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Environmental and Biological Effects of Cell Phone Radiation: A Review

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Abstract

In 21st century almost every person uses cell phone throughout the world. However, the exposures of radiation emitted by the cell phone are not known to the individuals. Enormous exposure of unwanted electromagnetic radiation emitted by cell phone in human life is increasing and expected to be in peak coming days due to the technological innovation such as 5G may have serious health hazards. There are numerous reports stated that radiation emitted by cell phone may be responsible biological as well as environmental hazards. However, due to the lack of awareness and knowledge of radiation emitted from cell phone, we expose our self in unnecessary radiation. Therefore, our main aim of the review article is to collect data from different studies and bring it up about the affect of cell phone radiation in human as well as in environment. The review also will focus on its exposure standards and its health and environmental implications, precautionary measure to avoid effect of cell phone radiation.

Keywords: Biological effect; Radiation; Radiofrequency radiation; SAR; Wireless technology;

Introduction

In 1979, the first cellular system in the world became operational by Nippon Telephone and Telegraph (NTT) in Tokyo, Japan. Two years later, the cellular reached Europe. In the United States, the Advanced Mobile Phone System (AMPS) was launched in 1982. Ten years later, 2G network was introduced in Finland which incorporated more advantages such as GSM (Global System for Mobile Access) to accesses internet and digital radio signal to offer more security over 1G spectrum (Sharma.2013).

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

In early 21st century, telecommunication industry was accelerated with the advent of CDMA (Code Division Multiple Access) and WCDMA (Wideband Code Division Multiple Access) technologies in Japan. This has started the era of 3G where the frequency ranges were 800–900 MHz and 1700–2100 MHz depending on the choice of the carrier. In 2010, the industry was further electrified with the inception of the concept of OFDM (Orthogonal Frequency division multiplexing). Internet speed was reached up to 100 Mbps in 4G networks where the frequencies were in the 700 MHz, 1700/2100 MHz and 2500–2690 MHz ranges. The fifth-generation wireless technology (5G) comprises with very high bandwidth with a faster data providing technology than 4G LTE (Long Term Evaluation) network. South Korea is the first country which has claimed to launch 5G in 2019. All these technology emits specific ranges of radiation.

It is believed that mobile phones produces Radio frequency (RF) energy of non-ionizing radiation which is too low to heat the tissues of the body, and hence is unlikely to have the same impact on human health as those produced by ionizing radiations such as X-rays. This fifth-generation wireless system is capable of supporting as much as 1000 users at a time though this number is further increasing (10000 and above) with the available technological supports of today's mobile world. The 5G technology deploy the millimeter waves in the ranges of low (0.6 GHz- 3.7 GHz), medium (3.7 GHz -24 GHz) and high (24 GHz and higher) frequencies. To quantify the biological damages associated with the exposure in electromagnetic radiation, there is a quantity called SAR (Specific Absorption Rate) which is defined as, where S = Electrical conductivity of tissue=Electric Field and r = mass density. This specific energy absorption rate of tissue is measured in watt per kilogram (W/kg). Tissue damage may occur if there is heat generation more than 1-2 ºC.

International Commission for Non-Ionizing Radiation Protection (ICNIRP) have recommended SAR limit (Table 1 and 2)(ICNIRP. 2009)

According to the guidelines of various international agencies, millimeter wavelength devices above 6 GHz (Federal Communications Commission) and above 10GHz (International commission on Non Ionizing Radiation Protection) need to be measured with power density (Fields 1997; ICNIRP. 2009). The maximum recommended permissible exposure (MPE) of FCC in terms of power density for frequencies between 1.5 and 100 GHz is 10 mW/cm^2 over a 30 minutes period (Fields 1997, Romanenko et al., 2014). The ICNIRP guidelines for non-thermal radiation protection are basis of the standards used worldwide (ICNIRP. 2009; Hardell.2017).

Here the effects on nerve stimulation and the other restrictions due to direct radiofrequency EMF effects within the ICNIRP guidelines have not been redefined (ICNIRP. 2010). Radiofrequency EMFs can generate heat in the body and it is important that this heat is kept to a safe level (ICNIRP. 2020). The Australian Radiation Projection and Nuclear Safety Agency (ARPANSA) have published a radiation projection for the maximum exposure level to RF-Field of frequency range 3kHz to 300GHz (Wood.2002). ICNIRP and ARPANSA guidelines for exposure limit of radiations are given in table3. Based on the ICNIRP and ARPANSA

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

guidelines if radiation level exposure increases beyond the limit, harmful effect of the radiation may be seen. Therefore, in this article we have emphasized to give an overview of environmental and biological effects of the radiation that's might help to the researches as well as common people to understand the harmful effects of cell phone radiation.

Environmental effects

The effect of RF-EMF has been studied only for short period on frogs, honey bees, residence sparrows, bats, and even people in India. However, there are very few reports on long term study across India. According to Sivani and Sudarsanam, alternation of cellular cellular metabolism such as calcium influx, morphology, blood-brain barrier, neurotransmitter activities and gene and protein expression in certain types of cells may occur at lower intensities due to RF-EMF radiation (Sivani and Sudarsanam.2012). To avoid the damage to the bio system and ecosystem it necessary to identify the frequency, intensity and duration of non-ionizing electromagnetic field which will help to use of wireless technology to enjoy its immense benefits with no side effects to health and environment.

Studies of RF radiation on plant indicates that top of the tress tend to dry if the trees are directly facing to the cell tower antennas. They also established that, the effect of cell tower radiation is higher when the plant roots are close to the water (Belyavskaya.2004). Another study was conducted on fruit bearing tress which revealed that due to the installation of cell tower near a farm, the out of fruit reduced drastically from 100% to 5% within 2.5 years (Kumar and Kumar. 2009). Sensitivity of nature towards the magnetic and electric field was studied. It is reported that sensitivity to electromagnetic field caused the disappearance of various species of birds, bees and other flying insects (Warnke.2007). In 2010, Sharma and Kumar reported that beehives exposed to 900MHz for 10 minutes results colony collapse disorder (CCD) with sudden vanishing of hive's occupants leaving only queen, eggs and a few inexperienced workers behind. The worker bees navigational skill is affected and their arriving duration to the hives are extended up to 10 days and egg production rate in queen bees have also been changed significantly from 350 eggs/ day to 100 eggs/day (Sharma and kumar.2010). Another study reported the effects of electromagnetic exposition by DECT telephone on the behaviors of honeybees. They studied foraging flight under the influence of electromagnetic radiation. The study found that there are navigational confusion, less honey production, and reduced bee survivorship on exposing of the radiation (Kimmel et al. 2007). Rubin et al. reported that EMFs from telecommunication infrastructure interfere with bees' biological clocks that enable them to compensate properly for the sun's movements. As a result, they may fly in the wrong direction when attempting to return to the hive (Rubin et al., 2006). A study conducted by Panagopoulos et al., in the year 2004 in University of Athens on fruit flies exposed to 6 minutes of 900 MHz pulsed radiation for 5 days showed the reduction in reproductive capacity (Panagopoulos et al., 2004). Likewise in 2007, in both 900 and 1800 MHz, similar changes in reproductive capacity with no significant difference between the two frequencies were observed (Panagopoulos et al., 2007). He concluded that, the

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

reason behind the degeneration of large numbers of egg chambers after DNA fragmentation due to radiation (Panagopoulos et al., 2010). When Drosophila melanogaster adult insects were exposed to the radiation of a GSM 900/1800 mobile phone antenna at different distances ranging from 0 to 100 cm, these radiations decreased the reproductive capacity by cell death induction at all distances tested (Levengood.1969). Amphibians are sensitive to EMF because their skin is always moist, and they live close to, or in water, which conducts electricity easily (Hotary and Robinson.1994). Toads when exposed to 1425 MHz at a power density of 0.6 mW/cm^2, develops arrhythmia (Sivani and Sudarsanam.2012). Increased mortality and induced deformities were noted in frog tadpoles (*Rana temporaria*). A study by the Centre for Environment and Vocational Studies of Punjab University reported that embryos of 50 eggs of house sparrows were damaged after being exposed to mobile tower radiation for 5–30 minutes (http://www.indiaenvironmentportal.org.in/content/341385/report-on-possible-impacts-of-communication-towers-on-wildlife-including-birds-and-bees/). Observed changes included reproductive and coordination problems and aggressiveness. Tower-emitted microwave radiation affected bird breeding, nesting, and roosting in Valladolid, Spain. Electromagnetic radiation can exert an aversive behavioral response in rats, bats and birds such as sparrows (Manville.2009).
Another study reported that storks were heavily impacted by the tower radiation during the 2002–2004 nesting season in Spain. In nesting sites located within 100 m of one or several cell phone tower antennae with the main beam of radiation impacting directly (Electric field intensity >2 V/m), and many young birds died from unknown causes. Couples frequently fought over nest construction sticks and failed to advance the construction of the nests. Some nests were never completed and the storks remained passively in front of cell site antennae. These results indicate the possibility that microwaves are interfering with the reproduction of white stork. Evidence of a connection between sparrows declined in UK and when introduction of phone mast GSM was established. The sparrow population in England has decreased in the last 30 years from 24 million to less than14 million (Balmori 2005; Balmori.2009). When rats are exposed for 2 hours in a day for 45 days at 0.21 mW/cm^2 power density SAR (0.038 W/kg), significant decreases in melatonin and increase in both creatine kinase and caspase 3 were observed (Kesari et al.,2011). The chronic exposure to these radiations may cause the possible tumor promotion (Balmori.2003). Deaths in domestic animals like hamsters and guinea pigs were also observed (Kevan and Phillips.2001). The most affected species due to the EMFs are bees, birds, and bats and without these pollinators visiting flowers, 33% of fruits and vegetables would not exist, and as the number of pollinators decline, the agricultural crops will fall short (https://www.emf-portal.org/en)

Biological effects

Recent evidences regarding the harmful effects of microwave exposure and their potential hazards specially in children is an eye opening for the scientific community and that leads to

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

numbers of studies conducted over the decades which are mainly based on the adverse biological effect of RFEMR (Markov.2018, ORSAA. https://www.orsaa.org/)

Reactive oxygen species (ROS) are a normal phenomenon of cellular process and cell signaling. Increase in production of ROS may not be balanced with either endogenous antioxidants or exogenous antioxidant. This may lead to the damage of the DNA, proteins, membrane lipids and mitochondria. Excess ROS is produced due to radiation exposure may damage human DNA and unbalance the antioxidant capacities of the body system thereby increase toxicity mainly due to the generation of ROS (Abdollahi et al., 2004; Drechsel and Patel.2008). Dasdag et al. investigated the long term effects of radiofrequency radiation emitted from a Wireless Fidelity (Wi-Fi) system on some of the miRNA in brain tissue. The study was carried out on 16 wistar albimo adult male rats by dividing them into two groups as sham (n=8) and exposure (n=8). The exposure group was exposed to 2.4GHz radiofrequency radiation for 24 hours a day for a period of one year. Rat group of sham category was also undergoing same procedure except with Wi-Fi system off. After the examination of brain they concluded that long term exposure to 2.4GHz effects the miRNA expression and may lead to adverse neurodegenerative disease (Dasdag et al., 2015).

RFEMR has been shown to cause an array of adverse effects like spoil of DNA integrity, damage of cellular membrane, flaws in gene expression, malfunction in protein synthesis and neuronal action, unwanted consequences in the blood brain barrier, interruption in melatonin production, sperm damage and immune dysfunction (La Vignera et al.,2012; Levine et al., 2017).

The National Toxicology Program published reports on whole-body exposure of radiofrequency on rats and mice that was modulated using the signal patterns commonly used by third generation wireless mobile telecommunications technology (3G). After a week of exposure, DNA damaged was assessed in different parts of the body cells - brain regions, liver cells and peripheral blood leukocytes; also using the micronucleus assay, chromosomal damage was assessed in immature and mature peripheral blood erythrocytes. Results of the comet assay showed significant increase in DNA damage in frontal coryex of male mice due to both types of signal modulations, leukocytes of female mice (for CDMA only) and hippocampus of male rates (for CDMA only). Increase in DNA damage judged to be equivocal were observed in several other tissues of rats and mice. National Toxicology Program (NTP) study is the most comprehensive study on the impact of RFR on tumor genesis till date and has recently provided clear evidence of carcinogenicity and DNA damage associated with exposure to RF-EMR (https://www.nih.gov/news-events/news-releases/high-exposure-radiofrequency-radiation-associated-cancer-male-rats; Smith-Roe et al., 2020).

Centre for Energy Efficient Communications, points out that the wireless systems use 15 to 23 times more energy than wired systems. Zhengmao Li of EVP China Mobile stated that the challenges of 5G deployment includes (i) need of more (three times in number) base stations for the same coverage that of LTE, and (ii) three times more power consumption by a single base station in comparison to 4G LTE (https://www.lightreading.com/mobile/5g/power-consumption-

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

5g-basestationsare-hungry-hungry-hippos/d/d-id/749979). In 2016, a study was conducted by the Department of Community medicine, MGM Medical College, Indore at India, to explore a cross sectional investigation to evaluate the impacts of over-use of smartphone among the students of different professional colleges and observed the visual problems like dry eyes, headache, sleeplessness among those students. They concluded that due to the over use of smartphone, their live became more sedentary, dry eyes and headache, feel disturbances in their sleep (Rai et al., 2016).

Research program on the implication of mobile phone user was carried out by number of countries. Longitudinal studies of 5, 50,000 cell phone users were completed in Denmark (Johansen et al., 2001). Among them from the Danish telephone registry, 4, 20,095 registered user of mobile phone were investigated for the prevalence of cancer during the period of 1982 to 1995. Overall, 3391 cancers were detected among the users primarily brain cancer, salivary gland etc. However, the relation between cell phone user and cancer could not be established and demanded further investigation.

In 2001, a study was conducted in USA, to understand the occurrence of brain tumors due to use of cell phone. The result of the investigation does not show any valid correlation occurrence of brain tumor danger with the use of cell phone (Inskip et al., 2001). In 2002, a similar type of study was performed in Finland to demonstrate the effects of wireless phone radiation on human cells rather than those to rats. Researcher found that mobile phone radiation can damage the blood-brain barrier (Karinen et al., 2008). In 2015, a study was done to demonstrate the effects of radio frequency radiation emitted from cell phones on human eye function and found significant changes in visual acuity (Visual acuity, Refraction) (Kafi et al.,2015)

Opacity of the crystalline lens is defined as cataract, which is the leading cause of visual impairment worldwide still now. Smoking, diabetes and consistent exposure to UVB light have been identified as the risk factors for cataract. A study by Abraham et al., found there is a possibility of receiving near field exposure in case 5-G application. Research has found that oxidative damage may be due to the cell phone radiation is one of the reason for age related cataracts (Abraham et al., 2006)

Diabetes, multiple sclerosis, asthma chronic fatigue, and fibromyalgia etc. are increasing rapidly in the human population and the reasons behind these are not well understood. Dirty electricity (environmental exposure to high-frequency voltage transients) may be one of the underlying causes behind these.

Despite shallow penetration (compared to lower frequencies) 5G millimeter waves pose harm to the largest organ of the body, the skin, with the possibility of permanent tissue damage. A person exposed in dirty electricity tends to develop more symptoms compared to normal environment. Neufeld and Kuster reported that wireless devices operating more than 10GHz, which allows fast connectivity, may raise the temperature level in skin of exposed people. In a novel analytical approach of pulsed heating is developed and applied to assess the peak-to-average temperature

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

ratio as a function of the pulse fraction α. It was reported that, peak-to-average ratio of 1000 tolerated by the ICNIRP, may lead to permanent tissue damage even for a short exposure (Neufeld & Kuster, 2018).

In another study, it has also been observed that more is power density more is the number of significant health complains and that females were statistically more affected than males (Pachuau et al., 2016)

According to MagdaHavas, the side effects of electromagnetic pollution in the form of dirty electricity, ground current, and radio-frequency radiation from wireless devices are increasing at an alarming rate, including asthma, diabetes, multiple sclerosis, chronic fatigue, and fibromyalgia (Havas.2006). The connection between electromagnetic pollution and various disorders has to be studied. The percentage of people affected by this form of energy should be determined. Epidemiological studies and in vivo experiments exhibited that the exposure to non-ionizing radiation (NIR) ranging from extremely low to microwave frequency electromagnetic fields EMF at exposure intensities far below the maximum limits in International guidelines increases anxiety, depression, and physiological stress and impairs cognitive functions. Furthermore, exposure to NIR contributes to neurodegenerative diseases including dementia, Alzheimer's disease, amyotrophic lateral sclerosis, multiple sclerosis, Parkinson's disease, attention deficit hyperactivity disorder and autism spectrum disorder. Individuals already impaired by electromagnetic exposure are more prone to environments contaminated with electro smog (Havas.2019).

Conclusion:

In the 21st century we cannot survive without the technology. Hence, Mobile phone is also a gift from the technology that is used across the globe. However, recent technological innovation has brought many sorts of technology starting from 2G to 5G which may provide high technological upgrade to reduce work time, education, defence and many more. However, it is required to monitor properly keeping in mind that there should be minimum effects of hazard in the environment and biological system we have given a brief description how environment and biological system have been disturbed by the radiation. However, there is no long term data available till date associated with the harmful effects of exposure in microwave radiation (used in 5G) on biological and environmental systems. There is an enormous need of deep and thorough research on 5G health effects. Telecom regulatory of various countries should follow the same guidelines to protect the human health. A particular sense of awareness should be parted amongst the people. This should not only be done in response to any kind of forced behavior, but, instead for the wellbeing of their own health. Besides cell phone towers, there is radiation from cell phones, wireless communications, computers, laptops, TV towers, FM towers, microwave ovens, etc but the awareness among the general people on radiation safely is very limited. With the drawbacks of the various hazards issued by the telecommunications centers across the globe, a set of protocols should be taken as this could lead to some disastrous effect on human. In order

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

to improve the longevity of our bodies, we must care for it and not fall in prey to the elements of radiation. The impact of hazards can be reduced using fiber and cable and proper regulation with safe technology which will help for the safety of the public health.

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References

1. Sharma, P. (2013). Evolution of mobile wireless communication networks-1G to 5G as well as future prospective of next generation communication network. *International Journal of Computer Science and Mobile Computing*, *2*(8), 47-53.
2. Fields, R. E. (1997). Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields. *OET bulletin*, *65*(10).
3. International Commission on Non-Ionizing Radiation Protection. (2009). ICNIRP statement on the "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)". *Health physics*, *97*(3), 257-258.
4. Wu, T., Rappaport, T. S., & Collins, C. M. (2015, June). The human body and millimeter-wave wireless communication systems: Interactions and implications. In *2015 IEEE International Conference on Communications (ICC)* (pp. 2423-2429). IEEE.
5. Romanenko, S., Siegel, P. H., Wagenaar, D. A., & Pikov, V. (2014). Effects of millimeter wave irradiation and equivalent thermal heating on the activity of individual neurons in the leech ganglion. *Journal of Neurophysiology*, *112*(10), 2423-2431.
6. Hardell, L. (2017). World Health Organization, radiofrequency radiation and health-a hard nut to crack. *International Journal of Oncology*, *51*(2), 405-413.
7. International Commission on Non-Ionizing Radiation Protection. Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). Health Phys 99:818–836; 2010.
8. International Commission on Non-Ionizing Radiation Protection. (2020). Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz). *Health physics*, *118*(5), 483-524.
9. Wood, A. W. (2002). Maximum exposure levels to radiofrequency fields: 3 kHz to 300 GHz: Radiation Protection Standard.
10. Sivani, S., & Sudarsanam, D. (2012). 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.
11. Belyavskaya, N. A. (2004). Biological effects due to weak magnetic field on plants. *Advances in space Research*, *34*(7), 1566-1574.

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

12. Kumar, N., & Kumar, G. (2009). Biological effects of cell tower radiation on human body. *ISMOT, Delhi, India*, 678-679.
13. Warnke, U. (2007). Bees, birds, and mankind: destroying nature by "Electrosmog". Effects of mobile radio and wireless communication. A series of papers by the competence initiative for the protection of mankind, environment, and democracy. Kempten.
14. Sharma, V. P., & Kumar, N. R. (2010). Changes in honeybee behaviour and biology under the influence of cellphone radiations. *Current Science(Bangalore)*, *98*(10), 1376-1378.
15. Kimmel, S., Kuhn, J., Harst, W., & Stever, H. (2007). Effects of electromagnetic exposition on the behavior of the honeybee. *Apis mellifera*, 1-6.
16. Rubin, E. B., Shemesh, Y., Cohen, M., Elgavish, S., Robertson, H. M., & Bloch, G. (2006). Molecular and phylogenetic analyses reveal mammalian-like clockwork in the honey bee (Apis mellifera) and shed new light on the molecular evolution of the circadian clock. *Genome research*, *16*(11), 1352-1365.
17. Panagopoulos, D. J., Karabarbounis, A., & Margaritis, L. H. (2004). Effect of GSM 900-MHz mobile phone radiation on the reproductive capacity of Drosophila melanogaster. *Electromagnetic biology and medicine*, *23*(1), 29-43.
18. Panagopoulos, D. J., Chavdoula, E. D., Nezis, I. P., & Margaritis, L. H. (2007). Cell death induced by GSM 900-MHz and DCS 1800-MHz mobile telephony radiation. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, *626*(1-2), 69-78.
19. Panagopoulos, D. J., Chavdoula, E. D., & Margaritis, L. H. (2010). Bioeffects of mobile telephony radiation in relation to its intensity or distance from the antenna. *International journal of radiation biology*, *86*(5), 345-357.
20. Levengood, W. C. (1969). A new teratogenic agent applied to amphibian embryos. *Development*, *21*(1), 23-31.
21. Hotary, K. B., & Robinson, K. R. (1994). Endogenous electrical currents and voltage gradients in Xenopus embryos and the consequences of their disruption. *Developmental biology*, *166*(2), 789-800.
22. http://www.indiaenvironmentportal.org.in/content/341385/report-on-possible-impacts-of-communication-towers-on-wildlife-including-birds-and-bees/. Accessed on 12 April, 2020.
23. Manville, A. M. (2009). Towers, turbines, power lines, and buildings–steps being taken by the US Fish and Wildlife Service to avoid or minimize take of migratory birds at these structures. In Proceedings of the Fourth International Partners in Flight Conference: Tundra to Tropics (Vol. 262272).
24. Balmori, A. (2009). Electromagnetic pollution from phone masts. Effects on wildlife. *Pathophysiology*, *16*(2-3), 191-199.
25. Balmori, A. (2005). Possible effects of electromagnetic fields from phone masts on a population of white stork (Ciconia ciconia). *Electromagnetic Biology and Medicine*, *24*(2), 109-119.

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

26. Kesari, K. K., Kumar, S., & Behari, J. (2011, August). Biomarkers inducing changes due to microwave exposure effect on rat brain. In *2011 XXXth URSI General Assembly and Scientific Symposium* (pp. 1-4). IEEE.
27. Martínez, A. B. (2003). THE EFFECTS OF MICROWAVE RADIATION ON THE WILDLIFE. PRELIMINARY RESULTS.
28. Kevan, P. G., & Phillips, T. P. (2001). The economic impacts of pollinator declines: an approach to assessing the consequences. *Conservation ecology*, *5*(1).
29. https://www.emf-portal.org/en . Accessed on 25th January, 2021.
30. Markov, M. (Ed.). (2018). *Mobile communications and public health*. CRC Press.
31. https://www.orsaa.org/ Accessed on 21st January, 2021.
32. Abdollahi, M., Ranjbar, A., Shadnia, S., Nikfar, S., & Rezaiee, A. (2004). Pesticides and oxidative stress: a review. *Medical Science Monitor*, *10*(6), RA141-RA147.
33. Drechsel, D. A., & Patel, M. (2008). Role of reactive oxygen species in the neurotoxicity of environmental agents implicated in Parkinson's disease. *Free Radical Biology and Medicine*, *44*(11), 1873-1886.
34. Dasdag, S., Akdag, M. Z., Erdal, M. E., Erdal, N., Ay, O. I., Ay, M. E., ... & Yegin, K. (2015). Effects of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on microRNA expression in brain tissue. *International journal of radiation biology*, *91*(7), 555-561.
35. La Vignera, S., Condorelli, R. A., Vicari, E., D'Agata, R., & Calogero, A. E. (2012). Effects of the exposure to mobile phones on male reproduction: a review of the literature. *Journal of andrology*, *33*(3), 350-356.
36. Levine, H., Jørgensen, N., Martino-Andrade, A., Mendiola, J., Weksler-Derri, D., Mindlis, I., & Swan, S. H. (2017). Temporal trends in sperm count: a systematic review and meta-regression analysis. *Human reproduction update*, *23*(6), 646-659.
37. https://www.nih.gov/news-events/news-releases/high-exposure-radiofrequency-radiation-associated-cancer-male-rats. Accessed on 3rd April., 2021.
38. Smith-Roe, S. L., Wyde, M. E., Stout, M. D., Winters, J. W., Hobbs, C. A., Shepard, K. G., ... & Witt, K. L. (2020). Evaluation of the genotoxicity of cell phone radiofrequency radiation in male and female rats and mice following subchronic exposure. *Environmental and molecular mutagenesis*, *61*(2), 276-290.
39. https://www.lightreading.com/mobile/5g/power-consumption-5g-basestationsare-hungry-hungry-hippos/d/d-id/749979. Accessed 1st May, 2021.
40. Rai, S., Saroshe, S., Khatri, A., Sirohi, S., & Dixit, S. (2016). A cross sectional study to assess the effects of excessive use of smartphones among professional college going students. *International Journal of Community Medicine and Public Health*, *3*(3), 758-763.
41. Johansen, C., Boice Jr, J. D., McLaughlin, J. K., & Olsen, J. H. (2001). Cellular telephones and cancer—a nationwide cohort study in Denmark. *Journal of the National Cancer Institute*, *93*(3), 203-207.

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

42. Inskip, P. D., Tarone, R. E., Hatch, E. E., Wilcosky, T. C., Shapiro, W. R., Selker, R. G., ... & Linet, M. S. (2001). Cellular-telephone use and brain tumors. *New England Journal of Medicine*, *344*(2), 79-86.
43. Karinen, A., Heinävaara, S., Nylund, R., & Leszczynski, D. (2008). Mobile phone radiation might alter protein expression in human skin. *BMC genomics*, *9*(1), 1-5.
44. Kafi, S. T., Ahmed, A. M., Ismail, B. A., Nayel, E. A., Awad, A. R., & Alhassan, E. A. (2015). Effects of RF Radiation Emitted from Cellphones on Human Eye Function (Vision Acuity/Refraction). *Journal of Electrical Engineering*, *3*, 128-133.
45. Abraham, A.G., Condon, N.G., Gower, E.W., 2006. The new epidemiology of cataract.Ophthalmol.Clin. North Am. 19, 415–425. ⟨https://www.researchgate.net/publication/6728154_The_New_Epidemiology_of_Cataract#pf9⟩.
46. Neufeld, E., & Kuster, N. (2018). Systematic derivation of safety limits for time-varying 5G radiofrequency exposure based on analytical models and thermal dose. *Health physics*, *115*(6), 705-711.
47. Pachuau, Z., & Pachuau, L. (n.d.). *Lallawmzuala, Pachuau and Pachuau Analysis of RF Radiation and its Health Effects in Lunglei District of Mizoram*. https://doi.org/10.22232/stj.2021.09.01.16
48. Havas, M. (2006). Electromagnetic hypersensitivity: biological effects of dirty electricity with emphasis on diabetes and multiple sclerosis. *Electromagnetic Biology and Medicine*, *25*(4), 259-268.
49. Havas, M. (2019). Electrohypersensitivity (EHS) is an Environmentally-Induced Disability that Requires Immediate Attention. *J Sci Discov*, *3*, jsd18020.

ISSN: 0011-9342 | Year 2021
Issue: 9 | Pages: 300 - 311

Table 1 SAR limits (100 kHz -10 GHz) according to International Commission for Non-Ionizing Radiation Protection (ICNIRP) **(**(Data has been taken from ICNIRP portal with copyright permission)

	Whole -body average SAR (W/kg)	Localized SAR (Head and trunk) (W/kg)	Localized SAR(Limbs) (W/kg)
Occupational Exposure	0.4	10	20
General Public Exposure	0.08	3	4
1. All SAR limits are to be average over any six-minute period. 2. Localized SAR averaging mass is any 10g of contiguous tissues; the maximum SAR to be obtained should be the value used for the estimation of exposure			

Table 2 Basic Restrictions associated with SAR according to International Commission for Non Ionizing Radiation Protection (ICNIRP) (Data has been taken from ICNIRP portal with copyright permission)

Types of Exposure	Frequency range	Whole-body Average SAR (W/kg)	Localized SAR (head and trunk) (W/kg)	Localized SAR (limbs) (W/kg)
Occupational	100kHz -10MHz 10MHz-10GHz	0.4 0.4	10 10	20 20
General public	100kHz -10MHz 10MHz-10GHz	0.08 0.08	2 2	4 4
Note 1-f is the frequency in Hertz Note 3- All SAR values are to be averaged over any 6-minute period. Note 4- The localized SAR averaging mass is any 10 g of contiguous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure.				