CHAPTER 3

EFFECTS OF ELECTROMAGNETIC FIELDS ON HUMAN HEALTH

Yusuf KUCUKBAGRIACIK[1]

INTRODUCTION

Electromagnetic fields (EMF) are used in many areas of our daily life such as security, health, mobile phones. The negative effects of EMFs on humans and the environment cause concerns and concerns on global societies. The effects of EMFs, which are an indispensable part of our lives, on health are still unclear. To minimize the negative effects of electromagnetic fields on humans and the environment, government and standardization organizations and non-governmental scientific committees have developed regulatory guidelines that set exposure limits (1-4).

ELECTROMAGNETIC FIELDS

RF-EMF frequencies are changing depending on constantly developing technologies (mobile phones, wireless, radar, base stations, satellite stations, electrical devices, etc.). There are extremely low frequency electromagnetic fields (ELF-EMFs), their sources, electrical devices we use in our daily lives, power plants, power lines and electrical cables. EMF's risks to humans and the environment also remain uncertain. For these reasons, it is very difficult to establish guidelines that set RF-EMF exposure limits. As the basic limit, it has been defined that the absorption of electromagnetic energy that will increase the body temperature by one degree in the average human body is harmful. According to this basic limit, the value of 4 W/kg is accepted as the limit value. The whole body average specific absorption rate (SAR) value is determined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 0.08 W/kg for public places. The SAR value for workplaces is 0.4 W/kg (5). Even though SAR is a crucial factor in determining thermal RF-EMF effects, exposure time, polarization, frequency, and modulation are key factors affecting biological RF-EMF effects (6).

[1] Asst. Prof. Dr., Yozgat Bozok University, Medical School, Department of Biophysics, yusufkba@gmail.com

The International Agency for Research on Cancer (IARC), a World Health Organization (WHO) agency, classified radiofrequency radiation as a "Group 2B-possible carcinogen" in 2011. According to the IARC, radiofrequency electromagnetic field (RF-EMF) exposure may have some risks and therefore its link with cancer should be closely monitored (7).

As we are the first generations to be exposed to man-made RF-EMF over a lifetime, it will take years to determine the effects on our health. Another problem is that due to the increasing wireless networks, almost everyone in the global population is exposed to RF-EMF in their daily lives, and there will be no control group for epidemiological studies. Another point that should not be overlooked is that RF-EMF exposure begins in infancy and even in the womb. In the future, we will see the possible health effects on people exposed to RF-EMF since infancy. With the developing technological discoveries, it means that a large part of people are currently exposed to RF-EMFs and the exposure will continue to increase in the near future.

According to the International Telecommunication Union (ITU) reports, it is estimated that around 4.9 billion humans (or 63 % of the global population) use the internet in 2021. While 4.6 billion people are using the internet in 2020, 4.9 billion humans are using the web in 2021, with a rising of nearly 300 million humans in 1 year (8). If this rapid pace in wireless communication continues, there will be no control groups required for future studies. In measurements made in 6 different countries, RF-EMF exposure levels tend to increase with the development of cities. In the measurements, it was reported that the downlink from mobile phone base stations contributed the most (9).

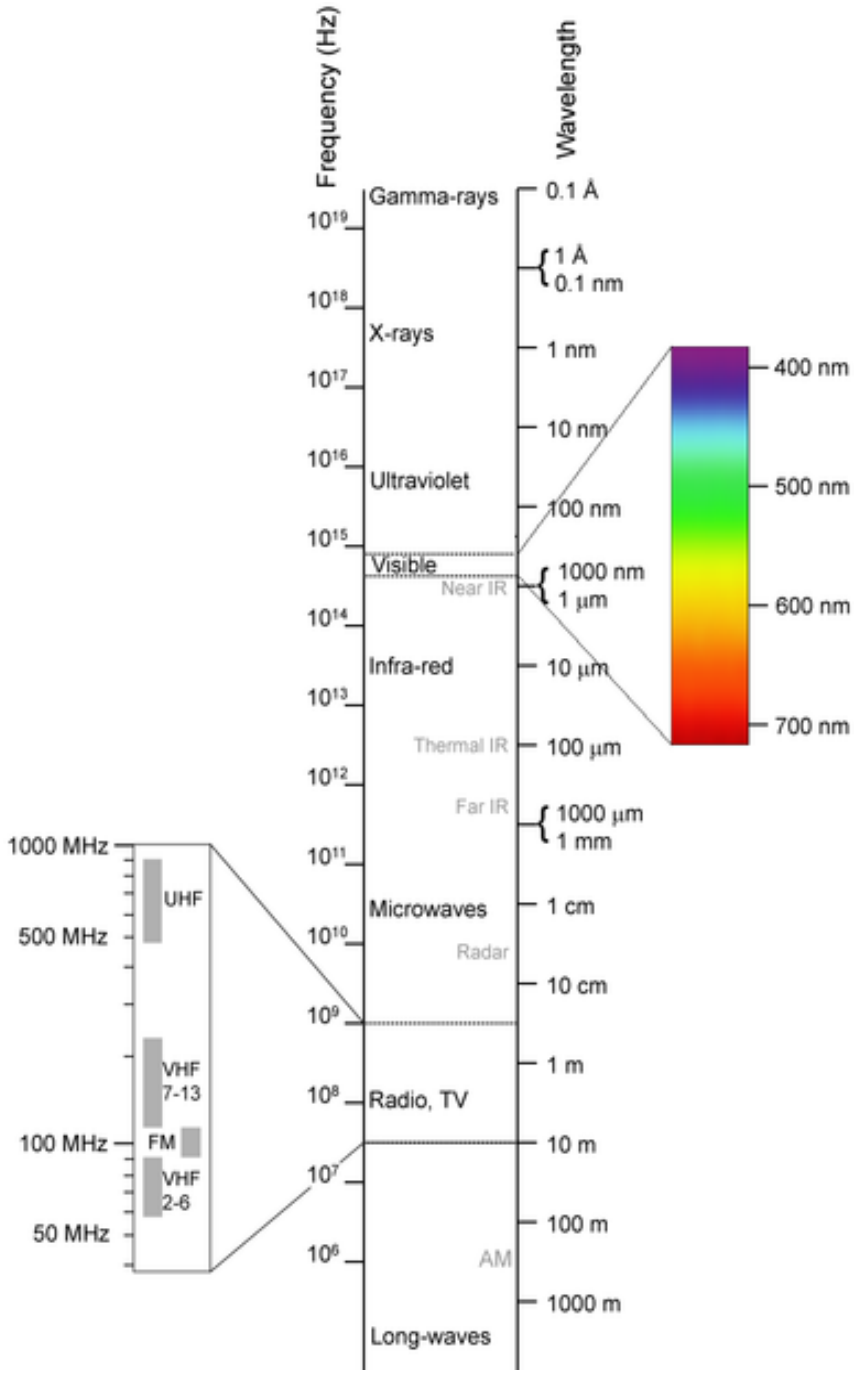

Figure 1: The spectrum of electromagnetic fields (10)

As the usage areas of RF-EMF increase, people are frequently exposed to RF-EMF at the same or different frequencies and doses from various sources. We still don't know anything about how RF-EMFs with multiple sources and frequencies affect human health. We have no information on the cumulative effect of such a combined exposure (11). It will take time to evaluate these effects with the frequency and exposure doses (5G and 6G etc.) constantly changing in proportion to the rapidly developing technologies. It is difficult to evaluate the cumulative effect of newly developed technologies. Most of the available literature describes biological changes after short-term exposure. Evaluating the critical consequences of RF-EMF exposure, 164 RF-EMF experts evaluated cancer, adverse birth outcomes, heat-related effects, cognitive impairment, electromagnetic hypersensitivity, negative pregnancy results, and also oxidative stress. While cancer is considered the most critical health problem by these experts, tumors in the head and neck region draw attention (12).

5G is the 5th generation mobile network. 5G technology offers humanity a more comfortable and easy lifestyle. However, since 5G technology uses shorter wavelength radio frequencies, it may raise health and safety questions. There is no consensus among scientists about the harms caused by existing 2G, 3G and 4G wireless technologies and there is still debate. The fact that the human and environmental effects of the use of high frequencies, which are increasing with 5G and future 6G technology, have been studied very little, increasing the concerns of the society.

Along with the developing technological applications, studies are continuing to investigate the effects on the biological and ecosystem. Public health issues arising from RF-EMF exposure raise concerns in the global population. Since we do not know the possible consequences of this kind of technology, which is increasing and becoming widespread, public awareness should be raised and a cautious approach should be taken.

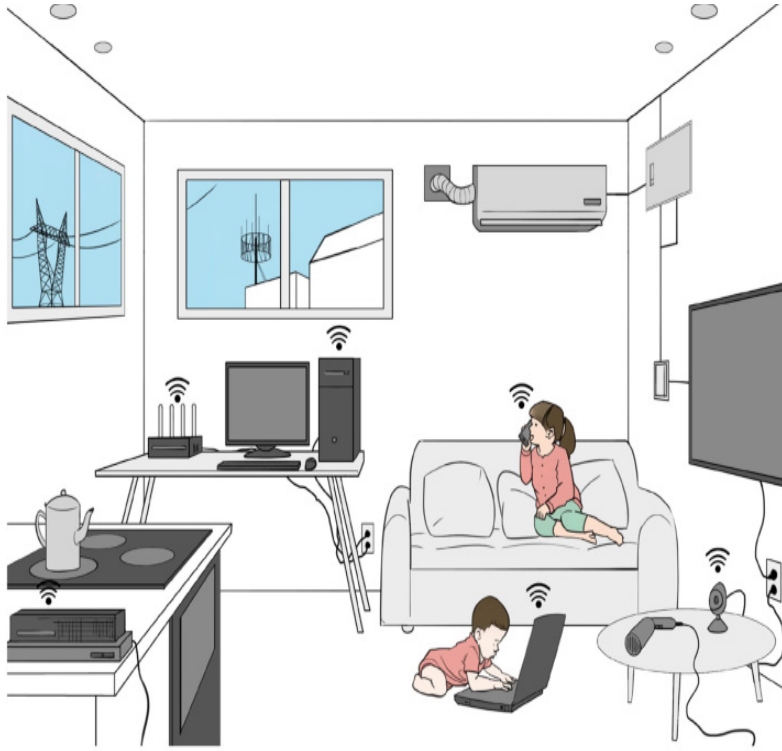

Figure 2: Various sources of electromagnetic fields (RF-EMFs & ELF-EMFs) (13).

This book chapter discusses the results of in vivo, in vitro and epidemiological studies in the literature on the effects of non-ionizing electromagnetic fields on humans. The negative effects of electromagnetic fields on humans and the environment are highlighted by the analysis of recent literature. Additionally, the role of EMFs in inducing oxidative stress and DNA damage and other adverse effects of electromagnetic fields are discussed.

ELECTROMAGNETIC FIELDS AND OXIDATIVE DAMAGE

Free radicals can interact with biomolecules such as DNA, proteins, lipids and initiate lipid peroxidation. Free radical damage is linked to the occurrence of many degenerative diseases, including cancer, cardiovascular disease, cataracts, and aging. Free radicals, also known as reactive oxygen species (ROS), cause oxidative stress by damaging cell components after exposure to substances such as UV radiation, ionizing radiation, and heavy metals. ROS can also induce multiple localized lesions, including base damage, single- and double-stranded breaks,

DNA-DNA crosslinks, and DNA-protein crosslinks. Excessive ROS generation can cause oxidative stress, leading to cell damage that can result in cell death. Cells have antioxidant mechanisms to balance the overproduced ROS. It is important to keep the balance between ROS and antioxidants at an optimal level (14). It has been shown by in vivo and in vitro experiments that RF-EMF increases the amount of ROS (15). The increase in ROS causes oxidative stress and thus may cause adverse effects such as cancer and decreased fertility (16).

Oxidative stress plays an important role in the mechanism of many chronic diseases such as cardiovascular diseases, atherosclerosis, alzheimer disease, diabetes, and cancer (17, 18). It is hypothesized that RF-EMF can cause oxidative stress in various cell types and thus endanger viability. In many in vitro and in vivo studies, RF-EMFs have been shown to increase oxidative stress (15, 19, 20). DNA damage induced in various tissues by RF-EMF exposure in male and female Sprague Dawley SD rats and B6C3F1/N mice was investigated by the National Toxicology Program (NTP). DNA damage was detected in various tissues. These results suggest that exposure to RF-EMF is associated with an increase in DNA damage (21).

POSSIBLE NEGATIVE EFFECTS OF ELECTROMAGNETIC FIELDS

Besides the possible effects of electromagnetic fields on brain cancer and blood cancer, there are many negative health effects. There is much debate about electromagnetic fields exposure, but most studies have focused on cancer, reproductive disorders, kidney damage, genetic damage, electromagnetic hypersensitivity, neurological disease, and cognitive effects. However, there are insufficient data to give a clear answer to the possible health risks of electromagnetic fields exposure. Therefore, uncertainty about the biological consequences of exposure to electromagnetic fields raises public concern.

In a study by Repacholi et al., they showed that exposure to pulsed 900 MHz RF radiation can increase the likelihood of developing lymphoma in mice carrying lymphomagenic oncogenes (22).

Cell phone use provides evidence that it can increase salivary gland tumors (23) and parotid tumors (24, 25).

Exposure to electromagnetic fields during embryonic development has shown to adversely affect the formation of ovarian follicles, and oocyte nuclei shrink and change shape. Thus, it may result in a decline in ovarian reserve and impaired fertility or infertility (26).

In the study on the effect of mobile phone radiation on cognition, thirty minutes of exposure to mobile phone radiation causes significant changes in the electrophysiological correlates of cognition (27).

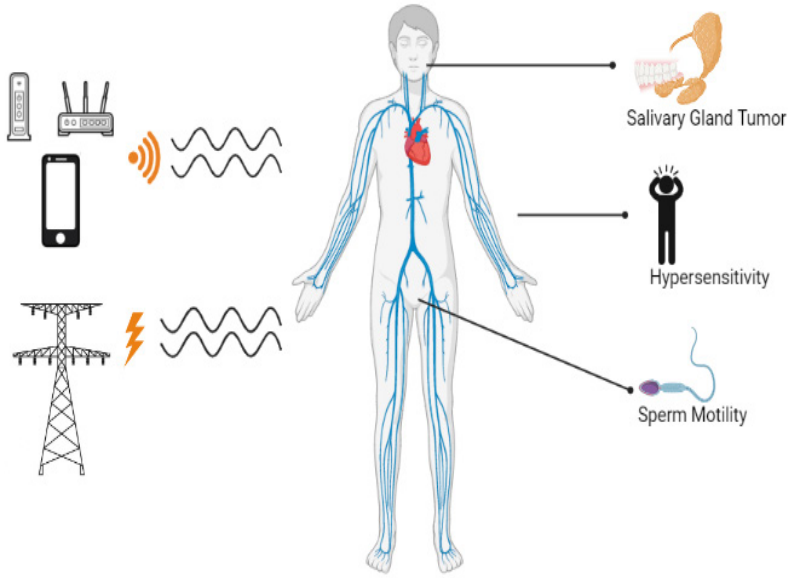

Figure 3: RF-EMFs & ELF-EMFs Health Risks (Created with BioRender.com)

Exposure to EMFs can cause electromagnetic hypersensitivity (EHS) with symptoms such as joint pain, headache, tinnitus, dizziness, fatigue, insomnia, memory loss, and temporary cardiovascular abnormalities (28). Gruber et al. showed that being female and middle-aged is an important risk factor for EHS. EHS is accompanied by symptoms such as anxiety disorder, fatigue syndrome, depression, and migraine (29). It has been reported that the symptoms decrease as one moves away from electromagnetic fields sources (such as closed environments and workplaces) (28, 29).

Carrying mobile phones in a pocket or near the testicles has potential effects on reproduction. Cell phone or microwave radiation increases the production of ROS in the testis, resulting in a decrease in sperm count, DNA damage, enzymatic and hormonal changes. RF-EMF can cause adverse health effects on the human reproductive system, such as infertility (30).

CONCLUSION

Establishing guidelines by the ICNIRP to set limits for exposure to EMFs to ensure a high level of protection for all people against the health effects resulting from exposure to EMFs (5).

Despite all these negative views about EMF, it should not be overlooked that the coin has two sides. Just like in Yin Yang philosophy, RF fields also contain positive and negative effects. Yin represents the negative dark side (negative effects of EMF), while Yang represents the positive light side (positive effects of EMF). EMF has the potential for the treatment of neurological pathologies such as Parkinson's and Alzheimer's (31, 32). There are many studies showing that it reduces tumor growth and increases cell proliferation in in vitro studies (33). (34). There are also studies showing that it accelerates wound healing and increases osteoblast formation (35, 36). Recently, with the adaptive response created by RF-EMF, cells or tissues are made more resistant to the negative effects of high doses of genotoxic substances and ionizing radiation (37, 38).

The biological effects of EMF are still controversial. Epidemiological, meta-analyses, in vivo, and in vitro studies are gradually increasing in the literature. With the developing technological innovations (such as WiFi, 5G, and 6G), discussions on the biological effects of EMF will continue. While the effects of lower frequency EMFs have not been fully explored, the use of technologies using higher frequency will further increase the concerns of society. Sources of EMF are very common in our current world and are likely to increase in the future, so there is no way to avoid exposure to it completely. We can only reduce exposure times to RF-EMF (WiFi, cell phone, etc).

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