Global Advanced Research Journal of Scientific Research and Essay (GARJSRE) Vol. 1(1) pp. 001-005, December 2013
Available online http://garj.org/garjsre/index.htm

Review

A review on recent studies on brain exposure to RF radiations

[1]Alao, Olumuyiwa Ademola and [2]Ajayi, Isaac Rotimi

[1]Department of Physical Sciences, Afe Babalola University, Ado Ekiti, Ekiti State, Nigeria
[2]Department of Physics, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria

Accepted 19 December 2013

This review study discusses the public perspectives based on cell phones radiation exposure to particularly the human brain, concentrating on the behavioural effect and disease factors due to RF exposures. Health endpoints reported to be associated with RF which includes brain tumours, genotoxic effects, neurological effects, immune system deregulation, allergic responses and some cardiovascular effects are classified and reviewed. This review however showed that there is strong and robust evidence that chronic exposures to electro magnetic frequency or radio frequency or microwave fields across the spectrum, through strength, consistency, biological plausibility and many dose-response relationships, cause increased rates of brain cancer and other carcinogenic symptoms. It can therefore be related that there is no safe threshold because of the genotoxic nature of the mechanism that may however be involved. The discussed study explains that the cell phone induced effects upon the blood –brain barrier permeability and in continuous hours of exposure to RF radiation may result in significant increase in protein extra vasations. Animal species of the sub group reviewed in this study are characterised by symptoms such as a decreased loco motor activity, increased grooming and reduced memory functions due to continuous long hour's exposure to RF-EMR at specified absorption rate during their early days of infancy.

Keywords: RF exposure, Human brain, Genotoxic effects, microwaves, Radio frequency, Disease factors

INTRODUCTION

Earlier before the advent of cell phones, when radar and microwave ovens posed apossible health problem, the possible risks of microwaves for the human body have attracted significant studies and research interest. The human brain which naturally functions for thinking, emotions and memory is a highly sensitive and complex organ of nervous system that responds to the electromagnetic radiations that use a wide range of extremely low frequencies (ELF). However, classical concepts of physics are used to explain interactions between external electromagnetic fields, the brain tissue and the activity of the brain. The fundamental processes involved are resonance, absorption and interference. Resonance signal is detected by the brainwhich subsequently synchronizes the ELF activity of the brain. The natural electromagnetic sensitivity of the brain gives a strong basis for accepting that electromagnetic field and radiation exposures at thousands to millions of times higher intensity than the natural resonancesignal can damage brain tissue and could cause brain cancer if the damage is genetic. A vital factor for brain damage is the

*Correspondent Authors E-mail: muiwaalao@gmail.com, isajayi@yahoo.com; Tel: +2347030067085, + 2348067445389

primary need for damaged brain cells to be repaired if possible, because of the nearly total lack of replacement. Oscar and Hawkins early performed studies on effects of radio frequency (RF) uponthe brain when they demonstrated that at very low energy levels (< 10W/m^2), the fields in a restricted exposure window caused a significant leakage of 14 Cmannitol, innulin and also dextran (same molecular weight as albumin) from the capillariesinto the surrounding cerebellar brain tissue (Oscar and Hawkins1977). Nonetheless, recent studies have also shown that Electromagnetic frequency at 1.8 GHz increases the permeability to sucrose of the brain (Schirmacher et al. 2000). Other Studies inferred that this part of the central nervous system in exposure to RF, pulsed and static magnetic fields usually give rise to a significant pinocytotic transport of albumin from the capillaries into the brain.

Hypothesis

The Resonance signal is a mainly tropically sourced radiating Electromagnetic frequency signal that is chronically globally available. This signal is characterized by mean vertical electric field strength in the range (0.013-0.33pW/cm^2), averaging about 0.1pW/cm^2. The brain's circadian and ELF activity is synchronized by this signal with a matching frequency range being resonantly absorbed in the brain tissue. Solar and Geomagnetic Activity (SGMA) induces changes in human health, including cancer, through modulating the resonance signal, altering brain activity and altering melatonin production. Melatonin which plays a vital role in free radical scavenging and in the competence of the immune system, shows that brain tissue responds to external ELF modulated signals by altering the rate of flux of calcium ions through neurons, at extremely low induced issue field intensities down to 10^{-8}V/cm. Strong evidences from hypothesis showed that resonance signal (particularly the Schumann Resonance (SR) Signal) is detected by the brain, and theSR signal synchronizes the ELF activity of the brain and that the brain tissue responds to external ELF modulated signals by altering the rate of flux of calcium ions through neurons, at extremely low induced issue field intensities down to 10^{-8}V/cm (Cherry N, 2002). The brain's circadian and ELF activity is synchronized by this signal with a matching frequency range being resonantly absorbed in the brain tissue. Solar and Geomagnetic Activity (SGMA) induces changes in human health, including cancer, through modulating the SR signal, altering brain activity and altering melatonin production. With SGMA activity, though the Schumann Resonance signal, altering human melatonin, then it is shown to be causally associated with a homeostatic relationship with variations in rates of cancer, cardiac, reproductive and neurological diseases andmortality, through a large body of multiple and independent studies.

Potential Changes Associated with RF Exposures

Genotoxic substances have been found to potentially causing genetic mutations or cellular damage that can contribute to the development of cancerous tumours. These have been the observation from the empirical studies of the potential of RF-EMFs to cause changes in a cell's genetic material (DNA) or to damage the genome.

Researchers who placed a cell phone at a one-meter or about a yard distance from human cells found a reduction in DNA repair in cells with double-strand DNA damage. The strongest effects were observed in stem cells. Since stem cells are more active in children, researchers argue that children may be at an increased risk of cancer from cell phone exposures (John Wargo et al, 2012). It was also discovered that neuron damage in the brain may occur after a long time exposure or intermittent exposure cell phones usage. Microwave radiation have been reported to cause cataracts and effects on the retina, cornea and other ocular systems, however, researchers have recommended further study of effects on the eye lens and lens epithelial cells since Electromagnetic fields from microwave radiation have been shown to have a negative impact on the eye lens. One study warns, High frequency microwave electromagnetic radiation from mobile phones and other modern devices has the potential to damage eye tissues. The addictive usage of cell phones has spontaneous behavioural effects and however become a concerned phenomena index to psychologist sover the years. Psychologists have warned that cell phone users that have become addicted to these devices are at the risk of experiencing withdrawal symptoms typically associated with substance abuse, such as anxiety, insomnia, and depression.

Other Effects Associated With RF Exposure

Electromagnetic Hypersensitivity (EHS) is an adverse medical symptom resulting from the exposure to electromagnetic fields. People with electromagnetic hypersensitivity (EHS) report symptoms from even low levels ofexposure to non-ionizing electromagnetic radiation (Hocking, B and Westerman R, 2001). Report showed that cell phones users associated with EHS are found with complaints such as headaches, nausea, dizziness and blurred vision. Recent studies on heart rate showed that pregnant women exposed to EMF emitted by mobile phones on telephone-dialing mode for 10 minutes a day during pregnancy and after birth had babies with statistically significant increases in fetal and neonatal heart rate. (RezkA Y et al, 2008). However, researchers suggested that this may result from a physiological response to the pulsed magnetic fields, and

Table 1. Recent Studies on Brain Exposure to RF Radiations: Effects on Cognition, Learning and Memory

Animal Model	Year	Frequency/SAR	Exposure Duration	Effect/Observation	Author
Human	2006	890.2MHz/NS	Continuous for 2 hours	Exposure to left side of brain slowed left hand response time	Eliyahu et al.
Human	2006	900MHz/2.8W/kg	Continuous for 1 hour	Changes in gene and protein expression. Mobile phone radiation exposure disturb the cytoskeleton component F – actin fibers by phosphorus	Leszczynski et al.
Human	2006	1.9GHz/1.0W/kg	Continuous for 1 hour	Significantly elevated the expression of heat shock proteins(HSPs) and showed stress response	Chauhan et al.
Human	2006	1.9GHz/1.0W/kg	Continuous for 6 hours, 5 minutes. On a 10 minutes off.	No changes in stress related gene expression	Chauhan et al.
Human	2005	1.95GHz/ 3.60 mW/kg	1,2 ,3 hours exposure durations	Affect the refolding kinetics of eukaryotic proteins. MW-EMF induces apopotosis through the activation of ras-erk survival signaling due to enhanced degradation of ras and Raf-1	Caragliaet al
Human	2004	900MHz/ NS	Continuous for 1 hour	Changes in protein expression involved in the structure of cell	Nylund and Leszczynski
Human		902MHz/NS	Continuous for 50 minutes	Pulsed EMF exposure impaired cognitive performance	Maier R et al.
Subgroup Model					
Rat	2010	900MHz-1.8GHz/NS	50 missed calls (45 sec.); within 1 hr per day for 4 weeks	Altered passive avoidance behaviour and hippocampal morphology	Narayan SN et al.
Rat	2009	840MHz/NS	Continuous for 3 hours/day from day 2 to day 14 after birth	Decreased locomotor activity, increased grooming and a tendency toward increased basal corticosterone levels	Daniel WM et al.
Rat	2008	900MHz/ 0.0006W/kg – 0.6W/kg	2 hours/week for 55 weeks	Reduced memory functions after GSM exposure	Nittby H et al.
Mouse	2010	900MHz/0.41W/kg – 0.98W/kg	1 hour 55 minutes for the first 3 days; 3 hours 45 minutes on the fourth day's probe trial	Deficits in consolidation and / or retrieval of learned spatial information	Fragopoulou AF et al.

recommend avoidance of cellular phone use during early weeks of gestation, and also recommend further studies.

Discussions of the Tabular Model

Table 1 shows varieties of studies of cell phone RF radiation on the brain system. Literature of facts explains that the mobile phone induced effects upon the blood – brain barrier permeability and in continuous hours of exposure to RF radiation may result in significant increase in albumin extravasations. Leszczynski et al evaluation discussed that when human endothelial cell lines are exposed to radio frequency radiation over a continuous 1 hour duration, changes in gene and protein are visible and also the cytoskeleton component F – actin fibers are disturbed. The GSM – 900MHz of brain power density 2.8W/kg was used for this study, (see Table 1).

Human Lymphoblustomy cell line exposed to a continuous 1 hour 1.9GHz -GSM machine with specific absorption rate (SAR) of 1 W/kg (Chauhan et al experiment) showed there was significantly elevation of heat shock protein (HSP) signifying a stress response. The same characteristic GSM equipment but with SAR 10W/kg showed no changes in stress related gene expression after a continuous exposure of the human model in 6 hours 5minutes RF radiation. Nylund and Leszczynsk inferred the same observation for 900MHz with no SAR, the observed property was changes in

protein expression in the structure of the endothelial cell. 902MHz/NS characteristic RF exposure impaired the cognitive performance of human model. Table 1 also showed the subgroup animal model in this study. Rat specimen exposed to RF radiation of system with 840MHz with NS specific absorption rate for continuous 3 hours on daily basis from day 2 to day 14 after birth exhibited a decreasedloco motor activity, increased grooming and a tendency toward increased basal cortiocosterone level (Daniel et al, 2009).

Relevance and Evaluation of the Specific Absorption Rate (SAR)

The specific absorption rate (SAR) is used as the dosimetric measure of frequencies. At lower frequencies (<100KHz), many biological effects are quantified in terms of current density in tissue and the parameter involved is often used as a dosimetry quantity. At higher frequencies, many interactions are due to the rate of energy per unit mass. The specific absorption rate (SAR) is the absorbed power per the absorbing mass which is expressed as Wkg^{-1}. However, the most obvious approach towards dosimetry analysis is to experimentally determine the SAR distribution in phantoms simulating animal and human bodies, as well as real cadavers. One way of determining the local or whole body SAR isby temperature measurement. Specific Absorption Rate (SAR) is proportional to the temperature increase only when the effects of heat diffusion can be neglected. With this limitations in view, SAR concept has proven to be a simple and useful tool in quantifying the interactions of RF/ microwave radiation with living systems. This enables us to compare the experimentally observed biological effects in various species under various exposure conditions. The SAR is defined however as the time derivative of the incremental energy (dW) absorbed by or dissipated in an incremental mass (dm) contained in a volume element (dV) of a given density (ρ). The possible mechanism use in the evaluation techniques shows that radio frequency of electromagnetic wave (EMW) transmits signals from cellular phones to the base stations and antennas. The frequencies of such waves are low and ranges mostly between 800MHz and 2200MHz. However there is risk to cell phones user because the human body can act as antennas that absorb the waves and convert them to eddy current.

$$SAR = \left(-\frac{d}{dt}\right)\left(\frac{dW}{dm}\right) = \left(\frac{d}{dt}\right)\left(\frac{dW}{\rho(dV)}\right) \quad (1)$$

$$SAR = C\frac{\Delta T}{\Delta t} \quad (2)$$

The SAR is proportional to the temperature increase (ΔT), when the effects o thermal conduction, convection and radiation are negligible, in the time interval (Δt).

C in equation (2) is the specific heat capacity of the body mass. The same can also be evaluated, using the poynting vector theorem for sinusoidal varying electromagnetic field:

$$SAR = -\left(\frac{\omega\varepsilon_0}{2\rho}\right) - |E_i|^2 \quad (3)$$

$$SAR = \left(\frac{\varepsilon}{2\rho}\right) - |E_i|^2 \quad (4)$$

where $|E_i|^2$ is the peak value of the internal electric field (Vm^{-1}). SAR is also dependent upon the wave type, that is, square, sine of triangular. The average SAR is defined as the ratio of the total power absorbed in the exposed body to the mass in which it is absorbed, which is not necessarily that of the total body.

Review Phenomena Indices of Epidemiological Effects of EMR on Human Brain

The effects of different intensities and modulations of RF on an animal model where the effects takes place in the cerebral medium have proven that sub thermal energies from both pulse-modulated and continuous RF fields – including those from real GSM mobile phones have the potency to significantly open the Blood- Brain Barrier (BBB) for the animals´ own albumin to pass out into the brain and to accumulate in the neurons and glial cells surrounding the capillaries (Malmgren1998; Persson et al. 1997). Similar results are found by others (Fritze et al.1997) pointing out that when such a relatively large molecule as albumin may pass the BBB, also many other smaller molecules, including toxic ones, may escape into the brain due to the exposure to RF. Nevertheless researchers have not really concluded that such leakage is harmful for the brain. Reports has however shown that autologous albumin injected into the brain tissue of an animal model (Rat) leads to damage the neurons at the injection site when the concentration of albumin in the injected solution is at least 25% of that in blood (Hassel et al.1994).

CONCLUSION

When aiming to prevent the central nervous system from chronic RF exposures that could cause seriousheallth effects, such as cancer, a precautionary approach is appropriate. This review assessment relies primarily on the informative study, given various kinds of evidence based on evaluation from association to causation. Biological mechanisms may also be helpful. The use of mobile phones is currently one of the fastest growing technological developments. The close proximity of the antenna of such a device to the head and consequently to the brain has raised concerns about the biological interactions between EMR and the brain tissues. The

direct epidemiological effects of exposure to EMR are hereby advised to be studied extensively.The present study has shown that exposure to EMR with a microwave frequency had a significant effect on brain, a significant spontaneous effects are observed in children since they represent a sensitive subgroup, as their brains are not yet completely mature and they may react differently to RF-EMF exposure. Studies showed deeper penetration of absorbed energy in a child's head, due to the facts that there is thinness of the outer ear and skull of young children.

REFERENCES

Caraglia M, Marra M, Mancinelli F, d'Ambrosio G, Massa R, Giordano A, Budillon A, Abbruzzese A, Bismuto E (2005). Electromagnetic fields at mobile phone frequency induce apoptosis and inactivation of the multi- chaperone complex in human epidermoid cancer cells, J. Cell Physiol. 204 539.

Chauhan V, Mariampillai A, Bellier PV, Qutob SS, Gajda GB, Lemay E, Thansandote A, McNamee JP (2006a). Gene expression analysis of human lyphoblastoma cell line exposed in vitro to an intermittent 1.9GHz pulse- modulated radiofrequency field, Radiat. Res. 165: 424

Chauhan V, Mariampillai A, Gajda GB, Thansandote A, McNamee JP (2006a). Analysis of proto- oncogene and heat shock protein expression in human derived cell- lines exposed in vitro to an intermittent 1.9GHz pulse- modulated radio. frequency field, Int. J. Radiat. Biol. 82: 347.

Cherry NJ (2002). "Schumann Resonances, a plausible biophysical mechanism for thehuman health effects of Solar/Geomagnetic Activity". Natural Hazards 56: 279-331.

Cherry ONZM (2002). Epidemiological studies of enhanced Brain/CNS Cancer incidence and mortality fromEMR and EMF Exposures Lincoln UniversityCanterbury, New Zealand June.

Daniels WM, et al (2009). The effect of electromagnetic radiation in the mobile phone range on the behaviour of the rat. *Metab Brain Dis*. 24 (4): 629-641.

Eliyahu I et al (2006). Effects of radiofrequency radiation emitted by cellular telephones on the cognitive functions of humans. *Bioelectromagnetics*. 27 (2): 119-126.

Fragopoulou, et al (2010). Whole body exposure with GSM 900 MHz affects spatial memory in mice. *Pathophysiol. Pathophysiol.* 17(3):179-187.

Fritze K, Sommer C (1997). Effect of global system for mobile communication (GSM) microwave exposure on BBB permeability in rat, Acta. Neuropathol. 94: 465–470.

Hassel B, Iversen EG, Fonnum F (1994). Neurotoxicity of albumin in vivo, Neurosci. Lett. 167: 29–32.

Hocking B, Westerman R (2001). Neurological abnormalities associated with CDMA exposure, *Occup. Med.* (Lond). 51(6):410-413

John Wargo et at (2012). Cell phones technology, exposures and health effects, Yale University ,Environment and human health, inc.

Leszczynski D, Meltz ML (2006). Questions and answers concerning applicability of proteomics and transcriptomicsin EMF research, Proteomics, 6: 4674

Maier R, Greter SE, Maier N (2004). Effects of pulsed electromagnetic fields on cognitive processes - a pilot study on pulsed field interferencewith cognitive regeneration. *Acta. Neurol. Scand.* 110(1):46-52.

Malmgren L (1998). Radio frequency systems for NMR imaging: coil development and studies of non-thermal biological effects. PhD Thesis. Lund, Sweden. Department of Applied Electronics, Lund University,

Narayanan SN, Kumar RS, Potu BK, et al (2010). Effect of radio-frequency electromagnetic radiations (RF-EMR) on passive avoidance behaviour and hippocampal morphology in Wistar rats. *Ups J. Med. Sci.* 115 (2): 91 – 96.

Narayanan SN, Kumar RS, Potu et al (2009). Spatialmemory performance of Wistar rats exposed to mobile phone. *Clinics.* 64(3):231-234.

Nittby H, et al (2011). Nonthermal GSM RF and ELF EMF effects upon rat BBB permeability. *Environmentalist*; 31 (2): 140-148.

Nylund R, Leszczynski D (2004). Proteomics analysis of human endothelial cell line EA. Hy 926 after exposure to GSM 900 radiation, Proteomics. 4: 1359.

Oscar KJ, Hawkins TD (1977). Microwave alteration of the BBB system ofrats, Brain Res. 126: 281–293.

Persson, T, Floderus B, Stenlund C (1997). "Occupational magnetic field exposure and site-specific cancer incidence: a Swedish cohort study. Cancer Causes Control. 10(5): 323-332

Rezk AY, Abdulqawi K, Mustafa RM, et al (2008). Fetal and neonatal responses following maternal exposure to mobile phones. Saudi. Med. J. 29(2):218-223

Schirmacher A, Winters S, Fischer S, Goeke J, Galla HJ, Kullnick U, Ringelstein EB, Stögbauer F (2000). Electromagnetic fields (1.8 GHz) increase the permeability to sucrose of the BBB in vitro, Bioelectromagnetics pp. 338–345.