

# Research Review on the Biological Effect of Cell Phone Radiation on Human

Ashraf A. Aly<sup>1</sup>, Safaai Bin Deris<sup>2</sup>, Nazar Zaki<sup>3</sup>

<sup>1, 2</sup>Faculty of Computer Science and Information Systems, Universiti Teknologi Malaysia

<sup>3</sup>College of Information Technology, UAE University, UAE

Ashraf.ahmed@uaeu.ac.ae, safaai@utm.my, nzaki@uaeu.ac.ae

## Abstract

The growth in the use of cellular phone has raised the concerns about the possible interaction between the electromagnetic fields (EMF) radiation and the biological effects on human tissues, particularly the brain and the human immune system. These concerns have induced a large volume of research studies. However, most of the previous review studies are concentrated on negative effects and no published work took in consideration all possible effects caused by the use of cell phones. In this paper we aim to provide review of some studies which investigated the possible negative and positive biological effects of cell phone radiation on human tissues. This review will provide answers for public concerns about the risk of using cell phone. Our conclusion shows that long-term exposure to EMF radiation from a cell phone could cause health effects, such as brain cancer. Some positive health effects due to the exposure to the EMF radiation such as improve bone healing and reduce toxic effects of chemotherapy are highlighted. Finally, some studies have also showed no effect due to exposure to EMF. More long-term studies and analysis are much needed

## 1. Introduction

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

Many research work provided evidences about the possible health effects such as; brain tumor, blood-brain barrier (BBB) permeability function, sleep problems, cognitive function, DNA damage, immunity system function and stress reaction not to mention the

increased incidence rate of traffic accidents due to the use of mobile phone while driving.

The risk of exposure to electromagnetic field was first highlighted and publicized in the late 1970s by Colorado study [2] that linked magnetic field exposure from power lines to the possible development of child leukemia. The amount of RF generated by cell phone is usually depends on the number of base stations around the area, the cell phone network traffic, and on how far the cell phone from base stations. The amount of the power which sent from a base station could vary from cell phone to another one even within the same area, depends on the interfering from obstacles such as buildings and trees [3]. Although, cell phones are designed to operate at power levels below a threshold for known thermal effects, radio frequency radiation could produce other kinds of effects, called biological effects. In Figure 1, 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.

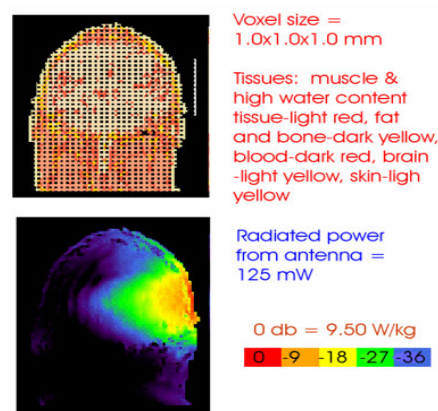


Fig. 1. calculation of specific absorbed radiation (SAR) (USAF/AFRL).

To solve the problem, many research projects are currently studying the effect of cell phone radiation on

human; however, there is an ongoing debate over human safety. Cell phone industry maintains there is no scientific evidence of harmful effects from electromagnetic radiation, while researchers show effect on cells after being exposed to electromagnetic fields. The cells showed a significant increase in DNA damage which could not always be repaired by the cell.

In this paper we managed to review and summarized the major studies on the effect of cell phone radiation on human. We categorized these studies based on the effect on human. Most of the previous studies concentrated more on negative effects and neglected the positive effects of cell phone radiation. Some cases show no effects are also discussed.

## 2. Cell phone Effects

Several effects have been reported due to exposure to long term EMF radiation from cell phones. These effects led us to divide the reported results into three major categories. These categories are as follows:

### 2.1. Positive effects category

From the literature, we found that many research studies have indicated positive effects to the exposure to the EMF radiation. However, we restricted our review on the state-of-the-art works which have massive experimental results. Some of these positive effects are the use of microwave therapy to reduce toxic effects of chemotherapy during the cancer treatment [4]. Satter, et al., [5] for instance has used EMF fields to improve bone healing. The study used low amplitude Pulsed EMF (PEMF) on 19 patients with non-union or delayed-union of the long bones. Electric voltage pulse of 0.3 mSec wide was used making a frequency of 80 Hz and magnetic fields were of 0.01 to 0.1 m Tesla. From 13 patients who completed the treatment period of 14 weeks, 11 of the 13 patients had successful bone healing. Similar results by Johnson et al. [6], suggested that exposure to EMF improve bone healing. Some effects of extremely low frequency electromagnetic fields (ELF-EMFs) on human spermatozoa were also reported by Iorio et al., [7]. In this particular study, significant mobility increase have been observed when spermatozoa were exposed to an ELF-EMF with a square waveform of 5 mT amplitude and frequency of 50 Hz. The effects induced by ELF-EMF (50 Hz; 5 mT) during the first 3 h of exposure persisted for 21 h after the end of the treatment. These results indicate that ELF-EMF exposure can improve spermatozoa motility and this effect depends on the field characteristics. Makar et al.,

[4], also investigated whether millimeter waves (MMWs) at  $61.22 \pm 0.2$  GHz can reduce the effect of cyclophosphamide (CPA) and anti-cancer drug on the immune functions of mice. Antenna aperture ( $1.5 \times 1.5$  cm) of MMW signal generator device produced  $61.22 \pm 0.2$  GHz wave radiation was used as exposure system and placed in front of each mouse's nose. Specific Absorption Rate (SAR) of  $885 \pm 100$  W/kg and  $31 \pm 5$  mW/cm<sup>2</sup> power densities were measured at the skin surface. Duration of the exposure was 30 min each day for 3 continuous days. The temperature increase at the end of 30 min was 1 °C. CPA injection (100 mg/kg) was given on the second day of exposure to MMWs. MMW exposure caused up-regulation in tumor necrosis factor-alpha (TNF- $\alpha$ ) production in peritoneal macrophages, also MMWs enhanced proliferative activity of T-cells. These results indicate that MMWs accelerate the recovery process on a T-cell-mediated immune response.

A recent study by Márquez-Gamiño et al., [8], has also indicated a significant thickness increase in cortical and trabecular *in vivo* stimulated bone tissues. In this case young adult rats were exposed to 1 Hz, 30 mT pulsed magnetic fields. Ten female rats were exposed to the 30 min magnetic stimulation sessions for 20 consecutive days. The anterior and posterior cortical bone transverse thicknesses were measured. The magnetic stimulation system which approved for human therapy was used to generate pulsed EMF.

### 2.2. Negative effects category

Many of the cell phone effects studies have shown evidences of negative effects [14]-[15]. Hardell et al., [14], and Repacholi et al., [15], reported risk of developing brain tumor due to the exposure to EMF radiation generated by cell phone. One of the earlier studies by Salford et al., [16] confirmed that blood brain barrier function could be affected by cell phone radiation. Phillips et al., [17], reported DNA damage due to exposure to EMF radiation. Caprani et al., [18], has found that the environmental electromagnetic field significantly increases the thrombo-embolic risks in the endothelial cell line. Hirata et al., [19] discussed the correlation between peak SAR and maximum temperature increase is blood flow in tissues. Togo et al. [20] investigated Heart Rate Variability (HRV) in the very low-frequency (VLF) range (0.003-0.04 Hz) during deep sleep in good sleepers. He find very low-frequency heart rate variability during deep sleep in humans. Anderson et al., [21], 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. Jonna Wilén et al., [22] found Changes in HRV among RF plastic sealer operators. A recent work by Lena Hillert et al. [23] studied the effect of RF on self-reported symptoms and detection of fields after a prolonged exposure time. The results showed that headache was more commonly reported after RF exposure. Tracy Lightfoot et al., [25] found memory errors, cognitive function and mental health problems due to exposure to EMF [25]-[26]. Ching et al., [27] has confirmed decreases in skin resistance [28]. Other recent study by Aly et al. [28] has found significant changes in neutrophil behavior, which includes shrinking, rolling, and neutrophil speed increased by 50% under RF.

More negative effects on blood brain barrier and DNA are discussed in the proceeding sections:

**2.3.1. Genotoxic, Blood Brain Barrier (BBB), and immune system effects.** Some research studies show association between cell phone radiation and cell changes including damage to chromosomes, alterations in the activity of certain genes and a boosted rate of cell division [29][30][31]. Salford et al., have studied the effects of EMF radiation on the rat brain. He found that the exposure to MRI induced leakage of Evans Blue labeled proteins normally not passing the BBB of rats. The study exposed male and female Fischer of 344 rats in a transverse electromagnetic transmission line chamber to microwaves of 915 MHz as continuous wave and SAR varied between 0.016 and 5 W/kg. All rats were sacrificed by perfusion-fixation of the brains under chloral hydrate anesthesia about 1 hour after the exposure. The brains were perfused with saline for 3-4 minutes and thereafter fixed in 4% formaldehyde for 5-6 minutes. The central coronal sections of the brains were dehydrated and embedded in paraffin and sectioned at 5 microns [16].

**2.3.2. DNA and cancer effects.** Many research works have focused on the effect of cell phone on brain tumors. Hardell et al., [14] Muscat et al., [31] and Lightfoot et al., [24] 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. The study investigated the effects of analogue and digital cellular phones and results were as follows: for analogue phones, OR=1.3, 95% CI=0.99-1.7; for digital phones, analysis significantly increased risk of acoustic neuroma was found with the use of analogue phones. Muscat *et al.*, [31] showed a statistically increased risk of acoustic neuroma due to exposure to EMF. In this case results were presented from a

hospital based case-control study on acoustic neuroma including 90 patients and 86 control subjects with non-malignant diseases. Cases used a cell phone on average for 4.1 years and controls for only 2.2 years. Use of cell phone for 1-2 years produced OR = 0.5 (95% CI 0.2 to 1.3; n = 7), increasing to OR = 1.7 (0.5 to 5.1; n = 11), in the group with 3-6 years' use. Another study by Christensen et al., [34], indicates that long-term cell phone use increases the risk of brain tumors. Randomly selected cases aged 20-69 years were identified as patient with glioma or meningioma during 2000-2002. Detailed information about cell phone use was collected from 371 (74%) glioma and 273 (85%) meningioma cases and 674 (71%) controls. For regular cell phone use, the odds ratio was 0.8 (95% confidence interval: 0.6, 1.0) for glioma and 0.7 (95% confidence interval: 0.5, 0.9) for meningioma. A recent self study by Khurana et al., [33], an Australian neurosurgeon, shows evidence for a link between cell phone usage and certain brain tumors and this danger has far broader public health concerns than smoking.

### 2.3. No effects category

Despite the fact that many studies have reported negative effects of the cell phone radiation on human health, however some studies have also indicated no effects. one of the earlier studies reported was done by Myers et al., in 1990 [9] which shows that ELF exposure has no effects. Schüz et al., [10] draws a conclusion that the use of cell phone in his experimental work is not related to an increased risk of glioma or meningioma. A recent study by Zeni et al., in 2008 [11] investigated the induction of genotoxic effects in human leukocytes. Peripheral blood from six healthy donors was used and, for each donor, intermittent exposures (6 min RF on, 2 h RF off) at the frequency of 1950 MHz were conducted at a specific absorption rate of 2.2 W/kg. The results indicated that intermittent exposures of human lymphocytes in different stages of cell cycle do not induce either an increase in micronucleated cells, or change in cell cycle kinetics. Moreover, indicate that repairable DNA damage was not induced. Other recent study by Kleinlogel et al., [12] also investigated the effects of both types of EMF, 1950 MHz (0.1 and 1 W/kg) and pulsed 900 MHz (1 W/kg) on the behavioral parameters, reaction time in 15 healthy subjects. A double-blind, randomized, crossover application of the test procedure was used. The results were also indicated no evidence for the effect of the EMF on normal healthy cell phone users. Another study by Silke Thomas et al., [13], indicates no link between EMF radiation and human health. In this particular study a random sample of 329 adults was assembled for

the study. They obtained an exposure profile over 24 h for three cell phone frequency ranges (measurement interval 1 s, limit of determination 0.05 V/m). Data on five groups of chronic symptoms and potential confounders were assessed during an interview. The study did not find any association between the exposure and acute symptoms chronic symptoms or between the exposure and chronic symptoms.

### 3. Discussion

Based on the literature analysis and review, most of the positive effect studies results were based on low numbers of case controls. The importance of some studies, such as; the study by Satter et al.,[5] was done on human patients, where, the rest of the studies used rats as a case control. Some of the advantages of other studies such as Makar et al.[4], is the use of microwave therapy to reduce toxic effects of chemotherapy during the cancer treatment. This is a good addition to chemotherapy treatments even if the mechanism of the radiation effect is unclear.

On the other hand, many research studies indicate link between EMF radiation and negative biological effects. The conclusion on the risk, specially for brain tumors associated with the use of cell phone have been mostly with an insufficiently long latency period [18][17], however, the studies showed a somewhat increase risk for shorter latency periods. Long term (10 years or more) studies [14][32] showed a statistically significant increase risk on the exposure to EMF radiation. The study by Hardell et al., [14] indicated that significant increase of risk of DNA damage was found with the use of analogue phones and the analysis showed less risk with digital phones. Moreover, many studies indicated another biological effects such as; blood-brain barrier (BBB) permeability function [16], sleep problems [1], immunity system function [28]. The biological effects are uncertain as the biophysical mechanisms behind their occurrence are unknown. Finally, some research studies indicated no clear association was found between the exposure to the EMF radiation and biological effects.

One of the important reasons for the work presented in this paper is to answer the question of whether the use of cell phone is harmful for users or not. However, the review presented in this paper has not entirely answered the question. More long term studies are needed. What we could conclude is that heavy cell phone could be under high risk of negative effects due to the exposure of EMF radiation. This conclusion indicate that caution is needed when using cell phones and more research is necessary for risk assessment based on higher number of long-term users.

The review results also show that much of the current research available was conducted on healthy adults. It spells out the need for more information regarding the specific absorption rates for children, pregnant women and fetuses, which absorb radiation differently from adults. Because many of the original tests were also conducted with rod-like exterior antennas, the review notes that certain tests need to be redone now that many cell phones have internal antennas that expose different parts of the body to radiation.

### 4. Conclusion and future work

In this paper we reviewed and summarized some of the crucial research done to study the biological effect of cell phone radiation. The work was motivated by the fact that the public is concern about the danger of using cell phone. We categorized the existing work into three categories based on the effect pointed out by researchers. These effects are positive effect, negative effect and no effect. Some research studies have indicated some positive health effects due to the exposure to the EMF radiation, such as improve bone healing and reduce toxic effects of chemotherapy.

Although, we have many evidence about the negative effect of the cell phone radiation on human health, but we still in need for more research work to confirm the evidence we have. Long-term experimental follow-up is much needed. Cancer for instance, needs time to develop the reason why only studies took over 10 years were able to indicate link between cell phone and biological effects on human tissues, particularly the brain and the human immune system. It's hard to reach a conclusion whether cell phone is harmful because most of the existing studies have not shown the same findings. And the effects may be very different depending on the type of electromagnetic radiation. GSM and GPRS (2.5G) phones for instance use pulsed radiation. In this case the levels rise and fall rapidly. 3G phones on the other hand use continuous levels. Since the 3G phones are becoming very common, we are planning to make more deep studies focuses on the effect of 3G cell phones on human.

### 5. Acknowledgements

This work was financially supported by the Research Affairs at the UAE University under a contract no. 04-01-9-11/08.

## 6. References

- [1] Hung CS, Anderson C, Horne JA, McEvoy, "Mobile phone 'talk-mode'signal delays EEG-determined sleep onset," *Neuroscience*, 421 (1): 82–86, 2000.
- [2] Champion EW, "Power lines, Cancer, and Fear." *The New England journal of medicine*, 337.1 : 44-6, 1997.
- [3] Inskip PD, Tarone RE, Hatch EE, "Cellular telephone use and brain tumors," *N. Engl J Med*, 344:79-86, 2001.
- [4] Makar VR, Logani MK, Bhanushali A, Kataoka M, Ziskin MC, "Effect of millimeter waves on natural killer cell activation," *Bioelectromagnetics*, 26:10-19, 2005.
- [5] Satter Syed S, Islam MS, Rabbani KS, Talukder MS, "Pulsed electromagnetic fields for the treatment of bone fractures," *Bangladesh Med Res Coun Bull*, 25:6–10, 1999.
- [6] Johnson MT, Vanscoy-Cornett A, Vesper DN, Swez JA, Chamberlain JK, Seaward MB, Nindl G, "Electromagnetic fields used clinically to improve bone healing also impact lymphocyte proliferation in vitro," *Biomed Sci Instrum* , 37 : 215 – 220, 2001.
- [7] Iorio R, Scrimaglio R, Rantucci E, Delle Monache S , Gaetano A Di, Finetti N, Francavilla F, Santucci R , Tettamanti E, Colonna R, " A preliminary study of oscillating electromagnetic field effects on human spermatozoon motility," *Bioelectromagnetics*, June 2006.
- [8] Márquez-Gamiño S, Sotelo F, Sosa M, Caudillo C, Holguín G, Ramos M, Mesa F, Bernal J, Córdova T, "Pulsed electromagnetic fields induced femoral metaphyseal bone thickness changes in the rat," *Bioelectromagnetics*, 29:406-409, 2008.
- [9] Myers, "ELF exposure has no effects," *ACM Transactions on Information Systems*, 8(3):289-320, 1990.
- [10] Schüz ab J, Jacobsen R, Olsen JH, Boice JD, McLaughlin JK, Johansen C, "Cellular Telephone Use and Cancer Risk: Update of a Nationwide Danish Cohort". *J. of the National Cancer Institute*, 98 (23): 1707–1713, 2006.
- [11] Zeni O, Schiavoni A, Perrotta A, Forigo D, Deplano M, Scarfi MR, "Evaluation of genotoxic effects in human leukocytes after in vitro exposure to 1950 MHz UMTS radiofrequency field," *Bioelectromagnetics*, 29:177-184, 2008.
- [12] Kleinlogel H , Dierks Th , Koenig Th , Lehmann H , Minder A , Berz R, "Effects of weak mobile phone - Electromagnetic fields (GSM, UMTS) on event related potentials and cognitive functions," *Bioelectromagnetics*, 29:488-497, 2008.
- [13] Silke Thomas, Anja Kühnlein, Sabine Heinrich, Georg Praml, Dennis Nowak, Rüdiger von Kries, Katja Radon, "Personal exposure to mobile phone frequencies and well-being in adults: A cross-sectional study based on dosimetry," *Bioelectromagnetics*, 29:463-470, 2008.
- [14] 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 brain tumours diagnosed during 1997–2003," *Int J Oncol*, 28:509–18, 2006.
- [15] Rrpacholi M H, "Lymphomas in E Mu-Pim1 Transgenic Mice Exposed to Pulsed 900 MHz Electromagnetic Fields," *Radiation research*, 147.5: 631-40, 1997.
- [16] Salford LG, Brun A, Stuesson K, Eberhard JL, Persson BR, " Permeability of the blood-brain barrier induced by 915 MHz electromagnetic radiation, continuous wave and modulated at 8, 16, 50, and 200 Hz," *Microsc. Res. Tech.* 15: 535-542, 1994.
- [17] Phillips JL, Ivaschuk O, Ishida-Jones T, Jones RA, Campbell-Beachler M, Haggren W, "DNA damage in Molt-4 T- lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro," *Bioelectrochem Bioenerg*, 45:103-110, 1998.
- [18] Caprani A , Richert A, Flaud P, "Experimental evidence of a potentially increased thrombo-embolic disease risk by domestic electromagnetic field exposure," *Bioelectromagnetics*, 25:313-315, 2004.
- [19] 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.
- [20] Togo F, Yamamoto Y, "Decreased fractal component of human heart rate variability during non-REM sleep," *Am J Physiol Heart Circ Physiol*, 280: H17-H21; Vol. 280, Issue 1, H17-H21, 2001.
- [21] 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.
- [22] Jonna Wilén, Urban Wiklund, Rolf Hörnsten, Monica Sandström, "Changes in heart rate variability among RF plastic sealer operators," *Bioelectromagnetics*, Volume 28 Issue 1, Pages 76- 79, 2007.
- [23] 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.
- [24] Tracy J Lightfoot, Christine F Skibola, "Risk of Non-Hodgkin Lymphoma Associated with Polymorphisms in Folate-Metabolizing Genes," *Cancer Epidemiology Biomarkers & Prevention*, Vol. 14, 2999-3003, 2005.
- [25] Christina M. Krause, Mirka Pesonen, "Brain oscillatory 4–30 Hz responses during a visual n-back memory task with varying memory load," *BrainResearch*, Volume 1138, 23, Pages 171-177, 2007.
- [26] Preece AW, "Mobile phones and human heads," *Neuro Report*, Vol 11 No 2, 2000.
- [27] 28. Chang Nam Ki , Sung Woo Kim, "Effects of RF exposure of teenagers and adults by CDMA cellular phones," *Bioelectromagnetics* Volume 27 Issue 7, Pages 509 – 514, 2006.
- [28] 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.
- [29] Panagopoulos DJ, Chavdoula ED, Nezis IP, Margaritis LH, "Cell death induced by GSM 900 MHz and DCS

1800 MHz mobile telephony radiation," *Mutation Research*, 626 (1-2): 69-78, 2007.

- [30] 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.
- [31] Muscat JE, "Handheld Cellular Telephone use and Risk of Brain Cancer," *JAMA;the journal of the American Medical Association* 284.23:3001-7, 2000.
- [32] Christensen H C, Schüz J, Kosteljanetz M, " Cellular telephone use and risk of acoustic neuroma," *Am J Epidemiol*, 159:277-83, 2004.
- [33] Khurana, Vini, "Mobile Phone-Brain Tumour Public Health Advisory" 3-4. self-pub, Retrieved on 2008.