



EFFECT OF MAGNETIC FIELD FROM MOBILE PHONE ON BRAIN

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ABSTRACT

Human exposure to electromagnetic field (EMF) comes from many different sources and occurs in various situations in everyday life. Man-made static fields are mainly found in occupational settings, such as close to magnetic resonance imaging (MRI) scanners, although DC high-voltage overhead transmission lines are being constructed, which are expected to expose larger parts of the population to static electric and magnetic fields. Today, for power regulation most modern electrical equipment uses electronics instead of transformers. Examples include the switched power supplies to laptops, drilling tools, chargers of mobile phones and similar devices. As a consequence, the frequency content of the daily magnetic field exposure has changed mainly by adding odd harmonics (150 Hz, 250 Hz, 750 Hz, etc.). In particular, the third harmonic (150 Hz) has become another dominating frequency in our environment. In particular for brain tissues, the mobile phone used at the ear remains the main source of exposure. However, since the first generation of mobile telephony, the technology aimed at reducing the emitted power of mobile handsets. In particular, for Global System for Mobile communication (GSM) already the introduction of dynamic power control reduced the average output power to about 50% of its rated value during calls, whereas the use of discontinuous transmission during voice calls gave a further 30% reduction in average emitted power. Adaptive power control became faster and more effective in the third-generation (3G) of mobile telephony systems leading to a further reduction (by about two orders of magnitude) in the specific absorption Specific energy Absorption Rate (SAR) compared to GSM phones. In addition, hands-free kits reduce the energy absorbed by the head drastically. Digital Enhanced Cordless Telecommunications (DECT) phones are another source of everyday exposure.

Indexing terms/Keywords

Magnetic field; Phone mobile; Health effects; Brain.

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INTRODUCTION

Peoples are exposed to Extremely Low Frequency (ELF) Electromagnetic Field (EMF) at their workplace as well as at the place of residence. Identifying biological effects on living bodies, due to exposure to ELF EMF have gained much attention of scientists during previous years[1]. Exposure assessment studies were carried out by considering exposure due to natural sources as well as manmade sources. There have been certain evidences which show that ELF's from manmade[2] as well as natural[3] sources are absorbed in body and hazardous to health. There are sensible scientific evidences also to establish link between Schumann resonance and sunspot relations to human health effects.[4] Various international organizations have initiated the research to determine the exact link between ELF exposure and human health [5] Exposure guidelines have been also set internationally [6] Growing concern about possible health effects, have caused extensive organizational and individual efforts to be carried out in this regards. Detailed review of these efforts can be found out elsewhere [7]

However an effort to determine possible effects of ELF EMF on brain activity, sleep disorders[8] , different electrophysiological signals and creating state of anxiety is still in its infancy. Wide research scope always exists to study effect of ELF EMFs on the modulation of brain tissue functions [9] , considering the set medical hypothesis of absorption of ELF EMF by human brain [2] Few attempts have been made by researches to study the possible exposure associated effects on behavior, anxiety and Electroencephalography (EEG). Present study was undertaken to generate detail information about efforts carried to determine proximity effects of ELF EMF on brain activity. Exposure to ELF EMF results in inducing internal fields in body. The particular threshold value of this internal field can be the triggering element which initiates biological changes. The Results of previous studies are inconsistent due to differences in exposure levels, durations and other experimental conditions. Apart from exploring the studies related to effect of ELF EMF on brain activity, this paper also suggests new areas of research in Bio-electromagnetism, medical and public health studies.

Modern technology has provided comfort and ease to human society but various other non-avoidable factors are also associated with these technical and communication devices. Electromagnetic radiations are included in these factors which are used in cell-phones and wireless devices for signal transmission [10]. Various research studies have illustrated that EMF radiations are found to be responsible for various harmful effects on health, development, reproduction, immune system, growth, sleep, skin and brain [11,12]. On the basis of various reports it has been found that EMF radiation adversely affect development which is supported by the results showing additional chick embryo mortality, significant delayed development and induced malformations in EMF exposed group as compared to normal control [13].

Various investigations have revealed the toxic effects of EMFs on brain cells of chick embryos which included increased number of apoptotic cells, degeneration of brain's tissues, severe hemorrhages and early death in embryonic stages. Similarly, other abnormal early developmental observations found trunked torsion, microphthalmia and neural tube malformations [14].

A long EMF treatment study for 45 min per day up to 21 days of development, the hatched chick birds showed higher expression of neural marker NSE (neural specific enolase) and very low expression of glycosaminoglycan as determined by immuno-histochemistry suggested that pulsed magnetic fields may be able to alter normal embryonic development and normal neural functioning [15].

The toxic effects of EMF on developing chick embryo brain cell organelles and membranes, affected blood brain barrier permeability, increased cellular apoptosis and torn blood vessels [16]. Another biochemical study on blood plasma of newly hatched chick embryos has found adverse effects of EMF exposure on endocrine system, having increased corticosterone level and decreased T 3 and T4 concentrations [17]. On the other hand, a development study has opined that EMF emitted by a mobile phone may cause derangement of chicken embryo retinal differentiation [13].

Although various researches and studies have noticed that EMF radiations are responsible for defects at tissue and differentiation level and also effect on growth rate. The present study is also an effort for determining the effect of duration and intensity of mobile phone radiation treatment on earlier stages of development [10].

The recent years have witnessed rapid worldwide growth in the use of cell phone and enormous attention about its effect on human health. This effect has raised concerns about the public exposure to radiation emitted from cell phone and the possible interaction between the radio frequency (RF) electromagnetic radiation and the biological effects on human tissues, particularly the brain and the human immune system [18].

Many research work provided evidences about the possible health effects such as; brain tumor, blood-brain barrier (BBB) permeability function, sleep problems, cognitive function, DNA damage, immunity system function and stress reaction not to mention the increased incidence rate of traffic accidents due to the use of mobile phone while driving [19] .

The risk of exposure to electromagnetic field was first highlighted and publicized in the late 1970s by Colorado study [20] that linked magnetic field exposure from power lines to the possible development of child leukemia. The amount of RF generated by cell phone is usually depends on the number of base stations around the area, the cell phone network traffic, and on how far the cell phone from base stations. The amount of the power which sent from a base station could vary from cell phone to another one even within the same area, depends on the interfering from obstacles such as buildings and trees [21]. Although, cell phones are designed to operate at power levels below a threshold for known thermal effects, radio frequency radiation could produce other kinds of effects, called biological effects.



MOBILE PHONES

Table 1. show the Historical development of mobile telephony systems (adapted from HPA [22] and Cardis et al. [23]), and lists the various mobile phone systems that have been used by the participants of the INTERPHONE study (was initiated as an international set of case-control studies focusing on four types of tumors in tissues that most absorb radiofrequency energy emitted by mobile phones) [23]. The next generations of mobile phones were expected to operate at frequency bands higher than 2 GHz. However, the transition from analogue to digital broadcasting will free a significant part of the spectrum (digital dividend), which may be reallocated to newer systems. The fourth generation (4G) of mobile phone systems in Europe is Long Term Evolution (LTE). Its main feature is fast data transmission with rates reaching up to 100 Mbps (megabits per second) downlink (from the base station to the mobile unit) and 50 Mbps uplink (from the mobile unit to the base station). Although current frequency and transmission powers of LTE mobile phones are comparable to those for 2G and 3G handsets, in the future use may be made of higher frequency bands (beyond 2 GHz) for this technology. Furthermore, coding and modulation schemes are different in the LTE system to allow for higher data rates. The data flows into several narrow frequency bands called subcarriers, which can be switched on and off. Another important aspect of LTE is the use of MIMO (Multiple Input Multiple Output) antennas, i.e. the presence of more than one antenna on the device, so that the signal can reach the latter following different routes and thus improving the quality of service. Following the tradition in the field of mobile telephony, where about every 10 years a next generation of systems is introduced, it is expected that 5G systems will be developed by 2020 to accommodate the demand for faster communications with higher data transfer rates. In this direction, EU has funded a flagship project within FP7, the METIS project (which stands for Mobile and wireless communications Enablers for the Twenty-twenty Information Society), with the objective of laying the foundation for 5G systems and building consensus prior to standardization. In order to fulfill the requirements of the test cases examined within METIS, the communicating devices must be equipped with radio access technologies at higher frequency ranges with large bandwidths. In the METIS project the highest priority for frequencies above 6 GHz was placed on frequencies between 40 and 90 GHz [24,25].

Concerning the values in Table 1., it is useful to note that the signal from most 2G terminals is pulsed. If a phone uses a TDMA (Time Division Multiple Access) technology, it transmits at regular intervals. The fraction of time that the phone transmits is given by the duty factor, i.e., a duty factor of 0.12 denotes that the phone transmits 12% of the time. The average power is calculated as the product of the maximum power with the duty factor. In the case of 3G phones (continuous transmission) the power can be up to 125 mW. This is, however, the maximum value, since in reality the output power of a mobile phone is considerably lower and is determined by the signal quality (strength). The use of Adaptive Power Control (APC) with which mobile phones reduce their output powers to allow for good signal quality gives longer life to their batteries. The network continually monitors signal quality and may reduce the emitted power of a mobile phone, by up to a factor of 1,000 for GSM and about 100,000,000 for UMTS (SCENIHR, 2009) [26].

Table 1. Historical development of mobile telephony systems

Generation	Start of commercial use in the region of next column	Region	System	Handset Band (MHz)	Base Station Band (MHz)	Burst duration(μs)	TDMA duty factor	Maximum emitted power (W) from handset	Average power (mW)
1	1981	Nordic countries France, Germany	NMT-450	453.5 – 457.5	463.5 – 467.5	-	1.0	(handsets) 0.9 car phone) 15 (version	900
	1986	Nordic countries	NMT-900	890 – 915	935 – 960	-	1.0	(handsets) 0.6 car phone) 6 version)	600
	1985	Italy, UK	ETACS	872 – 905	917 – 950	-	1.0	0.6	600
	1989	Japan	JTACS /NTACS	915 – 925	860– 870	-	1.0	0.6	600
				898 – 901	843 -846	-	1.0	0.6	600
				918.5 – 922	863.5 -867	-	1.0	0.6	600



	1987	Japan	NTT	925 – 940	870 – 885	-	1.0	0.6	600
				915 – 918.5	860 – 863.5				
				922 – 925	867 – 870				
	1985	Australia Canada, and New Zealand, Israel, USA	AMPS (N-AMPS)	824 – 849	869 - 894	-	1.0	0.6	600
2	1992	Canada, Israel, New Zealand	D-AMPS / TDMA-800	824 – 849	869 – 894	6666	1/3	0.6	200
	1993	Japan	PDC-800	940 – 956	810 – 826	3333 or 6666	1/3 or 1/6	0.8	or 133 or 266
	1994		PDC-1500	1429 – 1465	1477 – 1513				
	2003	Canada	GSM-850	824 – 849	869 – 894	576.9	0.12	2	240
	1992	All European countries and Australia Israel, New Zealand	GSM-900	890 – 915	935 – 960	576.9	0.12	2	240
	1993	All European countries and Australia Israel, New Zealand	GSM-1800	1710 – 1785	1805 – 1880	576.9	0.12	1	120
	2001	Canada	PCS (GSM-1900)	1850 – 1910	1930 – 1990	576.9	0.12	1	120
	1998	Canada	TDMA-1900	1850 – 1910	1930 – 1990	6666	1/3	0.6	200
	1998	Australia, Canada, Israel, New Zealand	CDMA-800	824 – 849	869 – 894	-	1.0	0.2	200
	1998	Japan	CDMA one	830 – 840	875 – 885	-	1.0	0.2	200
1997	Canada	CDMA-1900	1850 – 1910	1930 – 1990	-	1.0	0.2	200	
3	2001	Japan and rest of the world	W-CDMA	1920 – 1980	2110 – 2170	-	1.0	0.125	125

In a multinational study [27], software-modified GSM phones were distributed to more than 500 volunteers in 12 countries for 1 month each. The average output power of over 60,000 phone calls was approximately 50% of the maximum. The maximum power was used 39% of the time (on average) and was higher for rural areas. The fact that output power from mobile phones is higher in rural environments was confirmed by Persson et al. [28], who studied the uplink power of devices in a 3G network. In an urban environment they measured an average output power of 0.4 mW (median 0.02 mW) for voice calls and 2.0 mW (median 0.2 mW) for video upload. These results are in agreement with an older study by Gati et al. [29], who had noticed, however, that there is also a differentiation between indoor and outdoor environments, with the average output powers for voice calls in 3G systems being less than 5 mW for the former and less than 1 mW for the latter.

Mobile phones in standby mode are only active in periodic location updates, and this occurs with a frequency set by the network operator. Typical updates occur with 2-5h in between. During these time intervals the phone is to be considered as a passive radio receiver with no microwave emission (Hansson Mild et al., 2012). However, modern smart phones, which can operate in several modes other than voice and SMS transmission (e.g., by staying connected to the internet for



data transmission), seem to require location updates more often, thus contributing to the exposure of their users and the persons around them [30].

In order to assess the exposure of users to mobile phones the quantity of Specific energy Absorption Rate (SAR) is used and not the electric field directly next to its antenna, because it is not possible to measure so close to the antenna without perturbing the electric field to be measured and the operation of the phone itself. SAR is measured in W/kg and is the rate of specific absorption (SA), measured in J/kg, i.e. the rate at which energy is deposited in tissue. It is assessed with measurements in human body phantoms filled with appropriate liquids, which bear dielectric properties similar to those of human tissues. Another way of estimating the SAR is to use computational techniques and numerical phantoms derived from real humans with high resolution medical imaging techniques [31].

During the INTERPHONE study 1,233 maximum SAR values averaged over a 10g cube of tissue were registered [23]. (Cardis et al., 2011). They ranged from 0.01W/kg, which is actually the sensitivity limit for measurement equipment, to 1.7W/kg. The vast majority of values, however, were below 1W/kg. Although not statistically significant, a trend of decreasing (SAR) over a period of years was clear from this study. This trend was confirmed by Kühn et al.[32].

In epidemiological studies, cumulative specific absorption is also referred to as total cumulative specific energy and is commonly used as an exposure proxy, equivalent to dose. It is clear from the INTERPHONE study that cumulative specific absorption for the early analogue systems were manifold higher than for the next generations of handsets [23].

During operation, GSM mobile phones are the sources of magnetic fields at the ELF range. Perentos et al. [33], have measured a magnetic flux density value of less than 100 μ T at 217Hz, which is the main spectral component associated with the GSM pulses, and confirmed the presence of spectral components at 2.1 and 8.3 Hz. The maximum current density induced in the head of the mobile phone user was not larger than 28% of the International Commission on Non Ionizing Radiation Protection ICNIRP [34], limit, according to Jokela et al. [35], who measured the battery current pulses for seven GSM phones and calculated the exposure quotient in a simplified spherical head model. Ilvonen et al. [36], calculated lower values of the induced current density in a realistic human head phantom in the range of some μ A/m² about three orders of magnitude below the ICNIRP [34], limit of 2mA/m² at 217Hz.

There are some differences in energy absorption from mobile phones between children and adults. Children's heads are smaller and, therefore, mobile phones expose a larger part of their brains. Moreover, their tissues, like bone marrow, have a higher electrical conductivity due to larger water content; therefore, local energy absorption can become higher in these tissues. Nevertheless, the peak spatial (SAR) assessed with the standardized specific anthropometric mannequin (SAM) head phantom has been shown to yield a conservative exposure estimate for both adults and children using mobile phones [37]. Moreover, the value of the maximum local peak SAR in the SAM was always higher than in the adult and children models [38].

THE RADIO FREQUENCY SPECTRUM

X-rays, ultraviolet light, visible light, infrared light, microwaves, radio-frequency radiation radio frequency (RF or RFR), and electromagnetic fields from electric power systems are all parts of the electromagnetic spectrum. The parts of the electromagnetic spectrum are characterized by their frequency (or wavelength), and different electromagnetic frequencies produce fundamentally different types of biological effects. Cellular and personal communication systems (PCS) reside in the ultra high frequency (UHF) region from 300 to 3000 MHz. Here classical mathematical analysis with Maxwell's equations is usually appropriate, and there are few, if any, biological effects that cannot be attributed directly or indirectly to the heating of tissue [39].

Like any wave-related phenomenon, electromagnetic energy can be characterized by a wavelength and a frequency. The wavelength (λ) is the distance covered by one complete electromagnetic wave cycle. The frequency is the number of electromagnetic waves passing a given point in one second. The wavelength λ of an electromagnetic wave is related to the frequency (f) and velocity (v) by the expression

$$v = f \lambda \quad (1)$$

In free space the velocity of an electromagnetic wave is equal to the speed of light, i.e. , approximately 3×10^8 m/s. We usually talk about electromagnetic sources as though they produced waves of energy . However, electromagnetic energy can also act like particles, particularly at high frequencies; and the energy of these particles (photons) increases as the frequency increases. The energy carried by an electromagnetic (EM) photon ξ in Joules is

$$\xi = h f \quad (2)$$

Where h (6.625×10^{-34} Js⁻¹) is the Planck constant and f is the frequency of the wave in Hz (cycles/s). IEEE standard [40], for safety levels with respect to Human Exposure to radio Frequency Electromagnetic Fields emphasize the importance of the particle nature of electromagnetic energy because the energy per particle (photon energy) is a major determinant of what biological effects a particular frequency of electromagnetic energy will have [39].

For radio-frequency radiation, the energy flux, in watts per square meter (W/m² or mW/cm²) across a surface is called the "power density". Power density measures the strength of the incident radio-frequency radiation and is the favored metric of external exposure to radio-frequency radiation; in part because it is relatively easy to measure.

Table 2. ICNIRP reference levels for public exposure at mobile telecommunications frequencies

Frequency (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power Density (W/m ²)
400–2000	1.375f ^{1/2}	0.0037f ^{1/2}	f /200
2000 –3000	61	0.16	10

f is the frequency in MHz.

However, power density is an imperfect indicator of the relevant conditions inside an irradiated organism. Instead, scientists specify a metric of internal exposure, the specific absorption rate, SAR (in W/kg). The SAR is generally used as the dose metric in laboratory experiments, and SAR serves as the scientific basis of modern radio-frequency radiation safety standards. For typical biological tissue, the SAR is given by

$$SAR = \sigma E^2 / \rho \tag{3}$$

E is the electric field strength in the tissue, σ is the conductivity of the tissue, ρ is the mass density of the tissue. The SI unit of SAR is W/kg. The International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998) has recently recommended power-density guidelines for limiting exposure of the general public to RF radiation. These limits keep humans from being overheated by restricting exposures to levels that are relatively weak, compared, for example, to summer sunshine, which peaks at roughly 1000 W/m². Table 2. presents the ICNIRP reference levels for public exposure at mobile telecommunications frequencies (ICNIRP, 1998). The maximum allowed level is 10W/m² (1mW/cm²) [41].

EFFECTS OF RADIATION

In terms of potential biological effects, the electromagnetic spectrum can be divided into four portions with three of these portions being of Non-Ionizing part of spectrum [41] as follows :

- 1- The non-ionizing portion of the spectrum, which can be subdivided into :
 - a. The optical radiation portion, where electron excitation can occur (e.g., visible light ,infrared light).
 - b. The portion where the wavelength is smaller than the body, and heating can occur (e.g., microwave ovens, mobile phones, broadcast TV, FM radio). See Fig.1.
 - c. The portion where the wavelength is much larger than the body, and heating seldom occurs(e.g., AM radio, power frequency fields, static fields).
2. The ionizing radiation portion, where direct chemical damage can occur (e.g., X-rays).

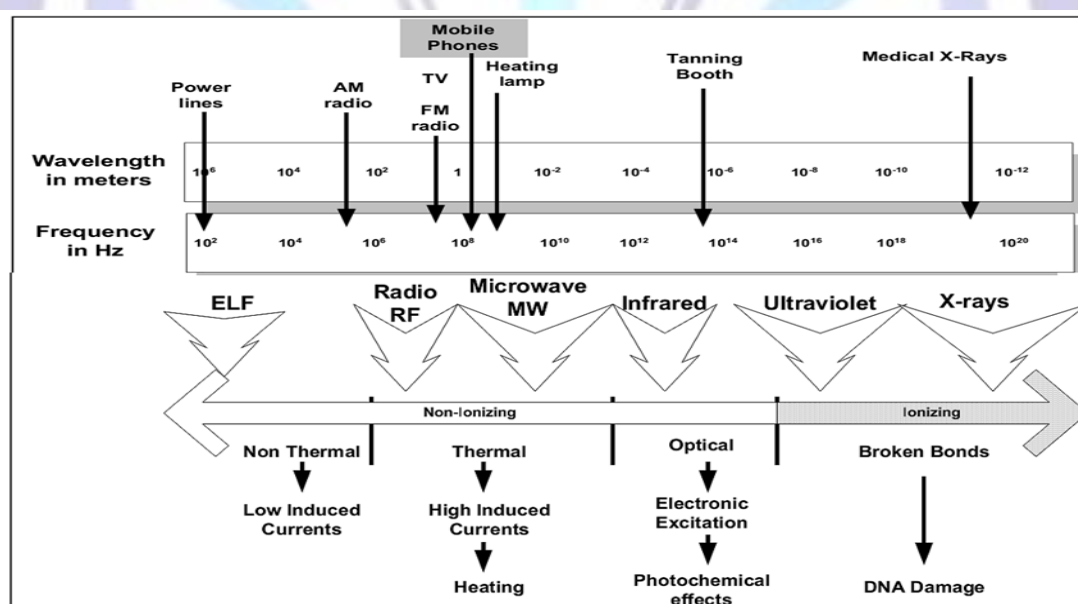


Figure1. Mobile phone position in electromagnetic spectrum

To effect a change in biological material through which it is passing, an EM wave must deposit enough energy to alter some structure significantly. But every material particle within the body already possesses an average thermal kinetic



energy (in joules, J) of the order of kT ; where k (1.38×10^{-23} J/K) is the Boltzmann constant and T is the absolute temperature (in Kelvin, K), and these particles continually collide with other particles of similar energy. For a change to occur in biological material the EM wave seemingly should transfer energy considerably above kT to selected particles, and at 310K (37°C, body temperature), kT is 4.3×10^{-21} J. Another standard of comparison is the chemical bond, because to be effective in promoting change the field should be able to deposit packets of energy larger than the bond energy, and bonds are typically within an order of magnitude of an electron volt (1.6×10^{-19} J) [41].

RESULTS AND DISCUSSIONS

Results of earlier studies on rodents have shown that the threshold at which acute RF exposure disrupts learned operant behavior lies between 2.5 and 8 W/kg whole-body SARs, with an associated rectal temperature rise of about 1°C. Deficits in the performance of a previously learned behavior occur following long-term exposure to 2.45 GHz fields at SARs as low as 2.3 W/kg whole-body exposure [42].

Blood-brain barrier, which prevents large molecules from crossing into the cerebrospinal fluid from the blood, might be susceptible to low level pulsed RF fields. Frey et al. [43], reported increased penetration of the blood-brain barrier of anaesthetized rats after acute low level exposure to pulsed or continuous-wave 1.2 GHz fields.

Previous studies show also little evidence that exposure to mobile phone radiation causes a stress response in mammalian cells, judged by elevated gene expression, the results on nematode worms are indicative of a non-thermal influence on gene expression [44]. Previous experiments on DNA synthesis also do not indicate changes in cell proliferation under conditions that mimic emissions from mobile phones or base stations.

Human laboratory studies of the acute effects of exposure to mobile phone signals suggest that exposure to mobile phone signals at exposure levels that fall within existing exposure guidelines have biological effects that are of sufficient magnitude to influence behavior. The causal mechanism is unclear, but could include a small, localized heating effect [45]. [However, these studies do not provide evidence directly relevant to the question of the safety of mobile phones in the long term. Experimental designs employed focus on only the consequences of short-term exposure.

Braune et al. [46] have reported acute effects on blood pressure in human volunteers exposed to a conventional GSM digital mobile phone positioned close to the right side of the head. After 35 minutes of exposure, heart rate, blood pressure and capillary perfusion were measured with the subject either supine or standing for 60 seconds. They found that the heart rate during these tests was slightly lower after exposure to RF radiation than following non-exposed control sessions, and both systolic and diastolic blood pressure were elevated by 5-10 mm of mercury.

A few epidemiological studies have directly examined the relationship of mobile phones to morbidity or mortality. Rothman et al., has examined mortality among customers of a large mobile phone operator in the USA [47]. It covered some 250,000 phone users, who were followed for one year. During this time, the overall death rate was similar in people using hand-held phones and in users of other mobile phones that didn't have an antenna in the handset, and therefore gave lower exposures to RF radiation. For those customers who had been listed as continuous users for at least three years, overall mortality was slightly lower in the hand-held phone users than the other mobile phone users, but the difference was not statistically significant (relative risk = 0.86). Numbers of brain tumor and leukemia deaths were small and showed no substantial indication of increasing risk with number of minutes of hand-held phone use per day, or with years of hand-held phone use [48]. A case-control study of 270 cases with a histopathological diagnosis of brain tumor in two regions of Sweden with 233 actually participating. Each was age and sex matched to two controls from a population register. The use of mobile (cellular) telephones over preceding years, including type of system and pattern of use was established for each case and each control. The proportion of mobile phone users was the same (38%) in each group, and no increased risk of brain tumor was found. Latency, type of tumor, position of tumor and amount of use of mobile phones were all examined for relation to tumor development. None was found [49]. These earlier epidemiological studies indicate that RF radiation is unlikely to induce or promote cancer in people.

A Larger-scale cross-sectional survey of some 11,000 mobile phone users was accomplished in Sweden and Norway [50]. This study has included information about various symptoms including fatigue, headache and warmth behind and on the ear. Of the participants, 13% in Sweden and 30% in Norway reported the occurrence of at least one symptom. For both analogue and digital phones, the prevalence of reported symptoms increased with minutes per day of phone use. The proportion of GSM phone users reporting a symptom was rather lower than in other groups.

The intensity of lipid peroxidation measured by levels of malon-dialdehyde (MDA) in the liver tissue is shown on Fig.2. The rats exposed to electromagnetic field develop oxidative stress in hepatocytes as evidenced by a significant increase in malon-dialdehyde level (MDA). The lipid peroxide level (MDA) significantly increased by 1.46 in exposed animals (2.24 ± 0.28 vs control 1.53 ± 0.21 $\mu\text{mol/g}$ proteins) which may be harmful by accelerating the loss of hepatocyte plasma membrane integrity Fig.2 [51].

Some brain structures are especially amenable to increased production of hydroxyl radicals (OH \cdot). Meanwhile, brain tissue are deficient of antioxidant enzymes such as superoxide dismutase (SOD), glutathion peroxidase (GSH-Px) and catalase (CAT). The distribution of these enzymes is unequal in different brain parts and it is age dependent [52].

The study [51], provides important findings related to oxidative stress in the brain and liver of animals exposed to mobile phones. We demonstrated that mobile phones caused oxidative damage in the brain and liver biochemically by increasing the levels of lipid peroxidation and MDA concentration Fig.2.

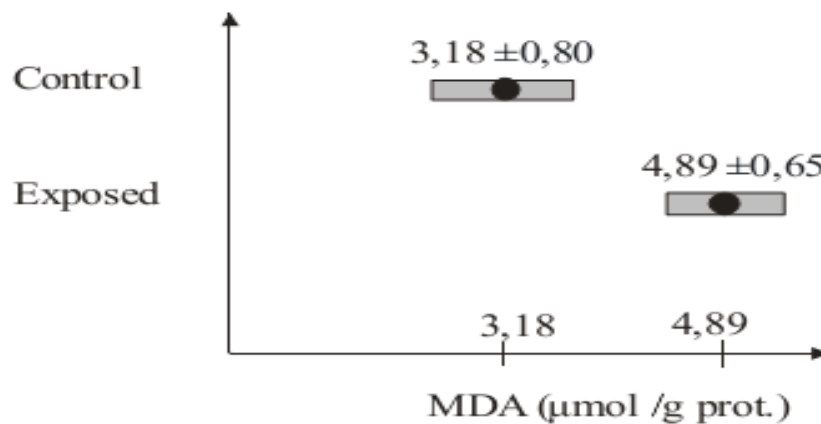


Figure 2. The intensity of lipid peroxidation in the brain tissue

Soroush Seifirad et al. [53], Show that rats were randomly allocated in five groups, no significant differences were observed between the mean weights of rats. (p value > 0.05). Normal distribution of data was observed between groups. Serum levels of high density lipo-protein (HDL) and MDA. We observed a significant increase in the serum levels of conjugated diens (CD) in one time exposed rats (4 hrs, 60 Hz) compared to the sham exposed group (p value < 0.000). After 72 hours, serum CD levels were decreased and normalized (p value > 0.05).

A similar pattern was observed in chronic exposed rats, however the increased CD levels were more remarkable compared to one time exposed rats (p value < 0.000). Serum levels of MDA, as a late marker for peroxidation, were also measured to assess the effect of ELF-MF exposure on lipid peroxidation. At the end of the study, MDA levels in one time exposed rats were slightly higher compared to the control group but the observed difference was not statistically significant (p value = 0.990). In chronic ELF-MF exposed group, serum MDA levels were even higher than the one time exposed group and were remained high after three days (p value < 0.000) [53].

Soroush Seifirad et al. [53], evaluate effects of acute and chronic ELF-MF exposure on serum lipid profile, lipid peroxidation, antioxidant system, and paraoxonase activity as mediators protecting against a thermogenesis and atherosclerosis. According to the results of this study, ELF-MF exposure changed lipid profile, increased lipid peroxidation, and affected antioxidant system.

Paraoxonase, HDL and serum total antioxidant capacity parallel alterations reflects their similar functions as measurements of antioxidant system. In this study, one time acute exposure to ELF-MF slightly increased their serum levels which showed that antioxidant system has been evoked. These mediators levels were normalized after 3 days in short time exposure, however after chronic exposure, antioxidant capacity remained low after 72 hours. Antioxidant capacity could be repaired after exposure, but its' ability to repair is dependent on duration and continuity of ELF-MF exposure. It should be noted that observed differences in HDL levels were not clinically significant; clinical significance of the above statistically observed differences needs further evaluation [53].

This study [53], evaluating the paraoxonase alterations after acute and chronic ELF-MF exposure. According to the results of Torres-Duran et al. serum HDL levels were increased after acute one time exposure to ELF- MF (Hz). Their results were in accordance with our findings [54], It has been shown that paraoxonase has antioxidant properties and could prevent cell-mediated oxidative modification of low density lipoprotein [55]; hence, impaired paraoxonase activity could increase risk of atherosclerosis due to increased lipoprotein peroxidation [56].

CONCLUSIONS

- Some new research results show no association between brain tumor and mobile phone radiation. Others, however, suggest that mobile radiation double the risk of developing cancer on the side of the head used, increase brain activity, can cause damage to nerves around ears and, more importantly, damages the BBB. Al though research studies on the impact of Mobil e phones radiation on health remains inconclusive, previous research results has taken the prevention of heating effects as a basis for exposure guidelines. But new research recent results demonstrate that mobile phones can affect cells without heating them.
- The ICNIRP guidelines was set based on the behavioral changes when experimental animals are exposed to RF radiation at levels which produce temperature rise of more than 1C o Therefore, new research results raise the question about the effectiveness of the ICNIRP exposure guidelines to prevent health implication to human. In fact some countries are starting to impose new exposure measures. For example, China is planning a new strict standards that would cap handset radiation emissions at half the levels allowed elsewhere.
- The amount of radiation that can be passed from a handset to a user, the SAR, will be limited to 1 Watt/ Kgm instead of 2Watt/ Kgm Even with those studies that show no relation between brain



tumors and mobile phones radiation, such investigations do not measure risks for cancers such as brain tumors with longer latency periods of induction or for slow growing tumors. Mobile phones have not been in use for long enough to allow comprehensive epidemiological assessment of their impact on health.

- Literature review indicated that the strength and exposure duration of ELF EMF has been found to be playing key role in initiating effects related to brain ,anxiety, sleep disorder, behavioral studies and electrophysiological signals.
- Wider scope of research is identified to establish exact link between ELF and EMF (especially electric field) and electrophysiological signal behavior. Refined research can be still carried out in determining exact threshold value, different range of frequencies and exposure scenarios too.

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