter cellular homeostasis, endocrine function, reproductive function, and fetal development in animal systems [24]. Use of electronic household items and cell phones are reported to decrease fertility potential in men by decreasing sperm count, motility, viability, inducing pathological changes in sperm and testes morphology, and so on [86]. Reproductive parameters reported to be altered by EMF exposure include male germ cell death, the estrous cycle, reproductive endocrine hormones, reproductive organ weights, sperm motility, early embryonic development, and pregnancy success. At the cellular level, an increase in free radicals and $[Ca^{2+}]$ may mediate the effect of EMFs and lead to cell growth inhibition, protein misfolding, and DNA breaks. The effect of EMF exposure on reproductive function differs according to frequency and wave, strength [energy], and duration of exposure [24].

Gye and Park, [24] reported that through in vitro and in vivo studies, EMF exposure was found to alter the reproductive endocrine hormones, gonadal function, embryonic development, pregnancy, and fetal development. Exposure to EMF adversely affects spermatogenesis, Sertoli and Leydig cells [7, 87-89], and atrophy of the seminiferous tubules [20] of experimental animals. Also, Khaki *et al.*, [90] reported that exposure to electromagnetic field in rats for 40 days caused a significant increase in apoptosis in testis, percentage of testis vein congestion, and a significant decreases in testis weight, serum testosterone. These effects were different according to the frequency, duration of exposure, and strength of EMFs. Humans in modern society cannot avoid various kinds of EMFs during household and occupational activities, but should be aware of the biological hazard of EMFs. The effort to avoid EMF exposure and techniques to protect or relieve EMF radiation are required to preserve our reproductive potential [24].

There was a positive relationship between occupational monitor labor during pregnancy and the natural abortion rate [91-93]. Epidemiological studies on birth defects and abortions in pregnant women working in offices revealed that the EMF generated from a computer monitor can negatively affect human reproduction [91, 94].

CONCLUSION

On the basis of above literature we can conclude that the Exposure of human and animals to EMFs have been a negative effects on cardiovascular system, CNS, endocrine, immune systems and reproductive system, the developing embryo/fetus. and cause a histopathological changes and disturbances in functions of different body organs.

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