

Radioepidemiologic and Experimental Evidence: Health Risks Associated with Radiofrequency Radiation Exposure



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Abstract: *Public exposure to Electromagnetic Radiation, which abbreviatedly known as EMR is a recurring phenomenon and it becomes among the factors contributing to the public concerns. EMR represents a new technology, such as base stations, overhead power lines and other sources of exposure, that is difficult to control by the affected individual. Non-ionizing and ionizing radiation are two major divisions of the electromagnetic spectrum. Both kinds of radiation can be differentiated based on which one has enough energy to knock electrons off atoms upon collision, as well as capable to give out lower-energy harm, such as breaking chemical bonds in molecules. Ionizing radiation is a type of radiation that has a short wavelength to interact with the electrons in biological chemicals. Alpha, beta, and gamma rays are examples of ionizing radiation. The literature on RF effects also focused on the human factor and health parameters, both from the laboratory and epidemiological study perspectives. The presence of this communication technology has given rise to media and public concerns about the possibility of RF radiation emitted by computers, phones and base stations that might cause a rise in diseases that affect the reproductive system, neurobehavioral parameters and various forms of cancers, especially brain tumours. More recently, concerns about the possible effects culminating from the massive development of base stations coupled with increasing use of mobile phones have begun to appear due to the enormous growth of wireless mobile communication, mainly handheld devices. This has led to increased apprehension as to whether non-ionizing radiation (NIR) used in present technologies could have short, medium and long-term biological effects.*

Keywords: *Radiofrequency radiation, mobile phone, base station, health effect*

I. INTRODUCTION

EMR and waves act as the main media for carrying signals, which can be in the form of a voice, image or data, from a certain source to the desired destination [1]. EMR may be

dangerous to the human body, based on the intensity of radiation released and ultimately absorbed by individual charged particles [2]. Meanwhile, non-ionizing radiation can be determined as it possesses insufficient energy to cause ionization. Even though ionizing radiation is more harmful than non-ionizing radiation, the former is suspected of causing biological effects in the long term [3]. RF electromagnetic fields are in the range of 3 kilohertz (kHz) to 300 Gigahertz (GHz). Usually, in mobile communication technology, RF sources of EMR are the type of radiation that are essentially involved. Other wireless applications such as cordless phones or wireless local area network (WLAN) systems normally operate with lower power output compared to mobile phones levels. The link between the network and the mobile phone is performed by base stations at different frequencies called RF transmitters [4]. Nowadays, given the increase in public awareness on RF, apprehension has grown among the public regarding the possible harmful effects emitted by EMR either by near-field or far-field exposure sources. Several sources of near-field exposures include cell phones and laptops. In the meantime, instances of far-field exposure origins include base stations for cellular phones, power lines and high-voltage overheads [5].

II. POTENTIAL HEALTH EFFECTS

World Health Organization (WHO) has categorised the RF emitted from mobile phones, WLAN and from other devices as Group 2B; which is a “possible”, human carcinogen. The term ‘carcinogenic risk’ refers to agents that have the probability in causing cancer [7]. There is increase in public concerns by the construction and through usage of high-voltage overhead power lines and ground stations as well as an increase in scientific debate on the potential health effects of RF to the community [8]. Some studies have confirmed the association based on distance and propagation model in between proxy measure. Whereas in some studies, the association was concluded to be at approximately 60%, especially when based on self-reported exposures [9][10].

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EMR produced by cellular phones has also given a raise in public concern about the impacts of RF on health. Symptoms such as headaches, tremors, changes in memory, depression, dizziness and sleep disturbance were exhibited by inhabitants living around mobile base stations and exposed to RF radiation [11].

Studies investigated the co-relationship between self-reported exposure and perceived adolescent well-being and found that self-reported mobile phone usage among adolescent was correlated with poor perceived health [12]-[14].

III. NEUROBEHAVIORAL EFFECTS

Neurobehavioral complaints such as headaches, dizziness, depression, changes in memory, sleep disturbance and tremors were reported to be significantly higher among exposed inhabitants compared to controls living around mobile base stations [11]. Continued exposure to EMR has given rise to familiar complaints such as headaches, impaired vision, dizziness, nausea and memory loss [15]. They also experienced certain unfamiliar non-specific health symptoms (NSHS) that were caused by EMR exposure. Headaches and sleep disturbances were reported to be statistically significant within a radius of 200 meters from the base station. Within a 100 meters' radius from the base station, complaints of loss of memory, dizziness and irritability were reported to be significant [16]. However, a study carried out in Austria involving 365 subjects revealed that effects on performance and well-being cannot be ruled out despite very low exposure to a high-frequency electromagnetic field (HF-EMF) [17]. As for the objective and subjective of sleep quality, the study did not provide any proof that EMR transmitted by the baseline stations will contribute to a short-term physiological. Despite having no evidence to support this factor, the result indicates that it might have a significant negative impact on the quality of sleep after being exposed to EMR emitted by base stations [18]. Hence, there is intense concern about this potential health effect due to exposure to EMR on children's health [19].

IV. REPRODUCTIVE EFFECT

Growing mobile phone users were deeply concerned about the potential impact of mobile phones exposures on themselves [20]. RF and microwave radiations emitted from mobile phones and base stations are measured by the macroscopical interaction between EMR and the biological system in terms of absorbed power [21]. Fertility is thought to be one of the biologic functions that can be threatened through electromagnetic radiation, especially in men. The testes, as a surface organ, could be more susceptible to radiation emitted from appliances containing EMR such as mobile phones. Among myriads of biological targets, the deoxyribonucleic acid (DNA) molecule has received the greatest concern compared to other biological targets due to potential EMR effects on cell function, mutation, viability, proliferation and cancer. Thus, because of these types of radiations, the problem related to the human reproductive system has led to several undesirable outcomes such as changes in enzyme level, low sperm count, metastasis,

invasion, apoptosis and cell proliferation. In animal studies, mobile phone exposure has shown a reduction in sperm count and findings on the decline in semen quality have been verified in past studies [22][23]. However, significant negative impacts of mobile phone use on human sperm motility have also been documented by five studies [24]-[28].

V. ELECTROMAGNETIC HYPERSENSITIVITY

Idiopathic environmental intolerance has been described by the WHO as a self-reported sensitivity to an EMR source [29]. Based on the scientific term, this type of sensitivity, which occurs only due to EMR or also known as electromagnetic hypersensitivity (EHS). In year 2005, however, the WHO suggested the word 'EMF-attributed idiopathic environmental sensitivity' (IEI-EMF) as an etiologically neutral classification [30]. According to several observations, it was suggested that this condition has a psychogenic origin. Physical symptoms caused by EMR exposure, either in an experimental context or in daily life based on clinical opinions, are both varying and unspecific. The most widely reported signs of EHS are headaches, tiredness, memory loss, cognitive impairment, skin rash or inflammation at different body parts or different locations [31][32].

A person with EHS also experiences anxiety, somatization, depression and higher levels of stress compared to average people [33]. However, when identifying the symptoms of EHS, there is always a concern regarding these studies in terms of recall bias. Selection bias in these case-control studies could alter the results. Further studies after case-control revealed that respondents overestimated the amount of cellular phone usage use after a comparison was made between operator data and questionnaire data, which speaks in favour of using a combined approach. Severe misclassification can also be caused by exposure assessment that relies exclusively on self-reports by subjects. Self-reports should be used as a parameter that indicates an individual's perception of being exposed [34]. Fig. 1 shows the mechanism of damage on spermatozoa by EMR emitted from mobile phones, starting from the central nervous system (CNS) to the male reproductive organ.

VI. SENSITIVITY OF CHILDREN

Children's possible exposure to RF radiation has caused great concern owing to their growing nervous system's sensitivity. The brain tissue of an infant is more vulnerable compared to an adult's since children have a higher ion concentration and water content. Due to a smaller head size, RF penetration is greater, and children have a greater absorption of RF energy at mobile phone frequencies in tissues of the head [35]. It have a consistent pattern of increased incidence of leukaemia. Swinburne University of Technology identified a constant and prolonged exposure of low-intensity RF is correlated with the increment of risk among children suffered from leukaemia. However, the data obtained is insufficient to consider the RF exposure as causal. The value 50 / 60Hz guidelines including 0 – 3 KHz which is in the ELF band was reviewed by Australian Radiation Protection Agency (ARPANSA)[6].



VII. RESULT

International Commission on Non-Ionizing Radiation Protection (ICNIRP) reported a published double-tier guideline in year 1998 contains similar security factor and the overall SAR average weight limit.

While the ICNIRP and 1991 IEEE recommendations were focused on restricting all of the revised Specific Absorption Rate (SAR) by resonant region bodies to 0.4 W / kg and 0.08 W / kg for upper and lower rates, the total SAR cap for regional disclosures differs, both in magnitude and average amount, respectively [6]. In Malaysia we have MARPA stand for Malaysian Radiation Protection Association (Persatuan Perlindungan Sinaran Malaysia). This is a non-governmental organization that was established on 15 September 2002. Non ionizing radiation protection also discussing in this organization. It represents a pool of professionals of highest skill in radiation protection and safety (<http://www.marpa.org.my>). Table. 1 shows the specific absorption rate (SAR) and health effects from RF exposure. Present knowledge suggests that RF exposure is correlated to health effects. Exposure levels during the use of mobile phones were slightly higher compared to exposure from base stations.

Exposure to RF radiation has triggered RF health-related effects on neurobehavioral systems, reproductive systems, and electromagnetic hypersensitivity (EHS). However, examining previous literature on long-term exposure to RF has shown that there is a remote possibility for a brain tumour to occur in long-term mobile phone users. Nevertheless, there have been consistent health effects after being exposed to levels below the ICNIRP limits (<https://www.icnirp.org>).

Table. 1 Specific absorption rate (The radiofrequency level in induce health effect)

| | RF health effect Simptom | Absortion rate (w/kg) |
|----|-----------------------------|-----------------------|
| 1. | Headaches | more than 0.01 |
| 2. | cancer | 0.13-1.4 |
| 3. | Insomia | more than 0.5 |
| 4. | Depression | 0.0317 |
| 5. | Ear tingling/burning | 1.6 (standard) |
| 6. | Loss of memory | more than 0.1 |
| 7. | Reproductive problem (male) | 0.0016-0.0105 |
| 8. | Children sensitivity | 0.0016 |

Based on results of in-vitro studies, evidence shows that gene expression is affected by RF exposure. Table 1 shows specific absorption rate (SAR) and health effects from RF exposure. Present knowledge suggests that RF exposure is correlated with health effects. Exposure levels during the use of mobile phones were slightly higher compared to exposure from base stations. Overall, the analysis showed that exposure to RF is correlated with cognitive processes, behaviour or memory and can cause pathological hazards.

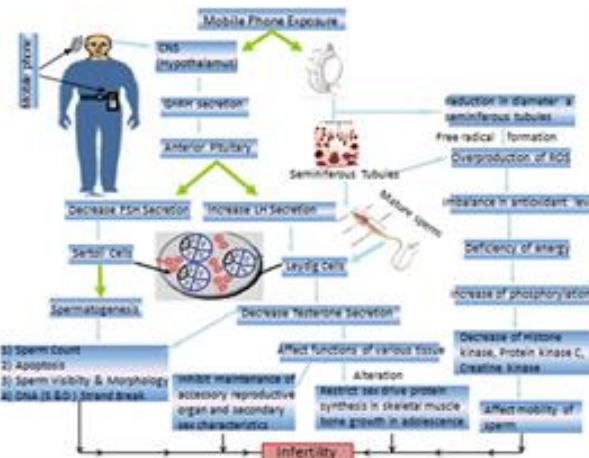


Fig. 1 Possible routes for mechanism of damage between central nervous system (CNS) and testis caused to spermatozoa by electromagnetic waves (EMW) released from cell phones [21].

According to Calvente et al., children continuously exposed to radiofrequency radiation been consistent signs of health effects after exposure to levels below the ICNIRP limits [36]. Based on results of in-vitro studies, evidence indicates that gene expression is affected by RF exposure. Overall, the analysis showed that exposure to RF is correlated with cognitive processes, behaviour or memory and can cause pathological hazards (Fig 2).

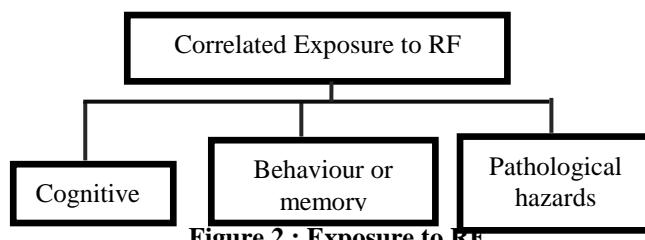


Figure 2 : Exposure to RF

VIII. CONCLUSIONS

This review summarized radiofrequency radiation health effects and risk of exposure to radiofrequency (RF) radiation. The literature review identified potential biological and health effects of RF by examining scientific evidence, which was in vitro (the isolation, growth and identification of cells) and in vivo (within living things).

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REFERENCES

1. A. Mousa, "Electromagnetic Radiation Measurements and Safety Issues of some Cellular Base Stations in Nablus," Journal of Engineering Science and Technology Review, vol. 4(1), 2011, pp. 35-42.
2. O. K. Felix, A. U. Gabriel, A. C. Emmanuel, "Investigation and Analysis on Electromagnetic Radiation from Cellular Base Station Transmitters and the Implications to Human Body," Journal of Environment and Ecology, vol. 5 (1), 2014, pp 46-60.

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3. O. Desouky, N. Ding, G. Zhou, "Targeted and non-targeted effects of ionizing radiation," *Journal of Radiation Research and Applied Sciences*, vol. 8(2), 2015, pp. 247–254.
4. International Commission on Non-ionizing Radiation Protection (ICNIRP): Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300GHz). *Health Physics*, vol. 99(6), 2010, pp 818-83.
5. M. Blettner, B. Schlehofer, J. Breckenkamp, B. Kowall, S. Schmiedel, U. Reis, P. Potthoff, J. Schüz, G. Berg-beckhoff, "Mobile phone base stations and adverse health effects: phase 1 of a population-based, cross-sectional study in Germany," *Occup Environ Med*, vol. 66 (2), 2009, pp 118 – 123.
6. K. H. Ng, "Electromagnetic Fields, Bioeffects Research, Medical Applications, and Standards Harmonization," International EMF Conference, Kuala Lumpur, Malaysia. University of Malaya. 4-6 June 2007.
7. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Non-Ionizing Radiation. Radiofrequency Electromagnetic Fields. International Agency for Research on Cancer: Lyon, France, 2013; 2(102). Available online: <http://monographs.iarc.fr/ENG/Monographs/vol102/index.php>.
8. G. Berg-Beckhoff, M. Blettner, B. Kowall, J. Breckenkamp, B. Schlehofer, S. Schmiedel, C. Bornkessel, U. Reis, P. Potthoff and J. Schüz, "Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measure radio frequency electromagnetic fields." *Occup Environ Med*. vol. 66 (2), 2009, pp 124-130.
9. J. F. Viel, S. Clerc, C. Barrera, R. Rymzhanova, M. Moissonnier, "Residential exposure to radiofrequency fields from mobile phone base stations, and broadcast transmitters: a population-based survey with personal meter." *Occup Environ Med*. vol. 66, 2009, pp 550-556.
10. P. Frei, E. Mohler, A. Burgi, J. Frohlich, G. Neubauer, C. Braun-Fahrlander, and M. Roosli, "Classification of personal exposure to radio frequency electromagnetic fields (RF-EMF) for epidemiological research: evaluation of different exposure assessment methods." *Environ. Int.* vol. 36 (7), 2010, pp 714–720.
11. G. Abdel-Rassoul, O. A. El-Fateh, M. A. Salem, A. Michael, F. Farahat, M. El-Batanouny, E. Salem, "Neurobehavioral effects among inhabitants around mobile phone base stations." *Neurotoxicology*, vol. 28(2), 2007, pp 434-440.
12. L. K. Koivusilta, A. H. Rimpela, S. M. Kautiainen, "Health inequality in adolescence. Does stratification occur by familial social background, family affluence or personal social position?" *BMC Public Health*, vol. 6 (110), 2005.
13. R. L. Punamaki, M. Wallenius, C. H. Nygard, L. Saarni, A. Rimpela A, "Use of information and communication technology (ICT) and perceived health in adolescence: the role of sleeping habits and waking-time tiredness." *J Adolesc.* vol. 30(4), 2007, pp 569–585.
14. F. Soderqvist, M. Carlberg, L. Hardell, et al. "Use of wireless telephones and serum S100B levels: a descriptive cross-sectional study among healthy Swedish adults aged 18–65 years." *Sci Total Environ.* vol. 407 (2), 2009, pp 798–805.
15. R. Maheshwari and M. Kumar, "Hazardous Impact of Electromagnetic Radiations on Human Health." *Bull. Env. Pharmacol. Life Sci.* vol. 2(3), 2013, pp 66-67.
16. A. Suleiman, T. T. Gee, A. D. Krishnapillai, K. M. Khalil, M. W. A. Hamid, M. Mustapa, "Electromagnetic Radiation Health Effects in Exposed and Non-Exposed Residents in Penang." *Journal of Geoscience and Environment Protection*. vol. 2, 2014, pp 77-83.
17. H-P Hutter, H. Moshammer, P. Wallner, M. Kundi, "Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations." *Occup Environ Med*, vol. 63 (5), 2006, pp 307–313.
18. H. Danker-Hopfe, H. Dorn, C. Bornkessel, C. Sauter, "Do Mobile Phone Base Stations Affect Sleep of Residents? Results from an Experimental Double-Blind Sham-Controlled Field Study." *Am J Hum Biol*, vol. 22 (5), 2010, pp 613–618.
19. J. Bakker, M.M. Paulides, E. Neufeld, A. Christ, N. Kuster, G. C. Van Rhooen, "Children and adults exposed to electromagnetic fields at the ICNIRP reference levels: theoretical assessment of the induced peak temperature increase." *Phys Med Biol*, vol. 56 (15), 2011, pp 4967–4989.
20. A. Agarwal, A. Singh, A. Hamada, K. Kesari, "Cell phones and male infertility: a review of recent innovations in technology and consequences." *Int Braz J Urol*, vol. 37 (4), 2011, pp 432–454.
21. K. K. Kesari, M. H. Siddiqui, R. Meena, H. Verma, S. Kumar, "Cell phone radiation exposure on brain and associated biological systems" *Indian J Exp Biol*. vol. 51(3), 2013, pp187-200.
22. K.K. Kesari, J. Behari, "Microwave exposure affecting reproductive system in male rats." *Appl Biochem Biotechnol*, vol. 162 (2), 2010, pp 416–428.
23. M. Rolland, J. Le Moal, V. Wagner, D. Royere, J. De Mouzon, "Decline in semen concentration and morphology in a sample of 26 609 men close to general population between 1989 and 2005 in France." *Hum Reprod* vol. 28, 2013, pp 462–470.
24. A. Agarwal, N. R. Desai, K. Makker, A. Varghese, R. Mouradi, E. Sabanegh, and R. Sharma, "Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study." *Fertil Steril*, vol. 92 (4), 2009, pp 1318–1325.
25. L. Ahmed, N. M. Baig, "Mobile phone RF-EMW exposure to human spermatozoa: an in vitro study." *Pakistan J Zool*, vol. 43, 2011, pp 1147–1154.
26. G.N. De Iuliis, R. J. Newey, B. V. King, R. J. Aitken "Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro." *PLoS One*, vol. 4 (7), 2009, e6446.
27. O. Erogul, E. Oztas, I. Yildirim, T. Kir, E. Aydur, G. Komesli, H. C. Irkilata, M. K. Irmak, and A. F. Peker, "Effects of electromagnetic radiation from a cellular phone on human sperm motility: An in vitro study." *Arch Med Res*, vol. 37, 2006, pp 840–843.
28. S.S. Al- Chalabi, Y. T. Al-Wattar, "Effect of mobile phone usage on semen analysis in infertile men." *Tikrit J Pharm Sci*, vol. 7, 2011, pp 77–82.
29. C. Baliatsas, I. V. Kamp, E. Lebret, G. J. Rubin, "Idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF): a systematic review of identifying criteria." *BMC Public Health* vol. 12, 2012, 643.
30. WHO: Fact Sheet No. 296: Electromagnetic fields and public health. 2005, World Health Organization, available from www.emfandhealth.com/WHO_EMSSensitivity.pdf (March 2016).
31. C. Baliatsas, J. Bolte, J. Yzermans, G. Kelfkens, M. Hooiveld, E. Lebret, I. V. Kamp, "Actual and perceived exposure to electromagnetic fields and non-specific physical symptoms: An epidemiological study based on self-reported data and electronic medical records." *Int J Hyg Environ Health*, vol. 218 (3), 2015, pp 331–344.
32. O. Hallberg, G. Oberfeld, "Will We All Become Electro sensitive?" *Electromagnetic Biology and Medicine*, vol. 25, 2006, pp 189-191.
33. A. Johansson, S. Nordin, M. Heiden, M. Sandstrom, "Symptoms, personality traits, and stress in people with mobile phone-related symptoms and electromagnetic hypersensitivity". *J Psychosom Res*, vol. 68 (1), 2010, pp 37–45.
34. M. Roosli, "Radiofrequency electromagnetic field exposure and non-specific symptoms of ill health: a systematic review." *Environ Res*. vol. 107(2), 2008, pp 277-287.
35. L. Kheifets, M. Repacholi, R. Saunders, E. V. Deventer. "The Sensitivity of Children to Electromagnetic Fields." *Pediatrics*, vol. 116(2), 2005, pp 303-313.
36. I. Calvente, C. D. Arias, O. O. Hernandez, R. P. Lobato, R. Ramos, F. A. Cordon, N. Olea, M. I. Nunez, M. F. Fernandez, "Characterization of Indoor Extremely Low Frequency and Low Frequency Electromagnetic Fields in the INMA Granada Cohort." *PLOS ONE*, vol. 9(9), 2014.

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