

A Review: Source and Effect of Mobile Communication Radiation on Human Health

Antim Bala Sharma*

(Research Scholar Department of ECE) SGVU, Jaipur (Rajasthan) India-302017

Dr. O. S. Lamba

(Professor Department of ECE) SGVU, Jaipur (Rajasthan) India

Abstract

With improving technology and affordability, the number of cell phone users increases continuously. As the number of base stations required, increases with greater mobile phone use with market competition, and with new technological capabilities. The microwave frequencies used in the mobile communication causes the thermal and non-thermal effects and leaves negative impact up on biological system. The EMR emitted by the mobile antennas used at the base stations and mobile handsets used by user's effects the cell structure of the living beings. Continuous and long term exposure to this radiation can have negative impact on biological system of human beings over the years. EMR are absorbed as it interacts with matter and transfers wave energy into the medium. The amount of RF-EMW radiation energy absorbed by human tissue depends on the frequency, intensity, polarization and duration of exposure. The EMR are also recognized as the major cause of cancer. Studies indicate that the population residing near mobile phone base stations complain of nonspecific symptoms of ill-health such as headache and sleep disturbances. The aim of this paper is to produce an independent review of the recent literature on the possible biological and health effects of low intensity microwave radiation and expected methods to reduce the effects.

Keywords- Electromagnetic Radiations, Base Station, Non-thermal health effect, Specific Absorption Rate, Radio Frequency-Electromagnetic Waves, and biological effect.

I. INTRODUCTION

Cell phone technology has several advantages and has grown rapidly. Presently 80 crores cell phone users and around 4.5 lakhs cell phone towers installed to provide the communication facilities in India. The number has increased tremendously due to the reduced price of the cell phones and its portability, without considering its disadvantages. "Towers are expected to grow at 3 percent CAGR for next five years and the total number of towers is expected to grow to more than 511,000 by financial year 2020, of which 30,000 towers are expected to be only supporting data sites," Deloitte India report said. The report Indian Tower Industry: The Future is Data estimates that there are about 400,000 mobile towers which include only 700 standalone 3G and 4G towers. Rowley and Joyner (2012) gathered together tower electromagnetic field (EMF) radiation data from measurement campaigns in 21 countries around the world spread over a few years. The database of over 173,000 individual data points shows that the global average exposure level from towers is as low as 0.73 mill watt per square meter, which is over 5,000 times below the WHO endorsed radiation norm for mobile towers for the frequency range considered (4 watts per square meter at 800 MHz).

Majority of these towers are mounted near the residential and office buildings to provide good mobile phone coverage to the users. Cell phone base stations may be free standing towers or mounted on existing structures, such as trees, water tanks, or tall buildings in urban areas (residential). The antennas need to be high enough to provide maximum coverage. Typical heights for cell towers are 50–200 feet. Sector antennas for 2G and 3G transmission, broader sector antennas for 4G transmission, and parabolic microwave antennas for point-to-point communications are used in urban and suburban areas. 4G technologies use more bandwidth than 2G or 3G networks (means more exposure to radiation). To make the latest handsets (smartphones) capable of receiving the full bandwidth power of 4G networks, smartphone manufacturers are equipping them with a series of antennae in one handset. According to health experts, this further intensifies the risk of being exposed to more radiation. So 4G phones are capable of emitting more radiation as a series of antennas in a handset can receive and transmit from multiple sources. These cell towers transmit radiation 24 hour per day, and the people living within the radius of 10's of meters from the tower will receive 10,000 to 10,000,000 times stronger signal than required for mobile communication (Girish, 2010). Continuous and long term exposure to low intensity microwave radiation can have negative impact on biological system of human beings. Every cell phone has a SAR (Specific Absorption Rate) rating which has a limit of 1.6W/Kg and it is calculated to be 6 minutes (360 seconds) per day usage for a person. Considering the SAR limit, a person should not make use of cell phone for more than 24 minutes per day following the safety standards. Unfortunately, majority of the cell phone users do not have this information, as a result many people make cell phone calls for more than an hour in a day without knowing the health damage related with this issue.

So, in this paper, we have discussed Effects of Mobile Tower Radiations on human health, some case study of different location of urban environment and expected methods to reduce the effects.

II. ELECTROMAGNETIC SPECTRUM AND RF-EMF RADIATION

The RF-EMF radiation falls in the range of 10 MHz–300 GHz. Cell phone technologies uses frequencies mainly between 800 MHz and 3 GHz, 4 GHz and cell tower antenna uses a frequency of 900 or 1800 MHz, pulsed at low frequencies, generally known as microwaves (300 MHz–300 GHz) frequency.

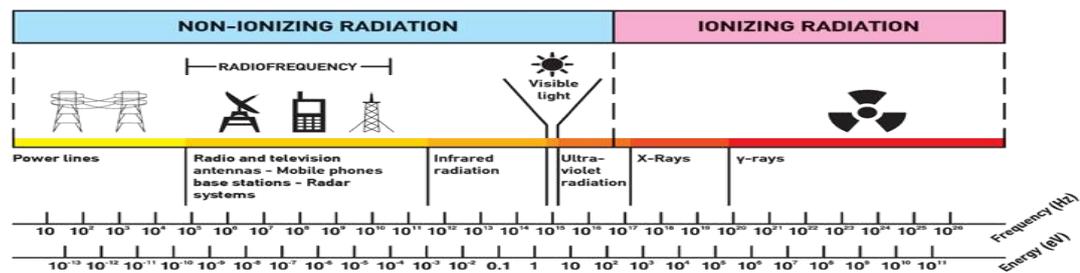


Fig. 1 Graphical representation of the electromagnetic energy spectrum

A. Electromagnetic radiation and Types-

Electromagnetic radiation can be classified based on the capability of a single photon having energy more than 10 eV to ionize oxygen or break chemical bonds. Types are: Ionizing radiation and Non-ionizing radiation [6].

1). *Ionizing Radiation*: EMR with enough energy to produce ions by interacting with matter (about 10 eV in biological systems). Examples are ultraviolet rays, X-rays, gamma rays, cosmic rays, etc. Primary health effects from ionizing radiation are destroy living tissues (acute) and Changes molecular structure which changes cell genetic tissue (chronic).

2). *Non-Ionizing Radiation*: RF energy characterized as non-ionizing radiation. The photon energies of RF electromagnetic waves are not enough to cause the ionization of atoms and molecules. Examples are radio waves, microwaves, infrared waves, etc. Primary health effect from non-ionizing radiation is heat generation in body tissue.

B. Microwave Radiation-

Microwave Radiation effects are classified as: Thermal Effects and Non-Thermal Effects. Non-thermal effects are several times more harmful than thermal effects. The

dependence between the microwave power applied in heating and the increase of temperature can be given by the equation

$$\nabla T = \frac{P * t}{V * C_p * \rho} \dots\dots\dots\text{eq. (1)}$$

Where, ∇T = Increase of mean temperature of heated body (K), P = Microwave Power used (W), V, C_p , ρ = Volume, Heat Capacity and Density (m^3 , J/kg.K, kg/m^3), t = Time of heating (Sec).

If the heat generated is small, the body's thermoregulatory mechanism can dissipate it without causing adverse effects. If the temperature exceeds this capacity, about 1 to 2 degree Celsius, tissue damage may occur. Hirata et al., [8] discussed the correlation between peak SAR and maximum temperature increase is blood flow in tissues. Anderson et al., [9], measured maximum temperature rises on the side of the face after 6 min of continuous cell phone operation. His results suggested that direct RF heating of the skin only contributes a small part of the temperature rise due to heat conduction from the handset. The following table roughly summaries the effects of static, ELF, RF and microwaves radiation which possibly could induce a biological change-

Frequency	Mechanism	Unit of deposition
Static magnetic field 0 Hz	Magnetic induction and magneto mechanical interactions	-
ELF 30 Hz – 300 Hz	Current induction in body	$A/\text{m}^2 = H_{A/m} \times f \times x$ Body length
RF & microwaves 0,1 MHz – 10 GHz	Energy deposition	SAR in W/kg
10 GHz – 300 GHZ	Surface tissue heating	Power density W/m^2

SAR = Specific energy Absorption Rate, A= Area, H = field strength

1). Interaction of microwave and human tissues-

Interaction of microwave and human tissues Human tissues are generally loss medium, microwave energy can be converted to thermal energy. When microwave propagates into these tissues, the energy of microwave will be absorbed. The specific absorption rate (SAR) of microwave energy in tissue is defined as a power dissipation rate normalized by tissue density. It is given by equation

$$SAR = \frac{\sigma}{\rho} |E|^2 \dots\dots\dots\text{eq. (2)}$$

Where E is the root mean square electric field (V/m), σ is the conductivity (S/m) and ρ is the mass density of the tissue (kg/m^3).

The microwave radiation cause the different SAR and temperature increase in human body at each frequency and power of heating source. Siriwitpreecha, analyzed that the maximum SARs and temperature increases are proportional to the power of heating sources. The low frequency of microwave can penetrates through the human body deeper than that of the high frequency [20].

III. SOURCES OF EM RADIATIONS IN TELECOMMUNICATION

EMR from mobile communication are categorized under of non-ionizing radiations. Different types of monitoring system are used to monitoring the continuous exposure of electromagnetic radiations that are radiated by cellular base stations antennas and also mobile units and other RF sources of radiation levels. Monitoring and comparing with FCC and also ICNIRP levels are prescribed for general public. There are two primary sources of EMR in mobile communication.

A. Radiations from Cell Phone Towers

Different type of base stations used by operators and they include the macro cell, micro cell, or pico cell in India. Macro cellular base station provides the main infrastructure for a mobile phone network and their antennas are mounted at sufficient height to give them adequately geographical coverage. The maximum power for individual macro cellular base station transmitter is 20 W. According to FCC (1999), depending on the cell tower height, the majority of cellular base stations in urban and suburban areas operate at an effective radiated power (ERP) of 100 W per channel or less. ERP is a quantity that takes into consideration transmitter power and antenna directivity. An ERP of 100 W corresponds to an actual radiated power of about 5–10 W, depending on the type of antenna used. In urban areas, an ERP of 10 W per channel (corresponding to a radiated power of 0.5–1 W) or less is commonly used. In India, cell tower sites transmit hundreds of watts of power with antenna gain of 50, so ERP sometimes equals 5000 W (Kumar, 2010). A mobile tower provides wireless communication link between the user and the network. It has a number of radio-transmitters which are combined and fed to Base station antenna through cables. So, the total radiated power will be equal to the sum of output from each transmitter. The maximum exposure to radiations will be at the peak hour when all the channels are used and the sector having the highest call traffic will have the highest exposure to EM radiations. Typical heights of these antennas are 15-50 meter from ground. A base station may consist of several “omni directional” antennas, each one is directed to a certain geographical direction, and the signal from this antenna is directed to cover the desired area in a relatively narrow beam in the vertical plane. Gain of antennas and transmission power levels also play a vital role in assessing the exposure of EM radiations from BTS. Omnidirectional antennas have higher gain than sector antennas which provide high efficiency and coverage but the risk of exposure also

increases. The primary lobes exhibit the maximum radiations in horizontal direction. Radiations from secondary lobes range from medium to low [6]. The level of radiation starts decreasing as we move away from the line of antenna to its side lobes. EM radiation from mobile towers depends on frequency, distance and duration of exposure.

B. Radiations from mobile phones

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. 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 [7]. 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. Every mobile phone comes with a SAR rating (although some manufacturers try to hide it). In Figure 3, we show a calculation of specific absorbed radiation (SAR) distribution in an anatomical model of human head positioned next to a 125 mW dipole antenna. The resulted Peak SAR is 9.5 W/kg over 1 mg which is a clear indication of the effect.

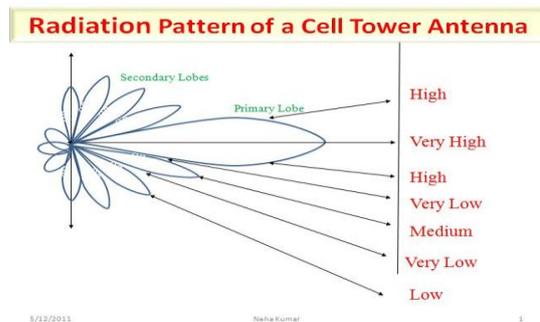


Figure 2. Radiation pattern of Cell Phone Tower

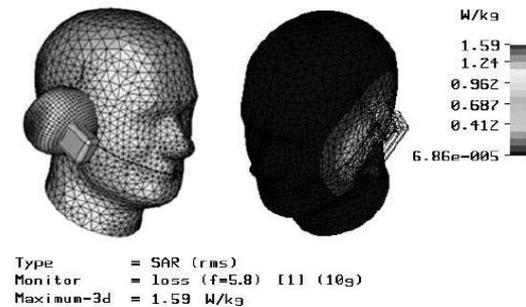


Figure 3: Calculation of Specific Absorbed Radiation (SAR)

The IEEE and many national governments [11] have established safety limits for exposure to various frequencies of electromagnetic energy based on SAR, mainly based on the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines [12].

IV. EFFECT OF EMR ON HUMAN HEALTH

Public is being exposed to continuous, low intensity radiations from these towers. The EMR radiations, also known as electrosmog cannot be seen, smelt or felt, one would

not realize their potential harm over long periods of exposure until they manifest in the form of biological disorders. EMR is a form of energy emitted and absorbed by charged particles, which exhibits wave like behavior as it travels through space (Wikipedia, 2012). The effects of EMR (Wiki, 2014) upon biological systems depend both upon the radiation's power and frequency. For lower frequencies of EMR up to those of visible light (i.e., radio, microwave, infrared), the damage done to cells and also too many ordinary materials under such conditions is determined mainly by heating effects, and thus by the radiation power. By contrast, for higher frequency radiations at ultraviolet frequencies and above (i.e. X-rays and gamma rays) the damage to chemical materials and living cells by EMR is far larger than that done by simple heating, due to the ability of single photons in such high frequency EMR to damage individual molecules chemically (Wikipedia, 2012). When a human body is exposed to the electromagnetic radiation, it absorbs radiation, because human body contains 70% of liquid. The human height is much greater than the wavelength of the cell tower transmitting frequencies, so there will be multiple resonances in the body, which creates localized heating inside the body. Continuous exposure to low intensity microwave radiations cause serious health problems over the years. This results in boils, drying up the fluids around eyes, brain, joints, heart, abdomen etc. EMR is a form of energy emitted and absorbed by charged particles which can be harmful to human body depending upon the radiated power density and the distance from the transmitter.

A. Interaction of electromagnetic fields with biological systems-

A major determinant for the induction of current or heat (energy) in a biological or non-biological system is frequency. The unit of deposition is current density (A/m^2) which depends on the field strength (H in A/m), the frequency and the body length. Exposure to ELF does not result in a deposition of energy in the body, whereas exposure to RF and microwaves, (such as 900 MHz and 1800 GSM-radiation etc.) does. The measure of the energy deposition or absorption in the body is the SAR. The energy of all electric, magnetic and electromagnetic fields is orders of magnitudes below that of ionizing radiation. Whereas ionizing radiation produces biochemical effects such as breaking covalent chemical bonds, generation of ions and other reactive chemical species, the primary consequence of the interaction of electromagnetic fields with biological systems is likely to be the induction of currents. These may invoke the formation of electric dipoles and/or the reorientation of dipoles already present. With cellular and animal systems no consistent relationship has been found between effects and either time varying or varying field strength at frequencies below 100 kHz and current density at or below $10 A/m^2$. At these levels of exposure, indeed, heat deriving from absorption of electromagnetic energy is well below that due to normal metabolic processes.

B. Biological effects of cell phone and cell tower radiation-

When a human body is exposed to the electromagnetic radiation, it absorbs radiation, because human body consists of 70% liquid. It is similar to that of cooking in the

microwave oven where the water in the food content is heated first. Microwave absorption effect is much more significant by the body parts, which contain more fluid (water, blood, etc.), like the brain which consists of about 90% water. Effect is more noticeable where the movement of the fluid is less, for example, eyes, brain, joints, heart, abdomen, etc. Also, human height is much greater than the wavelength of the cell tower transmitting frequencies, so there are multiple resonances in the body, which creates localized heating inside the body. This results in boils, drying up of the fluids around eyes, brain, joints, heart, abdomen, etc.

V. BIOLOGICAL HAZARD

There are various short-term and long-term effects from mobile radiations. Several health hazards associated with cell phones and cell towers are-

A. *The Blood Brain Barrier*

The brain is protected by tight junctions between adjacent cells of capillary walls by the blood-brain barrier (BBB), which selectively lets nutrients pass through from the blood to the brain, but keeps toxic substances out. A single two-hour exposure to a cell phone just once during its lifetime permanently damaged the blood-brain barrier. So there is a risk that disruption of this protection barrier may damage the brain. Hardell et al, [17], and Repacholi et al.,[14], reported risk of developing brain tumor due to the exposure to EMF radiation generated by cell phone. Besides increase in brain tumour and acoustic neuroma, there is an increased risk of several other types of cancers following prolonged exposure to mobile phone/ tower radiation, such as, salivary gland tumors, uveal melanoma, lymphoma, facial nerve tumors, skin, blood, testicular and breast cancer. Interphone study in May 2010 has also found a 'significantly increased risk' of some brain tumors for heavy users of mobile phones (> 20 minutes per day) for a period of 10 years or more. This is later substantiated by International Agency for Research in Cancer (IARC), part of WHO (World Health Organization) in May 2011.

B. *Risk to Pregnant Women*

A pregnant woman and the fetus both are vulnerable because of the fact that these RF radiations continuously react with the developing embryo and increasing cells. Microwave radiation can damage the placental barrier; the membrane which prevents the passage of some materials between the maternal and fetal blood, protecting the fetus, implying that pregnant woman should avoid exposure to cell phone and tower radiation.

C. *Risk to Children*

Children are more vulnerable to cell phone radiation as they absorb more energy than adults from the same phone owing to their smaller head and brain size, thinner cranial bones and skin, thinner, more elastic ears, lower blood cell volume, as well as greater

conductivity of nerve cells and the energy penetrates more deeply. Children's cells reproduce more quickly than adults which make cancers more deadly. Tracy Lightfoot et al., [13] found memory errors, cognitive function and mental health problems due to exposure to EMF. Ching et al., [15] has confirmed decreases in skin resistance [16].

D. Irreversible Infertility

In 2006, the American Society for Reproductive Medicine reported that use of cell phones by men is associated with decrease in semen quality, sperm count, motility, viability and normal morphology and is related to the duration of cell phone use. Studies have found 30% sperm decrease in intensive mobile phone users, in addition to damage of sperms. Radiation from cell phone can also produce DNA breaks in sperm cells that can mutate and cause cancer. Damage to sperm DNA increases the risk further and can pass on the genetic changes to subsequent generations. Cellular telephone frequencies can lead to damaged DNA. Studies show that microwave exposure at levels below the current FCC exposure standard, produces single and double strand breaks in DNA. Microwave radiation can also interfere with the natural processes involved in DNA replication and repair. Another possibility of DNA damage is via free radical formation inside cells. Free radicals kill cells by damaging macromolecules, such as DNA, protein and membrane and are shown to be carcinogenic [23]. Damage to DNA is a central mechanism for developing tumors and cancer. When the rate of damage to DNA exceeds the rate at which DNA can be repaired, there is the possibility of retaining mutations and initiating cancer. DNA damage in brain cells can affect neurological functions and also possibly lead to neurodegenerative diseases. Phillips et al.[10], reported DNA damage due to exposure to EMF radiation. Hardell et al., [14] Muscat et al., [18] found that exposures cause DNA damage and induce chromosome breaks. The study present the results of two case-control studies on benign brain tumors diagnosed during 1997-2003 including answers from 1,254 cases and 2,162 controls

E. Risk to Patients Carrying Pace Makers

The RF Exposure can adversely affect the heart: Pace Maker, Implantable Cardiovascular Defibrillators (ICDs) and Impulse Generators and become arrhythmic. These radiations produced by cell phone can interfere with the implanted pacemakers and stop to delivering pulses in a regular way or may generate some kind of external controlling pulse putting the patient to death.

F. Effect on Skin

Radiation from cell towers and mobile phones affects human skin. The radiation degrades the immune system and stimulates various allergic and inflammatory responses. The effect of Non-ionizing high radiation are Rashes /sores, redness of skin, crawling, biting and stinging sensations, and granules, threads or black speck-like materials on or beneath the skin.

G. Tinnitus and Ear Damage

The radiation emitted by mobile phones may damage the delicate workings of the inner ear, and long-term and intensive mobile phone use for more than four years and for longer periods than 30 minutes in a day are at a higher risk of developing hearing loss, which cannot be reversed. Today, more and more young people between 18 and 25 years of age are suffering from hearing loss, which doctors say is due to excessive use of mobile phones and other gadgets. Anyone who spends two to three hours on the cell phone every day runs the risk of partial deafness over three to five years. The problem starts with a pain in the ear that gradually develops into tinnitus or a ringing sensation which finally leads to hearing loss and ear tumour.

H. Effect on Eye/ Uveal Melanoma

Frequent use of mobile phones can also damage the visual system in many ways and cause uveal melanoma i.e. tumor of the eye. Increase in temperature close to the eye lens (as low as 3°C) can result in lens opacities and increase the risk of developing cataracts in humans, a condition characterized by clouding in the natural lens of the eye and lens opacities. Prolonged exposure to microwave radiation can lead to both macroscopic and microscopic damage to the lens and part of this damage seems to accumulate over time and does not heal.

I. Other Hazards

Electromagnetic fields have been shown to affect the brain physiology. Use of the cell phones before bed, delays and reduces sleep, and causes headaches, confusion and depression. The findings are especially alarming for children and teenagers as they use cell phones at night and also keep the phone next to their head; which may lead to mood and personality changes, depression, lack of concentration and poor academic performance. The percentage increase in sleep disturbance is proportional to the exposure dose. It has been reported that even at radiation density of 10 $\mu\text{W}/\text{m}^2$, disturbance in the sleep is of the order of 35%. When the transmitter was turned off, the symptoms resumed gradually.

Various studies are conducted in India on health hazards of EMR radiations on human body [21-23]. Majority of the subjects who were residing near the mobile base station complained of sleep disturbances, headache, dizziness, irritability, concentration difficulties, and hypertension.

VI. SAFETY GUIDELINES

EMR exposure at the highest frequencies is a source of serious biological damage. However, everyone should be aware that exposure to such radiation may not be completely safe at certain power levels and frequencies. It is always a good idea to avoid unnecessary radiation exposure whenever possible [9]. Health effects from

exposure to this form of radiation vary from no effect at all to death, and can cause diseases such as leukemia or bone, breast, and lung cancer. From the above discussion we come to know that EMR affects the human health. To protect ourselves, we just ensure to take some precautions-

- Human beings should spend less time on the cellular phones.
- Cellular phones with a lower specific absorption rate (SAR) should be used.
- Use of cell phones should be limited in case if children below 10 years.
- It should be avoided to make calls with a low signal and low battery as the cell phone will generate more radiation in an effort to compensate for it.
- For talking, keep your cell phone away from body. Use some hands-free device such as earphones or Bluetooth while communicating. Use more of landline phones as they use analog signals.
- Either keep your calls short or send a text message (SMS) instead. This advice applies especially to children, adolescents and pregnant women.
- People having active medical implants should keep their cell phone at least 30 cm away from the implant.

VII. CONCLUSION

Continuous exposure to EMR is harmful and can have adverse effect on human body depending upon the frequency, distance and duration of exposure. Out of all the mobile phone towers in metropolitan cities, almost 45% of them are illegal. They did not follow the norms that are set for the purpose and ignorantly put the lives of people at risk of cancer and other disastrous ailments. It is always recommended to avoid the unnecessary exposure to EM fields whenever possible. Though technology makes our life very comfortable but at the expense of our health, it is our first duty to save our life. Need to develop health based precautionary guidelines in the Country.

REFERENCES

- [1] Prof. Girish Kumar, "Report on Cell Tower Radiation," Submitted to Secretary DOT, Delhi, December 2010.
- [2] Prof. Sujoy K. Guha, Prof. Sudarsan Neogi, Prof. Girish Kumar, "Report on Cell Phone Towers Radiation Hazards," Submitted to West Bengal Environment Minister (Dr. Sudarsan Ghosh), October 2011.
- [3] [ICNIRP] International Commission on Non-Ionizing Radiation Protection. 1998.
- [4] Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Physics [Internet]; 74(4): 494-522. Available from: <http://www.icnirp.de/documents/emfgdl.pdf>.

- [5] [WHO] World Health Organization. EMF World Wide Standards Database [Internet]. Available from : <http://www.who.int/docstore/peh-emf/EMFStandards/who-0102/Worldmap5.htm>
- [6] [FCC] Federal Communication Commission. 1997. Guidelines for the environmental effects of radiofrequency radiation [Internet]. ET Docket 93-62. Available from: <http://www.fcc.gov/oet/dockets/et93-62/>
- [7] “Information paper On Effects of Electromagnetic Field Radiation from Mobile Towers and Handsets” by Telecom Regulatory authority of India.
- [8] Inskip PD, Tarone RE, Hatch EE, “Cellular telephone use and brain tumors,” *N. Engl J Med*, 344:79-86, 2001.
- [9] Hirata, “ Peak spatial-average SAR and temperature increase due to antennas attached to human trunk,” *Journal of the American College of Cardiology*, Volume 48 , Issue 1 , Pages 185 – 186, 2006.
- [10] Anderson V, Joyner KH, “Specific absorption rate levels measured in a phantom head exposed to radio frequency transmissions from analog hand-held mobile phones,” *Bioelectromagnetics*, 16:60-69, 1995.
- [11] *Electromagnetic Fields and Human Health*, by, Ph.D., Professor of Radiation Oncology
- [12] "Standard for Safety Level with Respect to Human Exposure to Radio Frequency Electromagnetic Fields,3KHz to 300GHz". IEEE STD (IEEE) C95.1. Oct 2005.
- [13] International Commission on Non-Ionizing Radiation Protection, “Guidelines for limiting exposure to time- varying electric, magnetic, and electromagnetic fields (up to 300 GHz)”, *Health Physics* 74 (4), April 1998
- [14] Preece AW, “Mobile phones and human heads,” *Neuro Report*, Vol 11 No 2, 2000.
- [15] Chang Nam Ki , Sung Woo Kim, “Effects of RF exposure of teenagers and adults by CDMA cellular phones, *Bio electromagnetics* Volume 27 Issue 7, Pages 509 – 514, 2006.
- [16] Ashraf Aly and Frank barnes, “Effects of 900-MHz Radio Frequencies on the Chemotaxis of Human Neutrophils-in-Vitro,” *IEEE Transactions On biomedical Engineering*, VOL. 55, NO. 2, 2008.
- [17] Harell L, Carlberg M, Hansson Mild K, “ Pooled analysis of two case-control studies on the use of cellular and cordless telephones and the risk of benign”
- [18] Muscat JE, ”Handheld Cellular Telephone use and Risk of Brain Cancer,” *JAMA;the journal of the American Medical Association* 284.23:3001-7, 2000.
- [19] World Health Organisation (WHO), Media centre, electromagnetic fields and public health: Mobile phones (2011).

- [20] Chia, S. E., Chia, H. P., & Tan, J. S. "Prevalence of headache among handheld cellular telephone users in Singapore": A community study. *Environmental Health Perspectives*, 108(11), 1059-1062, (2000).
- [21] A. Siriwitpreecha¹, T. Wessapan and P. Rattanadecho "Computational Analysis of SAR and Temperature Distributions in Human Body Exposed to Microwave":The Second TSME International Conference on Mechanical Engineering 19-21 October, 2011, Krabi.
- [22] Singh K, Nagaraj A, Yousuf A, Ganta S, Pareek S, Vishnani P. *J Int Soc Prev Community Dent* "Effect of electromagnetic radiations from mobile phone base stations on general health and salivary function". 6:54-59, 2016.<http://www.ncbi.nlm.nih.gov/pubmed/?term=27011934>
- [23] Lalrinthara Pachuau¹, Zaithanzauva Pachuau," Study of Cell Tower Radiation and its Health Hazards on human body",2014
- [24] Blackman, C. "Cell phone radiation: Evidence from ELF and RF studies supporting more inclusive risk identification and assessment", *Pathophysiology*, 16(2/3), 205-216, (2009)

