ISSN: 2321-7782 (Online)
e-ISJN: A4372-3114
Impact Factor: 7.327

Volume 7, Issue 2, February 2019

International Journal of Advance Research in Computer Science and Management Studies

Research Article / Survey Paper / Case Study

Available online at: www.ijarcsms.com

A Review on the Health Effects of Mobile Phones

Nailah Afshan[1]
Department of Computer Science and Engineering
Islamic University of Science and Technology
Awantipora, J&K – India

Rayees Ahmad Dar[2]
Department of Computer Science and Engineering
Islamic University of Science and Technology
Awantipora, J&K – India

Snowber Mushtaq[3]
Department of Computer Science and Engineering
Islamic University of Science and Technology
Awantipora, J&K – India

Abstract: ***In the last few decades, there has been a tremendous growth of cell phones with over several billions of users worldwide. Our society has been deeply affected by the cell phones and a life without cell phone can't be imagined. But the growth of cell phones and its deep interaction with the human body raised the question of whether the radiation from cell phone is harmful or not? There is increasing public concern regarding the health risks of radio-frequency (RF) radiation produced by mobile phones. The main concerns are about the possible interaction between the electromagnetic fields (EMF) radiation and the biological effects on human body cells, particularly the brain and the human immune system. Many epidemiological investigations have emerged due to the concern regarding the potential risks of exposure to EMFs, but still the effects of EMF exposure on human and other mammalian cells are unclear. Due to these concerns a large volume of research studies has been induced most of which are concentrated on negative effects and no published work took in consideration all possible effects. This work gives a brief review of all possible effects of mobile phone radiation with human tissues including both positive and negative effects. Improve bone healing and reduce toxic effects of chemotherapy are some positive health effects that are highlighted here. It is observed that more experimentation is done over cellular studies of the effects of RF EMFs than epidemiological and animal studies. Here a summary of the potential cellular effects of RF fields generated by cell phones is presented as well which can mainly be classified into those examining genotoxic and non-genotoxic effects. An attempt is made to provide an insight on the cellular and molecular responses to the RF electromagnetic fields. The understanding of such biological impacts is highly important for wireless power technology applications like the mobile phones.***

Keywords: Cellular Study; Genotoxic Effect; Non-Genotoxic Effect; Radio-Frequency (RF) Electromagnetic Fields (EMFs).

I. INTRODUCTION

Communication is one of the integral parts of science and is responsible for exchanging information or messages among the parties that are physically apart. History has witnessed tremendous improvement in the use of different devices used for communication. As time passed and technology improved, telephones replaced the telegrams and letters. Then came the era of 'mobile' communication that completely revolutionized the communication by opening up innovative applications and consequently, it has become the backbone of the society. The way of living has highly improved due to mobile system technologies, the main plus point being that it has privileged the common mass of society. Today, cellular phone has become a necessity for humans due to its mobility, small size and some useful applications provided in the chip. But there are increased concerns about possible health hazards due to extensive use of this kind of hand-held devices. There are hundreds of millions of cellular mobile telephone subscribers worldwide and this number is increasing at a rate of about 2% per month and the market

penetration is well more than 80% in some territories [1]. Cellular mobile telephones and related wireless devices emit radio frequency (RF) and microwave radiations having potential health effects which are a leading cause of concern among the users.

Due to enormous increase in mobile phone usage throughout the world, the effect of mobile phone radiation on human health has become the subject of recent interest and study [2]. The possible adverse health effects due to Electro-magnetic field (EMF) radiation from mobile towers and mobile handsets have led to growing public concern with the main one being the radiation emitted by the base transceiver stations (BTS) and mobile handsets [3], [4].. However, here the focus is on the study of effects of mobile handsets only. An overview of Electro-magnetic field (EMF) Radiation is discussed.

Electro-Magnetic Field Radiation

Electromagnetic field (EMF) radiation is the series of small quanta of energy called photons through space. These are of different types with each one characterized by the amount of energy found in the photons [5]. The range of all types of EM radiations is called the electromagnetic spectrum as shown in Figure 1.1. Short wavelength X-rays used in hospitals or the larger wavelength radio waves from a radio station are all part of this spectrum.

Types of EMF radiation

EMF radiations are divided into two categories, ionizing and non-ionizing, depending on frequency and the power level [6]. The electromagnetic radiations that comprise waves having energy sufficient enough to overcome the binding energy of electrons in atoms or molecules leading to the formation of ions are called **ionizing radiations**. e.g., Ultra-violet rays, X-rays, gamma rays and cosmic rays as shown in Figure 1.2.

While as **non-ionizing radiation** is the one that does not have sufficient energy per quantum that would lead to the ionization of atoms or molecules .Radio waves, microwaves, and infrared radiations are the examples of non-ionizing radiations.

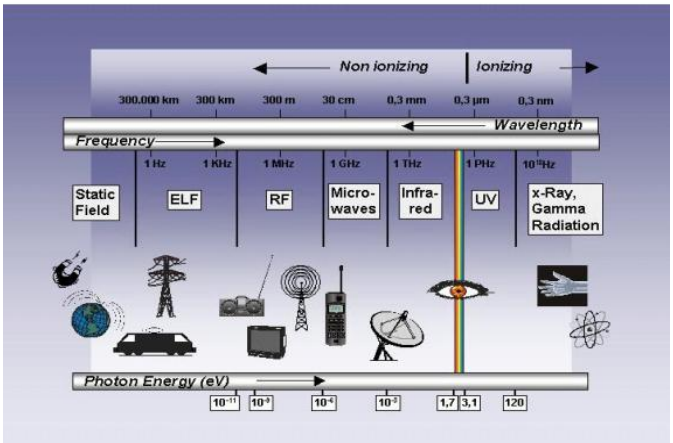

Figure 1.1: Complete Electromagnetic Spectrum [6]

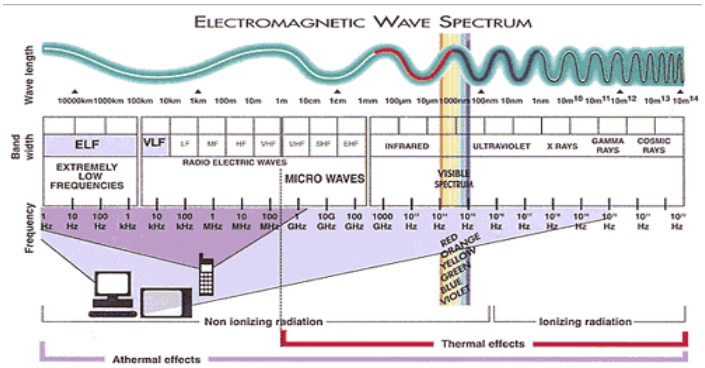

Figure 1.2: Types of EMF Radiation [6]

They lie in the frequency range of 1 Hz to 1THz (1000 GHz) and do not carry enough energy that would disturb the chemical bonds of the human body and the EMF health effects related to them includes tissue heating only and that too at levels above limits. However, the ionizing EM emissions with frequencies above 1 THz have enough potential to affect the chemical bonds of human body resulting in adverse health effects and serious genetic damage on prolonged exposure [7].

Ionization Effect

The EM radiations having tendency to ionize atoms/molecules may have an adverse effect on the living organisms because they can break the chemical bonds and damage vital molecules. The cells may be able to repair themselves if such damage is minor. But if the damage is at a higher rate, cell death would take place and the dead cells cannot be replaced quickly enough.Effects of EMF exposure on human health

Effects of EMF radiation can be studied in two ways i.e. bio-effects and health effects: -

Bio-effects include the measureable responses to a stimulus or responses to any sort of changes in the atmosphere. Such effects are not necessarily harmful to our health. Biological effects can be two types i.e. Thermal and Non-Thermal effects [8]. The energy or heat generated as a result of the absorption of EMF radiation refers to the thermal effects. Most of this thermal effect occurs at the surface of the head during the use of a cell phone, raising its temperature by a fraction of a degree. But a prolonged heating effect may lead to increase in body temperature as well. Non - thermal effects that include the induced electromagnetic effects inside the biological cells of the body are possibly more harmful.

Health effects are the changes which may be short term or long term. These effects stress the system and may be harmful to human health.

Mobile Service and EMF Radiation

In mobile services, there are two primary sources of the EMF radiations: - BTS and mobile handsets. The energy carried by them is unable to break or alter the chemical bonds in molecules as they fall in the lower end of EM spectrum. Thus, they fall under the non-ionizing radiation category. Here we need to focus on those of mobile handsets only.

Radiation from Mobile Handsets

Exposure to low-frequency electromagnetic fields normally results in negligible energy absorption and no measurable temperature rise in the body. However, exposure to electromagnetic fields at frequencies above 16,100 KHz can lead to absorption of energy and increase in body temperature. Significant absorption can occur in the neck and legs at frequencies between 100 kHz and 20 MHz, relatively higher absorption can occur in the whole body at frequencies in the range of 20 MHz to 300 MHz; significant local, non-uniform absorption occurs when frequencies are in the range of around 300 MHz to several GHz,; and energy absorption occurs primarily at the body surface when frequencies are above 10 GHz, [9].

Normally the frequencies in the range of 800 MHz to 2100 MHz are used in mobile phones, However, the power radiated from the headset is low around 1 W due to which the EMF radiation levels are within limits and each mobile phone operates within some prescribed Specific Absorption Rate (SAR) that reflects the amount of radio waves absorbed by the body tissue while using a mobile phone. In order to prevent whole body heat stress and excessive localized tissue heating the restrictions applied on SAR are between 100 kHz and 10 GHz. The strength of the electromagnetic field necessary to reach the body helps in determining and setting the limits for SAR and they are an indicator for ensuring that equipment like mobile phones are operating within the prescribed parameters.

SAR is a measure of the rate at which energy is absorbed by the human body when exposed to EMF. It is defined as the power absorbed per mass of tissue and has units of watts per kilogram (W/kg). SAR is usually averaged either over the whole body or over a small sample volume (typically 1 g or 10 g of tissue) [10]. The value cited is then the maximum level measured in the body part studied over the stated volume or mass. SAR values for mobile phones always refer to the maximum possible

transmission power. However, these values will only be reached under low field strengths in areas of low coverage. SAR values do not take into consideration the specific transmission properties of each mobile phone. They indicate the possible maximum and not the actual or average transmission power.

Different mobile handsets create varying electromagnetic fields owing to differences in their design and construction, as well as their electronics and antenna. Therefore, even though SAR values are an important indicator to compare the maximum possible EMF exposure, a single SAR value does not provide sufficient information about the amount of EMF exposure under practical usage conditions to reliably compare individual cell phone models.

II. LITERATURE REVIEW

A lot of research has already been done on the health effects of mobile phones and consequently, a good substantial amount of literature pertaining to this field is available. During the journey of this survey work, a number of related research papers, blogs and articles were observed. A brief description of some of them is presented as follows by giving their actual titles:

A. Cell Phones, Microwaves and the Human Health Threat

This article was published on April 28, 2011 on the MIT Technology Review blog [11]. Here, Bill Bruno, a theoretical biologist at Los Alamos National Laboratory in New Mexico, proposes that the microwaves that cell phones emit can interact with human tissue in an entirely new way. Bruno points out that there is another way in which photons could damage biological tissue, which has not yet been accounted for. He argues that the traditional argument (radiation emitted by cell phones cannot damage biological tissue because microwave photons do not have enough energy to break chemical bonds) only applies when the number of photons is less than one in a volume of space equivalent to a cubic wavelength. When the density of photons is higher than this, other effects can come into play because photons can interfere constructively. Bruno points to the well-known example of optical tweezers, in which coherent photons combine to push, pull and rotate small objects such as cells causing damage to cells while working at infrared frequencies. The question that Bruno poses is whether a similar effect could also work for microwave photons.

This boils down to two factors. The first is whether there is a high enough density of microwave photons from cellphones to generate a force capable of damaging biological tissues. The second is whether there are structures in the body with the required dielectric properties to be susceptible. On both counts, Bruno says there are reasons to be cautious. First, the density of microwave photons from cell phones and cell phone towers is many orders of magnitude higher than 1 per cubic wavelength. For this reason alone, Bruno says the traditional safety arguments do not apply. Second, the human body contains many structures including neurons up to a meter or so long that could be susceptible to the combined effect of many photons. Some of these structures may actually focus microwave photons, increasing the photon density inside the body. Bruno's conclusion is that the way safe dosage limits is determined is broken because it does not take this new tweezers-like mechanism into account.

B. Possible Effects of cell phone radiation

This paper summarizes the major studies on the effect of cell phone radiation including both positive and negative effects of cell phone radiation on human tissues [12].

1) Negative effects of cell phone radiation:

- Effects on people working near the vicinity of Microwave Radiation: A survey was done among twenty five microwave engineers, research students and technicians working eight hours per day in the microwave labs in India and found various problems such as headache, confusion, depression, perspiration, emotional instability, irritability, lack of concentration, dizziness, fatigue, weakness and insomnia. Some clinical reports say that posterior capsule changes in the eye lens were more prominent in microwave workers [13].

- Adverse effects on blood brain barrier
- Effects on auditory nerve and brain
- Effects on DNA
- Effects on cognitive function
- Effects on eyes (induction of cataracts or formation of lens opacity)

2) Positive effects of cell phone radiation: Many research studies have indicated that there are some positive effects due to the exposure of EMF radiation. EMF radiation is used for many therapeutic applications such as bone repair, nerve stimulation, wound healing, osteoarthritis treatment, electro acupuncture, tissue regeneration, immune system stimulation and neuroendocrine modulations. Therapy utilizing EM waves at wavelengths from several hundred to several tens of meters is known as Diathermy. Pulsed electromagnetic fields, pulsed radio frequency fields have been shown to promote healing when used as adjunctive therapy for a variety of soft–tissue injuries. Pulsed EMF (PEMF) stimulation promotes cell activation and proliferation by an effect on cell membranes and increases the rate of keratinocytes cells in partially healed skin wounds. Extremely Low Frequency (ELF) and RF fields have been applied to accelerate wound healing. Since skin wounds have unique electrical potentials and currents, stimulation of these electrical factors by a variety of EMFs can aid in healing process by causing dedifferentiation (i.e. conversion to a more primitive form) of nearby cells followed by accelerated cell proliferation [14].

C. Latest Radio Frequency Study Adds Credibility to Concerns about Cell Phone Hazards

It is one of the latest related research article published on June 15, 2016 by Dr Mercola [15].

In May 2011, the International Agency for Research on Cancer (IARC), the cancer research arm of the World Health Organization (WHO), declared cell phones a Group 2B 'Possible Carcinogen,' meaning a "possible cancer-causing agent," based on the available research. Researchers have demonstrated that wireless phones and other gadgets have the potential to cause all sorts of health problems, from headaches to brain tumors, with young children being at greatest risk. Heart and brain tumors found in rats exposed to cell phone radiation based on the study done by the National Toxicology Program (NTP), an interagency research program started by the U.S. Department of Health and Human Services (HHS) in 1978 and now housed at the National Institute of Environmental Health Sciences (NIEHS).Moreover, it has also been found that 1 in 4 car accidents caused by cell phones. It's not just the RF that makes cell phones dangerous. They also play a significant role in car accidents caused by distracted drivers, which took the life of nearly 3,330 people in 2012 and injured 421,000. Last year, the National Safety Council (NSC) reported that cell phone use is responsible for 26 percent of all car accidents in the U.S. International EMF scientists from 39 countries last May issued the International EMF Scientist Appeal to the United Nations calling for precautionary action, announced by spokesperson Dr. Martin Blank. Until the industry and regulators start taking this matter seriously, the responsibility to keep children safe falls on the parents and schools. To minimize the risk to your brain, and that of your child, Dr Mercola recommends the following set of advices:

- Don't let your child use a cell phone
- Keep your cell phone use to a minimum
- Reduce or eliminate your use of other wireless devices
- Opt for older portable home phones
- Limit cell phone use to areas with excellent reception
- Avoid carrying your cell phone on your body

- Don't assume one cell phone is safer than another
- Respect others; many are highly sensitive to EMF/RF
- Use a well-shielded wired headset
- Help educate your children's schools

D. Microwave frequency electromagnetic fields (EMFs) produce widespread neuropsychiatric effects including depression

This paper proposes that low intensity microwave EMFs produce neuropsychiatric effects, sometimes called microwave syndrome, and the focus is whether these are indeed well documented and consistent with the known mechanism(s) of action of such EMFs. Non-thermal microwave/lower frequency EMFs act via voltage-gated calcium channel (VGCC) activation. Calcium channel blockers block EMF effects and several types of additional evidence confirm this mechanism. VGCCs occur in very high densities throughout the nervous system and have near universal roles in release of neurotransmitters and neuroendocrine hormones [16].

Much of the impact of non-thermal microwave exposures in experimental animals occurs in the brain and peripheral nervous system, such that nervous system histology and function show diverse and substantial changes. These may be generated through roles of VGCC activation, producing excessive neurotransmitter/neuroendocrine release as well as oxidative/nitrosative stress and other responses. Excessive VGCC activity has been shown from genetic polymorphism studies to have roles in producing neuropsychiatric changes in humans. Two U.S. government reports from the 1970s to 1980s provide evidence for many neuropsychiatric effects of non-thermal microwave EMFs, based on occupational exposure studies. 18 more recent epidemiological studies provide substantial evidence that microwave EMFs from cell/mobile phone base stations, excessive cell/mobile phone usage and from wireless smart meters can each produce similar patterns of neuropsychiatric effects, with several of these studies showing clear dose–response relationships. Lesser evidence from 6 additional studies suggests that short wave, radio station, occupational and digital TV antenna exposures may produce similar neuropsychiatric effects. Among the more commonly reported changes are sleep disturbance/insomnia, headache, depression/depressive symptoms, fatigue /tiredness, dysesthesia, concentration/attention dysfunction, memory changes, dizziness, irritability, loss of appetite/body weight, restlessness/anxiety, nausea, skin burning/tingling/dermographism and EEG changes. In summary, then, the mechanism of action of microwave EMFs, the role of the VGCCs in the brain, the impact of non-thermal EMFs on the brain, extensive epidemiological studies performed over the past 50 years, and five criteria testing for causality ((1) strength of association; (2) biological credibility; (3) consistency; (4) time sequence; (5) dose–response relationship), all collectively show that various non-thermal microwave EMF exposures produce diverse neuropsychiatric effects.

E. Mobile phone use and stress sleep disturbances, and symptoms of depression among young adults - a prospective cohort study

The whole research shown by this research article can be divided into the following four subsections so as to get an overview in a precise manner [17].

Background: Because of the quick development and widespread use of mobile phones, and their vast effect on communication and interactions, it is important to study possible negative health effects of mobile phone exposure. The overall aim of this study was to investigate whether there are associations between psychosocial aspects of mobile phone use and mental health symptoms in a prospective cohort of young adults [18].

Methods: The study group consisted of young adults 20-24 years old (n = 4156), who responded to a questionnaire at baseline and 1-year follow-up. Mobile phone exposure variables included frequency of use, but also more qualitative variables: demands on availability, perceived stressfulness of accessibility, being awakened at night by the mobile phone, and personal overuse of the mobile phone. Mental health outcomes included current stress, sleep disorders, and symptoms of depression [19].

Prevalence ratios (PRs) were calculated for cross-sectional and prospective associations between exposure variables and mental health outcomes for men and women separately.

Results: There were cross-sectional associations between high compared to low mobile phone use and stress, sleep disturbances, and symptoms of depression for the men and women. When excluding respondents reporting mental health symptoms at baseline, high mobile phone use was associated with sleep disturbances and symptoms of depression for the men and symptoms of depression for the women at 1-year follow-up. All qualitative variables had cross-sectional associations with mental health outcomes. In prospective analysis, overuse was associated with stress and sleep disturbances for women, and high accessibility stress was associated with stress, sleep disturbances, and symptoms of depression for both men and women.

Conclusion: High frequency of mobile phone use at baseline was a risk factor for mental health outcomes at 1-year follow-up among the young adults. The risk for reporting mental health symptoms at follow-up was greatest among those who had perceived accessibility via mobile phones to be stressful. Public health prevention strategies focusing on attitudes could include information and advice, helping young adults to set limits for their own and others'

F. Effect of EMF on human body cells

In the preceding sections, various effects that include both positive and negative effects of radiations emitted from the cell phones have been discussed. Now the main work that has been done in this review work is gaining an insight into the effect of radiations on human cells. This section gives a brief overview of the same.

RF is a non-ionizing type of radiation, meaning it does not break chemical bonds. Within current FCC (Federal Communications Commission) exposure guidelines, it is generally believed to not produce sufficient heat to cause damage tissue. There is some research showing non-uniform absorption of RF and temperatures as high as 6 degrees higher in the hotspots, which refutes this assumption. However, RF appears to be able to cause damage in other ways. In a recent Scientific American interview, Jerry Phillips, Ph.D., a biochemist and Director of the Excel Science Center at the University of Colorado explained how living cells react to RF radiation: "The signal couples with those cells, although nobody really knows what the nature of that coupling is. Some effects of that reaction can be things like movement of calcium across membranes, the production of free radicals or a change in the expression of genes in the cell. Suddenly important proteins are being expressed at times and places and in amounts that they shouldn't be, and that has a dramatic effect on the function of the cells. And some of these changes are consistent with what's seen when cells undergo conversion from normal to malignant [20]."

When you consider the fact that your body is bioelectric, it's easier to understand how and why biological damage from wireless phones might occur. Our body uses electrons to communicate, and inside every cell are mitochondria, the power plants of the cell and these mitochondria can be adversely impacted by electromagnetic fields, resulting in cellular dysfunction. Other mechanisms of harm have also been discovered in recent years.

Cellular Research

Studies to evaluate RF EMF effects in cells, animals, and humans have used many approaches which can be grossly divided into genotoxicity and nongenotoxicity studies [21]. The general focus of studies on EMF has been on the relation between EMF carcinogenicity, where all studies are considered equally important irrespective of whether the results were obtained in humans, animals, or cells. However, for evaluation of effects that may occur in humans, the results are weighted as such that the epidemiological study is more significant than the experimental animal study, which in turn is more significant than the cellular study. When looking at the accuracy and reproducibility of the study, the results of cellular studies have greater accuracy and reproducibility than experimental animal studies, which in turn have greater accuracy and reproducibility than epidemiological studies.

Genotoxicity Studies

Micronucleus (MN) Formation: *MN formation in the mitotic phase is frequently examined in cellular genotoxicity studies of RF EMF effects. Most studies have shown no increase in MN formation after RF exposure at a specific absorption rate (SAR) 10 W/kg [22], however, some have shown more MN formation under these conditions. Increased MN formation is observed at an extremely high SAR (50 W/kg) associated with heating*.

Chromosomal Aberration and Sister Chromatid Exchange: *Chromosomal aberration was a typical indicator for genotoxicity used in early studies because the results can be observed visually. In cultured cells, chromosomal aberration can occur spontaneously, but this is extremely infrequent. An early study showed that RF exposure caused chromosomal aberration [23], but most recent studies have shown no effect on chromosomal aberration. Sister chromatid exchange has also not been detected in RF exposure [24].*

DNA Strand Breaks (Comet Assay): *DNA strand breaks are an index to show whether DNA strand is directly broken by cell genotoxicity. DNA strand breaks are usually examined using the so-called comet assay. DNA strand breaks after RF exposure can be detected as single-strand breaks in alkaline conditions and double-strand breaks in neutral conditions. Several studies have shown that DNA strand breaks are increased by RF exposure, including with intermittent RF exposure [25]. However, independently repeated experiment failed. RF in combination with mitomycin C, a DNA alkylating agent, was shown to increase DNA strand breaks more than with exposure to RF alone. Despite these findings, the weight of evidence supports the general consensus that RF exposure does not break DNA bonds. Therefore, many studies have concluded that RF exposure does not cause DNA strand breaks.*

Mutation: *The few studies that have examined the effects of RF exposure on mutation have all reached the conclusion that RF is unlikely to induce mutations [26].*

Non – Genotoxicity Studies

1. Cell Proliferation and Cell Cycle Distribution: *Cell proliferation is a basic cellular process. Increased RF exposure has been shown to decrease the cell proliferation rate and influence the cell cycle distribution [27] but most reports show no effect of RF exposure on cell proliferation and cell cycle distribution.*

2. Apoptosis: *Apoptosis is a term used to describe ''programmed cell death'' and is understood to be a ''defence mechanism'' to protect cells against damage. Signal transduction processes induce apoptosis in response to DNA damage induced by chemical agents and ionizing radiation. Most reports of the effect of RF exposure on apoptosis are negative [28].*

3. Gene Expression: *In simple terms, gene expression is an intracellular metabolic process in which a DNA sequence (a gene) is transcribed into mRNA and translated to protein, resulting in protein production. Effects on heat shock proteins (HSPs) have been a particular focus in studies of the effects of RF on gene expression. Many groups have examined the effect of RF exposure on HSP production. At a high SAR, such as more than 20 W/kg, cell temperature and HSP production increase in RF exposure. An effect on HSP levels has also been shown using a SAR at a level without heating, i.e., a ''non-thermal effect'' [29], with results showing that the increased HSP production influences signal transduction pathways being of particular interest. However, other studies have not found an effect of RF exposure on HSP production. The exposure system, cell line, frequency, SAR, and exposure time have differed among these studies, and it is difficult to reach a definite conclusion. Gene expression is a very interesting field of research for cellular responses to RF, and further studies are required.*

4. Transcriptomics (Microarray Analysis): *Microarray analysis allows exhaustive assessment of the expression levels of mRNAs in a given cell. This method has been used to study RF effects. Intermittent RF exposure has been shown to*

increase or decrease the expression of genes involved in multiple cellular functions (cytoskeleton, signal transduction pathways, metabolism, etc.). Cell-line-dependent effects of RF exposure on gene expression have also been shown, and cell lines with and without changes in gene expression due to RF exposure have been identified. There are also several reports showing that RF exposure has no effect in microarray analysis [30]. These reports indicate that it is difficult to find a marked cellular response to RF using microarray analysis, despite improvements in the technique.

5. Immune System*: The immune system protects hosts from infection and cancer. Thus, immune cells have an important role, and effects of RF on immune cell activity have been found. Peripheral blood mononuclear cells exposed to pulse-modulated RF fields and subsequently cultured showed changes in immune activity and a significantly higher response to mitogens and higher immunogenic activity (LM index) compared to control cultures. In contrast, no significant effects of RF exposure and no indication that emissions from mobile phones are associated with adverse effects on the human immune system have been found based on evaluation of interleukin (IL)-1, 2, and 4 and interferon (INF)- and INF- levels [31]. The levels of two pro-inflammatory cytokines, interleukin 6 (IL-6), and tumor necrosis factor-alpha (TNF-), released into the extracellular medium after exposure of cultured astroglial and microglial brain cells to RF, did not provide evidence for an effect of RF on damage-related factors in glial cells. Further studies are required to determine the effect of RF fields on the immune system.*

6. Reactive Oxygen Species (ROS): Stress due to aging, exercise, UV, and other sources increases production of reactive oxygen species (ROS). ROS include oxygen ions, free radicals, and inorganic and organic peroxides. Only a few studies have examined the effects of RF on ROS production. No significant differences in free radical production were detected after RF exposure, and no additional effects on superoxide radical anion production were found after co-exposure to RF [32]. Thus, no study has found that ROS production is increased by RF exposure.

For the RF exposure conditions in the cellular experiments, the frequencies used in the most aforementioned reports ranged from 800 MHz to 3 GHz. Many of them are the same signal as the RF field from cellular phones, e.g., GSM at around 900 or 1800 MHz; CDMA and time-division multiple access (TDMA) at around 800 or 1800 MHz; and the Universal Mobile Telecommunication System (UMTS) at around 900 or 1900 MHz. Some of them are continuous wave (CW) at 2450 MHz, such as the same as the RF field from a microwave oven. The SAR levels used in the most aforementioned reports range from 1.0 to 10 W/kg, except for high SAR levels at more than 20 W/kg in a few reports, and the exposure times are 30 min to 24 h.

III. CONCLUSION

Current understanding of the effects of RF exposure on cells can be summarized as follows. 1) RF energy does not cleave intracellular DNA directly. 2) Most genotoxicity studies have shown negative effects, except for exposure to RF fields with an extremely high SAR those results in a thermal effect. 3) Changes in gene expression associated with HSP production are an interesting cellular response to RF exposure. However, the results of studies of this effect are inconsistent, perhaps due to differences in cell lines, RF exposure system, frequency, SAR, and exposure time. Reproduction of results in different laboratories is of importance. 4) At present, microarray analysis has not provided definite evidence of an effect of RF exposure on cellular functions, including apoptosis, the immune system, and ROS production. In this review, there are some reports showing the positive effect and some other reports showing the negative effect in the study concerning one cellular criterion. Studies on cellular RF effects are ongoing worldwide, but the published evidence regarding the effects is weak or does not allow a definite conclusion at a cellular level. The rapid development of biotechnology has increased the potential for detection of micro responses in cells and genes, and future studies of RF effects should be performed using improved biotechnological methods. Finally, RF carcinogenicity was evaluated by the International Agency For Research on Cancer (IARC) on May 23–31, 2011, with RF carcinogenicity classified into Group 2B, indicating that ‘‘The agent is possibly carcinogenic to humans’’. At the cellular level, overall conclusion is ‘‘weak evidence’’ as a qualitative assessment, but not a quantitative assessment. The conclusion for each criterion was a weak evidence for the genotoxicity, such as micronucleus formation, DNA strand breaks,

and chromosomal aberration; and was an insufficient evidence for mutagenicity, immune function, genes, proteins and changes in cellular signaling, and reactive oxygen species. At present, there is no clear evidence that the RF exposures at SAR levels of current ICNIRP guidelines and IEEE standards do affect the genotoxicity and/or the nongenotoxicity in cellular studies. However, further studies are required to determine the effect of RF fields on these cellular analyses.

References

1. Abdul-Razzaq, Wathiq. "Cell Phone RF Radiation". The Physics Teacher 53.4 (2015): 236-237. Web.
2. Sharma, Rama and Sanjay Sharma "Impact Of Mobile Phone Radiations On Public Health". AS 10.1and2 (2015): 30-34. Web.
3. Awadalla H. Health effects of Mobile Phone. Webmed Central PUBLIC HEALTH 2013;4(1):WMC003946 doi: 10.9754/journal.wmc.2013.003946.
4. Naee, Zahid. "Health Risks Associated With Mobile Phones Use". International Journal of Health Sciences 8.4 (2014): v-vi. Web.
5. Buckus, Raimondas, Birute Strukcinskiene, and Juozas Raistenskis. "The Assessment Of Electromagnetic Field Radiation Exposure For Mobile Phone Users". Vojnosanitetski pregled 71.12 (2014): 1138-1143. Web.
6. "IEEE-EMBS Committee On Man And Radiation". Ewh.ieee.org. N.p., 2016. Web. 27 Nov. 2016.
7. Mustapha, AA and AO Owoyemi. "Review Of Public Health Implications Of Cell Phone Radiation And Other Sources Of Non-Ionizing Radiation And Ionizing Radiation". Tropical Journal of Health Sciences 14.1 (2007): n. pag. Web.
8. World Health Organization . WHO Research Agenda for Radiofrequency Fields. Geneva, Switzerland: World Health Organization; 2010.
9. Sridhar Raja, D. "A Case Study On Health Issues Caused By Mobile Phone Usage And Awareness Of SAR Value In Mobile Phones". Indian Journal of Science and Technology 8.32 (2015): n. pag. Web.
10. Bhoil, Rohit, Ashish Kumar, and Rohan Bhoil. "Cell Phones And SAR Value". Indian Journal of Public Health 59.4 (2015): 323. Web.
11. arXiv, Emerging. "Cell Phones, Microwaves And The Human Health Threat". MIT Technology Review. N.p., 2016. Web. 26 Nov. 2016.
12. E. Vinodha and S. Raghavan, "Possible effects of cell phone radiation: An overview paper," 2015 2nd International Conference on Electronics and Communication Systems (ICECS), Coimbatore, 2015, pp. 837-841.
13. Lena Hillert, Torbjörn Åkerstedt, "The effects of 884 MHz GSM wireless communication signals on headache and other symptoms: An experimental provocation study," Bioelectromagnetics, 29:185-196, 2008
14. Miyakoshi, Junji. "Cellular And Molecular Responses To Radio-Frequency Electromagnetic Fields". Proceedings of the IEEE 101.6 (2013): 1494-1502. Web.
15. "Cellphone Hazards And Radiation Effects". Mercola.com. N.p., 2016. Web. 27 Nov. 2016.
16. Pall, Martin L. "Microwave Frequency Electromagnetic Fields (Emfs) Produce Widespread Neuropsychiatric Effects Including Depression". Journal of Chemical Neuroanatomy 75 (2016): 43-51. Web.
17. Thomée, Sara, Annika Härenstam, and Mats Hagberg. "Computer Use And Stress, Sleep Disturbances, And Symptoms Of Depression Among Young Adults – A Prospective Cohort Study". BMC Psychiatry 12.1 (2012): n. pag. Web.
18. Pall, M.L., 2014. Electromagnetic field activation of voltage-gated calcium channels: role in therapeutic effects. Electromagn. Biol. Med. 33, 251
19. Thomee S, Dellve L, Harenstam A, Hagberg M: Perceived connections between information and communication technology use and mental symptoms among young adults - a qualitative study. BMC Public Health 2010, 10(1):66.
20. Hunt J, Eisenberg D: Mental health problems and help-seeking behaviour among college students. Journal of Adolescent Health 2010, 46(1):3-10.
21. S.K. Palit, "Biological effects of microwaves," a seminar presented in the dept. of elec. comm. Eng., Indian Institute of Science, Bangalore, India
22. Andre "RF/Microwave Interaction with Biological Tissues," Hoboken, New Jersey, A John Wiley & Sons, Inc., 2006. Vander Vorst, Arye Rosen, and Youji Kotsuka
23. M. Gaestel, "Biological monitoring of non-thermal effects of mobile phone radiation: Recent approaches and challenges," Boil. Rev., vol. 85, no.3, pp.489-500, 2010
24. Belyaev, I., 2015. Biophysical mechanisms for non-thermal microwave effects. In: Markov, Marko S. (Ed.), Electromagnetic Fields in Biology and Medicine. CRC Press, New York, pp. 49–67.
25. Karinen A, Heinävaara S, Nylund R, Leszczynski D, Mobile phone radiation might alter protein expression in human Skin, BMC Genomics, Finland,2008,9:77
26. S. Koyama, Y. Takashima, T. Sakurai, Y. Suzuki, M. Taki, and J. Miyakoshi, ''Effects of 2.45 GHz electromagnetic fields with a wide range of SARs on bacterial and HPRT gene mutations,'' J. Radiat. Res., vol. 48, pp. 69–75, 2007.
27. Aly, Ashraf A, Safaai Bin Deris, and Nazar Zaki. "The Effects On Cells Mobility Due To Exposure To EMF Radiation". Advanced Computing: An International Journal 2.4 (2011): 1-7. Web.
28. Goetz, Wilfried, Michelle N. M. Morgan, and Janet E. Baulch. "The Effect Of Radiation Quality On Genomic DNA Methylation Profiles In Irradiated Human Cell Lines". Radiation Research 175.5 (2011): 575-587. Web.
29. Vijayalaxmi, "Genetic Damage in Mammalian Somatic Cells Exposed to Radiofrequency Radiation: A Meta-analysis of Data from 63 Publications, 1990–2005," Radiation Research, 169(5):561–574, 2008.

30. Korpinen LH, Pääkkönen RJ: Self-report of physical symptoms associated with using mobile phones and other electrical devices. Bioelectromagnetics 2009, 30(6):431-437.
31. Johansson O, Disturbance of the immune system by electromagnetic fields—A Potentially underlying cause for cellular damage and tissue repair reduction which could lead to disease and impairment , Pathophysiology. 2009;16(2-3), 157-77, 2009.
32. Blank M, Goodman R. Electromagnetic fields stress living cells. Pathophysiology. 2009; 16(2–3):71–78.

