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Subchronic Exposure to Radiofrequency Electromagnetic Radiation Affects the Biochemical, Physiological, Behavioral Functions: A Review

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ABSTRACT

During the last few decades, there has been immense exposure to electromagnetic radiation through mobile phones, Wi-Fi towers, and other devices. Many studies have been conducted regarding their biological effects, pathological, physiological, behavioral, transgenetic studies and more. In the present literature review, it is observed that among the various studies that were performed on electromagnetic emission for various durations and radio-frequencies of irradiation on animals, the subchronic exposure i.e. between one month to three months duration shows maximum alterations in the biochemical parameters, physiological and pathological or behavioral conditions. Acute exposure, of up to one week, to electromagnetic field (emf), does not alter these conditions to much extent. There are fewer studies performed on chronic continuous exposure to rfemf thereby providing less data for prediction of biological effects of chronic exposure to rfemf.

INTRODUCTION:

The effect of mobile phone radiation on human/animal health is a subject of interest and study worldwide, due to the enormous increase in mobile phone usage throughout the world. Mobile phone uses electromagnetic radiation in the Microwave range (450-3800 MHz). Another digital wireless system, such as data communication networks, produce similar radiation. Recently the use of mobile phone is widespread in our society today more than 1.5 billion people are using mobile phones worldwide in which high-frequency waves are used and this number is even increasing; mainly four frequencies 800, 900, 1800, and 2450 MHz of electromagnetic waves are used for mobile phone communication these frequencies are called mobile phone frequencies. The common communication technologies are a global system for communication GSM 800, GSM 900, GSM 1800, and GSM 2450. The mobile phone radiations are classified as of two types such as ionizing and non- ionizing radiation. The non- ionizing radiation refers to a variety of electromagnetic radiation that only excites matter into another form of energy, it does not ionize molecules, which can cause more harmful radiation effects. In the following review, we have briefed the research works of various authors during the last three decades, in the field of electromagnetic radiation impact on biological systems.

In1987 D'Andrea JA et al. studied absorption of microwave radiation in the anesthetized rat. This study presents anatomic effects of EMF due to 2450 MHz frequency radiations in reference to absorption hotspots in the brain, rectum, and tail of a rat. Regions of intense energy absorption like brain are of little consequence as the natural thermal equilibrium mechanism of the body takes care of it. However, the regions of low energy absorption like tail and rectum had shown the considerable rise in post-irradiation local temperatures compared to the remaining body.

In 1997, Hermann DM reported neurological effects of microwave exposure related to mobile communication. This report presents experimental studies on putative electrophysiological, biochemical and morphological effects of continuous or pulsed microwave radiations. According to these results, there is no evidence that pulsed or continuous microwave exposure in the non-thermal range confers elevated risk to the health of the brain. (What is duration/pattern of exposure).

World Health Organization, Geneva, Switzerland (1998) Michael H. Repacholi emphasized

electromagnetic fields, their health effects, and research needs. Effects of low-level EMF due to RF fields having frequencies in the range of about 10 MHz to 300 GHz were presented to identify any health hazards from the exposure. It was momentarily concluded that, although hazards from exposure to high-level (thermal) RF fields were established, no known health hazards were associated with exposure to RF sources emitting fields too low to cause a significant temperature rise in biological tissues. However, the need of further exploration on further replication and study of proliferation effects, effects on genes, signal transduction effects and alterations in membrane structure and function, and biophysical and biochemical mechanisms of exposure was established. These included in vitro studies of cell kinetics in reference to cancer promotion, effects on DNA, nervous system, eye and vision, pregnancy and other routine body activities and functions due to use of mobile phones.

Acute exposure to pulsed 2450 MHz microwaves in 2000 by Wang B et al showed decreased water-maze performance of rats. According to author the effect of acute microwave exposure on spatial learning and memory functions was studied in this work, the capability of rats to locate a platform in a circular pool of opaque water by using cues in the environment. Microwave-irradiated animals were slower than sham-exposed and cage control animals in learning to locate the platform. However, there was no significant difference in swim speed among the three groups of rats, indicating that the difference in learning was not due to a change in motor functions or motivation. However, a change in learning strategy and deficit in spatial "reference" memory was observed in the exposed rats.

David R. B. Performed studies on (2003) radiofrequency (RF) effects on blood, hormonal and immune functions. Effects of radiofrequency electromagnetic fields on the pituitary-adrenocortical (ACTH), growth (GH), and thyroid (TSH) hormones have been extensively studied in this paper and the coherent effects on reproductive hormones (FSH and LH) have been presented. The identified effects are made out to be caused by heating. Studies of the exposed blood cells have shown that changes or damage do not occur unless the cells are heated. White cells (leukocytes) are much more sensitive than red cells but white cell maintains their consistency due to normal physiological responses to systemic temperature fluctuations. Lifetime studies of exposed animals show no cumulative adverse effects in their endocrine, hematological, or immune systems. The cardiovascular tissue is not directly affected adversely in the absence of significant heating or electric currents. The regulation of

blood pressure is not affected by ultra-high frequency (UHF) at the levels commonly encountered in the use of mobile communication devices.

A repeated low-level microwave was irradiated to study the effect on memory in 2004 by Cobb BL et al. This study examines possible changes in working memory of rats following whole body exposure to microwave irradiation. The study was conducted as an attempt to confirm the results of a previous study (publication id 109). According to the author, analysis of error rates revealed no significant irradiation effect, no significant drug effect and no significant interaction between the two factors. The authors concluded that there is no evidence from the current study that exposure to microwave irradiation under these parameters caused decrements in the ability of rats to learn the spatial memory task through some other studies of possible working memory changes to show different results.

Koyu A, (2005), the effects of exposure to a 900 megahertz (MHz) EMF on serum thyroid stimulating hormone (TSH) and triiodothyronine-thyroxin (T3-T4) hormones levels of adult male Sprague-Dawley rats were studied using control, sham exposed and exposed groups. The exposures were performed 30 min/day, for 5 days/week for 4 weeks to 900 MHz EMF. The TSH values and T3-T4 at the 900 MHz EMF group were significantly lower than the sham-exposed group ($p<0.01$). There were no statistically significant differences in serum TSH values and T3-T4 hormone concentrations between the control and the sham-exposed group ($p>0.05$), while the exposure decreased serum TSH and T3-T4 levels.

Cosquer B et al after acute 2.45 GHz exposure reported in 2005 lack of alteration in anxiety response. This experiment assesses effect of electromagnetic field of frequency 2.45 GHz (2 micros pulse width, 500 pulses per second, whole-body and time-averaged of SAR 0.6 W/kg +/-2 dB, brain-averaged SAR of 0.9 W/kg +/-3 dB) for 45 min on diazepam treated (0.5 and 1.0 mg/kg) and normal rats under light intensity 2.5, 10, 30 and 200 lux in the elevated plus maze. Whatever light intensity was used, EMF exposure failed to induce any significant effect on anxiety responses in the plus maze. This experiment demonstrates that exposure to EMFs, which was previously found to increase the number of benzodiazepine receptors in the rat cortex does not alter anxiety responses.

Forgács Z et al. studied the effect of 1800MHz microwave exposure (2006) on testicular function and histology in mice. This work presents the effects of whole-body exposure to1800 MHz GSM-like microwave exposure on male reproduction. After repeated exposure

of mice to microwaves at 0.018-0.023 W/kg, whole-body specific energy absorption rate (SAR) an elevated serum testosterone level was measured, but no histopathological alteration could be detected in the reproductive organs. In exposed animals, the red blood cell count and the volume of packed red cells were increased.

K. Moon et al., 2007after long-term exposure of rats to 2.45 GHz emf reported effects on reproductive function. The objective of this study was to investigate the effects of electromagnetic field radiation on the sperm count, morphology, histological structure of testes, and on the hormonal level of rats exposed to microwave radiation. Thirty male Sprague- Dawley rats (4 weeks of age) were exposed to a 2.45 GHz EMF for 1 hour or 2 hours a day. The results indicated that even the small duration exposure leads to increased leydig cell hyperplasia with serum testosterone level and decreased spermatocyte due to the EMF radiation. These changes suggest that long-term exposure to EMF has adverse effects on the proliferation and differentiation of spermatogonia and may induce male infertility.

EMF from the cellular phone was shown by Yan JG et al to have the detrimental effect on Sperm motility in rats. (2007) this paper evaluates the effects of cellular phone emissions on rat sperm cells. 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 through chi-squared analysis. In addition, abnormal clumping of sperm cells was present in rats exposed to cellular phone emissions and was not present in control group rats. These results suggest that carrying cell phones near reproductive organs could negatively affect male fertility.

M. Jadidi in 2007, reported that low-power density of 950 MHz radiation does not affect long-term potentiation in rat dentate gyrus. This study was planned for evaluating the effects of whole-body exposure to 950 MHz field of GSM signals on rats.

There were no significant differences in population spike amplitude, EPSP slope and EPSP slope maintenance among the groups. This study provides no evidence that long-term exposure to the GSM system affects the parameters.

2007, Kavindra Kumar Kesari reported in his study on whole body 900 MHz radiation exposure effect on enzyme activity in male Wistar rats, Microwave (MW) from cellular phones affects biological system by increasing free radicals, which may enhance lipid peroxidation (LP) and by changing the antioxidative activities which lead to oxidative

damage. Their findings showed a significant decrease in GPx and SOD of exposed rat brain, liver, and sperm ($p<0.001$), whereas Catalase activity shows a significant increase in the brain ($p <0.001$), liver ($p <0.05$) and sperm ($p<0.001$) samples as compared to control. The results conveyed that the regular use of the mobile phone at the domestic level can have a negative impact on human enzymatic activity.

Sinha R K (2008) studied the effects of chronic exposure to low energy 2450 MHz nonthermal microwave irradiation on thyroid hormones, reactiveness and emotional behavior of rats. The 2Hrs a day exposure resulted in thyroid hormone changes and behavioral changes due to exposure for up to 21 days with power: 12.5 mW, power flux density: 16.5 µW/cm², SAR: 3.6 µW/g average parallel to E plane, SAR: 0.98 µW/g average over mass parallel to the H plane. The field view tests resulted in increased edema and edematous swelling, thyroid hormones (triiodothyronine, thyroxine, and thyroid stimulating hormone: radioimmunoassay). The authors finally conclude that low energy microwave irradiation may be harmful as it is sufficient to alter the levels of thyroid hormones as well as the emotional reactivity of rats.

Gustav Grafström, 2008, studied Histopathological changes of rat brains after long-term exposure to GSM-900 mobile phone radiation. This paper mimics lifelong exposure to the electromagnetic fields emitted by mobile phones for rat exposures. In this study, no significant alteration of studied histopathological parameters was found, when comparing the sham-exposed controls.

2008, Kim TH, et al, studied Local exposure of 849 MHz and 1763 MHz emf to mouse heads to induce cell death or cell proliferation in the brain. Even though there is no direct evidence to prove the cellular and molecular changes induced by radiofrequency (RF) radiation itself, they could not completely exclude the possibility of any biological effect of mobile phone frequency radiation. In the chamber laced with 849 and 1763 MHz, animals were irradiated intermittently at 7.8 W/kg for a maximum of 12 months. No effect was observed on body weight. No changes could be found in brain tissues after 6 and 12 months in reference to histology and cell proliferation. Thus the exposure could not induce cellular alterations such as proliferation, death, and reactive gliosis

S J Mousavy, in 2009, studied effects of mobile phone radiofrequency on the structure and function of the normal human hemoglobin. In this paper, the effect of mobile phone RF

(910MHz and 940 MHz) on the structure and function of HbA was investigated. The results indicated that mobile phone EMFs altered oxygen affinity and tertiary structure of HbA. The decrease of oxygen affinity of HbA corresponded to the EMFs intensity and time of exposure.

2009, Effects of different electromagnetic fields on circadian rhythms of some haematochemical parameters in rats, were studied by Contalbrigo L.et al. This report aims to investigate the effects of electromagnetic fields of 50 Hz and 1.8 GHz with different field intensities on a few hematochemical parameters. Different changes occurred in the parameters for glucose, triglycerides, and total cholesterol ($P < 0.05$). Exposure to electromagnetic fields is found responsible for the variations of some haematochemical parameters in rats.

2009**,** Kumar RS et al reported Hypoactivity of Wistar rats exposed to a mobile phone on elevated plus maze. This study presents effects of mobile phone exposure on the behavior of rats in the elevated plus maze using continuous calls of 1minute each. The preliminary data indicated that the mobile phone exposure induced behavioral changes in rats expressed as a deficit in open arm exploration in the elevated plus maze. The number of defecation pellets of exposed animals was also increased compared to control animals.

The effects of exposure to a 900 MHz electromagnetic field (EMF) on plasma cholesterol and triglyceride levels of adult male Syrian hamsters were evaluated by Lotfi A et al [2009]. Three independent Groups of 24 hamsters each were used as controls and exposed for 10 and 50 days respectively using cellular phones. Significant differences were observed for concentrations of cholesterol ($p<0.05$) and triglyceride ($p<0.01$) between experimental groups. The long-term EMF (900 MHz) exposure decreases plasma total cholesterol and triglyceride rates in rodents significantly; may be due to a reversible accumulation of either triglyceride or of their precursors in the liver following the acute exposure.

Ali Moghimi, et al (2009) studied Histological Characteristics of Hippocampus and Learning Behaviours. In this study, the possibility of changes in working memory and hippocampal histological characteristics effects in mice brain following whole body exposure to microwave radiation was studied using GSM. The results showed that the exposed group didn’t show any statistically significant loss of hippocampal volume but there is a significant decrease in learning capability to find spatial memory task.

A M Roushandeh (2010) studied Lipocalin 2 Expression in Mouse Liver under a high-frequency electromagnetic field. Expression of Neutrophil gelatinase-associated lipocalin (NGAL/Lcn2) in RNA of the liver due to electromagnetic field exposure (50 Hz EMF for 2 months, 4 hr/day) has been investigated in this study. It has been also proved that the electromagnetic field (EMF) produces reactive oxygen species. The light microscopic studies revealed that the number of lymphocyte cells was increased compared to control and dilation of sinusoids was observed in the liver. Lcn2 was up-regulated in the mice exposed to EMF both in mRNA and protein levels**.**

Fragopoulou AF, (2010) studied whole body exposure with GSM 900 MHz to affect spatial memory in mice. This work tests the effects of mobile phone radiation on spatial learning and memory using the Morris water maze. They had applied a 2h daily dose of pulsed GSM 900MHz radiation from commercially available mobile phone for 4 days at SAR values ranging from 0.41 to 0.98W/kg. Statistical analysis revealed that during learning, exposed animals showed a deficit in learning skills and memory.

I. Abdel Aziz (2010) studied the effect of an electromagnetic field on body weight and blood indices in albino rats and the therapeutic action of vitamin c or e. The work investigated effects of EMF radiated from mobile base stations with a frequency equal to 900 MHz on body weight, blood indices and some liver enzymes of albino rats after exposing them to the electromagnetic field for 2 weeks. This work focuses on the therapeutic action of vitamin C or E against harmful effects induced by an electromagnetic field. Results showed that electromagnetic field exposure caused a significant increase in WBC count, mean corpuscular hemoglobin concentration (*MCHC*), blood platelets count (*PLT*), Serum aminotransferase (AST), alkaline aminotransferase (ALT) and alkaline phosphatase. A significant decrease in a growth rate, RBC count, hemoglobin incidence (*HB*), hematocrit value, the mean corpuscular volume (*MCV*) and mean corpuscular hemoglobin concentration (*MCHC*). Treatments with vitamin C and E yield improvements in the body weight growth rate, the hematological parameters and the serum of liver enzymes during the exposure to treatments with the electromagnetic field.

Augner C, et al. studied effects of exposure to GSM signals on salivary cortisol, alpha-amylase, and immunoglobulin A.This study aimed to study the effects of exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by mobile phone base stations GSM 900 MHZ. Each rat went through five 50-minute exposure sessions with low, medium

and high exposure conditions. An increase of cortisol was detected after session 3 and 4, while in scenarios 1 and 2, a higher concentration of alpha-amylase related to the baseline was identified as compared to that in scenario 3. IgA concentration was not significantly related to the exposure. RF-EMF with considerably lower field densities than ICNIRP-guidelines may influence certain psychobiological stress markers.

Histochemical studies by Judita Orendáčová, Martin Orendáč on effects of short-duration electromagnetic radiation on early postnatal neurogenesis in rats were reported in 2010. In this paper, immediate effects of whole body electromagnetic radiation (EMR) were used to study postnatal neurogenesis in the subventricular zone (SVZ) and rostral migratory stream (RMS) of Wistar rats of both sexes. Newborn postnatal day 7 (P7) and young adult rats (P28) were exposed to pulsed electromagnetic fields (EMF) at a frequency of 2.45 GHz and mean power density of 2.8 mW/cm^2 for 2 h. The findings indicate that EMR causes faster age-related changes in the production of nitric oxide (NO), which may lead to different courses of the proliferation cascade in newborn and young adult neurogenesis.

Maskey D, et al in 2010 found Chronic 835-MHz radiofrequency exposure to mice hippocampus alters the distribution of calbindin and GFAP immunoreactivity. This study investigates the effect of cell phone RF exposure on rat hippocampus at 835 MHz with low energy (specific absorption rate: SAR=1.6 W/kg) for 3 months by using both CB and glial fibrillary acidic protein (GFAP) specific antibodies by immunohistochemical method. A decrease in CB immunoreactivity (IR) was noted in exposed (E1.6) group with loss of interneurons and pyramidal cells in the CA1 area and loss of granule cells. Also, an overall increase in GFAP IR was observed in the hippocampus of E1.6. By TUNEL assay, apoptotic cells were detected in the CA1, CA3 areas and dentate gyrus of the hippocampus, which reflects that chronic RF exposure may affect the cell viability. Chronic RF exposure to the rat brain suggested that the decrease of CB IR accompanying apoptosis and increase of GFAP IR might result in the hippocampus damages.

Achudume, Albert in 2010 studied induction of oxidative stress in rats that were subchronically exposed to electromagnetic fields of non-thermal intensities. This work investigates the oxidative stress-inducing potential of non-thermal electromagnetic fields in rats. Exposure was in three forms: continuous waves, or modulated at 900 MHz/1800MHz or modulated GSM non-DTX for a continuous 40 or 60 days duration. The rats were assessed for thiobarbituric and reactive species (TBARS), reduced glutathione (GSH) content, catalase

activity, glutathione reductase (GR). After 40 days, electromagnetic radiation failed to induce any significant alterations. However, at 60 days of exposure, various said attributes evaluated decreased. The experiment showed some biochemical changes that may be associated with a prolonged exposure to electromagnetic fields.

Arendash GW et al reported in 2010 that the electromagnetic field treatment protects against and reverses cognitive impairment in Alzheimer's disease mice. This report presents the evidence that the defined long-term EMF exposure directly associated with cell phone use (918 MHz; 0.25 w/kg) provides cognitive benefits. Both cognitive-protective and cognitive-enhancing effects of EMF exposure were discovered for both normal mice and transgenic mice destined to develop Alzheimer's-like cognitive impairment. The cognitive interference task utilized in this study for Alzheimer's disease mice indicated reduced brain amyloid-beta (Abeta) deposition through Abeta anti-aggregation actions and increased brain temperature during exposure periods. Several inter-related mechanisms of EMF action are proposed, including increased Abeta clearance from the brains of Alzheimer's disease mice, increased neuronal activity, and increased cerebral blood flow. They concluded that EMF exposure may represent a non-invasive, non-pharmacologic therapeutic against Alzheimer's disease. However, this may subject to duration, uniformity of field, polarization etc).

Maskey D, et al. in 2010 explored the effect of 835 MHz radiofrequency radiation exposure on calcium-binding proteins in the mouse brain**.** This paper presents studies on the biological effects of GSM radiations on the brain and nervous system. The Radiofrequency (RF) radiation might alter intracellular signaling pathways due to changes in calcium (Ca^{2+}) permeability and changes in the expression of calcium binding proteins (CaBP) like calbindin D28-k (CB) and calretinin (CR). Body weights did not change significantly. CB immunoreactivity (IR) displayed moderate staining of cells in the Cornu ammonis (CA) areas and prominently stained granule cells. Exposure for 1 month produced almost complete loss of pyramidal cells in the CA1 area. CaBP differences could cause changes in cellular Ca^{2+}levels, which could have a deleterious effect on normal hippocampal functions.

Fatma A, et al (2011) reported studies on the cardiovascular effects of electromagnetic field exposure. This study explores the negative effect of electromagnetic radiofrequency (EMR) from cell phones on the heart and circulatory system functions by carrying out a scheduled wide range of cardiac parameter measurements and histopathological tests after one and two months exposure to the two groups followed by subsequent one to three hours per day

exposure in four subgroups each. The Obtained results revealed that systolic blood pressure was significantly increased in all EMF-exposed rats compared to their respective controls. The heart rate, deduced from the ECG tracings, was non-significantly altered in all groups exposed to EMF for 4 weeks and in the 8 weeks-1hr/day exposure group but was significantly reduced in rats exposed to EMF for 2hrs or 3hrs/day for 8 weeks. Most of the measured parameters reported an increase in two months exposure group. A few parameters reported some increase in the 1-month group followed by 2hrs and 3hrs/day exposure. The histopathological examination revealed hypertrophy, fragmentation, and vacuolation of the myocardium, which was directly proportional to the exposure time. Long-term exposure to cell phone EMF increases the liability for hypertension reflected on the ECG and cardiac weights which is accompanied by histopathological changes in the myocardium. In addition, an interaction of EMF with biological functions was observed in the form of increased PRA, decreased plasma total antioxidant capacity and hypocalcemia.

Marc Bouji, et al. (2012) presented effects of 900 MHz radiofrequency on corticosterone, emotional memory, and neuroinflammation in middle-aged rats. The use of mobile phones raised exposure of the human brain to electromagnetic fields (EMF, 900 MHz) and its effects. Previous studies reported increased levels of the glial fibrillary acidic protein (GFAP) in the rat's brain after a single exposure to 900 MHz., suggesting the potential inflammatory process. The study predicts the need of study of effects of the EMF on the aging process of adult brains of rats due to 15 min exposure. The results indicate that the acute GSM exposure did not induce astrocytes activation. The results showed an IL-1β increase in the olfactory bulb and enhanced contextual emotional memory in GSM-exposed middle-aged rats and increased plasmatic levels of CORT in GSM-exposed young adults. Altogether, the data showed an age dependency of reactivity to GSM exposure in neuroimmunity, stress and behavioral parameters. Reproducing these effects and studying their mechanisms may allow a better understanding of mobile phone EMF effects on neurobiological parameters.

Celikozlu SD, et al., in 2012 reported the effects of long-term exposure to 900-MHz GSM radiation on some biochemical parameters and brain histology in rats. This study explores the effects of 900MHz GSM EMF on a few blood parameters and neurons in rats especially during a prenatal and postnatal period of 80 days. The waves of cell phones were found to increase blood glucose levels by roughly 50% while it increased serum protein level roughly by 250% compared to control. Significant statistical differences haven’t been observed in the

blood cholesterol concentration compared to control. Weekly weight gain rate has decreased in all groups compared to the control. The EMF exposure has decreased pyramidal neuron numbers 51,15 % and increased ischemic neuron numbers 73 % at cortex region of the brain. The vascular dilatations have increased subjectively but clearly in group F2. The exposure did not have any effect on hippocampal pyramidal cell numbers. It has increased the number of ischemic neurons three folds compared to the control.

In 2012 rat testicular impairment induced by electromagnetic radiation from a conventional cellular telephone by Mona Abdullah Al-Damegh, and the protective effects of the antioxidants vitamins C and E were observed up to 60 min daily for two weeks. This study investigates the effects of cell phone electromagnetic radiations on the status of oxidants and antioxidants in rat blood and testicular tissue. It further determines the possible protective role of vitamins C and E in preventing the detrimental effects of electromagnetic radiation on the testes. There was a significant increase in the diameter of the seminiferous tubules with a disorganized seminiferous tubule sperm cycle interruption in the electromagnetism-exposed group. The serum and testicular tissue conjugated diene, lipid hydroperoxide and catalase activities increased 3-fold, whereas the total serum and testicular tissue glutathione and glutathione peroxidase levels decreased 3-5 fold in the electromagnetism-exposed animals. The results indicate that the adverse effects of the generated electromagnetic frequency had a negative impact on testicular architecture and enzymatic activity. This finding also indicates the possible role of vitamins C and E in mitigating the oxidative stress imposed on the testes and restoring normality of the testes.

A.D. Usman, et al., 2012 studied the effect of radiofrequency electromagnetic field exposure on hematological parameters of mice. Radiofrequency electromagnetic field (RF-EMF) exposures due to Global System for Mobile communication (GSM) frequency band at a field of 6mW/m2 and specific absorption rate 0.3W/kg were investigated in this study. No changes in hematological and histopathological parameters were observed at the end of exposure for 4 weeks. However, observation of the individual and collective behavior of the mice shows some manifestation in the form of increased aggressiveness and hyperactivity.

P Sima Saravani et al., in 2013 presented their work on electromagnetic waves generated by base transceiver station on liver enzymes in female rats. This study investigates the effect of mobile communication electromagnetic waves (900 MHz) on liver enzymes. Test groups were daily exposed for four hours at four different times to the electromagnetic waves.

Exposure to EMF is found to have a significant effect on liver enzymes composition in mature and immature rats. All the leaver common enzymes in immature test group decreased significantly compared with their respective control groups ($p<0.05$). But only ALP in mature-test groups increased significantly compared with their respective control groups ($p<0.05$). The findings suggested that the exposure has a deleterious effect on liver enzymes and is more severe in immature animals.

In 2013 review on a biophysical evaluation of radiofrequency electromagnetic field effects on the male reproductive pattern was forwarded by Kesari KK et al., This review examines the possible concerns on radio frequency radiation and its biological effects such as enzyme induction, and toxicological effects, including genotoxicity and carcinogenicity, testicular cancer, and reproductive outcomes. Though there are a few contradictory findings related to this issue in the course of time, there is enough published evidence that consistent and continuous exposure to EMF radiations leads to testicular infertility or testicular cancer due increased level of reactive oxygen species (ROS). It also leads to testicular cancer due to ROS formation and causes the biological damage further leading to several changes like decreased sperm count, enzymatic and hormonal changes, DNA damage, and apoptosis formation. This paper also discussed physics of mobile phone including possibilities of future research on various aspects.

Whole-body exposure to 915 MHz RF and secretory functions of the thyroid system in rats were investigated in 2013 by Hye Sun Kim, et al., This paper investigates the potential risks of radiofrequency radiations on human health at 915 MHz RFID using rats. It significantly affected the secretory function of the thyroid system. Plasma levels of triiodothyronine (T3), thyroxine (T4), and thyroid-stimulating hormone (TSH) were evaluated via enzyme-linked immunosorbent assay. No changes in T3, T4, or TSH were observed over time between the sham- and RFID-exposed groups. It is concluded that the exposure does not cause significant effects on thyroid secretory function.

Kumari Kajal studied (2013) radiofrequency electromagnetic field exposure effects on antioxidant enzymes and liver function tests. The aim of this study was to investigate the effect of mobile phone and microwaves (2.45 GHz) radiation on the oxidative status of the liver. Animals were exposed at two different frequencies of mobile phone and 2.45 GHz of MWs. Exposure was given for 2 hr a day for 35 days. The effect of these radiations was observed on parameters related to liver functioning tests (LFT). The result shows that the

exposure decreased the level of GPx and SOD in the exposed group as compared to the sham-exposed group. While CAT level was found to be increased in the exposed group as compared to sham exposed. The study concluded that the chronic exposure to these radiations adversely affect the liver functioning and may be an indication of possible tumor promotion due to significant (P<0.05) changes occurring in antioxidative enzymes.

In 2013 A review came on Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem by S Sivani & D Sudarsanam. This paper summarizes the effect of radio-frequency electromagnetic field (RF-EMF) from cell towers and wireless devices on the biosphere. Based on the currently available literature, it is justified to conclude that RF-EMF radiation exposure can change neurotransmitter functions, blood-brain barrier, morphology, electrophysiology, cellular metabolism, calcium efflux, and gene and protein expression in certain types of cells even at lower intensities. Though the biological effects of such exposures are not clear, the studies of these effects will enable mankind in enjoying its immense benefits, while ensuring own and environment safety.

An experimental study was carried out (2014) by Tomoyuki Shirai, et al., with rats to evaluate the effects of three levels of whole-body exposure to 2.14 GHz band code division multiple access (W-CDMA) signals for 20 h a day, over three generations. It was concluded that under the experimental conditions applied, multigenerational whole-body exposure to 2.14 GHz W-CDMA signals for 20 h/day did not cause any adverse effects on any offspring. However, the selection of the exposure duration was not justified. In recent days the leaving beings are subjected to 24x365 RF radiations due to increased wireless communication activities.

DISCUSSION:

After reviewing the works reported by various researchers we plotted the effects of rfemf radiation on various biological parameters studied versus the time duration and observed that the studies have been performed on the wide time frame. Some have exposed the animals for few hours, others have done it for a few days, few weeks or months, none have exposed to rfemf for whole day continuously, but for few hours a day. Nevertheless, we tried to correlate the findings with respect to length of time and came to the conclusion that while the rfemf can influence the biological parameters acutely, to some extent, it affects the animal more if

exposed to a period of few weeks or say for 1-3 months. Most of the researchers have reported some change in the value of the parameter they studied, either increased or decreased, mainly during a subchronic period. For long duration, however, fewer studies have been performed and the available data doesn't suggest any untoward effect on the biological parameters.

Table 1: Effect of exposure time on different parameters:

EXPOSSURE TIME--> /PARAMETER	1-60 mins/day	1-10 hrs/day	10-20 hrs/day	1 week	4 weeks	8 weeks	12 weeks	24 weeks	36 weeks	48 weeks	55 weeks
sperm count		+						<			
histological structure of testes		<									
testosterone level		+									
male infertility		+						+			
							<				
body weight					<		*			*	
WBC count					+						
MCHC					+						
PLT					+						
RBC					<						
HB					<						
MCV					<						
Serum aminotransferase (AST),		<			+						
alkaline aminotransferase (ALT)		<			+						
alkaline phosphatase		<			+						
fibrillary acidic protein (GFAP)											
corticosterone (CORT)	+										
interleukin (IL)-1β	+										
emotional memory	+	<		<	+		<			+	
TSH				*	<	*		*	*		

(T3-T4) hormones		*	> <			*			*	
NADPH			<		<					
Catalase			+		<					
glutathione reductase			<		<					
lipid peroxidation (LPO)			<			<				
thiobarbituric and reactive species (TBARS),			<		<					
edema										
Fearfulness										
Anxiety	*									
blood glucose level								+		
serum protein level								+		
blood cholesterol		<		<			*			
triglyceride levels		<	<							
apoptotic cells	+						*	+		*
Calcium binding proteins										
neurobehavioral function						*	<			
Ischemic neurons							+			
Astrocytes							+			
pyramidal cells			<				<			
heart rate			*			<				
blood pressure systolic			+			+				
plasma renin activity			+		+					
Calcium			*		<					

Where *--indicates no significant change, + indicates some significant change, < indicates values reduces significantly, > indicates values increase significantly.

REFERENCES:

1. Abdel Aziz I, et al., Effect of Electromagnetic Field on Body Weight and Blood Indices in Albino Rats and the Therapeutic Action of Vitamin C or E, Romanian J. Biophys., 20(3): 235–244 (2010)
2. Achudume A, Induction of Oxidative Stress in Male Rats Subchronically Exposed to Electromagnetic Fields at Non-Thermal Intensities, J. Electromagnetic Analysis and Applications, http://www.faqs.org/periodicals/201008,(2010)
3. Achudume AC, et al., Bioeffects of an electromagnetic base station on glutathione reductase, lipid peroxidation and total cholesterol in different tissues of Wistar rats, Biology and Medicine, 1 (3): 33-38, (2009)
4. Arendash GW, et al., Electromagnetic field treatment protects against and reverses cognitive impairment in Alzheimer's disease mice. J Alzheimers disease 19(1):191-210 (2010)
5. Behari J, Biological responses of mobile phone frequency exposure, Indian journal of experimental biology,48:959-81(2010)
6. Black DR, Heynick LN, Radiofrequency (RF) Effects on Blood Cells, Cardiac, Endocrine, and Immunological Functions, Bioelectromagnetics Supplement 6: S187-S195 (2003)
7. Bouji M, et al., Effects of 900 MHz radiofrequency on corticosterone, emotional memory and neuroinflammation in middle-aged rats., Experimental Gerontology, 47 (6):444-451(2012)
8. Celikozlu SD, et al., The effects of long-term exposure of magnetic field via 900-MHz GSM radiation on some biochemical parameters and brain histology in rats, Electromagnetic biology and medicine, 31(4):344-55(2012)
9. D'Andrea JA, et al., Absorption of microwave radiation by the anesthetized rat: electromagnetic and thermal hotspots in body and tail, Bioelectromagnetics, 8(4):385-96(1987)
10. Fatma AM, et al., Study of the Cardiovascular Effects of Exposure to Electromagnetic Field, Life Science Journal, 8(1):260-274 (2011)
11. Grafström G, et al., Histopathological examinations of rat brains after long-term exposure to GSM-900 mobile phone radiation, J.brain research bulletin, l77(5):257-63(2008)
12. Henry Lai, Neurological effects of radiofrequency electromagnetic radiation, Published on http://www.mapcruzin.com/ (1998)
13. Jelodar GA, Effect of Electromagnetic Waves Generated by Base Transiver Station on Liver Enzymes in Female Rats, Zahedan J. of Res. in Medical Sciences, 15(7): 19-21 (2013)
14. Kesari KK, Behari J, Whole body 900 MHz radiation exposure effect on enzyme activity in male Wistar rats, http://wifiinschools.org.uk/resources/Kesari+and+Behari+.pdf
15. Kim HS, et al., Effects of Whole-Body Exposure to 915 MHz RFID on Secretory functions of the Thyroid System in Rats, Bioelectromagnetics 34:521-529 (2013)
16. Kim TH, Local exposure of 849 MHz and 1763 MHz radiofrequency radiation to mouse heads does not induce cell death or cell proliferation in the brain, Experimental and Molecular medicine, 40(3):294-303(2008)
17. Koyu A, et al., Effects of 900 MHz electromagnetic field on TSH and thyroid hormones in rats, Toxicol lett, 157(3):257-62: (2005)
18. Kumar RS, et al., Hypoactivity of Wistar rats exposed to a mobile phone on elevated plus maze, Indian J Physiol Pharmacol 53 (3): 283 - 286 (2009)
19. Lotfi A, Shahryar HA, Effects of 900 MHz Electromagnetic Fields Emitted by Cellular Phone on Total Cholesterol and Triglyceride Levels of Plasma in Syrian Hamsters, Journal of Applied Biological Sciences, 3(2): 93-96(2009)
20. M. Jadidi, Low-power density of 950 MHz radiation does not affect long-term potentiation in rat dentate gyrus, Iran. J. Radiat. Res., 5 (3): 119-124(2007)
21. Maskey D, et al., Effect of 835 MHz radiofrequency radiation exposure on calcium-binding proteins in the hippocampus of the mouse brain, Brain Research,1313:232-41(2010)
22. Maskey D, et al., Chronic 835-MHz radiofrequency exposure to mice hippocampus alters the distribution of calbindin and GFAP immunoreactivity, Brain Research, 30(1346):237-46(2010)
23. Moghimi A, et al., Effect of Mobile Phone Microwaves on Fetal Period of BALB/ c Mice in Histological Characteristics of Hippocampus and Learning Behaviors, Iranian Journal of Basic Medical Sciences, 12(3-4): 150-157(2009)

24. Mona Abdullah Al-Damegh, Rat testicular impairment induced by electromagnetic radiation from a conventional cellular telephone and the protective effects of the antioxidants vitamins C and E, Clinics (Sao Paulo), 67(7): 785–792 (2012).
25. Moon K, et al., Long-Term Exposure of Rats to 2.45 GHz Electromagnetic Field: Effects on Reproductive Function, IFMBE proceedings, 14(16): 2767-2769 **(**2007)
26. Orendáčová J, Effects of short-duration electromagnetic radiation on early postnatal neurogenesis in rats: Fos and NADPH-d histochemical studies, Acta Histochemica, 113(7):723-8(2011)
27. Repacholi MH, Low-Level Exposure to Radiofrequency Electromagnetic Fields: Health Effects and Research Needs, Bioelectromagnetics, 19:1–19 (1998)
28. Roushandeh AM, High-Frequency Electromagnetic Field Induces Lipocalin 2 Expression in Mouse Liver, Iranian Journal of Basic Medical Sciences, 13(3): 139-145(2010)
29. Sinha RK, Chronic non-thermal exposure of modulated 2450 MHz microwave radiation alters thyroid hormones and behavior of male rats, Int J Radiat Biol, 84 (6): 505 - 513 (2008)
30. Sivani S, Sudarsanam D, Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem – a review, Biology and Medicine, 4 (4) 202–216(2012)
31. Tomoyuki S, Norio I, et al., Multigenerational Effects of Whole Body Exposure to 2.14 GHz W-CDMA Cellular Phone Signals on Brain Function in Rats, Bioelectromagnetics, 35(7):497–511(2014).