108年委託研究報告

基地臺電磁波安全研究之文獻回顧與探討

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基地臺電磁波安全研究之文獻回顧與探討

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Contents

Abstract

Introduction

High-speed mobile broadband service has become a daily necessity of citizens in Taiwan, but it has to depend on excellent infrastructure of cellular mobile phone base stations. However, the construction of mobile phone base station is still a dilemma because different academic reports have presented different opinions regarding health risks of exposure to electromagnetic fields (EMFs) from mobile phone base stations. More and more unauthentic information turned into mass panic as increasing fake news reported variety of negative health problems, caused protest activities staging one after another to against the basic construction of cellular base station. Thus, people's right to use high-quality cellular networks has always been affected due to delayed construction of mobile phone base stations.

In order to provide the correct science concept regarding health risks from mobile phone base stations to general public, more attention must be given to negative effects of exposure to EMFs. Moreover, in the future, the 5th generation of mobile networks (5G) is being designed to work in conjunction with a range of macro cells, small cells, and dedicated in-building systems. Further, the 5G's cellular mobile phone base stations will be integrated and be more close to people's daily life. Therefore, building a bridge and reducing the diversity between public concerns regarding exposure to EMFs from mobile phone base stations and development of infrastructure are required on an urgent basis. This project is commissioned by the National Communications Commission. We aim to create mutual trust and dialogue with general public by collecting and translating recent research publications, which have authentication for public health and EMFs from prestigious journals and major international professional organizations. Once general public with positive empirical basis for the exposure of EMFs and its associated biological health effects, the opportunity to break through the construction of 5G dilemma is able to fulfill, and also meeting the internet of things with billions of connected devices, and tomorrow's

innovations.

Materials and methods

In this report, numerous studies and epidemiological reports on the relationship between the EMFs exposure and human health over years were analyzed. We surveyed and compiled peer-reviewed articles and collected by-laws or guidelines of different countries and organizations, such as WHO and IRPA. We also integrated literature reports and information, which had authentication for public health and EMFs from prestigious journals and major international professional organizations.

Part of these documents were translated into Chinese so that they can be more beneficial to the communities.

Significant finding

Recent literature reviews revealed no adequate evidence to prove that exposure to extremely low frequency or radiofrequency EMFs was involved in the development of any acute or long-term pathogenesis. On the other hand, we also described and compared various diseases and biological effects between countries

Comments and suggestions

Although some international organizations considered exposure to EMFs as a risk factor on people's health, on the basis of the principle of radiation biology effects, exposure to only very high energy level radiation, such as ionizing radiation, can damage the DNA inside living cells. Additionally, nonionizing radiation is an extremely low-energy-level radiation and is thought to be harmless to people. As a result, the scientific evidence for the association between exposure to EMFs from mobile phone base stations and disease incidence has not been not established.

I. Timely and practicable suggestion:

We should be popularizing the correct concepts regarding EMFs and make the general public understand the different scientific essence between ionizing radiation and nonionizing radiation.

II. Long-term suggestion:

We suggested that clarify the different scientific essence of ionizing and non-ionizing radiation could be used as an education strategy to the general public and different filed specialist. Awareness of the correct concept of radiation, can make people realize the importance and convenience of 5G high-speed mobile phone services.

Keywords: Nonionizing radiation, electromagnetic fields, health risks

Chapter 1 Literature reviews

1.1 Child growth and development

1. Karipidis K, Henderson S, Wijayasinghe D, et al. (2017). Exposure to Radiofrequency Electromagnetic Fields from Wi-Fi in Australian Schools. Radiat Prot Dosimetry. 175(4):432-439

Literature review:

This study discussed typical and peak RF level from Wi-Fi and other sources have the potential to adversely affect children. The results showed that measurement values were much lower than one ten-thousandth limit value (Wi-Fi limit is 1.0 mW/cm^2). The exposure was inversely proportional to the square of the distance. The frequency range of Wi-Fi was mostly in 2.4 or 5 GHz, and there was no definitive evidence that such non-ionizing radiation being harmful to health*.

* International Commission on Non-Ionizing Radiation Protection (ICNIRP), Wi-Fi. http://www.icnirp.org/en/applications/wi-fi/index.html

2. Sage C, Burgio E. (2018). Electromagnetic Fields, Pulsed Radiofrequency Radiation, and Epigenetics: How Wireless Technologies May Affect Childhood Development. Child Dev. 89(1). 129-136

Literature review:

Suggested implications based on some reference works of literature, the electromagnetic field (EMF) and pulsed radiofrequency radiation (RFR) were possible to change in some developments and behaviors regarding to neurons. In fact, some cases demonstrated in this article remains to be verified, because the reproducibility of animal experiments and changes in genetic factors were not directly related to a single factor, such as EMF or RFR exposure. Therefore, the discussion in this article was uncountable, and still need more scientific data to be confirmed.

3. Hardell L. (2018). Effects of Mobile Phones on Children's and Adolescents' Health: A Commentary. Child Dev. 89(1).137-140

Literature review:

The paper cited the IARC conclusion in May 2011 that devices emitted nonionizing RF radiation were sorted as “Group 2B”, that is, a "possible" human carcinogen. However, WHO 193 report conclusion is: A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use. Furthermore, several surveys from different countries have also found that the number of brain cancers does not increase with the use of mobile phones, so whether mobile phone electromagnetic waves are Group 2B carcinogenic factors is still being questioned by various countries. In addition, neurological diseases, physiological addiction, cognition, sleep and behavior problems were not able to be effected only by exposure to non-ionizing radiation.

4. Sultan AM, Qasem A, Waseem MH. (2018). Mobile Phone Base Station Tower Settings Adjacent to School Buildings: Impact on Students’ Cognitive Health. Am J Mens Health. 13(1):1557988318816914.

Literature review:

This study investigated the impact of exposure to radiofrequency electromagnetic field (RF-EMF) radiation generated by mobile phone base station towers (MPBSTs) on cognitive functions. During 2 years period, volunteer male students were exposed to RF-EMFR for 6 hours per day, 5 days a week. Their study outcome, demonstrated a positive link between exposure to RF-EMF and decline in cognitive function such as gross motor skills, spatial working memory and attention. However, students whose residences were adjacent to high power lines or MPBSTs and students who commonly used and kept cordless phones and Wi-Fi devices in their bedrooms were excluded from this study. So, there still had chances of exposure to RF-EMF generated from

other sources such as television, remote devices, and wireless networks. The conclusion of this study may be unfair when declaring high correlation between RF-EMF and cognitive function of young students if only this MPBSTs are exposed.

1.2 Health risks

5. Moore SM, McIntosh RL, Iskra S, et al. (2017). Effect of Adverse Environmental Conditions and Protective Clothing on Temperature Rise in A Human Body Exposed to Radiofrequency Electromagnetic Fields. Bioelectromagnetics. 38(5):356-3

Literature review:

This study was found that different environmental conditions had minimal impact on the magnitude of the thermal response due to RF-EMF exposure. In principle, if exposed to non-ionizing electromagnetic waves with a large number of high-frequency, it just induced weary micro-currents on the surface of the skin, which further induced merely heat sensation. Take the sunlight for example, as long as it doesn't transmit too much energy in a short duration, tissues are allowed to be thermal regulated physically. Therefore, exposure to non-ionizing electromagnetic waves under a safe range does not cause cumulative damage.

6. Stefi AL, Margaritis LH, Skouroliakou AS, et al. (2019). Mobile Phone Electromagnetic Radiation Affects Amyloid Precursor Protein and α-Synuclein Metabolism in SH-SY5Y Cells. Pathophysiology. pii: S0928-4680(18)30352-3

Literature review:

In this study, the effects of low-level, GSM emitted electromagnetic field (EMF) on Amyloid Precursor Protein (APP) and alpha-synuclein (α-syn) in human neuroblastoma cells were investigated. This experiment was designed as an in-vitro experiment, which was susceptible to external factors. In contrary, according to the mechanism of cell growth and the activities inside the body were different from that in vitro. In addition, it was too far-fetched that cell variability in this article was

directly inferred to be related to the pathogenesis of a disease. Therefore, results presented here required further investigations to determine potential links of EMF with the molecular pathogenic mechanisms in Alzheimer's and Parkinson's Diseases.

7. Zhang J, Sumich A, Wang GY. (2017). Acute Effects of Radiofrequency Electromagnetic Field Emitted by Mobile Phone on Brain Function. Bioelectromagnetics. 38(5). 329-338

Literature review:

This study suggested that MP EMF exposure was harmful on brain function, but the detection of brain function or diseases herein were only using neurological angiography or electroencephalography (EEG) which were the most common clinical examination procedure. In fact, the functional images from magnetic resonance imaging (fMRI) and positron emission tomography (PET) were also used for detecting blood flow of brain and region of neuron activities; On the other hand, electroencephalography (EEG) allowed observation of changes in voltage produced by the flow of ions from neurons in the brain. Total 16 related references cited in this article, most of the literature results showed no significant effect, and a few literature results showed that there was a decrease in alpha wave on the EEG. The results measured by EEG were highly susceptible to interference, so it was often necessary to cooperate with other tests to support the evidence in clinical. Therefore, the conclusions of this paper need more research to be confirmed.

8. Taheri M, Mortazavi SMJ, Moradi M, et al. (2017). Evaluation of The Effect of Radiofrequency Radiation Emitted from Wi-Fi Router and Mobile Phone Simulator on The Antibacterial Susceptibility of Pathogenic Bacteria Listeria Monocytogenes and Escherichia Coli. Dose Response.15(1). 1559325816688527

Literature review:

This article mentioned that microorganisms were antibiotic resistance after exposure to radiofrequency electromagnetic fields (EMF). The results in this article showed that some strains had different responses to EMF in which kind of cellular changes of mechanism and factor. Furthermore, it was unknown that specific systems were activated, such as ion channels, membranes, changes of DNA repair systems, ion efflux pumps in cell membranes, and molecular interactions. Therefore, this conclusion requires more rigorous researching design to clarify the uncertainties mentioned above.

9. Mortazavi SAR, Mortazavi G, Mortazavi SMJ. (2017). Comments on Radiofrequency Electromagnetic Fields and Some Cancers of Unknown Etiology: An Ecological Study. Sci Total Environ. 609

Literature review:

This article referred that there was a relationship between exposure of radiofrequency electromagnetic fields (RF-EMF) and the incidence of cancer, such as lymphomas and brain tumors. The literature of this paper was an epidemiological study, including population division, average exposure, and frequency of disease in different regions (microenvironments). These investigations were not appropriate for population selection and control of sample amount; In 1996, the United States National Academy of Sciences reported: "It cannot prove that something (such as electromagnetic waves) is not carcinogenic, electromagnetic waves do not produce evidence similar to other well-known carcinogens (1A) namely after numerous studies". Because it is impossible to prove the null hypothesis, it is impossible to prove that something is absolutely safe.

10. Gallastegi M, Jiménez-Zabala A, Molinuevo A, et al. (2019). Exposure and Health Risks Perception of Extremely Low Frequency and Radiofrequency Electromagnetic Fields and The Effect of Providing Information. Environ Res. 169. 501-509

Literature review:

Participants were highly concerned regarding both exposure and health-risk perception of EMF-NIR. Variables that were repeatedly associated with higher perceptions included manual social class. Providing information on exposure levels found at home had a small impact only on exposure perception. It is recommendable that public bodies join efforts in providing comprehensive information on exposure and health-risks of EMF-NIR. Future studies should address the best ways to provide information in order to be effective. In the past decade, Taiwan government agencies (such as National Communications Commission, Environmental Protection Administration, Executive Yuan; Health Promotion Administration, Ministry of Health and Welfare, etc.) have executed education training and promotion on RF-EMF in various local areas, as well as to conduct environmental testing of RF-EMF. Based on these experiences, we find that proper education about the distinction between non-ionization and ionization radiations essentially enables to eliminate the public's fears and doubts on EMF.

11. Lowden A, Nagai R, Åkerstedt T, et al. (2019). Effects of Evening Exposure to Electromagnetic Fields Emitted by 3G Mobile Phones on Health and Night Sleep EEG Architecture. J Sleep Res. e12813

Literature review:

The study was to investigate the effects of exposure to RF-EMF from third-generation 3G signals on subsequent night sleep architecture and perceived health symptoms and performance during experimental sessions. These results confirmed that previous findings on radiofrequency post-exposure in the evening had a very tiny influence on electroencephalogram architecture but possible on spindle range activity (11.0-12.75 Hz). At present, this literature only discusses the human who had self-evaluated sleepiness situation, but it did not expand the research to correspond to the state of human sleep, such as shallow sleep or abnormal life and work. Therefore, it was still

unable to determine that RF exposure has a direct impact on the sleeping disorder.

12. Gulati S, Yadav A, Kumar N, Priya K, Aggarwal NK, Gupta R. (2018). Phenotypic and Genotypic Characterization of Antioxidant Enzyme System in Human Population Exposed to Radiation from Mobile Towers. Mol Cell Biochem. 440(1-2):1-9.

Literature review:

In this article, the author mentioned that there was an association of genetic polymorphism of antioxidant genes with genetic damage has been observed in the human population exposed to radiations emitted from mobile towers. In fact, there are thousands of enzymes in the human body, they act as some macromolecular biological catalysts that accelerate chemical reactions. Most Importantly, these chemical reactions can keep us alive to perform our necessary metabolism. It all relies on the work that enzymes carry out. Until now, enzymes were known to catalyze more than 3,000 biochemical reaction types in our body. In our opinion, the mechanism of cellular activities in our body is quite complicated, and the changes in enzyme activity in the body are not independent exposure by electromagnetic field alone, so it seems to be unreasonable that the average value changes of the three biological enzymes are related to genetic damage.

13. Mortazavi SMJ, Balas VE, Zamani A, Zamani A, Mortazavi SAR, Haghani M, Jaberi O, Soleimani A. (2018). The Importance of Quantification of Data in Studies on the Health Effects of Exposure to Electromagnetic Fields Generated by Mobile Base Stations. Soft Computing Applications, Advances in Intelligent Systems and Computing 633.

Literature review:

It was mentioned in this article that if people are exposed to these low-intensity

RF-EMFs for a very long time, serious health problems can occur. In fact, this study was sort of “community survey”, and the survey items were too subjective and lacking quantitative data, such as muscle pain, heart palpitations, fatigue, tinnitus, attention problems, and nervousness. That’s why the conclusion in this study seems to be inappropriate.

14. Davide C, Bjorn T, Christer T, Quirino B. (2018). RF Energy Absorption by Biological Tissues in Close Proximity to Millimeter-Wave 5G Wireless Equipment. EEE Access(6). 4974 - 4981.

Literature review:

Energy absorption mechanisms and near-field body-antenna interactions were studied at frequencies of relevance for the next generation of mobile communication networks, 5G. While at the lower frequencies (e.g. 2 GHz) and for short separation distances, the energy deposition is dominated by the coupling of the reactive near-field. Part of the reflected energy at the skin interface interacts with the antenna and is scattered back towards the body. The presence and relevance of this phenomenon is dependent by the antenna design, the separation distance and operating frequency. At or around the millimeter-wave range, the electromagnetic fields from the antenna in free-space can be used to characterize the energy absorption in the skin also for devices intended to be used in close proximity of the body. Overall, in relation to the wide safety margins typically included in the exposure limits, the effects of near-field body interactions are negligible when evaluating compliance at the mW when a high-frequency range of interest for mobile communications (24 GHz to 100 GHz) is used. Currently, most researches indicated that there is no evidence that EMF can produce deterministic damage to human. If the public still has doubts about this issue, it may be recommended to pay attention to the use of the mobile phone, as follows: 1. Mobile phones should be used for emergency needs, and try to shorten the talk time or replace it with a message; 2. Mobile phones should try to avoid long-term Internet access or

play online games; 3. When the signal is bad, try to avoid using the mobile phone; 4. Shutdown before going to bed, and avoid placing the mobile phone near the head when sleeping; 5. At home or in the office, use a wired phone whenever possible.

15. Qin F, Shen T, Cao H, Qian J, Zou D, Ye M, Pei H. (2019). CeO_2NPs Relieve Radiofrequency Radiation, Improve Testosterone Synthesis, and Clock Gene Expression in Leydig Cells by Enhancing Antioxidation. Int J Nanomedicine. 14:4601-4611.

Literature review:

This study demonstrated that CeO_2NPs was able to prevent the adverse effects on testosterone synthesis induced by RF exposure. But, there is no evidence that EMF can produce deterministic damage to human; moreover, the mechanism underlying the protective function of CeO_2NPs in the male reproductive system is still unknown.

1.3 Risk perception

16. Berihun M. Zeleke, Chhavi RB, et al. (2019). Radiofrequency Electromagnetic Field Exposure and Risk Perception: A Pilot Experimental Study. Environmental Research. 170. 493-499

Literature review:

This study aimed to demonstrate if people provided with objectively measured RF-EMF levels from mobile phone base stations (MPBS), compared to those provided with precautionary principles or only basic information, will be less likely to consider MPBSs risky to their health. It demonstrated that, compared to those provided with precautionary messages and basic information, people provided with personal RF-EMF exposure data did not have significantly different scores for their exposure or risk perception towards RF-EMF in general or that from MPBS, but had greater confidence in being able to protect themselves from RF-EMF. In the past

decade, in order to promote the correct concept, Taiwan government agencies (such as National Communications Commission, Environmental Protection Administration, Executive Yuan; Health Promotion Administration, Ministry of Health and Welfare, etc.) invited many experts and scholars to educate and communicate in the towns and villages of counties and cities, and also conduct environmental measurements on the spot for people with doubts. These experience feedback has indeed eliminated the public's fear of EMF and further enhanced the confidence of the people.

17. Ramirez-Vazquez R, Gonzalez-Rubio J, Arribas E, et al. (2019). Characterisation of Personal Exposure to Environmental Radiofrequency Electromagnetic Fields in Albacete (Spain) and Assessment of Risk Perception. Environmental Research. 172. 109-116

Literature review:

The study characterized personal exposure to environmental RF-EMF in Albacete, and assess the effect of sharing results on participants' risk perception. The mean personal exposure value showed differences in temporal fields (weekdays or weekend days) and spatial fields (homes or workplaces), respectively. Overall, the main exposure sources were enhanced cordless telecommunications, followed by mobile phones and WiFi. Levels of personal exposure were extremely low for all the frequencies compared to the levels set by ICNIRP and those set out in local legislation. Since the measured power density value in this article was very small, it was expressed in a smaller unit ($\mu W/m^2$). Compared with the ICNIRP standard, the power density unit is mW/cm^2, and the difference between the two units is up to 10^7. It may be caused confusion for the public; therefore, there re-emphasizes that the exposure is much lower than the ICNIRP guidelines.

1.4 RF evaluation and protection

18. Buckus R, Strukčinskienė B, Raistenskis J, et al. (2017). A Technical Approach to the Evaluation of Radiofrequency Radiation Emissions from Mobile Telephony Base Stations. Int J Environ Res Public Health. 14(3). pii: E244

Literature review:

The measurements of the RF electric field strength and RF-EMF power density conducted in the near- and far-fields of the mobile telephony base station antennas, lead to the following conclusions: (1) In the near-field (up to a distance of 30 m), the values of the strength of the RF electric field radiated by the antennas varied from 7 to 195 V/m. In the near-field, the RF EMR intensity parameters exceeded the range from allowable values (ICNIRP Guidelines); (2) The RF-EMF power density values of the high effective radiation power emitted into the environment by the mobile antenna up to a distance of 500 m amount to approximately 0.01%–10% of the allowable level (10 μW/cm^2); (3) The high effective radiation power of the directional mobile antenna revealed that the antenna with a height of 30 m has small values of RF-EMF power density, reaching about 0.01%–0.04% of the allowable values (10 μW/cm^2); (4) The RF-EMF power density values of the mobile antenna with a height of 14 m at a distance of 50 m reached 0.98 μW/cm^2 , but decreased significantly at greater distances (100 m or more), and amounted to only 0.005%–0.01% compared with the ICNIRP allowable values; (5) The RF-EMF power density values on the ground surface at a distance of 50–200 m from the mobile antenna were very small and varied from 0.01 to 0.98 μW/cm^2, which is 100 to 10 times lower than the allowable values (10 μW/cm^2). In the regulations of Taiwan, Article 14 of the "Management for Mobile Communication Network Service on Base Stations": The setting height and direction of the antennas of outdoor base stations are differentiated according to the maximum RF output power of the base station transmitters, and the level should be ensured. There shall be no legal buildings above the antenna in the direction of the following distance: 1. more than 7.94 W: 15 meters; 2. the micro base station: 8 meters. The

radio frequency power at the input of the base station antenna is greater than 2W, and the antenna set for the outdoor radio wave coverage shall not be installed indoors. Therefore, on the whole, the regulations by Taiwan are more rigorous and standardized, and they can ensure the safety of the people.

19. Emma C, Marta B, Serena F, et al. (2019). Radio Frequency Electromagnetic Fields Exposure Assessment in Indoor Environments: A Review. Int. J. Environ. Res. Public Health . 16(6). 955

Literature review:

The RF-EMF generated by the environment depends on many outdoor sources, but it is not much different from the contribution of different sources at different times. On behalf of the public, the demand for wireless communication equipment is high but still lower than the International Non-Isolated Radiation Protection Committee (ICNIRP) specification.

20. Masao T. (2016). Bioelectromagnetics Researches in Japan for Human Protection from Electromagnetic Field Exposures. IEEJ Transactions on Electrical and Electronic Engineering. 11(6). 683-695

Literature review:

Researches on bio-electromagnetics in Japan were reviewed with a focus on the efforts devoted to the issue of human protection from EMF exposures. The results of these studies consistently showed no hazardous effect of RF-EMF within the exposure levels of the internationally accepted guideline. It was also recommended that biology/medical and engineering collaborations should carefully be conducted to improve the reliability of the experiment and to assess the health effects. There are still many doubts about the potential health effects of exposure, so we should continue to investigate and determine the safe usage of EMF. Finally, establish a healthy

society with a coordinated development of technology.

1.5 Asia

21. Jonghyuk C, Jung-Hwan H, Hyungrul L, et al. (2018). Assessment of Radio Frequency Electromagnetic Field Exposure from Personal Measurements Considering The Body Shadowing Effect in Korean Children and Parents. Science of The Total Environment. 627.1544-1551

Literature review:

In recent years, with the rapid technological development of wireless communication, mobile phones had become increasingly popular in Korea. Seoul is a metropolitan area showing the highest level (1.7 times) compared to other cities. Among all the activities, it was the highest in the metro. Meanwhile, it also higher than those reported in European countries and Australia. Since the measured power density value was very small, it expressed in $\mu W/m^2$ as the unit. Compared with the ICNIRP standard, the power density unit is mW/cm^2, and the difference between the two units is up to 10^7. Hence, the regulations in Taiwan are also in accordance with the standard of ICNIRP. So, when people doubt the measured EMF exposure value is too high in the future, they should remember to confirm the unit to avoid unnecessary confusion.

22. Lin YJ, Chiu HY, Chiou MJ, et al. (2017). Trends in The Incidence of Primary Malignant Brain Tumors in Taiwan and Correlation with Comorbidities A Population-Based Study. Clin Neurol Neurosurg. 159:72-82

Literature review:

In recent years, with the rapid technological development of wireless communication, mobile phones have become increasingly popular in Taiwan. A slightly decreased trend in the incidence of primary malignant brain tumors was observed in the Taiwanese general population since 1999. Over the past 15 years, we have seen

improvement in the short-term survival of primary malignant brain tumors, especially in adults, the incidence of primary malignant brain tumors was still reduced. These indicate that under the simultaneous development of wireless communication and medical technology, the rate of primary malignant brain tumors has not increased with the popularity of mobile communication, and also indicate the pathogenesis of primary malignant brain tumors were not directly related to RF-EMF exposure.

1.6 Public issue

23. Cindy L. (2018). 5G Wireless Telecommunications Expansion: Public Health and Environmental Implications. Environmental Research(165). 484-495.

Literature review:

This article mentioned that the impact on 5G radiofrequency electromagnetic radiation (RF EMR) should be taken seriously, as well as the need for a precautionary approach in advancing new wireless technologies. The World Health Organization (WHO) summary of Environmental Health Criteria from a Warsaw conference stated: "More data on the relationship between biological and health effects and the frequency and mode of generation of the radiation, particularly in complex modulations, are needed." They further state, "Prevention of potential hazards is a more efficient and economical way of achieving control than belated efforts to reduce existing levels."

With the progress of science and technology, small cell deployments can be used as high capacity Wi-Fi hotspots forming an outdoor mesh network with an intergenerational mix of communications networks with 5G added later. Public, private and academic partnerships have been developed to advance this initiative. In conclusion, the intensity of the RF EMR emitted by the cell base station was extremely low, so there is no need to worry too much on such an issue.

24. Pall ML. (2018). Wi-Fi is an Important Threat to Human Health. Environ Res. 164:405-416.

Literature review:

Recently, studies showed that Wi-Fi causes oxidative stress, sperm/testicular damage, neuropsychiatric effects including EEG changes, apoptosis, cellular DNA damage, endocrine changes, and calcium overload. Sperm/testicular damage and EEG changes may be activated due to close contact of WiFi, whereas other effects may be activated due to the voltage-gated calcium channels (VGCCs) changes by WiFi. However, these studies were limited to in vivo and in vitro trial (e.g. cell or rat tests); even more, the reasonableness and reproducibility of the experimental design are still questioned. Therefore, there is no specific evidence to prove that RF-EMF generated by WiFi was directly produced body damage.

1.7 Biological experiments

25. Piccinetti CC, De Leo A, Cosoli G, Scalise L, Randazzo B, Cerri G, Olivotto I. (2018). Measurement of The 100-MHz EMF Radiation in Vivo Effects on Zebrafish D. Rerio Embryonic Development: A Multidisciplinary Study. Ecotoxicol Environ Saf. 154:268-279.

Literature review:

As proposed in this study, zebrafish is also an essential and widely used vertebrate model organism in scientific research, the reason for the rapid expansion of zebrafish colonies in research labs is the optical transparency of zebrafish embryos, *in vitro* fertilization, embryonic transparency, short embryonic development period (2-3 days), easy process of organ formation, short sexual maturity (3 months), physical and chemical methods in producing mutant fish, molecular biology methods can be used to change specific gene expression and production of genetically modified fish and other characteristics. The results obtained in this study demonstrated unequivocally that 100 MHz EMF had biological effects on ZF embryonic development, particularly

evident at 48 hours post fertilization (hpf). However, these effects were no more evident at hatching time, because of the exposure frequency and simulation used in this article were also different from the electromagnetic exposure of mobile phones. Therefore, this conclusion does not provide a basis for amending the current guidelines for EMF exposure.

26. Wlodzimierz K. (2017). Non-Thermal Effects of Electromagnetic Fields in Biology and Medicine. IFMBE Proceedings(65).

Literature review:

This article mentioned how electromagnetic fields (EMFs) affect the growth of corn seedlings and cress seeds. However, there was a bundle of related experiments and studies just clarified this kind of experiment was not able to reproduce and had no science theoretical basis. Many years ago, the Netherlands and Denmark conducted relevant experiments and researches. During the test, many environmental variables had fully grasped, and it is impossible to know, such as the illumination time of the plant, the number of daily watering, the control of the surrounding temperature, etc. , may become an essential factor affecting plant survival. Therefore, in terms of simple experimental design and results, it was impossible to confirm that the electromagnetic field is directly related to the inhibition of plant growth. Moreover, sunlight is also an electromagnetic wave, and plants do not inhibit their growth because of it.

27. Vargová B, Majláth I, Kurimský J, Cimbala R, Kosterec M, Tryjanowski P, Jankowiak Ł, Raši T, Majláthová V. (2018). Electromagnetic Radiation and Behavioural Response of Ticks: An Experimental Test. Exp Appl Acarol. 75(1):85-95.

Literature review:

The author mentioned that the survival and distribution of ticks were affected by exposure of radiofrequency electromagnetic fields (RF-EMF). But this kind of

commentary was weird because the distribution and density of organisms in nature were affected by complex biological factors and were therefore not caused only by a single factor, such as electromagnetic exposure.

28. Kumar R, Deshmukh PS, Sharma S, Banerjee B. (2019). Activation of Endoplasmic Reticulum Stress in Rat Brain Following Low-Intensity Microwave Exposure. Environ Sci Pollut Res Int. 26(9):9314-9321.

Literature review:

Low-intensity microwave radiation proposed in this paper was able to change the proteins that condense within the endoplasmic reticulum. The concentration of intracellular calcium ion is stimulated by the extracellular environment, which plays an important role in various life phenomena such as cell proliferation, cell death, muscle contraction, and immune response. In contrary to the cytosol, the endoplasmic reticulum contains about 10,000 folds in calcium ion. In addition, there are many enzymes or molecular chaperones in the endoplasmic reticulum, which can bind to calcium ions. When the endoplasmic reticulum can not maintain the calcium ion concentration, the function is significantly reduced, which may eventually cause cell death. The association and impact of this change on human-related diseases are not clearly stated in the article.

29. Gholamali J, Fatemeh S, Mansour A. (2018). Vitamin C Improves Passive Avoidance Learning and Memory in Rats Exposed to Radiofrequency Waves Generated by a Base Transceiver Station (BTS) Antenna Model. ZahedanJ Res Med Sci. 20(11):e80229.

Literature review:

This article suggested the use of vitamin C improve the likelihood of passive avoidance learning and memory from the rat experiment. Although some studies have

confirmed that antioxidants are related to learning and memory; however, the energy is not enough to destroy or affect brain operation and development for mobile phone RF electromagnetic waves. So there is currently no evidence and no consensus that RF-EMFs are carcinogenic; moreover, the mechanism underlying the use of vitamin C for improving the passive avoidance learning and memory are needed to prove.

30. Melnick RL. (2019). Commentary on The Utility of The National Toxicology Program Study on Cell Phone Radiofrequency Radiation Data for Assessing Human Health Risks Despite Unfounded Criticisms Aimed at Minimizing The Findings of Adverse Health Effects. Environ Res. 168:1-6.

Literature review:

In 2011, an IARC expert working group of international scientists classified radiofrequency radiation (RFR) as a possible human carcinogen based on limited evidence of carcinogenicity in humans and in experimental animals. In past decades, the association between RFR and carcinogenesis was often limited by experiments with lower reproducibility or false-positive data. Recently, literature has reported a significant increase in heart schwannomas in male Sprague-Dawley rats exposed to GSM-modulated RFR at a field strength of 50 V/m. The incidence of heart Schwann cell hyperplasia was also increased in that exposure group. The combined incidence of schwannomas and preneoplastic Schwann cell hyperplasias is highly significant ($p = 0.01$). These findings are consistent with the results from the NTP study and demonstrate that the proliferative effect of modulated RFR in heart Schwann cells is a reproducible finding. Even a small increase in cancer risk could have a serious health impact due to the widespread use of cell phones (5 billion worldwide). However, according to ICNIRP 2018 note:" Final results are now available from two large animal studies that investigated whether long-term exposure to RF-EMFs associated with mobile (or cell) phones or base stations is carcinogenic; these studies hale from the US NTP and the Ramazzini Institute in Italy, respectively. We also noted some

major weaknesses, including a lack of blind test, difficulties interpreting statistical analyses due to the association between longer lifespans and tumor occurrence in the irradiated group of rats (NTP only). ICNIRP concluded that these substantial limitations preclude conclusions being drawn concerning RF-EMFs and carcinogenesis".

Chapter 2 Conclusion and suggestions

A country's development is closely related to its advances in transportation and transmission and communication systems, and such systems raise electromagnetic field (EMF) safety concerns and health risk issues. Furthermore, incorrect information is often disseminated to the public, causing citizens to perceive EMF as harmful to health.

Commonly asked questions regarding EMF safety include the following: "Does long exposure to EMF cause cancer?" and "Are common wireless household appliances, such as Wi-Fi routers and mobile phones, safe?" In the past decades, scholars have discussed EMF-related health issues and come to both positive and negative conclusions. In the positive discourse, recent literature primarily focuses on brain research and the influence of EMFs on the brain. EMFs can slightly alter electroencephalogram signals, thereby improving healthy adults' cerebral cortex nerve efficiency and basic cognition–exercise processes and boosting the glucose metabolism of their brain cells in the regions closest to the antenna. However, the deterministic biological effect does not reveal any definite pathogenesis effects caused by acute or chronic exposure to radio frequency (RF) radiation. The present study was extended to encompass different age groups in different environments from various countries and to measure the EMF absorption rate and power density accumulated in the environment due to RF products. The review conducted in this study included 3, 8, 2, and 2 studies on child growth and development, health risks, risk perception, and biological experiments, respectively, the deterministic biological effect also does not reveal any definite pathogenesis effects caused by acute or chronic exposure to RF radiation. Within the research conducted by Asian scholars on this topic, studies conducted in South Korea have revealed that the total EMFs are substantially stronger in that country than in European countries and the country has more base stations. The results of investigations over 15 years in Taiwan revealed that the incidence rate of primary malignant brain tumor was decreased slightly over the 15-year period (two

studies conducted in Asia). Furthermore, studies on different RF-EMF sources (e.g. numerous indoor and outdoor sources) did not obtain proof that exposure to RF-EMFs within the international guidelines caused safety concerns (three studies on RF protection evaluation and two studies on the public issue).

Meanwhile, ICNIRP in 2018 note also indicated: “An important issue addressed in the scientific literature is whether RF-EMFs are carcinogenic. Because there is currently no verified mechanism that would predict that RF-EMFs would be carcinogenic (ICNIRP 2009), this issue has primarily been addressed empirically using in vitro, in vivo, or epidemiological methods. In general, in vitro research has tested for effects of RF-EMF exposure on a large range of cellular processes that could potentially mediate carcinogenesis, experimental animal-model studies have tested whether cancer rates themselves are affected by RF-EMF exposure, and epidemiological research has tested for associations between cancer outcomes and reported usage patterns of devices that utilize RF-EMF. As described in the reviews by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR 2015), the Health Council of the Netherlands (HCN 2016), and the Swedish Radiation Safety Authority (SSM 2018), there is currently no evidence and no consensus that RF-EMFs are carcinogenic.”

In the negative discourse, most scholars proposed the possible effects of RF waves on behavior, cognition, and sleep in the past decades. The literature states that these problems are mainly caused by cellphones, which have changed people’s lifestyles and further negatively affected behavior, cognition, and sleep. However, no evidence has yet been obtained to directly prove that the RF-EMFs emitted by cellphones are the main cause of such problems. As an example, pedestrians and drivers commonly check their cellphone messages or commercial content while commuting, which can result in traffic accidents. Statistically, those using cellphones have lower environmental awareness, and the devices cause a lack of sleep. However, whether these behavioral and cognitive changes are the result of human factors or wholly caused by RF-EMFs requires further discussion.

Currently, in the negative discourse the US National Toxicology Program (NTP) initiated a research project to test for effects of GSM and CDMA-modulated (Code-Division Multiple Access) RF-EMF exposure over (nearly) the entire lives of a large number of mice and rats, with a particular focus on carcinogenicity. Contemporaneously, the Ramazzini Institute in Italy conducted an RF-EMF base-station exposure carcinogenicity study in rats, which provided a limited set of results directly relevant to the outcomes in the NTP draft reports. Both studies claimed to have shown that RF-EMF exposure is carcinogenic in the irradiated group of rats. However, ICNIRP indicated that although both studies reported significantly elevated rates of carcinogenic outcomes in male rats, their results are not consistent with each other, nor with the NTP mouse or female rat results. The NTP's outlying finding is further complicated by important methodological limitations including the effect of the greater lifespans of the irradiated group of RF-exposed rats on the statistical analyses, lack of blind test in the pathological analyses, and a failure to account multivariate statistical analyses. Collectively these two studies' limitations preclude drawing conclusions about carcinogenicity in relation to RF-EMFs. According to the ICNIRP guidelines, "nonionizing radioactive-frequency radiation emitted by equipment operating at 30 kHz to 300 GHz is classified as a Group 2B 'possible carcinogen'." Currently, there is insufficient evidence that the decisive generation on cancers when materials belong to Group 2, 3, and 4 carcinogens. Aside from the mixed-effect of interacting parameters, the recovery ability of the human body and auxiliary implementations directly affect whether substances are essential to cancer development. Therefore, this study suggests that the government conduct a comprehensive evaluation and simulate the accumulated energy generated by RF-EMFs in the infrastructure, thereby measuring whether the accumulated energy levels comply with ICNIRP regulations and achieve both economic development and public safety measures. To improve the health of citizens, this study suggests that the government held discussions with health and education institutions to establish preventive measures for children and pregnant women who use devices that emit

RF-EMFs. Such measures would be educational and prevent these two groups from being exposed to carcinogens.

In conclusion, international organizations do currently acknowledge the potential risks of RF-EMFs. However, according to biological-effect principles, RF-EMFs must emit a certain amount of energy if they are to cause damage to the body by generating ionized radiation. This amount of energy is more than 1,000,000 times that of RF-EMFs that emit nonionizing radiation. Therefore, the nonionizing radiation emitted by mobile-device-induced RF-EMFs is insufficient to directly and significantly damage the human body. In addition, whether temporal energy accumulation (e.g. metabolic mechanisms) has a strong biological effect remains uncertain. Substantial amounts of group data and thorough quantification processes are required to reach a conclusion. Therefore, the researchers suggest that the following concepts are employed as directions for investigating EMF-related issues: (1) ionizing radiation definitely has biological effects, and (2) nonionizing radiation may have biological effects. Actually, nonionizing radiation is an extremely low-energy-level radiation and is thought to be harmless to people. As a result, the scientific evidence for the association between exposure to EMFs from mobile phone base stations and disease incidence has not been not established.

We should be popularizing the correct concepts regarding EMFs and make the general public understand the different scientific essence between ionizing radiation and nonionizing radiation. We suggested that clarify the different scientific essence of ionizing and non-ionizing radiation could be used as an education strategy to the general public and different filed specialist. Awareness of the correct concept of radiation, can make people realize the importance and convenience of 5G high-speed mobile phone services.

References

1. Karipidis K, Henderson S, Wijayasinghe D, et al. (2017). Exposure to Radiofrequency Electromagnetic Fields From Wi-Fi in Australian Schools. Radiat Prot Dosimetry. 175(4):432-439
2. Sage C, Burgio E. (2018). Electromagnetic Fields, Pulsed Radiofrequency Radiation, and Epigenetics: How Wireless Technologies May Affect Childhood Development. Child Dev. 89(1). 129-136
3. Hardell L. (2018). Effects of Mobile Phones on Children's and Adolescents' Health: A Commentary. Child Dev. 89(1).137-140
4. Sultan AM, Qasem A, Waseem MH. (2018). Mobile Phone Base Station Tower Settings Adjacent to School Buildings: Impact on Students' Cognitive Health. Am J Mens Health. 13(1):1557988318816914.
5. Moore SM, McIntosh RL, Iskra S, et al. (2017). Effect of Adverse Environmental Conditions and Protective Clothing on Temperature Rise in A Human Body Exposed to Radiofrequency Electromagnetic Fields. Bioelectromagnetics. 38(5):356-3
6. Stefi AL, Margaritis LH, Skouroliakou AS, et al. (2019). Mobile Phone Electromagnetic Radiation Affects Amyloid Precursor Protein and α-Synuclein Metabolism in SH-SY5Y Cells. Pathophysiology. pii: S0928-4680(18)30352-3
7. Zhang J, Sumich A, Wang GY. (2017). Acute Effects of Radiofrequency Electromagnetic Field Emitted by Mobile Phone on Brain Function. Bioelectromagnetics. 38(5). 329-338
8. Taheri M, Mortazavi SMJ, Moradi M, et al. (2017). Evaluation of The Effect of Radiofrequency Radiation Emitted From Wi-Fi Router and Mobile Phone Simulator on The Antibacterial Susceptibility of Pathogenic Bacteria Listeria Monocytogenes and Escherichia Coli. Dose Response.15(1). 1559325816688527
9. Mortazavi SAR, Mortazavi G, Mortazavi SMJ. (2017). Comments on Radiofrequency Electromagnetic Fields and Some Cancers of Unknown Etiology: An Ecological Study. Sci Total Environ. 609
10. Gallastegi M, Jiménez-Zabala A, Molinuevo A, et al. (2019). Exposure and Health

Risks Perception of Extremely Low Frequency and Radiofrequency Electromagnetic Fields and The Effect of Providing Information. Environ Res. 169. 501-509

11. Lowden A, Nagai R, Åkerstedt T, et al. (2019). Effects of Evening Exposure to Electromagnetic Fields Emitted by 3G Mobile Phones on Health and Night Sleep EEG Architecture. J Sleep Res. e12813

12. Gulati S, Yadav A, Kumar N, Priya K, Aggarwal NK, Gupta R. (2018). Phenotypic and Genotypic Characterization of Antioxidant Enzyme System in Human Population Exposed to Radiation from Mobile Towers. Mol Cell Biochem. 440(1-2):1-9.

13. Mortazavi SMJ, Balas VE, Zamani A, Zamani A, Mortazavi SAR, Haghani M, Jaberi O, Soleimani A. (2018). The Importance of Quanti□cation of Data in Studies on the Health Effects of Exposure to Electromagnetic Fields Generated by Mobile Base Stations. Soft Computing Applications, Advances in Intelligent Systems and Computing 633.

14. Davide C, Bjorn T, Christer T, Quirino B. (2018). RF Energy Absorption by Biological Tissues in Close Proximity to Millimeter-Wave 5G Wireless Equipment. EEE Access(6). 4974 - 4981.

15. Qin F, Shen T, Cao H, Qian J, Zou D, Ye M, Pei H. (2019). CeO_2NPs Relieve Radiofrequency Radiation, Improve Testosterone Synthesis, and Clock Gene Expression in Leydig Cells by Enhancing Antioxidation. Int J Nanomedicine. 14:4601-4611.

16. Berihun M. Zeleke, Chhavi RB, et al. (2019). Radiofrequency Electromagnetic Field Exposure and Risk Perception: A Pilot Experimental Study. Environmental Research. 170. 493-499

17. Ramirez-Vazquez R, Gonzalez-Rubio J, Arribas E, et al. (2019). Characterisation of Personal Exposure to Environmental Radiofrequency Electromagnetic Fields in Albacete (Spain) and Assessment of Risk Perception. Environmental Research. 172. 109-116

18. Buckus R, Strukčinskienė B, Raistenskis J, et al. (2017). A Technical Approach to the Evaluation of Radiofrequency Radiation Emissions from Mobile Telephony

Base Stations. Int J Environ Res Public Health. 14(3). pii: E244

19. Emma C, Marta B, Serena F, et al. (2019). Radio Frequency Electromagnetic Fields Exposure Assessment in Indoor Environments: A Review. Int. J. Environ. Res. Public Health . 16(6). 955

20. Masao T. (2016). Bioelectromagnetics Researches in Japan for Human Protection from Electromagnetic Field Exposures. IEEJ Transactions on Electrical and Electronic Engineering. 11(6). 683-695

21. Jonghyuk C, Jung-Hwan H, Hyungrul L, et al. (2018). Assessment of Radio Frequency Electromagnetic Field Exposure from Personal Measurements Considering The Body Shadowing Effect in Korean Children and Parents. Science of The Total Environment. 627.1544-1551

22. Lin YJ, Chiu HY, Chiou MJ, et al. (2017). Trends in The Incidence of Primary Malignant Brain Tumors in Taiwan and Correlation with Comorbidities A Population-Based Study. Clin Neurol Neurosurg. 159:72-8

23. Cindy L. (2018). 5G Wireless Telecommunications Expansion: Public Health and Environmental Implications. Environmental Research(165). 484-495.

24. Pall ML. (2018). Wi-Fi is an Important Threat to Human Health. Environ Res. 164:405-416.

25. Piccinetti CC, De Leo A, Cosoli G, Scalise L, Randazzo B, Cerri G, Olivotto I. (2018). Measurement of The 100 MHz EMF Radiation in Vivo Effects on Zebrafish D. Rerio Embryonic Development: A Multidisciplinary Study. Ecotoxicol Environ Saf. 154:268-279.

26. Wlodzimierz K. (2017). Non-Thermal Effects of Electromagnetic Fields in Biology and Medicine. IFMBE Proceedings(65).

27. Vargová B, Majláth I, Kurimský J, Cimbala R, Kosterec M, Tryjanowski P, Jankowiak Ł, Raši T, Majláthová V. (2018). Electromagnetic Radiation and Behavioural Response of Ticks: An Experimental Test. Exp Appl Acarol. 75(1):85-95.

28. Kumar R, Deshmukh PS, Sharma S, Banerjee B. (2019). Activation of Endoplasmic Reticulum Stress in Rat Brain Following Low-Intensity Microwave

Exposure. Environ Sci Pollut Res Int. 26(9):9314-9321.

29. Gholamali J, Fatemeh S, Mansour A. (2018). Vitamin C Improves Passive Avoidance Learning and Memory in Rats Exposed to Radiofrequency Waves Generated by a Base Transceiver Station (BTS) Antenna Model. ZahedanJ Res Med Sci. 20(11):e80229.

30. Melnick RL. (2019). Commentary on The Utility of The National Toxicology Program Study on Cell Phone Radiofrequency Radiation Data for Assessing Human Health Risks Despite Unfounded Criticisms Aimed at Minimizing The Findings of Adverse Health Effects. Environ Res. 168:1-6.