PKP
PUBLIC KNOWLEDGE PROJECT

Journal of Biological Studies
ISSN 2209-2560

JBS
An Open Access Peer Reviewed Journal

Review Full-Text Paper

Positive and negative effects of electricity on human health

Fariba Momeni Torkaman[1]*, Farzaneh Momeni[2]

[1] *Department of Electrical Engineering, Damavand Branch, Islamic Azad University, Tehran, Iran*
[2] *Oral and Maxillo-facial Radiologist, Tehran, Iran*

Received: December 23, 2022; **Accepted:** January 09, 2023; **Published online:** May 10, 2023

Abstract: The human cells are electrical units and therefore are so sensitive to the electrical fields. More recent investigation has shown that the human cells have the ability to change direction as much by as 180° in response to electrical fields, according to which, positive or negative impact of electricity on human life have been argued in a number of studies. *In vitro* and in *in vivo* studies and clinical observations have shown that natural and artificial electric/electromagnetic fields may affect negatively or positively on human health. In one hand, the positive effects of electrical fields have been reported in tissue regeneration, wound healing, cancer treatment, controlling the infection, and etc.; on the other hand, negative impact of electricity has been demonstrated on human health. It has been reported that electric/electromagnetic fields may have a significant role in cancer development. This review article aims to investigate the positive and negative impact of electric/electromagnetic fields on human health and life.

Keywords: Electri fields, Electromagnetic field, Human health

1 Introduction

New technologies have been able to solve many problems of human life today. However, some aspects of technology have also brought negative effects. The debate about electricity and electromagnetic waves and their effect on the biological cycle has always been ongoing, and scientists have always looked for reliable evidence about the effects of these waves (Dilli, 2021).

Electromagnetic waves, with both natural and human origins, play an important role in our lives today. These waves are used for radio, television, telecommunication networks and all wireless communications. Therefore, the presence of electromagnetic fields around us increases

*e-mail: faribamomenitorkaman@gmail.com

day by day and our body is exposed to these fields. Along with the increase in the applications of electromagnetic waves in modern technologies, the biological effects of these waves have become one of the hottest debates among people (Georgiou et al, 2022).

Electricity is everywhere. Even if we run away from man-made things, electricity can be found in nature in the form of lightning or in our body in the form of nerve synapses.

But what is electricity and what is the relationship between electricity and electromagnetic waves?

1. 1. Electricity

A set of natural phenomena that depend on the presence and flow of electric charge is called electricity or electric force. According to the description of Maxwell's equations, electricity is related to magnetism and both are part of the electromagnetic phenomenon. Various common phenomena are related to electricity such as lightning, static electricity, electric heating, etc.

Electricity produces Electric and Magnetic fields. The location, speed and direction of an electric charge determine the force acting on it. This force is defined by two vector fields:

1. The electric field that expresses the force on a stationary charge.
2. The magnetic field which expresses the component of force on the moving charge (Lucas et al., 2019).

1. 1. 1. Electric fields

A positive or negative electric charge, causes the generation of an electric field. In other word as a result of the attraction and repulsion of electric charges, an invisible force field is created, which is called an electric field. The farther away we are from the source of the electric field, the intensity of it decreases. Its unit of measurement is volts per meter (V/m) (Lin, 2012).

1. 1. 2. Magnetic fields

The movement of electric charge, which is called electric current, produces a magnetic field.

The magnetic field created by single charges, current-carrying wires, orientation of magnetic dipoles (permanent magnets), conductive fluid flow (Earth's magnetic field) (Batool et al., 2019; Huang et al., 2013).

1. 2. Electromagnetic field

The interaction of two perpendicular magnetic and electric fields creates an electromagnetic field or EMFs. The electromagnetic spectrum includes a wide range of different frequencies of electromagnetic waves and radiations, which provide us information about the wavelength, radiation temperature, and photon energy related to the wave.

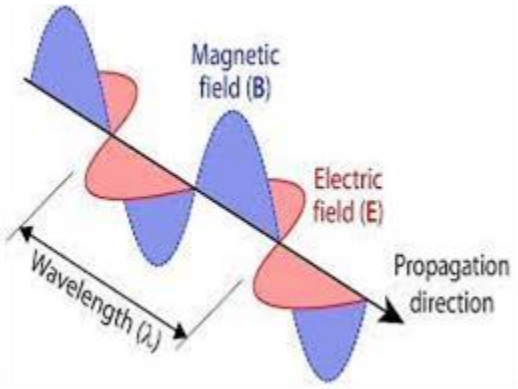

Figure 1. Electromagnetic Waves

These waves pass through empty space, air and other materials. Electromagnetic radiation can range from very low energies to very high energies, and we know this range of variations in the amount of energy as the electromagnetic spectrum. There are two types of radiation in the electromagnetic spectrum; Ionizing radiation and non-ionizing radiation.

The higher the energy of the radiation, the greater its power and, as a result, the greater the risk. Each part of the electromagnetic spectrum has different applications in our daily life. They play a prominent role in technology. Most of the devices that we use in our daily life using these waves. Electromagnetic waves at low frequencies are referred to as electromagnetic fields and those at very high frequencies are called electromagnetic radiations (Havránková, 2020; Lin, 2012). The types of electromagnetic radiation are broadly classified into the following classes (regions, bands or types):

1. Gamma radiation
2. X-ray radiation
3. Ultraviolet radiation
4. Visible light
5. Infrared radiation
6. Microwave radiation
7. Radio waves

This classification goes in the increasing order of wavelength and decreasing the order of frequency, which is characteristic of the type of radiation (Zamanian and Hardiman, 2005).

- Higher-frequency EMFs, which include Gamma radiation and X-ray radiation and can damage DNA or cells directly.

- Low- to mid-frequency EMFs, which include magnetic fields from electric power lines and appliances, radio waves, microwaves, infrared radiation, and visible light. These EMFs are not known to damage DNA or cells directly (Jargin, 2020).

The waves that we deal with in our daily life are low and medium frequency EMF waves, which we call non-ionizing EMFs. Low- to mid-frequency EMFs are produced by natural and artificial sources (Dilli, 2021; Lin, 2012; Jargin, 2020).

After the discovery of electricity in the 19th century, there has always been a discussion about the effects of electromagnetic waves in human life.

In response to public concerns about the use of these waves on human health, in 1996, the World Health Organization (WHO) began research efforts in this field. In May 2011, the International Agency for Research on Cancer (IARC) of the World Health Organization published a summary of the health risks of electromagnetic fields and classified ELF (including power frequencies of 50 and 60 Hz) EMFs as "probably carcinogenic to humans." Classified (Repacholi, 2012).

The study of the relationship between the magnetic field and various aspects of human life has continued until today. As an example, the following can be mentioned.

The effect of magnetic fields on cells, Magnetic fields and nervous system, The effect of magnetic fields on bone and cartilage, Magnetic fields and pregnancy, Magnetic fields and cancer.

1. 3. Negative impact of electrical/electromagnetic fields on human health

Due to the development of new technologies, concerns about the harmful effects of electromagnetic waves on human health are increasing. Most of the studies conducted by researchers in the past years were concerned with the biochemical or cellular effects of electromagnetic fields.

The effects of stable voltage gradients on various biological systems were first investigated by Burr and Northrop in 1935. According to this theory, stable voltage gradients lead to many drastic changes in the organism, including growth and local injury. These effects are related to changes in the distribution of ions. This research was later followed and completed by other scientists (Batool et al., 2019). Also, these studies showed that there is a connection between electromagnetic fields and the destruction of bee colonies in Europe and America, as well as the migration of birds 9 (Tong and Hei, 2020; Chaturvedi and Jain, 2019).

Many epidemiologic studies and comprehensive reviews of the scientific literature have evaluated possible associations between exposure to ELF-EMFs (Extremely Low Frequency Electromagnetic Fields) and risk of cancer in adult and children (Kassouf et al., 2019; Saliev et al., 2019; Prihoda, 2019). Although these types of waves cannot directly damage DNA or cells, some scientists thought that ELF-EMF can cause cancer through other mechanisms, such as reducing the level of the hormone melatonin which according to some evidence, melatonin may suppress the development of certain tumors, so in this case exposure to these waves and the very small changes in cells in the body are of great clinical importance (Pooam et al., 2020; Chatterjee and Chatterjee, 2020).

The thermal effect or temperature increase caused by very high frequency EFM leads to various changes in cell function that may lead to cell destruction (Diab, 2020; Kaur et al., 2023).

Most of the studies that have been conducted and published in recent years were related to the biochemical or cellular effects of electromagnetic fields. Studies conducted by researchers have shown that static or very low frequency electromagnetic fields may lead to biological effects related to the redistribution of ions and may penetrate deeper tissues (Gómez-Ríos, 2020)

Also, the possibility of ELF-EMF effect on several cell functions such as cell proliferation and differentiation, effect on apoptosis, DNA synthesis, RNA transcription, protein expression, ATP synthesis, hormone production, antioxidant enzyme systems, metabolic activity and NFkB and cell destruction by various researchers. Have been investigated (Ciecholewska-Juśko et al.,

2022; Asadian et al., 2021; Fioranelli et al., 2022, Pooam et al., 2020, Goodman and Henderson, 1988; Zrimec et al., 2002; Paksy et al., 2000; Kula et al., 2000; Milani et al., 2001; Wolf et al., 2005).

The thermogenic effect of very high frequency EMF on biological systems has been studied by many researchers. This effect is related to the intensity of EMF, which is expressed as Specific Absorption Rate (SAR). On the other hand, an increase in temperature leads to various changes in cell function that may lead to cell destruction (Jamshed et al., 2019; Hirata et al., 2021; Moon, 2020). Even at very small temperature changes in vitro experimental models, these biological effects may occur (Carter et al., 2020).

1. 4. Positive impact of electrical/electromagnetic fields on human health

Electromagnetic fields in the RF (Radio Frequency) range are used in some medical applications. Therapeutic applications such as soft tissue healing devices, hyperthermia for cancer treatment, or exposed diathermy that, in order to achieve the desired biological effects, the patient is exposed to a high dose of electromagnetic waves. (Moon, 2020; Miller et al., 2019; Chatterjee and Chatterjee, 2020).

Researchers have found that medium frequency EMF stops the growth of cells and this effect of inhibiting cell growth can be used in cancer treatment (Mahmud et al., 2022).

Electromagnetic fields can have positive and negative effects on adult stem cells (Maziarz et al., 2016).

For years, EMF waves have been used to treat bone disorders and the results have always been satisfactory (Kim et al., 2019; Kostoff et al., 2020). It is clinically useful for treating osteoarthritis, eliminating bone fractures, and reducing pain (Asa et al., 2020). The use of EMF causes the density of bone minerals, thus strengthening bones and reducing osteoporosis (Zhu et al., 2017). The use of EMF creates potentials and endogenous electric currents in the wounded tissues and when the healing process is completed, the wounds disappear and have positive effects in all stages of wound healing.

The use of EMF at low (300-300 kHz) and very low (30-30 Hz) frequencies has been observed in processes such as: cell migration and proliferation, expression of growth factors, nitric oxide signaling, cytokine modulation, etc.

In a study, murine stromal stem cells were exposed to EMF radiation and different cellular responses were observed depending on the gender (Maziarz et al., 2016). Therefore, the importance of the behavior of mature human stem cells according to the gender of people after EMF stimulation needs more research and investigation.

One of the basic medical problems is the treatment of wounds that are difficult to heal. Studies show that the use of low-frequency magnetic fields is useful for the regeneration of tissues damaged in accidents, thermal traumas or other factors that disrupt the continuity of tissues. Among the diseases that can be treated with electromagnetic waves, the following can be mentioned: chronic infections, bedsores, diabetic foot ulceration of the lower leg, scalds. (Gualdi et al., 2021; Georgiou et al., 2022).

Another work done by researchers is the effect of electromagnetic field on biofilms. Biofilm formation is halted by applying electromagnetic fields with a specific frequency range (Jargin, 2020). Considering the problems that exist in conventional methods, the application of

electromagnetic field can be a good alternative to remove biofilm (Kang et al., 2013; Kassouf et al., 2019)

2 Finding highlights

In vitro and *in vivo* studies and clinical observations have shown that natural and artificial electric/electromagnetic fields may affect positively or negatively on human health. In one hand, the positive effects of electrical fields have been reported in tissue regeneration, wound healing, cancer treatment, controlling the infection, and etc.; on the other hand, negative impact of electricity has been demonstrated on human health. It has been reported that electric/electromagnetic fields may have a significant role in cancer development or other diseases. But it has been shown that:

1- The results obtained have been contradictory and more research is needed in this matter.

2- No consistent evidence was found for a link between any source of low frequency EMFs (ELF-EMFs) and cancer.

3- No mechanism has been identified and there is no support to explain these experimental studies.

4- It also found that epidemiological studies of radiofrequency exposure did not show an increased risk of brain tumors or other head and neck cancers.

5- In some findings, EMF has been considered as a mutagenic and involvement in chemical reactions that produce free radicals, but EMF does not seem to exert mutagenic effects and the generation of free-radicals that might be linked to several other factors, beside the variability of EMF exposure.

Most of the negative results were caused by the impact of electromagnetic waves on laboratory samples and *in vitro* not on living organisms. Because in living organisms, the effect of various agents must be considered.

3 Conclusion

According to the scientists, although there have been many researches on the effects of electromagnetic waves for more than 30 years, there has not been a general acceptance that exposure to these waves is dangerous to human health or not. For this purpose, some studies have been carried out on animal models (*in vivo*) and cell cultures (*in vitro*). However, the findings are still inconclusive, and more researches should be done.

Undoubtedly, short-term exposure to very high levels of electromagnetic fields can be harmful to health.

Acknowledgments

The author would like to thank Global Research, Education and Event Network staff for their support and help.

Conflict of interests

The author has no conflicts of interests to declare.

References

Asa, E., Mohammad, M., Onar, O. C., Pries, J., Galigekere, V., & Su, G. J. (2020, June). Review of safety and exposure limits of electromagnetic fields (EMF) in wireless electric vehicle charging (WEVC) applications. In *2020 IEEE Transportation Electrification Conference & Expo (ITEC)* (pp. 17-24). IEEE. ,http://doi: 10.1109/ITEC48692.2020.9161597

Asadian, N., Jadidi, M., Safari, M., Jadidi, T., & Gholami, M. (2021). EMF frequency dependent differentiation of rat bone marrow mesenchymal stem cells to astrocyte cells. *Neuroscience Letters*, *744*, 135587. https://doi.org/10.1016/j.neulet.2020.135587

Batool, S., Bibi, A., Frezza, F., & Mangini, F. (2019). Benefits and hazards of electromagnetic waves, telecommunication, physical and biomedical: a review. *European Review for Medical and Pharmacological Sciences*, *23*(7), 3121.

Carter, C. S., Huang, S. C., Searby, C. C., Cassaidy, B., Miller, M. J., Grzesik, W. J., Piorczynski, T. B., Pak, T. K., Walsh, S. A., Acevedo, M., Zhang, Q., Mapuskar, K. A., Milne, G. L., Hinton Jr., A. O., Guo, D. F., Weiss, R., Bradberry, K., Taylor, E. B., Rauckhorst, A. J., Dick, D. W., Akurathi, V., Falls-Hubert, K. C., Wagner, B. A., Carter, W. A., Wang, K., Norris, A. W., Rahmouni, K., Buettner, G. R., Hansen, J. M., Spitz, D. R., Abel, E. D., & Sheffield, V. C. (2020). Exposure to static magnetic and electric fields treats type 2 diabetes. *Cell Metabolism*, *32*(4), 561-574. https://doi.org/10.1016/j.cmet.2020.09.012

Chatterjee, R., & Chatterjee, J. (2020). ROS and oncogenesis with special reference to EMT and stemness. *European Journal of Cell Biology*, *99*(2-3), 151073. https://doi.org/10.1016/j.ejcb.2020.151073

Chaturvedi, A., & Jain, V. (2019). Effect of ionizing radiation on human health. *International Journal of Plant and Environment*, *5*(03), 200-205. doi: 10.18811/ijpen.v5i03.8

Ciecholewska-Juśko, D., Żywicka, A., Junka, A., Woroszyło, M., Wardach, M., Chodaczek, G., Szymczyk-Ziółkowska, P., Migdał, P. & Fijałkowski, K. (2022). The effects of rotating magnetic field and antiseptic on in vitro pathogenic biofilm and its milieu. *Scientific Reports*, *12*(1), 8836. https://doi.org/10.1038/s41598-022-12840-y

Diab, K. A. (2020). The impact of the low frequency of the electromagnetic field on human. *Cell Biology and Translational Medicine, Volume 7: Stem Cells and Therapy: Emerging Approaches*, 135-149. doi: 10.1007/5584_2019_420

Dilli, R. (2021). Implications of mmWave radiation on human health: State of the art threshold levels. *IEEE Access, 9*, 13009-13021. doi: 10.1109/ACCESS.2021.3052387

Fioranelli, M., Roccia, M. G., Beesham, A., Flavin, D., Ghaeni, M., & AZIZ, F. (2022). A model for considering effects of extremely low frequency electromagnetic fields on quail embryonic cells. *AIMS Biophysics*, *9*(3), 198-207. doi: 10.3934/biophy.2022017

Georgiou, C. D., Kalaitzopoulou, E., Skipitari, M., Papadea, P., Varemmenou, A., Gavriil, V., Sarantopoulou, E., Kollia, Z., & Cefalas, A. C. (2022). Physical Differences between Man-Made and Cosmic Microwave Electromagnetic Radiation and Their Exposure Limits, and Radiofrequencies as Generators of Biotoxic Free Radicals. *Radiation*, *2*(4), 285-302. https://doi.org/10.3390/radiation2040022

Gómez-Rios, D. (2020). Effects and Mechanisms of Interaction of Electromagnetic Fields on Cells. doi: 10.20944/preprints202001.0301.v1

Goodman, R., & Henderson, A. S. (1988). Exposure of salivary gland cells to low-frequency electromagnetic fields alters polypeptide synthesis. *Proceedings of the National Academy of Sciences*, *85*(11), 3928-3932. https://doi.org/10.1073/pnas.85.11.3928

Gualdi, G., Costantini, E., Reale, M., & Amerio, P. (2021). Wound repair and extremely low frequency-electromagnetic field: insight from in vitro study and potential clinical application. *International Journal of Molecular Sciences*, *22*(9), 5037. https://doi.org/10.3390/ijms22095037

Havránková, R. (2020). Biological effects of ionizing radiation. *Casopis Lekaru Ceskych*, *159*(7-8), 258-260.

Hirata, A., Diao, Y., Onishi, T., Sasaki, K., Ahn, S., Colombi, D., De Santis, V., Laakso, I., Giaccone, L., Joseph, W., Rashed, E. A., Kainz, W., & Chen, J. (2021). Assessment of human exposure to electromagnetic fields: Review and future directions. *IEEE Transactions on Electromagnetic Compatibility*, *63*(5), 1619-1630. doi: 10.1109/TEMC.2021.3109249

Huang, Y. J., Samorajski, J., Kreimer, R., & Searson, P. C. (2013). The influence of electric field and confinement on cell motility. *PloS One, 8*(3), e59447. doi: 10.1371/journal.pone.0059447

Jamshed, M. A., Heliot, F., & Brown, T. W. (2019). A survey on electromagnetic risk assessment and evaluation mechanism for future wireless communication systems. *IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology*, *4*(1), 24-36., doi: 10.1109/JERM.2019.2917766

Jargin, S. V. (2020). Radiofrequency electromagnetic fields and possible cancer risk: photochemical aspects. *J Mod Med Chem*, *8*, 85-7. https://doi.org/10.12970/2308-8044.2020.08.10

Kang, K. S., Hong, J. M., Kang, J. A., Rhie, J. W., Jeong, Y. H., & Cho, D. W. (2013). Regulation of osteogenic differentiation of human adipose-derived stem cells by controlling electromagnetic field conditions. *Experimental & Molecular Medicine*, *45*(1), e6-e6. https://doi.org/10.1038/emm.2013.11

Kassouf, T., Fraguada, L. E., & Bigger, E. E. (2019, September). Awareness jacket: EMF-shielding garment. In *Proceedings of the 2019 ACM International Symposium on Wearable Computers* (pp. 284-289). https://doi.org/10.1145/3341163.3346941

Kaur, P., Rai, U., & Singh, R. (2023). Genotoxic Risks to Male Reproductive Health from Radiofrequency Radiation. *Cells*, *12*(4), 594. https://doi.org/10.3390/cells12040594

Kim, J. H., Lee, J. K., Kim, H. G., Kim, K. B., & Kim, H. R. (2019). Possible effects of radiofrequency electromagnetic field exposure on central nerve system. *Biomolecules & Therapeutics*, *27*(3), 265. doi: 10.4062/biomolther.2018.152

Kostoff, R. N., Heroux, P., Aschner, M., & Tsatsakis, A. (2020). Adverse health effects of 5G mobile networking technology under real-life conditions. *Toxicology Letters*, *323*, 35-40. https://doi.org/10.1016/j.toxlet.2020.01.020

Kula, B., Sobczak, A., Kuska, R. (2000). Effects of static and ELF magnetic fields on free – radical processes in rat liver and kidney. *Electromagnetic Biology and Medicine, 19*(1), 99-105. https://doi.org/10.1081/JBC-100100300

Lin, J. C. (2012). *Electromagnetic fields in biological systems* (p. 458). Taylor & Francis. 3-8-2020 - No DOI registered in CrossRef for ISBN 9781439859995

Lucas, R. M., Yazar, S., Young, A. R., Norval, M., De Gruijl, F. R., Takizawa, Y., Rhodes, L. E., Sinclair, C. A., & Neale, R. E. (2019). Human health in relation to exposure to solar ultraviolet radiation under changing stratospheric ozone and climate. *Photochemical & Photobiological Sciences, 18*(3), 641-680. https://doi.org/10.1039/C8PP90060D

Mahmud, A., Islam, M. R., Noni, S., & Khan, M. M. U. A. (2022). The Impact of Electromagnetic Pollution on Human Health and Environment: Recommendation for an Effective Regulatory Framework in Bangladesh. *Ecology, Environment and Conservation*. http://doi.org/10.53550/EEC.2022.v28i02s.012

Maziarz, A., Kocan, B., Bester, M., Budzik, S., Cholewa, M., Ochiya, T., & Banas, A. (2016). How electromagnetic fields can influence adult stem cells: positive and negative impacts. *Stem Cell Research & Therapy*, *7*(1), 1-12. https://doi.org/10.1186/s13287-016-0312-5

Milani M, Balerini, M, Ferraro L, Zabeo M, Barberis M, Cannona M, Faleri M. (2001). Magnetic field effects on human lymphocytes. Electromagnetic field effects on human lymphocytes. *Electromagnetic Biology and Medicine, 20*(1), 81-106. https://doi.org/10.1081/JBC-100103162

Miller, A. B., Sears, M. E., Morgan, L. L., Davis, D. L., Hardell, L., Oremus, M., & Soskolne, C. L. (2019). Risks to health and well-being from radio-frequency radiation emitted by cell phones and other wireless devices. *Frontiers in Public Health*, *7*, 223. https://doi.org/10.3389/fpubh.2019.00223

Moon, J. H. (2020). Health effects of electromagnetic fields on children. *Clinical and Experimental Pediatrics*, *63*(11), 422. doi: 10.3345/cep.2019.01494

Paksy, K., Thuróczy, G., Forgács, Z., Lázár, P., & Gaáti, I. (2000). Influence of sinusoidal 50-Hz magnetic field on cultured human ovarian granulosa cells. *Electro-and Magnetobiology*, *19*(1), 91-97. https://doi.org/10.1081/JBC-100100299

Pooam, M., Jourdan, N., El Esawi, M., Sherrard, R. M., & Ahmad, M. (2020). HEK293 cell response to static magnetic fields via the radical pair mechanism may explain therapeutic effects of pulsed electromagnetic fields. *Plos One*, *15*(12), e0243038. https://doi.org/10.1371/journal.pone.0243038

Prihoda, T. J. (2019). Comprehensive review of quality of publications and meta-analysis of genetic damage in mammalian cells exposed to non-ionizing radiofrequency fields. *Radiation Research*, *191*(1), 20-30. https://doi.org/10.1667/RR15117.1

Repacholi, M. (2012). Concern that "EMF" magnetic fields from power lines cause cancer. *Science of the Total Environment*, *426*, 454-458. https://doi.org/10.1016/j.scitotenv.2012.03.030

Saliev, T., Begimbetova, D., Masoud, A. R., & Matkarimov, B. (2019). Biological effects of non-ionizing electromagnetic fields: Two sides of a coin. *Progress in Biophysics and Molecular Biology*, *141*, 25-36. https://doi.org/10.1016/j.pbiomolbio.2018.07.009

Tong, J., & Hei, T. K. (2020). Aging and age-related health effects of ionizing radiation. *Radiation Medicine and Protection*, *1*(1), 15-23. https://doi.org/10.1016/j.radmp.2020.01.005

Wolf, F. I., Torsello, A., Tedesco, B., Fasanella, S., Boninsegna, A., D'Ascenzo, M., Grassi, C., Azzena, G. B., Cittadini, A. (2005). 50-Hz extremely low frequency electromagnetic fields enhance cell proliferation and DNA damage: possible involvement of a redox mechanism. *Biochimica et Biophysica Acta (BBA)-Molecular Cell Research, 1743*(1-2),120-129. https://doi.org/10.1016/j.bbamcr.2004.09.005

Zamanian, A., & Hardiman, C. J. H. F. E. (2005). Electromagnetic radiation and human health: A review of sources and effects. *High Frequency Electronics*, *4*(3), 16-26.

Zhu, S., He, H., Zhang, C., Wang, H., Gao, C., Yu, X., & He, C. (2017). Effects of pulsed electromagnetic fields on postmenopausal osteoporosis. *Bioelectromagnetics*, *38*(6), 406-424. https://doi.org/10.1002/bem.22065

Zrimec, A., Jerman, I., & Lahajnar, G. (2002). Alternating electric fields stimulate ATP synthesis in Escherichia coli. *Cellular and Molecular Biology Letters*, *7*(1), 172-175.