Biological Effects of RF-EM Radiation: A Review

Neel Mani Rangesh[1] and Sanjay Kumar[2]

Department of Electronics & Communication Engineering

Birla Institute of Technology Mesra, Ranchi, 835215 Jharkhand, India

E-mail:- *neelmr@gmail.com[1], skumar@bitmesra.ac.in[2]*

DOI:- https://doi.org/10.47531/MANTECH/ECC.2021.14

Abstract

Today the use of wireless communication in our daily life is fast-growing, and it has changed the fundamental characteristics of our communications. Wireless communication has now become one of the most important and suitable in the communication network today. With the rapid development of low-cost devices coupled with advanced capabilities for connectivity, flexibility in deployment and operation and allowing more advanced applications and software to run in the miniature environment, the growth in usage of wireless communication is phenomenal. With the Internet of Things, M2M communications and 5G mobile communication knocking the door of today's world, there is also a tremendous surge in wireless Radio Frequency – Electromagnetic field (RF-EMF) radiation exposure in our environment, and it is accelerating very fast. The spurt in RF-EMF exposure level is also raising concern over its effects on the living or biological system. Contradictory and confusing research findings are inhibiting the unequivocal conclusion on the real effect of RF-EM radiation on biological systems. This study deliberates over and examines the various research-based on in-vitro, in-vivo, epidemiological and provocation studies on the effect of RF-EM radiation exposure. The study presents data from different studies and analysis done to estimate the biological effects of RF-EM radiation exposure. The findings are inconsistent, and hence interpretation is difficult. However, emphasis is given on identifying the research needs for future studies so that results are more consistent and conclusive.

Keywords:- *Electromagnetic Fields, Radio Frequency, RF-EM Radiation exposure, Biological effects, 5G mobile communication.*

INTRODUCTION

The whirlwind proliferation of wireless communication and its ubiquitous use by all of us in all the dimensions of our life is modifying the very fundamental characteristics of our communications. Wireless Communication has now become a necessity for all of us because of its ease of operation, flexibility and suitability to our daily routines. With the rapid development of low-cost devices coupled with advanced capabilities for connectivity, flexibility in deployment and operation and allowing more advanced applications and software to run in the miniature environment, the growth in usage of wireless communicationis phenomenal. Apart from the natural growth in traditional mobile communication, there are various new technologies emerging in the field of wireless communication, indicating a technological revolution of a kind that Steam Engine or Personal Computer had brought about in the World. The more and more generous use of Low Power Wide Area Network (LPWA), Wireless Body Area Network (WBAN) and other advancements in cellular & other wireless network have provided for the growth of devices such as RFID (Radio Frequency Identifiers) tags being implemented for almost all the things/products available in the market. RFID microchips are now available for sizes as small as a grain of rice and can be implanted in humans, animals, plants or attached to anything or any possessions. In an alarming evaluation, the International Agency for Research on Cancer (IARC) has concluded that "Radiofrequency electromagnetic fields are possibly carcinogenic to humans (Group 2B)" [1, p419]. This has given an impetus to studies on more detailed analysis of RF, especially the Millimetre-wave (being the media for future technology) induced biological effects, its measurement parameters, and identifying safe limits of exposure. With this perspective and importance of the problem that is looming large over the society, an extensive, thorough literature

review resulted in some understanding of the RF-EMF, the interaction mechanism and the biological effects of RF-EMFs. Most of the studies have concluded that the impacts which are observed are limited to thermal effects only. However, some studies have indicated non-thermal effects also, for example, effects due to prolonged exposure to low-intensity millimeter waves. These results from these limited studies are inconsistent as the effects are related to many factors such as the frequency of operation, the modulation technique used, the power density of exposure, cell density during exposure and the duration of exposure.

BIOLOGICAL INTERACTION AND MEASUREMENTS

A. Thermal Effect

In thermal effect, the temperature is increased by a fraction of a degree due to heat generation by absorption of the radiation. The temperature rise is due to the friction between charged particles and molecules of the surrounding [2]. Being exposed to a longer duration of time to this thermal effect of radiation results in an increase in increase in body temperature.

B. Non-Thermal Effect

In the non-thermal effect, the induced EM effects are generated in the biological cells of the body due to radiation exposure. It is the direct interaction of the electromagnetic fields with the tissue [3]. Non-thermal effects may lead to more harmful conditions.

C. Specific Absorption Rate (SAR)

A measure of the EMF absorbed by the human body is the Specific Absorption Rate (SAR). SAR measures the amount of RF-EMF energy absorbed by the tissue in a human body exposed to RF-EM radiation. This depends upon the induced E-field of the radiation, the conductivity and the density of tissue mass [4]. It is measured by averaging or integrating over a fixed volume. The fixed volume generally used are either 1-gram or 10-gram area. It is expressed as watt per kilogram or milliwatt per gram. In the US, 1-gram area averaging is used, and the SAR limit for mobile devices is fixed as 1.6 watts per kilogram averaged over the 1-gram area of tissue. Europe uses averaging over a 10-gram area, and the SAR limit for a mobile device has been fixed as 2 watts per kilogram averaged over a 10-gram area of the tissue. International Commission for Non-Ionizing Radiation Protection (ICNIRP) has also prescribed the same SAR limits as used in Europe. India switched from European standard to US standard for SAR limit from 01 September 2012. The Department of Telecommunication, Government of India, has also fixed the maximum limit of RF-EM radiation for mobile towers, which is ten times less than that prescribed by ICNIRP [5]. The limits set for mobile towers in India are in Table I.

Table I: EMF Emission limits for mobile towers in India

a. f is frequency in MHz

Range of Frequency	Electric Field intensity in Volts per meter	Magnetic Field Intensity in Amperes per meter	EM Power Density in watt per square meter
400 MHz to 2000 MHz	$0.434f^{\frac{1}{2}}$ a	$0.0011f^{\frac{1}{2}}$ a	f/2000 a
2 GHz to 300 GHz	19.29	0.05	1

Mobile phones may have scarcely different quantified exposure levels at maximum output power. However, it may be termed as safe, being below the safety margin, which is included in the limits as an additional large margin so that mobile phones are always in the safe zone. Also, the testing is done in a way to find the maximum SAR data, and this may not show the exact exposure in a practical usage environment. Furthermore, mobile devices dynamically steer the minimum power required to sustain mobile battery life and successfully mature quality call by using adaptive power control, and this depends on many factors such as the distance of the device from the latched base station and the reception of signals.

The interaction of RF-EMF with the biological structure such as human tissues with anatomically realistic human phantoms and voxel models for different age, sex, size, posture, movement together with the use of numerical dosimetry, experimental techniques and advanced computational measurement techniques provide more accurate measurement of SAR, Whole Body SAR (wbSAR), Peak Spatial SAR (psSAR), Organ-specific SAR (oSAR), Tissue-Specific SAR (tsSAR) over a wide range of exposure setup which may be interpreted analytically to improve safety guidelines [6]. However, there are uncertainties inaccurate measurement due to the performance of the electric field probe, dielectric properties of biological structures, dimension and resemblance of phantoms, exposure conditions, the accuracy of numerical techniques, and repeatability of several measurements.

The recent mobile technologies which use millimeter waves have penetration less than one to two millimeters. Also, it is mostly absorbed in the surface of the body, particularly the skin of a human being and cornea surface layers of the eyes. Millimeter waves with a power density of more than 5 to 10 milliwatt per square centimeters

result in thermal effects. The radiation energy of antennas preferred in millimeter-wave technologies, such as high gain directional and adaptive antenna arrays, are designed to emphasize a particular or specific direction. This may result in maximizing thermal effect if the high-energy main narrow lobe of radiation is exposed to the human body.

BIOLOGICAL EFFECTS OF RF-EM RADIATION

A. In-vitro and In-vivo Research

The in-vitro research is to look for possible effects of exposure on living cell or other elements of the body part outside the human or animal. The in-vivo research is to look for possible effects of direct exposure to living animals. In both cases, the research focuses on identifying the metabolic alteration, physiological changes, disease-resistance level, biochemical changes or any other changes that are useful in relating any harmful effects with the exposure.

1) Adverse effects

An in-vivo study on the effect of the electromagnetic field on the development of chick embryo by Najam Siddiqi and Nasser Al Nazwani [7] indicated that the high dose RF-EM radiation exposed group tends to show an increase in Heat Shock Protein 70 and mRNA, which may cause serious biological effects and threat to health. Denis Habauzit et al. [8] reported that the severe millimeter-wave exposure resulted in inducing expression of some genes such as IL7R, NOG and ADAMT86. Swedish Radiation Safety Authority's (SSM) Scientific Council on Electromagnetic Fields, in its eleventh report [9], observed that in certain examinations of endpoints, impacts on boundaries identified with apoptosis had been accounted for, albeit transient.

2) No major adverse effects

The genotoxic analysis on the Hematopoietic system after Mobile Phone Type Radiation Exposure in Rat was performed by Kumar Gaurav et al. [10], and it was found that there are not many changes in the hematopoietic system of rats when it is exposed to RF radiations of various SAR count with 900/1800 MHz CW/PM wave. Chen Zhijian et al. [11] studied the impact of 1.8 -GHz radiofrequency radiation (RFR) on DNA damage and repair induced by doxorubicin in human B-cell lymphoblastoid cells and observed that there is no major increase in DNA damage with exposure to SAR of 2 watts per kilogram with 1.8 GHz RF-EM radiation for two hours on human B-cell lymphoblastoid cells in-vitro when compared with the same exposure to the sham. Thus, it was found that there is no non-thermal effect of RF-EM radiation as far as DNA damage is involved. Report of Partial Findings from the National Toxicology Program (NTP), US Dept of Health and Human Service, 2018 on Carcinogenesis Studies of Cell Phone Radiofrequency Radiation in Hsd: Sprague Dawley® SD rats [12] found no major biological effects in the brain and heart of female rats with varied RF-EM radiation exposure. However, it has also observed some linkage of RF-EM radiation exposure with neoplastic lesions in the heart of male rats as compared to its heart. Health Protection Agency Report of the independent Advisory Group on Non-ionizing Radiation (AGNIR) on Health Effects from Radiofrequency Electromagnetic Fields [13] found that there is no conclusive evidence from in-vitro studies of the effects of RF-EM radiation below prescribed limits. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), in its technical report [14] on review of Radiofrequency Health Effects Research, found that data related to in-vitro or in-vivo studies are related to thermal effects only, and it is very less probable that any requirement to review restrictions. The European Commission Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), in its opinion [15] on potential health effects of exposure to electromagnetic fields (EMF), has observed that in-vitro and in-vivo studies have mostly no adverse effects of RF-EM radiation, particularly non-thermal effects. However, few studies have indicated a break in DNA strands and mitotic spindle disturbances.

B. Epidemiology Research

Epidemiology Research methods are primarily an observational science with an advanced understanding of scientific methods and knowledge to control disease and public health. This is basically an applied form of research, and it is problem-oriented. Based on the source of exposure, it is classified as environmental exposure, occupational exposure and personal exposure. Case-control, ecological, cohort, cross-sectional etc., are some of the categories of epidemiology research.

1) Adverse effects

R. Bann et al. [16], in their assessment report for IARC Monograph, has indicated the possible linkage of RF-EM radiation exposure to cell signaling, apoptosis, genotoxicity and oxidative stress. These results suggest a weak mechanistic

link to cancer in humans due to RF-EM radiation exposure.

2) No major adverse effects

In a recent study by James C. Lin [17] on the significance of Primary Tumors in the National Toxicology Program (NTP), US Dept of Health study of Chronic Rat Exposure to Cell Phone Radiation and found that although there is an upsurge in the pace of gliomas was seen in female rodents exposed to RF-EMF at the most elevated field intensity (50 V/m), yet it was not esteemed factually critical. Health Protection Agency Report of the independent Advisory Group on Non-ionizing Radiation (AGNIR) on Health Effects from Radiofrequency Electromagnetic Fields [13] observed that information from accomplice studies and assessment of disease frequency patterns in different western nations give no sign of brought hazards up according to cell phone use and the accessible information doesn't recommend a causal relationship between cell phone use and quickly developing tumors, for example, harmful glioma in grown-ups. Swedish Radiation Safety Authority's (SSM) Scientific Council on Electromagnetic Fields, in its eleventh report [9], found nonappearance of the relationship with the introduction from fixed site transmitters during studies on symptoms, in spite of the fact that non-differential presentation misclassification stays a test for these investigations. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), in its technical report [14] on review of Radiofrequency Health Effects Research, concluded that no convincing adverse effects had been observed in many epidemiological studies exploring occupational and environmental RF-EM radiation exposure.

C. Provocation Research

In provocation research, the living biological organism is deliberately exposed under the controlled environment to analyze the biological effects of exposure. It includes an examination of physiological changes, perceptions, and other behavioral changes in the subject to get an insight into the biological effect induced due to exposure.

1) Adverse effects

The effects of pulsed (100 Hz) microwave radiation on heart rate variability (HRV) on 25 subjects in the age group 37-79 years was done by M. Havas et al. [18], and evidences were found for developing heart palpitations, heart flutter or rapid heartbeat or symptoms such as nausea, dizziness in some individuals due to electromagnetic radiation exposure.

2) No major adverse effects

A study on 30 healthy male in the age group of 20-30 years was carried out by C. Sauter et al. [19] to analyze the effect of terrestrial trunked radio, TETRA (385 MHz), on cognitive performance, well-being, mood or somatic complaints and it found that the results are not indicative of an adverse impact on cognitive performance or well-being due to exposure to the TETRA transmitter. A recent provocation study by Heidi Danker-Hopfe et al. [20] found that although there are more sleep effects due to RF-EM radiation exposure in females, there are no sleep disorders observed due to RF-EM radiation exposure irrespective of gender. Setsu Nakatani-Enomoto et al. [21] did a study on the effects of electromagnetic fields emitted from W-CDMA-like Mobile Phones on sleep in Humans and found that there are no observed effects on sleep in humans with exposure to EM wave radiation from W-CDMA-like Mobile Phones for three hours. No evidence was found to suggest any effect in EEG power spectra of Stage W and Stage N2 or sleep spindles. The effect of short-term radiation emitted by W-CDMA mobile phones on teenagers and adults was studied by Soo Beom Choi et al. [22], and it found no linkage of RF-EM radiation exposure from WCDMA devices for thirty-two minutes on adults or teenagers. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), in its technical report [14], has also not found any major linkage of cognitive and performance measures of human function as well as heart functions with low-intensity RF-EM radiation exposure. Furthermore, the European Commission Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), in its opinion [15] on the potential health effects of exposure to electromagnetic fields (EMF), have observed that there are no provocation studies providing any support for the potential difference with people with exposure or without exposure to RF-EM radiation. There are many studies that have indicated adverse effects, and also many studies have reported no major adverse effects of RF-EM radiation exposure, and some are contradictory to each other also. However, some of the studies have observed a significant direct linkage of RF-EM radiation to major health-related issues. These adverse effects of RF-EM radiation are classified broadly into seven major health risks, namely (a) Cancer (b) DNA damage (c) Effects on Mental Health and Cognitive Health (d) Pregnancy and Infertility (e) Auditory System Damage (f) Effects on Childhood Development (g) Blood-related disorders [23]. Most of the studies

on the biological effects of RF-EM radiation exposure are currently giving insight on whether the above six major biological effects or health-related issues are directly linked to the RF-EM Radiation exposure or not. Table II gives the comparative details of the results of various studies which have observed health-related issues due to RF-EM radiation.

Table II: Comparative results of various studies observing health related issues due to RF-EM radiation

Health Related Issues	Type of Study	Method used	Results/Observations
Cancer	In-vivo	9 hours per day (10 minutes on & 10 minutes off cycle) exposure of Hsd: Sprague Dawley® SD rats from the womb to two years or almost life-span to RF-EM radiation in 2G and 3G spectrum.	Found conclusive link between RF-EMF radiation in 2G and 3G spectrum with tumors in the heart, the adrenal gland and the brain of male rats [24].
	In-vivo	19 hours per day full body exposure of male and female Sprague Dawley® SD rats for total life-span to 1.8 GHZ RF-EM radiation	1.8 GHz RF-EM radiation induced a remarkable increase in tumors of heart in male SD rats [25].
	Epidemiology	Two case-control studies for the patients diagnosed with malignant brain tumors for two different periods with 20-80 years and 18-75 age groups.	RF-EM radiation giving rise to glioma and acoustic neuroma [26].
DNA damage	In-vivo	2G and 3G RF-EM radiation exposure on chick embryo for 12 days (75 minutes exposure in 12 hours daily followed by no exposure for 12 hours).	2G and 3G RF-EM radiation resulted in many structural changes and DNA damage which is more distinct in 3G radiation exposure [27].
	In-vitro	4,16, 24 hours exposure of human trophoblast HTR-8/SVneo cell to 1.8 GHz EM fields with different AM GSM signals (5 min on & 10 min off cycle).	GSM signal can affect DNA integrity and may lead to temporary DNA breakage [28].
	In-vitro	5,10, 20 minutes exposure of primary rat neocortical astroglial cell cultures for 14 days to 900 MHz RF-EM radiation.	RF-EM radiation give rise to a notable increase in reactive oxygen species and lead to DNA damage [29].
Effects on Mental Health and Cognitive Health	Epidemiology	Cross-sectional study on 85 residents near the Base Trans receiver Station with the matched control group.	Greater risk was observed for having neuropsychiatric diseases for people exposed to RF-EM radiation [30].
	Epidemiology	Cross-sectional study of 808 men and women in the age group 12-70 years in a community	Remarkable likelihood of headache in people using handheld mobile phones operating in RF spectrum [31].
	Provocation	5 men and 20 women in the age group 37-79 years were exposed to 2.4 GHz RF-EM radiation for 3-minute intervals.	Evidences were found for developing heart palpitations, heart flutter or rapid heartbeat or symptoms such as nausea, dizziness in some individuals due to electromagnetic radiation exposure [18].
Pregnancy and Infertility	In-vivo	900/1800/1900 MHz RF-EM radiation exposure of 90 male Wistor albino rats for 15-, 30- and 60-minute duration for 14 days	Remarkable indication of the effect of RF-EM radiation on oxidative stress in testicular tissue and leading to adversely affecting serum quality and lower sperm motility [32].
	Epidemiology	Case study of 13 men with normal spermiogramm without five-day exposure to RF-EM radiation and after four-weeks at 6 hours daily exposure to RF-EM radiation.	Pronounced reduction in motility of rapid progressive spermatozoa under the influence of RF-EM radiation was observed [33].

	In-vivo	1800 MHz RF-EM radiation exposure of 40 female rats with 1hour per day and 2 hour per day for 1-, 2- and 3-week exposure duration.	Chronic stress leading to prenatal and postnatal developmental adverse effect observed due to RF-EM radiation exposure during pregnancy [34].
Auditory System Damage	Epidemiology	Case-control study of 100 patients with the tinnitus problem with the matching control group.	Indicated that the long and high level of RF-EM radiation exposure possibly conceivably linked to tinnitus [35].
Effects on Childhood Development	Epidemiology	Cross-sectional study of 1484 children in the age group 8-12 years and 1508 children in the age group 13-17 years.	Association observed for behavioral problems in children with the exposure to RF-EM radiation exposure [36].
	Epidemiology	Cohort study of the mothers of 13,159 children from pregnancies to the 7-years age of the children.	Prenatal RF-EM radiation exposure was observed to be associated with behavioral anomalies in children [37].
	Review	Systematic review of various studies on the effect of RF-EM radiation exposure on childhood development.	Many neuro developmental issues such as learning, cognition, memory attention and behavioral abnormalities are observed to be occurring due to epigenetic reasons due to the effects of RF-EM radiation exposure [38].
Blood related disorders	In-vivo	Two-hour exposure of 344 male and female rats to 915 MHz EMF.	Electromagnetic radiation has the potential to break the blood-brain-barrier (BBR) for albumin and may also lead neuronal damage if exposed for more duration [39].

DISCUSSION

Although studies as in Table II have observed adverse biological effects of RF-EM radiation that induces some major health issues, there is no conclusive explanation available that manifests scientifically the biological interactions and mechanism which leads to observed adverse effect due to RF-EM radiation. Also, the exposure conditions used in in-vivo studies are not completely similar to the practical RF-EM radiation exposure faced by human beings. In-vitro and in-vivo studies are not very consistent; most of the studies so far have concluded that there is no significant RF-EMF exposure effect. Few studies have reported some adverse effect. However, these studies need to be explored more with sham-exposed samples, dosimetry or temperature control. Research needs includes replication of in-vitro studies which have earlier reported genotoxic effects (i.e. damage of DNA) or non-genotoxic effects (i.e. changes in functions of cells) due to RF-EMF exposure are needed to confirm the results, and in-vivo studies are needed to investigate biological outcomes, which are designed having very good characterized exposure systems incorporating detailed dosimetry. Some of the epidemiology studies have noticed that frequent users of mobile phones have an increase in the likelihood of acoustic neuroma and glioma. Although cohort studies and time-trend studies have not found such linkage in the case of glioma, they got an insight into possible linkage with acoustic neuroma. The results of other epidemiology researches have not found any conclusive evidence for linkage with other serious diseases such as cancer. Research needs are primarily to investigate the lasting biological effect, latency for longer duration and trends with respect to time in mobile phones, especially through cohort studies in adults, children and adolescents. The provocation research method is the most direct way of analyzing biological effects. However, moral, ethical & practical unsuitability restricts its usage to a large extent. Research needs are primarily to assess the impact of exposure to new technologies using millimeter waves on the environmental and the individual basis and to assess the impact from time-varying several sources. Also, the sample may be kept heterogenous with sufficient sample size and established exposure levels and using the latest analytic tool to provide the correct results.

CONCLUSION

The results of various research have now established the fact that there is a rise in temperature inside some specific organs due to the heating or the thermal effect of RF-EM radiation. However, proof for the non-thermal impacts is, as of now, not convincing, and many studies for investigating non-thermal effects are continuing. Some epidemiological examinations have detailed

a relationship between frequent mobile phone usage with severe diseases such as cancer; in any case, other explorations have not affirmed these outcomes. Although the results of researches published have shown the potential of RF-EMF to induce certain harmful effects to DNA, a scientific mechanism to the lasting impact as carcinogenic and mutagenic is still not very much clear. Most of the in-vitro researches have been carried out using cell culture and in-vivo research involving animal models, and some of them have indicated oxidative stress or DNA distress on different RF-EMFs exposures. However, these finding may not be providing a true picture if we try to simply extrapolate these findings directly to human beings. These findings have to be studied directly involving humans, which is difficult as there are obvious ethical and technological issues involved. In these circumstances, many researchers are using epidemiology and observation only. As a result, these limitations prevent the presentation of a genuine and correct effect of RF-EMF exposure for humans. We need to have more studies that are more objective-based and have a holistic approach. There are various elements involved, and all those must be integrated to have multi-disciplinary long-term human experimental research by different peer groups to arrive at a definite conclusion about the biological effects of RF-EMF waves.

REFERENCES

1. International Agency for Research on Cancer (IARC), “Monograph Non-Ionizing Radiation Part-2 Radiofrequency Electromagnetic Fields”, Volume 102, 2013.
2. Andrew W. Wood and Ken Karipidis, “Non-ionizing Radiation Protection: Summary of Research and Policy Options”, First Edition, John Wiley & Sons Inc., 2017.
3. Y. G. Lv and J. Liu, “A theoretical way of distinguishing the thermal and non-thermal effects in biological tissues subject to EM radiation”, Forschung im Ingenieurwesen, Volume 67, 2003.
4. J. C. Wang, E. G. Lim, M. Leach, Z. Wang, K. L. Man and Y. Huang, “Two Methods of SAR Measurement for Wearable Electronic Devices”, International Multi Conference of Engineers and Computer Scientist, Hong Konk, 2016
5. http://www.dot.gov.in/journey-emf.
6. Yijian Gong, Myles H. Capstick, Sven Kuehn, Perry F. Wilson, John M. Ladbury, Galen Koepke, David L McCormick, Ronald L Melnick, and Niels Kuster, “Life-Time Dosimetric Assessment for Mice and Rats Exposed in Reverberation Chambers for the Two- Year NTP Cancer Bioassay Study on Cell Phone Radiation”, IEEE Transactions on Electromagnetic Compatibility, 2017
7. Najam Siddiqi and Nasser Al Nazwani, ““Effects of Electromagnetic Field on the Development of Chick Embryo: An In Vivo Study”, Electromagnetic Fields and Waves, Kim Ho Yeap and Kazuhiro Hirasawa, IntechOpen, 2019.
8. Denis Habauzit, Catherine Le Quément, Maxim Zhadobov, Catherine Martin, Marc Aubry, Ronan Sauleau, Yves Le Dréan, Transcriptome, “Analysis Reveals the Contribution of Thermal and the Specific Effects in Cellular Response to Millimeter Wave Exposure”, PLoS ONE 9(10): e109435, 2014.
9. Swedish Radiation Safety Authority’s (SSM) Scientific Council on Electromagnetic Fields, “Recent Research on EMF and Health Risks”, Eleventh Report 2016:15, 2016.
10. Kumar Gaurav, McIntosh Rl, Anderson Vitas, McKenzie Rj, Wood Aw, “A Genotoxic Analysis on Hematopoietic system after Mobile Phone Type Radiation Exposure in Rats”, International Journal of Radiation Biology, 2015.
11. Chen Zhijian, Li Xiaoxue, Lu Yezhen, Chen Shijie, Jin Lifen, Lou Jianlin, Lu Deqiang, He Jiliang, “Impact of 1.8-GHz radiofrequency radiation (RFR) on DNA damage and repair induced by doxorubicin in human B-cell lymphoblastoid cells”, Mutation Research, vol. 695, pp. 16–21, 2010.
12. Report of Partial Findings from the National Toxicology Program (NTP), “Carcinogenesis Studies of Cell Phone Radiofrequency Radiation in Hsd: Sprague Dawley® SD rats (Whole Body Exposures)”, 2018.
13. Health Protection Agency Report of the independent Advisory Group on Non-ionizing Radiation (AGNIR), “Health Effects from Radiofrequency Electromagnetic Fields”, RCE-20, 2012.
14. Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), “Report by the ARPANSA Radiofrequency Expert Panel on Review of Radiofrequency Health Effects Research – Scientific Literature 2000 – 2012”, Technical Report 164, 2014.
15. European Commission Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), “Opinion on Potential health effects of exposure to electromagnetic fields (EMF)”, 2015.
16. Robert Baan, Yann Grosse, Béatrice Lauby-Secretan, Fatiha El Ghissassi, Véronique Bouvard, Lamia Benbrahim-Tallaa, Neela

Guha, Farhad Islami, Laurent Galichet, Kurt Straif, “Carcinogenicity of radiofrequency electromagnetic fields”, Assessment Report for IARC Monograph Volume 102, 2011.

17. James C. Lin, “The Significance of Primary Tumors in the NTP Study of Chronic Rat Exposure to Cell Phone Radiation” IEEE Microwave Magazine, 2019.
18. Magda Havas, Jeffrey Marrongelle, Bernard Pollner, Elizabeth Kelley, Camilla R.G. Rees, Lisa Tully, “Provocation study using heart rate variability shows microwave radiation from 2.4 GHz cordless phone affects autonomic nervous system”, European Journal of Oncology, Volume. 5, 2010
19. Cornelia Sauter, Alexander Marasanov, Torsten Eggert, Hans Dorn, Gernot Schmid, Thomas Bolz, Marie-Luise Hansen, Anita Peter, Heidi Danker-Hopfe, “Do signals of a hand-held TETRA transmitter affect cognitive performance, well-being, mood or somatic complaints in healthy young men? Results of a randomized double-blind cross-over provocation study”, Environmental Research, Volume 140, 2015.
20. Heidi Danker-Hopfe, Hans Dorn, Cornelia Sauter, Gernot Schmid, Torsten Eggert, “An experimental study on effects of radiofrequency electromagnetic fields on sleep in healthy elderly males and females: Gender matters!” Environmental Research, 2020
21. Setsu Nakatani-Enomoto, Toshiaki Furubayashi, Akira Ushiyama, Stefan Jun Groiss, Kazumune Ueshima, Shigeru Sokejima, AllyY. Simba, Kanako Wake, So-ichi Watanabe, Masami Nishikawa, Kaori Miyawaki, MasaoTaki, and Yoshikazu Ugawa, “Effects of Electromagnetic Fields Emitted From W-CDMA-like Mobile Phones on Sleep in Humans”, Bioelectromagnetics, volume. 34, pp.589-598, 2013.
22. SooBeom Choi, Min Kyung Kwon, Jai Won Chung, JeeSoo Park, KilSoo Chung and Deok Won Kim, “Effects of short-term radiation emitted by WCDMA mobile phones on teenagers and adults”, BMC Public Health 2014, 14:438, 2014.
23. Naren, A. Elhence, V. Chamola and M. Guizani, "Notice of Retraction: Electromagnetic Radiation Due to Cellular, Wi-Fi and Bluetooth Technologies: How Safe Are We?", IEEE Access, vol. 8, pp. 42980-43000, February 2020.
24. National Institute of Environmental Health Sciences. High Exposure to Radio Frequency Radiation Associated With Cancer in Male Rats. Accessed: Sep. 10, 2019.
25. L. Falcioni, L. Bua, E. Tibaldi, M. Lauriola, L. De Angelis, F. Gnudi, D. Mandrioli, M. Manservigi, F. Manservisi, I. Manzoli, I. Menghetti, R. Montella, S. Panzacchi, D. Sgargi, V. Strollo, A. Vornoli, F. Belpoggi, “Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission”, Environmental Research, vol. 165, August 2018.
26. L. Hardell and M. Carlberg, "Comments on the US National Toxicology Program technical reports on toxicology and carcinogenesis study in rats exposed to whole-body radiofrequency radiation at 900 MHz and in mice exposed to whole-body radiofrequency radiation at 1,900 MHz", Int. J. Oncol., vol. 54, no. 1, pp. 111-127, 2019.
27. Mary Hydrina d’Silva, Rijied Thompson Swer, J. Anbalagan, Bhargavan Rajesh, "Effect of radiofrequency radiation emitted from 2G and 3G cell phone on developing liver of chick embryo–A comparative study.", Journal of clinical and diagnostic research: JCDR, vol. 11.7, July 2017.
28. S. Franzellitti, P. Valbonesi, N. Ciancaglini, C. Biondi, A. Contin, F. Bersani, & E. Fabbri, “Transient DNA damage induced by high-frequency electromagnetic fields (GSM 1.8 GHz) in the human trophoblast HTR-8/SVneo cell line evaluated with the alkaline comet assay”, Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis, vol. 683(1-2), January 2010.
29. A. Campisi, G. Marisa, A. Rosaria, B. Paolo, R. Giuseppina, G. Rosaria, M. Francesco, V. Angelo and T. Antonio, "Reactive oxygen species levels and DNA fragmentation on astrocytes in primary culture after acute exposure to low intensity microwave electromagnetic field.", Neuroscience letters, vol. 473, no. 1, pp. 52-55, March 2010.
30. G. Abdel-Rassoul, O. Abou El-Fateh, M. Abou Salem, A. Michael, F. Farahat, M. El-Batanouny, and E. Salem. "Neurobehavioral effects among inhabitants around mobile phone base stations.", Neurotoxicology, vol. 28, no. 2, pp. 434-440, March 2007.
31. Sin-Eng Chia, Hwee-Pin Chia, and Jit-Seng Tan. "Prevalence of headache among handheld cellular telephone users in Singapore: a community study.", Environmental health perspectives, vol. 108, no. 11, pp. 1059-1062, November 2000.
32. Mona Abdullah Al-Damegh, "Rat testicular impairment induced by electromagnetic radiation from a conventional cellular telephone and the protective effects of the antioxidants vitamins C and E.", Clinics vol. 67, no. 7, pp. 785-792, July 2012.

33. M. Davoudi, C. Brössner, and W. Kuber. "Der Einfluss elektromagnetischer wellen auf die Spermienmotilität.", Journal für Urologie und Urogynäkologie, vol. 9, pp. 18-22, 2002.
34. Alchalabi, Ali SH, Erkihun Aklilu, F. Malek, S. H. Ronald, and Mohd Azam Khan. "Different periods of intrauterine exposure to electromagnetic field: influence on female rats' fertility, prenatal and postnatal development." Asian Pacific Journal of Reproduction, vol. 5, no. 1, pp. 14-23, March 2016.
35. Hans-Peter Hutter, Hanns Moshammer, Peter Wallner, Monika Cartellieri, Doris-Maria Denk-Linnert, Michaela Katzinger, Klaus Ehrenberger, and Michael Kundi. "Tinnitus and mobile phone use.", Occupational and environmental medicine, vol. 67, no. 12, pp. 804-808, December 2010.
36. Silke Thomas, Sabine Heinrich, Rüdiger von Kries, and Katja Radon. "Exposure to radio-frequency electromagnetic fields and behavioural problems in Bavarian children and adolescents.", European journal of epidemiology, vol. 25, no. 2, pp. 135-141, February 2010.
37. Hozefa A. Divan, Leeka Kheifets, Carsten Obel, and Jørn Olsen. "Prenatal and postnatal exposure to cell phone use and behavioral problems in children.", Epidemiology, pp. 523-529, July 2008.
38. Cindy Sage and Ernesto Burgio. "Electromagnetic fields, pulsed radiofrequency radiation, and epigenetics: how wireless technologies may affect childhood development.", Child development, vol. 89, no. 1, pp. 129-136, January 2018.
39. Leif G. Salford, Arne Brun, Kerstin Sturesson, Jacob L. Eberhardt, and Bertil RR Persson. "Permeability of the blood-brain barrier induced by 915 MHz electromagnetic radiation, continuous wave and modulated at 8, 16, 50, and 200 Hz.", Microscopy research and technique, vol. 27, no. 6, pp. 535-542, April 1994.