

## **Richard R. Lester, CEP**

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March 8, 2022

Michael P. Collins  
Commissioner of Public Services and Engineering  
City of Beverly  
191 Cabot Street  
Beverly, MA 01915

Re: 60 Hz Electromagnetic Fields (EMF) and Health Effects – Literature Review from 2019 to Present

Dear Mr. Collins:

I write to provide an updated review of the literature regarding extremely low frequency (60 Hz) electromagnetic fields (EMF) and potential health effects. Extremely low frequency EMF are produced by the transmission and distribution of electricity. As you are aware, Exponent, Inc. previously performed a literature search for the period 2014-2018 entitled, *Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health 2014-2018*. Exponent concluded that the literature from the period 2014-2018 did not significantly alter the previous findings of the World Health Organization (WHO). There is limited evidence of a link between power line frequency EMF and childhood leukemia, but it is not clear if the link is causal. Selection bias (individuals participating in the study differ from the general population) and exposure misclassification (studies generally do not measure magnetic fields) increase uncertainty in the conclusions regarding childhood leukemia. Scientific evidence of other health effects is either much weaker or is sufficient to conclude that EMF does not cause disease.

This literature review updates the Exponent literature review to include more recent literature published between 2019 and 2021. No literature was yet identified for 2022 at the time the search was conducted.

### **Literature Review Procedure**

The updated literature review included searching relevant databases of journal articles and texts for search terms related to ELF EMF and health from 2019 to the present. Databases included Science Direct, a very large database of scientific, technical, and medical research, and PubMed, a National Library of Medicine maintained databased of references on the life sciences and biomedical topics. The search included the following search terms:

- Electric and magnetic fields
- Electromagnetic
- Electromagnetic field
- EMF
- Exposure
- Health

- 50 Hz
- 60 Hz

The abstracts of identified journal articles are appended to this letter. Typos or errors in the abstracts are those that were present in the databases from which they were extracted. Based on the abstracts, full text articles were obtained for the most relevant studies on 60 Hz EMF and human health.

### **Previous Literature Reviews and Recent Literature Regarding EMF and Health Effects**

A health risk assessment of EMF conducted by the World Health Organization (WHO) in 2007 involved a comprehensive review of the literature to that time. The WHO review is generally considered to be a fair review with minimal bias.<sup>1</sup> The key conclusions of the WHO review were that 50 Hz or 60 Hz EMF remains classified as a possible human carcinogen. Epidemiological studies indicate a correlation between exposure to 60 Hz magnetic fields at levels greater than 3 or 4 mG and an increased risk of childhood leukemia. This correlation does not necessarily indicate that EMF is the cause of the increased risk at low levels. Other explanations include selection bias in the studies or confounding factors that also correlate with exposure to EMF. Attempts to identify a mechanism and a direct causal relationship between magnetic fields and cancer have not been successful. The WHO strongly supports additional research to reconcile the epidemiological data which shows a correlation between EMF and childhood leukemia, and direct experimental data which have not been able to identify a risk or causal relationship whereby EMF causes childhood leukemia. Because no causal relationship can be established based on the WHO review, no exposure limits for EMF were recommended, but WHO did suggest precautionary measures. WHO did not identify a strong relationships between EMF and other adverse health effects.

Exponent's update based on the literature between 2014 and 2018 does not significantly alter the findings of the WHO risk assessment. Exponent's review suggests that recent large studies and pooled analyses indicate weaker associations and non-statistically significant associations between EMF and childhood leukemia, but that the association between leukemia and magnetic fields in previous studies remains unexplained. It continues to be the case that scientific studies have been unable to identify a causal relationship between EMF and childhood leukemia.

The literature for the period 2019 to 2021 does not significantly alter the findings of the previous literature reviews. There is no significant new evidence that strengthens or weakens the previous findings regarding EMF and childhood leukemia. Several recent studies have examined the potential for EMF to affect the production of reactive oxygen species or oxidative stress in animals or workers (for example, Schuermann and Mevissen, 2021; Guleken, 2021; Bagheri, 2021; Lai, 2019). Some changes were observed, but no direct relationship was identified that would indicate a mechanism linking EMF to cancer.

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<sup>1</sup> Information from the WHO on electromagnetic fields is available at <https://www.who.int/health-topics/electromagnetic-fields>.

Specific requests by the City of Beverly regarding health effects and EMF are addressed in the sections that follow.

### **City of Beverly Request – “Health Effects of Electromagnetic Fields on Children”**

The City of Beverly specifically requested comments on the article entitled “Health effects of electromagnetic fields on children” authored by Jin-Hwa Moon (2020). This article was both identified in the original literature search and was also provided by the City of Beverly. The City asked for comments on the section of the article entitled “Different Tones for Human Carcinogenicity”.

Regarding power line frequency EMFs, this article concludes that although studies on the effects of EMFs on children’s health are unestablished, precautionary principles should be followed for children and the exposure to EMFs among children should be minimized. The author emphasizes that the designation of EMF as a possible carcinogen should not be overlooked. The section on differences in tone for human carcinogenicity states that the World Health Organization (WHO) concluded that there were no substantive health issues related to power line frequency electric fields at levels generally encountered by the public. The International Agency for Research on Cancer (IARC) evaluated power line frequency EMF and concluded the EMF was possibly carcinogenic based on a possible association between childhood leukemia and 60 Hz magnetic fields greater than 3 or 4 mG. The author argues that the difference of opinion between WHO and IARC is possibly due to differences in the backgrounds of members in WHO and IARC. The author states that many committee members of WHO’s EMF project were associated with electricity associated industries, whereas IARC membership is more epidemiologists and health specialists.

As background, both WHO and IARC are very well-respected international organizations that attempt to minimize bias in their scientific work. The two groups, in fact, are related. WHO is an agency of the United Nations responsible for international public health. IARC is an agency within WHO that focuses specifically on cancer research.

In reviewing the Moon article, the article overstates the difference of opinion between WHO and IARC. As the article states, WHO concludes that there are no substantive health issues related to power line frequency electric fields at levels generally encountered by the public. What the author seems to be missing, however, is that there is a difference between “electric fields” and “magnetic fields” or “EMF”. Above ground transmission lines produce both electric and magnetic fields, together referred to as EMF. Electric fields are easily shielded by trees and building materials used in residences or other structures. In the case of an underground cable, the earth between the cable and the ground surface provides sufficient shielding that electric fields are negligible. When WHO concludes that there are no health issues associated with electric fields at typical levels, this is a widely held opinion, and does not conflict with IARC’s views. In fact, WHO specifically states in their Environmental Health Criteria document that new research

published since IARC's 2002 determination that power line frequency magnetic fields are a possible human carcinogen do not change IARC's classification.

When IARC reviews a chemical or a physical agent such as power line frequency EMF, they perform a comprehensive review of the science related to that agent and classify its carcinogenicity. Agents are categorized as either "carcinogenic to humans", "probably carcinogenic to humans", or "possibly carcinogenic to humans". If there is not enough evidence to place the chemical or agent in one of those classes, it is listed as "not classifiable as to its carcinogenicity to humans". Power line frequency EMF was listed in the "possibly carcinogenic" category. It is not known with certainty that it is a carcinogen, but because it is possibly carcinogenic, a precautionary approach is typically recommended to reduce exposure to EMFs. There is little disagreement that a precautionary approach is prudent. Where there is some disagreement is the degree to which precautions should be taken.

The siting of all new power lines uses a precautionary approach. The Energy Facilities Siting Board reviews EMFs associated with new projects to make sure that EMF from the project will not be excessive and will not exceed levels permitted in the past. The orientation of the conductors in underground cables including for the Beverly project is in a triangular delta configuration for a large portion of the route which allows EMFs from the three conductors to partially cancel, reducing EMF above ground. Because underground conductors are placed closer together than overhead lines, magnetic fields will decrease more quickly with distance from the underground cables. Magnetic fields will still be measurable above and in the vicinity of the cable. Magnetic field modeling of the cable indicates magnetic fields will not exceed levels already found in the vicinity of operating electric appliances. Some people will believe these are sufficient precautions while others will believe that magnetic field strengths should be minimized to the greatest extent possible.

### **City of Beverly Request – EMF – MBTA Exposure vs. Residential Exposure**

The City of Beverly also requested comments on how exposure to commuters on the MBTA would differ from exposure to residents if the cable were installed along the railroad tracks as opposed to a residential street.

If the project were installed along the railroad tracks, the configuration of the cables would likely differ vs. an installation beneath a residential street. Due to the configuration, magnetic field strengths along the MBTA tracks would differ in some places from those that would occur if the cable were placed below a residential street. Resulting field strengths could be higher or lower depending on the configuration. Furthermore, depending on exactly where the cable was installed on the MBTA right of way, people on the MBTA could be closer to the cables or further from the cables than people in residences, resulting in higher or lower levels of exposure.

The primary difference between MBTA exposure vs. residential exposure would be one of exposure duration. If MBTA commuters were closer to the transmission cable, they would experience stronger magnetic fields, but for a short duration, akin to driving beneath or alongside

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a transmission line which is a common occurrence. Residents will likely be further from the cable and will experience lower levels of exposure, but for a longer duration.

### **Contact Information**

Please contact me with any questions or comments about the updated literature review associated with the Beverly Regional Transmission Reliability Project. Please let me know if you would like full text version of any of the articles included in the review. If I have not already requested the full text of the requested article, I should be able to obtain it within a few days. I may be reached at 857-366-2015 or [richlester@gmail.com](mailto:richlester@gmail.com).

Sincerely,



Richard R. Lester, CEP  
Certified Environmental Professional

cc: Mayor Michael P. Cahill

### **Abstracts of Identified Journal Articles**

1. Schuermann, D. and M. Mevissen (2021). "Manmade Electromagnetic Fields and Oxidative Stress—Biological Effects and Consequences for Health." *International Journal of Molecular Sciences* 22(7).

Concomitant with the ever-expanding use of electrical appliances and mobile communication systems, public and occupational exposure to electromagnetic fields (EMF) in the extremely-low-frequency and radiofrequency range has become a widely debated environmental risk factor for health. Radiofrequency (RF) EMF and extremely-low-frequency (ELF) MF have been classified as possibly carcinogenic to humans (Group 2B) by the International Agency for Research on Cancer (IARC). The production of reactive oxygen species (ROS), potentially leading to cellular or systemic oxidative stress, was frequently found to be influenced by EMF exposure in animals and cells. In this review, we summarize key experimental findings on oxidative stress related to EMF exposure from animal and cell studies of the last decade. The observations are discussed in the context of molecular mechanisms and functionalities relevant to health such as neurological function, genome stability, immune response, and reproduction. Most animal and many cell studies showed increased oxidative stress caused by RF-EMF and ELF-MF. In order to estimate the risk for human health by manmade exposure, experimental studies in humans and epidemiological studies need to be considered as well.

2. Quamruzzaman, M., et al. (2021). Electromagnetic Radiation from Cell Phones Used in Dhaka City. 4th International Conference on Smart Trends for Computing and Communications, SmartCom 2020, January 24, 2020 - January 25, 2020, Bangkok, Thailand, Springer.

Substantial anxieties have been presented regarding probable health effects from exposure to radiofrequency Electromagnetic Fields (EMF) particularly after the speedy ushering in of contemporary amenities like the mobile telecommunication practices. Several epidemiological surveys on the probable unfavorable health consequences linked to environmental contact to extremely low frequency (ELF) (0-300Hz) non-ionizing radiation (NIR) similar to that produced by electrical substations and power cables associate such contact to brain cancer, leukemia, skin cancer, eye melanoma, etc. Extensive, well conducted epidemiological and laboratory studies need to be performed extensively. Cell phones are being used everywhere on earth due to its success in making one's life comfortable for all walks of life including academic, office, and business. Millions of cell phones are also being consumed in Bangladesh. EMF is emitted by these phones too. There have not been more studies done in Bangladesh. The study was performed from multiple locations in Dhaka city, Bangladesh. Epidemiological surveys were performed on the users of these cell phones. Also power radiated for normal data (on but not talking), with mobile data, with Wi-fi, and with signals (on and talking) were measured for these phones. These outcomes indicated that in many instances the magnetic field emitted from the various sources are higher than the threshold value and cell phone users underwent different sorts

of ailments, e.g., headaches, pain in hands, insomnia, etc., due to extended exposure to EMF. Smoking further added to their usual health difficulties. 2021, The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd.

3. Piszczek, P., et al. (2021). "Immunity and electromagnetic fields." *Environmental Research* 200: 111505.

Despite many studies, the question about the positive or negative influence of electromagnetic fields (EMF) on living organisms still remains an unresolved issue. To date, the results are inconsistent and hardly comparable between different laboratories. The observed bio-effects are dependent not only on the applied EMF itself, but on many other factors such as the model system tested or environmental ones. In an organism, the role of the defense system against external stressors is played by the immune system consisting of various cell types. The immune cells are engaged in many physiological processes and responsible for the proper functioning of the whole organism. Any factor with an ability to cause immunomodulatory effects may weaken or enhance the response of the immune system. This review is focused on a wide range electromagnetic fields as a possible external factor which may modulate the innate and/or adaptive immunity. Considering the existing databases, we have compiled the bio-effects evoked by EMF in particular immune cell types involved in different types of immune response with the common mechanistic models and mostly activated intracellular signaling cascade pathways.

4. Layen, G. S., et al. (2021). "Effects of Low-frequency Electromagnetic Waves on the Spleen, Liver, and Kidney Weight and Therapeutic Role of Vitamin C in Mice." *Journal of Fasting & Health* 9(1): 75-81.

Electronic devices generate electromagnetic fields, and the recent increase in their use has urged researchers to investigate the effects of electromagnetic fields on human health. The present study aimed to evaluate the effects of extremely low-frequency electromagnetic fields on the weight of spleen, liver, and kidneys and the therapeutic role of vitamin C in mice. This experimental study was conducted on 24 adult male mice (BALB/c), which were divided into three groups. The control group included eight mice, which were kept in normal conditions. Another included eight mice with exposure to an electromagnetic field (ELF) with low frequencies (50Hz and 4Mt) for 15 days, and the third group (n=8) had ELF exposure (50Hz and 4Mt) and received vitamin C for 15 days, with vitamin C injected intraperitoneally seven times. After 15 days, the mice were weighed, and the collected samples were dissected. The spleen, liver, and kidneys of the animals were removed at the final stage for the measurements. Data analysis was performed using one-way analysis of variance (ANOVA). According to the results, the ELFs caused a significant reduction in the weight of the spleen and liver of the animals. Furthermore, the appropriate dose of vitamin C could decrease the damage caused by the ELF frequency of 50 Hz.

5. Lai, H. (2021). "Genetic effects of non-ionizing electromagnetic fields." *Electromagnetic Biology and Medicine* 40(2): 264-273.

This is a review of the research on the genetic effects of non-ionizing electromagnetic field (EMF), mainly on radiofrequency radiation (RFR) and static and extremely low frequency EMF (ELF-EMF). The majority of the studies are on genotoxicity (e.g., DNA damage, chromatin conformation changes, etc.) and gene expression. Genetic effects of EMF depend on various factors, including field parameters and characteristics (frequency, intensity, wave-shape), cell type, and exposure duration. The types of gene expression affected (e.g., genes involved in cell cycle arrest, apoptosis and stress responses, heat-shock proteins) are consistent with the findings that EMF causes genetic damages. Many studies reported effects in cells and animals after exposure to EMF at intensities similar to those in the public and occupational environments. The mechanisms by which effects are induced by EMF are basically unknown. Involvement of free radicals is a likely possibility. EMF also interacts synergistically with different entities on genetic functions. Interactions, particularly with chemotherapeutic compounds, raise the possibility of using EMF as an adjuvant for cancer treatment to increase the efficacy and decrease side effects of traditional chemotherapeutic drugs. Other data, such as adaptive effects and mitotic spindle aberrations after EMF exposure, further support the notion that EMF causes genetic effects in living organisms.

6. Guleken, Z. (2021). "Chronic low-frequency electromagnetic field exposure before and after neonatal life induces changes on blood oxidative parameters of rat offspring." *Annals of Medical of Research* 28(2): 361-365.

**Aim:** It is aimed to investigate the chronic effects of extremely low-frequency magnetic fields (ELF-MF) exposure on blood oxidative and anti-oxidative levels. Rat offsprings during intrauterine (IU) and extrauterine (EU) period exposure to chronic 50 Hz electromagnetic fields included to the study to see the ELF-MF induced changes in blood biochemical levels. To evaluate the cell's physiological response, the levels of glutathione (GSH) and malondialdehyde (MDA) were measured as a label. Recently, the use of electromagnetic (EM) energy has increased in worldwide. Numerous reports indicate that prenatal and postnatal period repetitive ELF-MF leads to health-related issues on physiological responses and affect the activity of the enzymes. **Materials and Methods:** Pregnant female Wistar Albino rats (n = 21), weighing 250 – 300 g were randomly divided into MF exposed group (Group I) and sham group (Group II). Eleven pregnant females were exposed to MF for 24 hours a day for IU exposure and exposed to 50 Hz 500 $\mu$ T ELF-MF radiating magnetic field cages for 24 hours for the duration of pregnancy for 21 days. Following the birth, first generation newborn rats (n=11) were continued to expose 50 Hz 500 $\mu$ T ELF-MF, 24 hours, for additional 50 days in EU period. Sham group (n=10) without any radiation. Groups' blood samples were collected and analyzed. The levels of an oxidative stress marker MDA and antioxidant scavenger GSH activities were investigated. **Results:** Long-term exposure to ELF-MF increased MDA concentration in blood plasma of rat offspring and decreased GSH levels significantly. No correlation was shown between MDA and GSH levels. **Conclusion:** Long-term ELF-MF exposure causes oxidative stress that results an increase on lipid peroxidation and a reduction on antioxidative parameters of blood tissue.



7. Chen, G. X., et al. (2021). "Associations of Occupational Exposures to Electric Shocks and Extremely Low-Frequency Magnetic Fields With Motor Neurone Disease." *Am J Epidemiol* 190(3): 393-402.

In a New Zealand population-based case-control study we assessed associations with occupational exposure to electric shocks, extremely low-frequency magnetic fields (ELF-MF) and motor neurone disease using job-exposure matrices to assess exposure. Participants were recruited between 2013 and 2016. Associations with ever/never, duration, and cumulative exposure were assessed using logistic regression adjusted for age, sex, ethnicity, socioeconomic status, education, smoking, alcohol consumption, sports, head or spine injury, and solvents, and was mutually adjusted for the other exposure. All analyses were repeated stratified by sex. An elevated risk was observed for having ever worked in a job with potential for electric shocks (odds ratio (OR) = 1.35, 95% confidence interval (CI): 0.98, 1.86), with the strongest association for the highest level of exposure (OR = 2.01, 95% CI: 1.31, 3.09). Analysis by duration suggested a nonlinear association: Risk was increased for both short duration (<3 years; OR = 4.69, 95% CI: 2.25, 9.77) and long duration (>24 years; OR = 1.88; 95% CI: 1.05, 3.36) in a job with high level of electric shock exposure, with less pronounced associations for intermediate durations. No association with ELF-MF was found. Our findings provide support for an association between occupational exposure to electric shocks and motor neurone disease but did not show associations with exposure to work-related ELF-MF.

8. Bagheri Hosseinabadi, M., et al. (2021). "Oxidative stress associated with long term occupational exposure to extremely low frequency electric and magnetic fields." *Work* 68: 379-386.

**BACKGROUND:** Occupational exposure to extremely low frequency electromagnetic fields (ELF-EMFs) may have harmful effects on biologic systems and has raised many concerns in the last decades. **OBJECTIVE:** The aim of this study was to determine the effects of exposure to extremely low frequency electric and magnetic fields on lipid peroxidation and antioxidant enzyme activities. **METHODS:** This study was conducted on 115 power plant workers as the exposed group and 145 office workers as the non-exposed group. The levels of Malondialdehyde (MDA), superoxide dismutase (SOD), Catalase (Cat), and total antioxidant capacity (TAC) were measured in the serum of all subjects. Exposure to ELF-EMFs was measured based on spot measurements and the IEEE Std C95.3.1 standard. **RESULTS:** The levels of MDA, SOD, and Cat in the exposed group were significantly higher than in the non-exposed group. However, the level of TAC was not significantly different between the exposed ( $2.45 \pm 1.02$ ) and non-exposed ( $2.21 \pm 1.07$ ) groups. The levels of MDA and SOD were higher among workers with higher exposure to electric fields than workers with low exposure. All oxidative stress indicators increased with increased exposure to magnetic fields, except TAC. **CONCLUSIONS:** The antioxidant system imbalance among power plant workers may be related to long term occupational exposure to electromagnetic fields.

9. Soldati, M. and I. Laakso (2020). "Effect of Electrical Conductivity Uncertainty in the Assessment of the Electric Fields Induced in the Brain by Exposure to Uniform Magnetic Fields at 50 Hz." IEEE Access 8: 222297-222309.

International exposure standard/guidelines establish limits for external electromagnetic field strengths. At low frequencies, these maximum allowable exposure levels are derived from the limits defined for internal electric field strengths which have been set to avoid adverse health effects. In the IEEE International Committee on Electromagnetic Safety standard, the relationship between internal and external fields was obtained through homogeneous elliptical models without considering the dielectric properties of tissues. However, the International Commission on Non-Ionizing Radiation Protection guidelines were established using computational dosimetry on realistic anatomical models. In this case, variability in the electrical conductivity of the tissues represents a major source of uncertainty when deriving allowable external field strengths. Here we characterized this uncertainty by studying the effect of different tissue conductivity values on the variability of the peak electric field strengths induced in the brain of twenty-five individuals exposed to uniform magnetic fields at 50 Hz. Results showed that the maximum electric field strengths computed with new estimations of brain tissue conductivities were significantly lower than those obtained with commonly used values in low-frequency dosimetry. The lower strengths were due to the new brain conductivity values being considerably higher than those usually adopted in dosimetry modeling studies. A sensitivity analysis also revealed that variations in the electrical conductivities of the grey and white matter had a major effect on the peak electric field strengths in the brain. Our findings are intended to lessen dosimetric uncertainty in the evaluation of the electric field strengths due to electrical properties of the biological tissues. 2013 IEEE.

10. Rubtsova, N., S. Perov and O. Belaya (2020). The Comparison of Approaches to Power Frequency Electromagnetic Field Hygienic Regulations. 21st International Symposium on High Voltage Engineering, ISH 2019, August 26, 2019 - August 30, 2019, Budapest, Hungary, Springer Science and Business Media Deutschland GmbH.

Power frequency electromagnetic fields are the risk factor for occupational and general public health. International and national electromagnetic safety guidelines set the exposure limit values and have some significant differences. The goal of this paper is to compare Russian hygienic norms with ICNIRP guidelines, EU Directive requirements for 50Hz electromagnetic fields occupational and general public exposure, analyze and demonstrate the principal differences. The protection from harmful human electromagnetic field effect is based on principles: protection by time, protection by distance and protection by protective equipment. Various hygienic regulations use different approaches to the human harmful effect definitions therefore there are distinctions of electromagnetic fields permissible limit values in International and national electromagnetic safety standards and guidelines. ICNIRP guidelines and Directive EU regard safety limits only from short-term, acute effect. Chronic electromagnetic field exposure harmful effect threshold is a basis for Russian hygienic norm. These thresholds are defined as a results of biomedical complex researches. Protection by time principle is realized in Russian

hygienic norms, which are strong time dependent for occupational exposure. It is the main distinctive characteristics from International hygienic guidelines and is based on chronic exposure harmful human health effect threshold definition and electromagnetic field cumulative effects concept. Russian permissible limit value (25kV/m) may be higher than ICNIRP (10kV/m) and Directive EU (20kV/m) levels, but is limited by working time (no more than 10min per day). In Russia for general public permissible limit values are graded according to possible exposure time per day. 2020, Springer Nature Switzerland AG.

11. Nakatani-Enomoto, S., et al. (2020). "Effects of electromagnetic fields from long-term evolution on awake electroencephalogram in healthy humans." *Neuroscience Research* 156: 102-107.

Mobile phones are indispensable for daily life, and the adverse effects of the electromagnetic field (EMF) emitted by mobile phones have been a great concern. We studied the effects of long-term evolution (LTE)-like EMF for 30 min on an awake electroencephalogram (EEG). Thirty-eight healthy volunteers, aged 20–36 years old, participated in this study. The maximum local SAR (specific absorption rate) averaged over 10-g mass was 2.0 W/kg. The EEG was recorded before and after real or sham exposures. The effects of exposure conditions (real or sham) and the recording time (before, during, and after exposure) on each EEG power spectrum of  $\theta$ ,  $\alpha$ , and  $\beta$  frequency ranges were analyzed. The  $\theta$  and  $\alpha$  band waves were enhanced after both exposure conditions. These results may be explained by the participants' drowsiness during the EEG recording in both exposures. We conclude that an LTE-like exposure for 30 min in this study showed no detectable harmful effects on awake EEGs in healthy humans.

12. Moon, J.-H. (2020). "Health effects of electromagnetic fields on children." *Clinical and experimental pediatrics* 63(11): 422-428.

In today's world, most children are exposed to various manmade electromagnetic fields (EMFs). EMFs are electromagnetic waves less than 300 GHz. A developing child's brain is vulnerable to electromagnetic radiation; thus, their caregivers' concerns about the health effects of EMFs are increasing. EMF exposure is divided into 2 categories: extremely low frequencies (ELFs; 3-3,000 Hz), involving high-voltage transmission lines and in-house wiring; and radiofrequencies (RFs; 30 kHz to 300 GHz), involving mobile phones, smart devices, base stations, WiFi, and 5G technologies. The biological effects of EMFs on humans include stimulation, thermal, and nonthermal, the latter of which is the least known. Among the various health issues related to EMFs, the most important issue is human carcinogenicity. According to the International Agency for Research on Cancer's (IARC's) evaluation of carcinogenic risks to humans, ELFs and RFs were evaluated as possible human carcinogens (Group 2B). However, the World Health Organization's (WHO's) view of EMFs remains undetermined. This article reviews the current knowledge of EMF exposure on humans, specifically children. EMF exposure sources, biological effects, current WHO and IARC opinions on carcinogenicity, and effects of EMF exposures on children will be discussed. As well-controlled EMF experiments in children are nearly impossible, scientific knowledge should be interpreted objectively. Precautionary

approaches are recommended for children until the potential health effects of EMF are confirmed.

13. Liu, Y., et al. (2020). Effects of Extremely Low Frequency Electromagnetic Fields Exposure in an Informationalized Perspective. International Conference on Data Processing Techniques and Applications for Cyber-Physical Systems, DPTA 2019, November 15, 2019 - November 16, 2019, Shanghai, China, Springer Science and Business Media Deutschland GmbH.

The article gives an overview of effects occurred with extremely low frequency electromagnetic fields(ELF-EMF) exposure in an informationalized perspective and concludes that reasonable suspicion of any health consequences does not exist based on current evidence of effects at ambient relevant levels, with which, limited exposures regulated by national safety standards and guidelines for habitable areas adjacent to all power lines may not reasonably be presumed to result in relevant adverse impacts and calls for additional multiple effects detecting means of informational techniques. And all special precautions and protective measures should be taken into action to reduce the exposure to electromagnetic fields in aspects of both intensity and frequency as low as reasonably attainable, no matter the effects of electromagnetic fields be as trivial as reasonably negligible. Traditional detecting means show that concrete evidence of electromagnetic fields pathophysiology such as chemical, morphological, and electrical alterations remains uncertain. Nevertheless, in the present information era, mankind is exposed to exceedingly multiple surrounding threats simultaneously, e.g., varied electromagnetic fields and air pollutants, and each combination or the stand-alone risk could potentially have beneficial or harmful effects, thus the definite evidence is far from been founded unless more detailed and large population based trials are to be done and multiple effects detecting means of informational techniques such as image recognition, speech recognition and motion recognition are to be further studied and deployed. 2020, Springer Nature Singapore Pte Ltd.

14. International Commission on Non-Ionizing Radiation, P. (2020). "Gaps in Knowledge Relevant to the "Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz–100 kHz)"." *Health physics* 118(5).

Sources of low-frequency fields are widely found in modern society. All wires or devices carrying or using electricity generate extremely low frequency (ELF) electric fields (EFs) and magnetic fields (MFs), but they decline rapidly with distance to the source. High magnetic flux densities are usually found in the vicinity of power lines and close to equipment using strong electrical currents, but can also be found in buildings with unbalanced return currents, or indoor transformer stations. For decades, epidemiological as well as experimental studies have addressed possible health effects of exposure to ELF-MFs. The main goal of ICNIRP is to protect people and the environment from detrimental exposure to all forms of non-ionizing radiation (NIR). To this end, ICNIRP provides advice and guidance by developing and disseminating exposure guidelines based on the available scientific research. Research in the low-frequency range began more than 40 years ago, and there is now a large body of literature available on which ICNIRP set its protection guidelines. A review of the literature has been

carried out to identify possible relevant knowledge gaps, and the aim of this statement is to describe data gaps in research that would, if addressed, assist ICNIRP in further developing guidelines and setting revised recommendations on limiting exposure to electric and magnetic fields. It is articulated in two parts: the main document, which reviews the science related to LF data gaps, and the annex, which explains the methodology used to identify the data gaps.

15. Górski, R., et al. (2020). "Effect of low-frequency electric field screening on motility of human sperm." *Annals of Agricultural & Environmental Medicine* 27(3): 427-434.

**Introduction.** The human body is constantly exposed to an extremely low electromagnetic field (ELF-EMF), in particular at 50 Hz, emitted by power lines, domestic distribution lines, electrical appliances, etc. It is assumed that the increase in electromagnetic exposure may cause adverse effects upon human health, as well as raising concerns regarding the impact on human fertility. **Objective.** The aim of this in vitro study was to investigate the influence of ELF-EMF with a frequency of 50 Hz on the motility of human sperm. At the same time, the effectiveness of the dielectric screen constructed by ADR Technology® in absorbing the emitted radiation was examined. **Materials and method.** Semen samples of 20 patients were exposed to the influence of an extremely low electromagnetic field. After 5, 15 and 30 min., spermatozoa motility was analysed using a computer-assisted spermatozoa motility analysis system. The following sperm motility parameters were examined: 1) velocity straight linear motility; 2) cross-beat frequency; 3) lateral head displacement; 4) homogeneity of progressive motility velocity. **Results.** It was found that the ELF-EMF presented a negative effect on the motility of human spermatozoa. A significant decrease in spermatozoa motility speed and a significant increase in lateral head deviation values were observed under the influence of the electromagnetic field. ELF-EMF did not show an effect on either lateral head displacement or homogeneity of progressive motility velocity. **Conclusions.** A positive effect of the dielectric screen ADR Technology® was found. This effect compensated spermatozoa motility changes induced with ELF-EMF

16. Deruelle, F. (2020). "The different sources of electromagnetic fields: Dangers are not limited to physical health." *Electromagnetic Biology and Medicine* 39(2): 166-175.

The impact of electromagnetic waves on health has been clearly established by many studies in recent decades. No State, with the exception of Russia, takes any real precautions in terms of standards for the population. Conflicts of interest and political lies are used to hide the truth about the dangers of electromagnetic pollution. In addition, it would seem that other sources of radiation than the most well-known ones (mobile phones, digital enhanced cordless telecommunication (DECT) phones, bluetooth, base stations, Wi-Fi, 4G, 5G) come into play. A system such as HAARP (High-frequency Active Auroral Research Program), as well as directed wave beams (related to past and recent scandals) must be analyzed and considered in a comprehensive way to understand why the wave level is only increasing despite the considerable amount of scientific work demonstrating that the standards are not adequate to maintain public health. Thus, official documents show that the impact of electromagnetic waves is not only physical and biological. Indeed, the climate and the behavior of the population are also targeted.

17. Darie, E. and L. Pislaru-Dnescu (2020). "Distribution of magnetic field and exposure level around of overhead power lines." *EEA - Electrotehnica, Electronica, Automatica* 68(4): 59-65.

This paper analyses the distribution of magnetic field sizes in the vicinity of high voltage overhead power lines (400 kV), in the context in which there is an intense concern about the effects of the electromagnetic field in the vicinity of high voltage and very high voltage power lines on the living organisms and especially on the humans. This concern is based on the assumption that exposure to extremely low frequency electromagnetic fields and especially to the 50 Hz magnetic field generated by high voltage overhead power lines can unduly affect the functioning of living cells and cause unwanted effects on health. The exposure limit values (ELVs), which produce undesirable effects on health, are different depending on the frequency range. The degree of exposure (public) results from the analysis of the values of the magnetic field quantities, obtained with the magnetic field tester, Hioki FT 3470-50. The values obtained are compared with the limits imposed by the present standards, regarding the public exposure to electromagnetic fields. 2020, Editura ELECTRA. All rights reserved.

18. Carlberg, M., et al. (2020). "Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and the association with acoustic neuroma." *Environmental Research* 187: 109621.

Exposure to extremely low-frequency electromagnetic fields (ELF-EMF) was in 2002 classified as a possible human carcinogen, Group 2B, by the International Agency for Research on Cancer at WHO based on an increased risk for childhood leukemia. In case-control studies on brain and head tumours during 1997–2003 and 2007–2009 we assessed life-time occupations in addition to exposure to different agents. The INTEROCC ELF-EMF Job-Exposure Matrix was used for associating occupations with ELF-EMF exposure ( $\mu\text{T}$ ) with acoustic neuroma. Cumulative exposure ( $\mu\text{T}$ -years), average exposure ( $\mu\text{T}$ ) and maximum exposed job ( $\mu\text{T}$ ) were calculated. No increased risk for acoustic neuroma was found in any category. For cumulative exposure in the highest exposure category 8.52+  $\mu\text{T}$  years odds ratio (OR) = 1.2, 95% confidence interval (CI) = 0.8–2.0, p linear trend = 0.37 was calculated. No statistically significant risks were found in the time windows 1–14 years, and 15+ years, respectively. In conclusion occupational ELF-EMF was not associated with an increased risk for acoustic neuroma.

19. Wilson, B. (2020). "Electromagnetic field and health: No clear answers." *Forum for Applied Research and Public Policy; (United States);* 9:2

Answers are as murky as ever: Is exposure to extremely low-frequency electric and magnetic field dangerous to human health Some scientists say yes, and some equally qualified scientists say no. [open quotes]A clear answer may take years to uncover,[close quotes] concede researchers Frederic A. Morris and Bary W. Wilson of Battelle, Yet, they not, the public and the media are becoming more and more interested in the issue, creating a need for [open quotes]clear, credible, and consistent information about what is known and not known.[close quotes] Scientific work, which began in the 1970s, falls into three main categories, Morris and

Wilson explain: epidemiological studies that seek to identify human health risks; laboratory biological studies that attempt to detect and define biological effects; and studies that suggest physical mechanisms to account for the effects observed in the laboratory. Some scientists claim that epidemiologic studies suggest that exposure to electromagnetic fields created by electric power increases the risk for cancer, miscarriage, and mood disorder. Other scientists question the validity of the studies and say the evidence is too weak to form the basis of a conclusion. This ambiguity makes communication with a lay audience difficult, Morris and Wilson concede, but it also makes science-based communication even more urgent.

20. Zipse, D. (2020). "Health effects of extremely low-frequency (50- and 60-Hz) electric and magnetic fields." *IEEE Transactions on Industry Applications* (Institute of Electrical and Electronics Engineers); (United States); 29:2

The news/publishing media has attempted to capitalize on or exploit the concern over health effects of electric and magnetic fields. This paper will provide assistance to the scientific and technical community to put the subject into perspective while the furor abates. The concern over the health effects of extremely low-frequency, 50-60 Hz, electric and magnetic fields is addressed. The voltages and currents generated within the human body are detailed. The values of directly applied voltages and currents that occur when a person comes into contact with energized conductors, that are hazardous to humans, are compared with the nonhazardous induced voltages and currents. An overview of the animal, cell, and human research with the epidemiological studies is presented with the object of familiarizing the reader with the wide scope of the subject. The positions being expounded by the various concerned groups are listed. The existing standards and values that have been developed by consensus groups are presented. Continuation of prudent research is advocated.

21. Villard, S., et al. (2019). "Impact of extremely low-frequency magnetic fields on human postural control." *Exp Brain Res* 237(3): 611-623.

Studies have found that extremely low-frequency (ELF, < 300 Hz) magnetic fields (MF) can modulate standing balance; however, the acute balance effects of high flux densities in this frequency range have not been systematically investigated yet. This study explores acute human standing balance responses of 22 participants exposed to magnetic induction at 50 and 100 mTrms (MF), and to 1.5 mA alternating currents (AC). The center of pressure displacement (COP) was collected and analyzed to investigate postural modulation. The path length, the area, the velocity, the power spectrum in low (< 0.5 Hz) and medium (0.5-2 Hz) bands have computed and showed the expected effect of the positive control direct current (DC) electric stimulation but failed to show any significant effect of the time-varying stimulations (AC and MF). However, we showed a significant biased stabilization effect on postural data from the custom experimental apparatus employed in this work, which might have neutralized the hypothesized results.

22. Soffritti, M. and L. Giuliani (2019). "The carcinogenic potential of non-ionizing radiations: The cases of S-50 Hz MF and 1.8 GHz GSM radiofrequency radiation." *Basic & Clinical Pharmacology & Toxicology* 125(S3): 58-69.

Abstract Epidemiological studies have suggested that human exposure to extremely low-frequency electromagnetic fields from the electric power and to mobile phone radiofrequency electromagnetic fields induce an increased risk of developing malignant tumours. However, no adequate laboratory data, in particular long-term carcinogenicity bioassays to support the epidemiological evidence, have yet been available. This motivated the Ramazzini Institute to embark on a first project of four large life-span carcinogenic bioassays conducted on over 7000 Sprague Dawley rats exposed from prenatal life until natural death to S-50 Hz MF alone or combined with gamma radiation or formaldehyde or aflatoxin B1. Results now available from these studies, which started concurrently, have shown that exposure to Sinusoidal-50 Hz Magnetic Field (S-50 Hz MF) combined with acute exposure to gamma radiation or to chronic administration of formaldehyde in drinking water induces a significantly increased incidence of malignant tumours in males and females. A second project of two large life-span carcinogenic bioassays was conducted on over 3000 Sprague Dawley rats exposed from prenatal life until natural death to 1.8 GHz GSM of mobile phone radio base station, alone or combined with acute exposure to gamma radiation. Early results from the experiment on 1.8 GHz GSM alone show a statistically significant increase in the incidence of heart malignant schwannoma among males exposed at the highest dose.

23. Saliev, T., et al. (2019). "Biological effects of non-ionizing electromagnetic fields: Two sides of a coin." *Progress in Biophysics and Molecular Biology* 141: 25-36.

Controversial, sensational and often contradictory scientific reports have triggered active debates over the biological effects of electromagnetic fields (EMFs) in literature and mass media the last few decades. This could lead to confusion and distraction, subsequently hampering the development of a univocal conclusion on the real hazards caused by EMFs on humans. For example, there are lots of publications indicating that EMF can induce apoptosis and DNA strand-breaks in cells. On the other hand, these effects could rather be beneficial, in that they could be effectively harnessed for treatment of various disorders, including cancer. This review discusses and analyzes the results of various in vitro, in vivo and epidemiological studies on the effects of non-ionizing EMFs on cells and organs, including the consequences of exposure to the low and high frequencies EM spectrum. Emphasis is laid on the analysis of recent data on the role of EMF in the induction of oxidative stress and DNA damage. Additionally, the impact of EMF on the reproductive system has been discussed, as well as the relationship between EM radiation and blood cancer. Apart from adverse effects, the therapeutic potential of EMFs for clinical use in different pathologies is also highlighted.



24. Poljak, D. and M. Cvetković (2019). Chapter 1 - On Exposure of Humans to Electromagnetic Fields – General Considerations. *Human Interaction with Electromagnetic Fields*. D. Poljak and M. Cvetković, Academic Press: 1-20.

The scope of this chapter is to review various aspects of human interaction with electromagnetic fields (EMFs) from artificial sources, thus covering basic ideas of environmental electromagnetic fields, the public fear related to the use of EMF, biomedical applications of EMF, coupling mechanisms between humans and static electric, static magnetic, and time-varying fields, summary of the established biological effects of electromagnetic fields related to static, low-frequency and high-frequency range, respectively, international safety guidelines and standards related to limiting human exposure to EMF and their legislative status in several world countries, relevant exposure limits and safety measures. Finally, some remarks on electromagnetic and thermal dosimetry are given.

25. Panagopoulos, D. J. (2019). "Comparing DNA damage induced by mobile telephony and other types of man-made electromagnetic fields." *Mutation Research-Reviews in Mutation Research* 781: 53-62.

The number of studies showing adverse effects on living organisms induced by different types of man-made Electromagnetic Fields (EMFs) has increased tremendously. Hundreds of peer reviewed published studies show a variety of effects, the most important being DNA damage which is linked to cancer, neurodegenerative diseases, reproductive declines etc. Those studies that are far more effective in showing effects employ real-life Mobile Telephony (MT) exposures emitted by commercially available mobile phones. The present review - of results published by my group from 2006 until 2016 - compares DNA fragmentation induced by six different EMFs on the same biological system - the oogenesis of *Drosophila melanogaster* - under identical conditions and procedures. Such a direct comparison between different EMFs - especially those employed in daily life - on the same biological endpoint, is very useful for drawing conclusions on their bioactivity, and novel. It shows that real MT EMFs are far more damaging than 50 Hz alternating magnetic field (MF) - similar or much stronger to those of power lines - or a pulsed electric field (PEF) found before to increase fertility. The MT EMFs were significantly more bioactive even for much shorter exposure durations than the other EMFs. Moreover, they were more damaging than previously tested cytotoxic agents like certain chemicals, starvation, dehydration. Individual parameters of the real MT EMFs like intensity, frequency, exposure duration, polarization, pulsing, modulation, are discussed in terms of their role in bioactivity. The crucial parameter for the intense bioactivity seems to be the extreme variability of the polarized MT signals, mainly due to the large unpredictable intensity changes.

26. Ohayon, M. M., et al. (2019). "The potential for impact of man-made super low and extremely low frequency electromagnetic fields on sleep." *Sleep Medicine Reviews* 47: 28-38.

Summary An ever-growing number of electromagnetic (EM) emission sources elicits health concerns, particularly stemming from the ubiquitous low to extremely low frequency fields from

power lines and appliances, and the radiofrequency fields emitted from telecommunication devices. In this article we review the state of knowledge regarding possible impacts of electromagnetic fields on melatonin secretion and on sleep structure and the electroencephalogram of humans. Most of the studies on the effects of melatonin on humans have been conducted in the presence of EM fields, focusing on the effects of occupational or residential exposures. While some of the earlier studies indicated that EM fields may have a suppressive effect on melatonin, the results cannot be generalized because of the large variability in exposure conditions and other factors that may influence melatonin. For instance, exposure to radiofrequency EM fields on sleep architecture show little or no effect. However, a number of studies show that pulsating radiofrequency electromagnetic fields, such as those emitted from cellular phones, can alter brain physiology, increasing the electroencephalogram power in selective bands when administered immediately prior to or during sleep. Additional research is necessary that would include older populations and evaluate the interactions of EM fields in different frequency ranges to examine their effects on sleep in humans.

27. Mandrea, L., I. Curta and M. Costea (2019). The influence of the low frequency electric fields on the human being. 7th IEEE International Conference on E-Health and Bioengineering, EHB 2019, November 21, 2019 - November 23, 2019, 16 Universitatii Street, Iasi, Romania, Institute of Electrical and Electronics Engineers Inc.

The study of electromagnetic fields influence on human body is of large interest and many methods are used to investigate it. In this paper an unconventional method, based on results offered by a Bio Well device, was applied to observe the power frequency electric field effect on some healthy human subjects. The paper presents the results of two sets of experiments performed in the High Voltage Laboratory from University "Politehnica" of Bucharest. The first experiment was made with two persons who underwent a power frequency (50 Hz) electric field short time exposure at 3.60 kV/m and later at 4.65 kV/m. The health and mood status of the human subjects were measured before and after the exposure. The second experiment was made with five persons in the same conditions. Conclusions were obtained in each case in terms of the energy and health of each person. 2019 IEEE.

28. Mahaki, H., et al. (2019). "A review on the effects of extremely low frequency electromagnetic field (ELF-EMF) on cytokines of innate and adaptive immunity." *Electromagnetic Biology and Medicine* 38(1): 84-95.

Extremely low frequency electromagnetic field (ELF-EMF) is produced extensively in modern technologies. Numerous in vitro and in vivo studies have shown that ELF-EMF has both stimulatory and inhibitory effects on the immune system response. This review was conducted on effects of ELF-EMF on cytokines of innate and adaptive immunity. Mechanisms of ELF-EMF, which may modulate immune cell responses, were also studied. Physical and biological parameters of ELF-EMF can interact with each other to create beneficial or harmful effect on the immune cell responses by interfering with the inflammatory or anti-inflammatory cytokines. According to the studies, it is supposed that short-term (2-24 h/d up to a week) exposure of ELF-EMF with strong density may increase innate immune response due to an increase of innate

immunity cytokines. Furthermore, long-term (2-24 h/d up to 8 years) exposure to low-density ELF-EMF may cause a decrease in adaptive immune response, especially in Th1 subset.

29. Lai, H. (2019). "Exposure to Static and Extremely-Low Frequency Electromagnetic Fields and Cellular Free Radicals." *Electromagnetic Biology and Medicine* 38(4): 231-248.

This paper summarizes studies on changes in cellular free radical activities from exposure to static and extremely-low frequency (ELF) electromagnetic fields (EMF), particularly magnetic fields. Changes in free radical activities, including levels of cellular reactive oxygen (ROS)/nitrogen (RNS) species and endogenous antioxidant enzymes and compounds that maintain physiological free radical concentrations in cells, is one of the most consistent effects of EMF exposure. These changes have been reported to affect many physiological functions such as DNA damage; immune response; inflammatory response; cell proliferation and differentiation; wound healing; neural electrical activities; and behavior. An important consideration is the effects of EMF-induced changes in free radicals on cell proliferation and differentiation. These cellular processes could affect cancer development and proper growth and development in organisms. On the other hand, they could cause selective killing of cancer cells, for instance, via the generation of the highly cytotoxic hydroxyl free radical by the Fenton Reaction. This provides a possibility of using these electromagnetic fields as a non-invasive and low side-effect cancer therapy. Static- and ELF-EMF probably play important roles in the evolution of living organisms. They are cues used in many critical survival functions, such as foraging, migration, and reproduction. Living organisms can detect and respond immediately to low environmental levels of these fields. Free radical processes are involved in some of these mechanisms. At this time, there is no credible hypothesis or mechanism that can adequately explain all the observed effects of static- and ELF-EMF on free radical processes. We are actually at the impasse that there are more questions than answers.

30. Karimi, S. A., et al. (2019). "Effects of exposure to extremely low-frequency electromagnetic fields on spatial and passive avoidance learning and memory, anxiety-like behavior and oxidative stress in male rats." *Behavioural Brain Research* 359: 630-638.

There are many controversies about the safety of extremely low-frequency electromagnetic field (ELF-EMF) on body health and cognitive performance. In the present study, we explored the effects of ELF-EMF on oxidative stress and behaviors of rats. Seventy-two adult male Wistar rats were randomly divided into following groups, control, sham exposure group and the ELF-EMF exposure groups (1  $\mu$ T, 100  $\mu$ T, 500  $\mu$ T, and 2000  $\mu$ T). After 60 days exposure (2 h/day), elevated plus maze (EPM), Morris water maze (MWM) and Passive avoidance learning (PAL) tasks were used to evaluate the anxiety-like behavior, spatial and passive learning and memory, respectively. Some days after behavioral examination, oxidative stress markers were measured. During spatial reference memory test, animals in ELF-EMF exposure groups (100, and 2000  $\mu$ T) spent more time in target zone ( $F(4, 55) = 5.699, P = 0.0007$ , One-way ANOVA). In PAL retention, the step through latency in the retention test (STLr) in ELF-EMF exposure groups

(100,500, and 2000  $\mu\text{T}$ ) was significantly greater than control group ( $F(4, 55) = 29.13$ ,  $P < 0.0001$ , One-way ANOVA). In EPM test, ELF-EMF exposure (500 and 2000  $\mu\text{T}$ ) decreased the percentage of the entries into the open arms ( $F(4, 55) = 26.31$ ,  $P < 0.0001$ , one-way ANOVA). ELF-EMF exposure (100, and 500  $\mu\text{T}$ ) increased Malondialdehyde (MDA) concentration ( $F(4, 25) = 79.83$ ,  $P < 0.0001$ , One-way ANOVA). Our results may allow the conclusion that exposure to ELF-EMFs can improve memory retention (but not acquisition) in the adult male rats. Although exposure to ELF-EMFs could be a factor in the development of anxious state or oxidative stress.

31. Judakova, Z. and L. Janousek (2019). Low Frequency Electromagnetic Field in Microenvironments and Their Possible Health Impacts. 20th IEEE International Conference on Computational Problems of Electrical Engineering, CPEE 2019, September 15, 2019 - September 18, 2019, Lviv-Slavske, Ukraine, Institute of Electrical and Electronics Engineers Inc.

The electromagnetic field is an inseparable part of the contemporary world. Ubiquity of low and extremely low-frequency electromagnetic field produced by the distribution of household electricity has attracted special attention. A number of dosimetric analyzes of the electromagnetic field realized by various researchers have detected high exposure values in the different microenvironment of human life. Other studies report potential associations between exposure to low and extremely low-frequency electromagnetic field and various health outcomes. This paper shows an overview of the electromagnetic situation in our life microenvironments and her possible health impacts. 2019 IEEE.

32. Hosseinabadi, M. B., et al. (2019). "Effect of long-term occupational exposure to extremely low-frequency electromagnetic fields on proinflammatory cytokine and hematological parameters." *International Journal of Radiation Biology* 95(11): 1573-1580.

**Purpose:** The present study aimed to investigate the effect of extremely low-frequency electromagnetic fields (ELF-EMFs) on proinflammatory cytokines and hematological parameters, among the employees of a power plant, which are one of the most important occupational groups exposed to ELF-EMFs extensively. **Materials and methods:** The studied population included 112 employees of a power plant as the exposed group and 138 unexposed employees who were enrolled based on inclusion and exclusion criteria. The magnetic flux density and the strength of the electric field were determined by spot measurements and according to the IEEE C95.3.1 standard. Proinflammatory cytokines including serum interleukin-1 $\beta$  (IL-1 $\beta$ ), interleukin-6 (IL-6), and tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ); and hematologic parameters of all subjects were measured. **Results:** The mean level of IL-1 $\beta$  and IL-6, white blood cell count (WBC) and red blood cell count (RBC), lymphocyte percentage (Lym%), mean corpuscular volume (MCV), platelet count (PLT) and procalcitonin (PCT) were significantly more in the exposed group, than the unexposed group. The mean serum levels of IL-6, IL-1 $\beta$  and some of the hematological parameters including WBC, lymphocyte, RBC and hematocrit were higher in technicians which had the highest level of exposure to magnetic fields compared to

other groups and these relations were linear. Conclusions: Long-term exposure to ELF-EMFs probably affects immune responses, by stimulating the production of proinflammatory cytokines, and increasing some hematological parameters.

33. Hosseinabadi, M. B. and N. Khanjani (2019). "The Effect of Extremely Low-Frequency Electromagnetic Fields on the Prevalence of Musculoskeletal Disorders and the Role of Oxidative Stress." *Bioelectromagnetics* 40(5): 354-360.

Extremely low-frequency electromagnetic fields (ELF-EMFs) may cause negative health effects. This study aimed to investigate the direct and indirect effects of chronic exposure to extremely low-frequency electric and magnetic fields on the prevalence of musculoskeletal disorders (MSDs). In this cross-sectional study, 152 power plant workers were enrolled. The exposure level of employees was measured based on the IEEE Std C95.3.1 standard. Superoxide dismutase (SOD), catalase (Cat), glutathione peroxidase (GPx), total antioxidant capacity (TAC), and malondialdehyde (MDA) (independent variables) were measured in the serum of subjects. The Nordic musculoskeletal questionnaire was used to assess MSDs (dependent variable). The mean exposure of electric and magnetic fields were 4.09 V/m (standard deviation [SD] = 4.08) and 16.27  $\mu$ T (SD = 22.99), respectively. Increased levels of SOD, Cat, GPx, and MDA had a direct significant relation with MSDs. In the logistic regression model, SOD (odds ratio [OR] = 0.952, P = 0.026), GPx (OR = 0.991, P = 0.048), and MDA (OR = 0.741, P = 0.021) were significant predictors of MSDs. ELF-EMFs were not related to MSDs directly; however, increased levels of oxidative stress may cause MSDs. *Bioelectromagnetics*. 2019;40:354-360. © 2019 Bioelectromagnetics Society. (© 2019 Bioelectromagnetics Society.)

34. Habash, M., et al. (2019). "Scoping review of the potential health effects of exposure to extremely low-frequency electric and magnetic fields." *Critical Reviews in Biomedical Engineering* 47(4): 323-347.

Previous studies suggest that extremely low-frequency (ELF) electric and magnetic fields (EMFs) may impact human health. However, epidemiologic studies have provided inconsistent results on the association between exposure to ELF EMFs and various health outcomes. This scoping review reports on primary investigations that were published during the ten-year period of 2007-2017 on the association between ELF EMFs and cancer, cardiovascular disease (CVD), reproductive health effects, and neurodegenerative diseases. We identified a total of 361 articles from two bibliographic databases (PubMed and EMBASE). Of these, 39 articles (19 cancer studies, two CVD studies, nine reproductive health studies, and ten neurodegenerative disease studies [with one repeated for two outcomes]) met inclusion criteria. Articles identified in this study focus on three different types of exposure: occupational (22 studies), residential (15 studies), and electric blanket (two studies). This review suggests that ELF EMFs may be associated with neurodegenerative diseases, specifically Alzheimers disease; however, limited evidence was found to suggest that ELF EMFs are associated with several types of cancer, CVD, and reproductive outcomes. Additional epidemiological studies in large study populations with improved exposure assessments are needed to clarify current inconclusive relationships. 2019 by Begell House, Inc.

35. Dong, X. W. and M. Lu (2019). Research on low frequency electromagnetic environment of electric vehicle and human health. 2nd International Conference on Numerical Modelling in Engineering, NME 2019, August 19, 2019 - August 22, 2019, Beijing, China, IOP Publishing Ltd.

In order to study the influence of electromagnetic environment produced by low frequency current in power cables of electric vehicle on driver's and co-driver's tissues, especially in the central nervous system (CNS). The distribution of the magnetic induction intensity and the induction electric field intensity in human trunk and CNS of the driver's and co-driver's are calculated and analysed. The results are compared with the related standards of International Committee on Non-ionizing Radiation Protection (ICNIRP). The study shows that the induced fields in human trunk and CNS are much smaller than the occupational and public exposure limits defined by ICNIRP. Therefore, the low frequency current would be safe for human health to some extent. Published under licence by IOP Publishing Ltd.

36. Carpenter, D. O. (2019). "Extremely low frequency electromagnetic fields and cancer: How source of funding affects results." *Environmental Research* 178: 108688.

While there has been evidence indicating that excessive exposure to magnetic fields from 50 to 60 Hz electricity increases risk of cancer, many argue that the evidence is inconsistent and inconclusive. This is particularly the case regarding magnetic field exposure and childhood leukemia. A major goal of this study is to examine how source of funding influences the reported results and conclusions. Several meta-analyses dating from about 2000 all report significant associations between exposure and risk of leukemia. By examining subsequent reports on childhood leukemia it is clear that almost all government or independent studies find either a statistically significant association between magnetic field exposure and childhood leukemia, or an elevated risk of at least  $OR = 1.5$ , while almost all industry supported studies fail to find any significant or even suggestive association. A secondary goal of this report is to examine the level of evidence for exposure and elevated risk of various adult cancers. Based on pooled or meta-analyses as well as subsequent peer-reviewed studies there is strong evidence that excessive exposure to magnetic fields increases risk of adult leukemia, male and female breast cancer and brain cancer. There is less convincing but suggestive evidence for elevations in several other cancer types. There is less clear evidence for bias based on source of funding in the adult cancer studies. There is also some evidence that both paternal and maternal prenatal exposure to magnetic fields results in an increased risk of leukemia and brain cancer in offspring. When one allows for bias reflected in source of funding, the evidence that magnetic fields increase risk of cancer is neither inconsistent nor inconclusive. Furthermore adults are also at risk, not just children, and there is strong evidence for cancers in addition to leukemia, particularly brain and breast cancer.

37. Bagheri Hosseinabadi, M., et al. (2019). "DNA damage from long-term occupational exposure to extremely low frequency electromagnetic fields among power plant

workers." Mutation Research/Genetic Toxicology and Environmental Mutagenesis 846: 403079.

Extremely low frequency electromagnetic fields (ELF-EMFs) are not known as definite occupational carcinogens, but some studies have reported the genotoxic effects of these fields on cell lines. The present study aimed to evaluate the effects of long-term occupational exposure to these fields on DNA damage. In this cross-sectional study, blood samples were taken from 102 thermal power plant workers as the exposure group and 136 subjects as the unexposed group. DNA damage was evaluated using alkaline comet assay and flow cytometry. Exposure to ELF-EMFs was measured based on spot measurements and the IEEE Std C95.3.1 standard. The indices of comet assay, tail DNA percent, tail factor (%), and damage index were significantly higher in the exposed group compared to the unexposed group. Increased exposure to magnetic fields enhanced comet assay indices, except tail length; while exposure to electric fields had no significant effect on such indices. The percentage of cells at early apoptosis and late apoptosis phases caused by exposure to magnetic fields, respectively, decreased and increased significantly. Long-term occupational exposure to ELF-EMFs can probably cause genotoxic effects.

38. Bagheri Hosseinabadi, M., et al. (2019). "The effect of chronic exposure to extremely low-frequency electromagnetic fields on sleep quality, stress, depression and anxiety." *Electromagnetic Biology and Medicine* 38(1): 96-101.

Exposure to extremely low-frequency electromagnetic fields (ELF-EMF) is inevitable in some industries. There are concerns about the possible effects of this exposure. The present study aimed to investigate the effect of chronic exposure to extremely low-frequency electromagnetic fields on sleep quality, stress, depression and anxiety among power plant workers. In this cross-sectional study, 132 power plant workers were included as the exposed group and 143 other workers were included as the unexposed group. The intensity of ELF-EMF at work stations was measured by using the IEEE Std C95.3.1 standard and then the time weighted average was calculated. Sleep quality, stress, depression and anxiety were measured by using the Pittsburgh Sleep Quality Index Questionnaire; and the Depression, Anxiety and Stress Scale. The workers in the exposed group experienced significantly poorer sleep quality than the unexposed group. Depression was also more severe in the exposed group than the unexposed group ( $P = 0.039$ ). Increased exposure to ELF-EMF had a direct and significant relation with increased stress, depression, and anxiety. Sleep quality in technicians with the highest exposure was significantly lower than the other groups. This study suggests that long-term occupational exposure to ELF-EMF may lead to depression, stress, anxiety and poor sleep quality.

39. (2019). "IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz."

Abstract: Safety limits for the protection of persons against the established adverse health effects of exposures to electric, magnetic, and electromagnetic fields in the frequency range 0 Hz to 300 GHz are presented in this standard. These exposure limits are intended to apply generally to

persons permitted in restricted environments and to the general public in unrestricted environments. These exposure limits are not intended to apply to the exposure of patients by or under the direction of physicians and medical professionals, as well as to the exposure of informed volunteers in medical or scientific research studies, and might not be protective with respect to the use of medical devices or implants. Scope: This standard specifies exposure criteria and limits to protect against established adverse health effects in humans associated with exposure to electric, magnetic, and electromagnetic fields in the frequency range of 0 Hz to 300 GHz.<sup>1,2</sup> These limits, incorporating safety margins, are expressed in terms of dosimetric reference limits (DRL) and exposure reference levels (ERL). DRLs are expressed in terms of in situ electric field strength, specific absorption rate (SAR), and epithelial power density. ERLs, which are more easily determined, are limits on external electric and magnetic fields, incident power density, induced and contact currents, and contact voltages intended to ensure that the DRLs are not exceeded. The limits, which protect against adverse health effects associated with electrostimulation of tissue and local and whole-body heating, are intended to apply to the described human exposure conditions. However, these levels are not intended to address exposures of patients or human research subjects under the care of medical professionals for which other risks and benefits might apply. These exposure limits might not prevent interference with medical and other devices that might exhibit susceptibility to electromagnetic interference (EMI). Purpose: The purpose of this standard is to provide science-based exposure criteria to protect against established adverse health effects in humans associated with exposure to electric, magnetic, and electromagnetic fields; induced and contact currents; and contact voltages, over the frequency range of 0 Hz to 300 GHz. 2019 IEEE.

40. Auger, N., et al. (2019). "Maternal proximity to extremely low frequency electromagnetic fields and risk of birth defects." *European Journal of Epidemiology* 34(7): 689-697.

Causes of birth defects are unclear, and the association with electromagnetic fields is inconclusive. We assessed the relationship between residential proximity to extremely low frequency electromagnetic fields from power grids and risk of birth defects. We analyzed a population-based sample of 2,164,246 infants born in Quebec, Canada between 1989 and 2016. We geocoded the maternal residential postal code at delivery and computed the distance to the nearest high voltage electrical transmission line or transformer station. We used log-binomial regression to estimate risk ratios (RR) and 95% confidence intervals (CI) for the association of residential proximity to transmission lines and transformer stations with birth defects, adjusting for maternal and infant characteristics. The prevalence of birth defects within 200 m of a transmission line (579.4 per 10,000 per live births) was only slightly higher compared with distances further away (568.7 per 10,000). A similar trend was seen for transformer stations. Compared with 200 m, a distance of 50 m was not associated with the risk of birth defects for transmission lines (RR 1.00, 95% CI 1.00–1.01) and transformer stations (RR 1.01, 95% CI 1.00–1.03). There was no consistent association when we examined birth defects in different organ systems. We found no compelling evidence that residential proximity to extremely low frequency electromagnetic fields from electrical power grids increases the risk of birth defects. Women residing near electrical grids can be reassured that an effect on the risk of birth defects is unlikely.



41. Mansuori, E., A. Alihemmati and A. Mesbahi (2020). "An overview on the effects of power frequency electromagnetic field exposure on the female reproduction system, pregnancy outcome and fetal development." *Journal of medicinal and chemical sciences* 3(1): 60-70.

This article presents a review of the published scientific studies on the potential adverse effects of power frequency electromagnetic field (50-60 Hz) from domestic and occupational sources and electric transmission lines on female reproduction system and pregnancy outcome. In this review, publications in English were searched in the ISI Web of Knowledge, PubMed databases and Google Scholar from January 2000 to December 2017 articles. For ascertaining the reliability of study, data were extracted independently and in duplicate by two investigators. According to some of the conducted studies, environmental exposure to power frequency EMF (electromagnetic field) exposure was found to adversely affect sex hormones, female genital system, embryonic development, pregnancy outcome and fetal and offspring development, while other studies reported no significant effect of power frequency EMF exposure on reproductive parameters and embryonic and fetal development. Overall, the results were not convergent and there was controversy regarding the findings. However, it can be concluded that a part of controversy can be attributed to differences in field strength and exposure time, the experiment condition in terms of in vivo and in vitro which had a significant impact on the observed results.

42. Zhang, Y., et al. (2020). "Examination of the Effect of a 50-Hz Electromagnetic Field at 500  $\mu$ T on Parameters Related With the Cardiovascular System in Rats." *Frontiers in Public Health* 8.

Background: Whether electromagnetic field (EMF) exposure affects the function of the cardiovascular system is under debate. The present study aimed to investigate the effects of 500  $\mu$ T EMF exposure on the cardiovascular system in rats. Methods: Forty-eight-week-old male Sprague-Dawley rats were randomly divided into two groups: the sham group and the exposure group. During 24-week EMF exposure (20 h per day), the blood pressure and pulse rate were recorded every 4 weeks. Before sacrifice, electrocardiography, echocardiography, and cardiac catheterization analysis were conducted to evaluate the cardiac function. Meanwhile, hematoxylin-eosin (HE) staining, Western blot, and real-time polymerase chain reaction (PCR) were performed to identify morphological and molecular changes indicative of cardiac remodeling. Results: The heart rate, blood pressure, and pulse rate were not influenced by EMF exposure compared with the control group. In addition, HE staining showed no change in the morphology and arrangement of cardiomyocytes. Further, we found that the mRNA and protein levels of cardiac hypertrophy-related genes were not affected by EMF exposure. Finally, no significant difference was observed in cardiac function between the two groups by echocardiography and cardiac catheterization detection. Conclusion: The 24-week exposure to EMF at 500  $\mu$ T did not have apparent effects on the cardiovascular system in rats, at least for the variables studied.

43. Binboğa, E., S. Tok and M. Munzuroğlu (2021). "The Short-Term Effect of Occupational Levels of 50 Hz Electromagnetic Field on Human Heart Rate Variability." *Bioelectromagnetics* 42(1): 60-75.

Previous studies have indicated that there is no consensus on the effects of extremely low-frequency electromagnetic (ELF-EMF) exposure on the cardiovascular system. This study aimed to explore the short-term effect of ELF-EMF exposure on heart rate (HR) and HR variability (HRV). The sample consisted of 34 healthy males aged 18-27 years. The participants were randomly assigned to the EMF (n = 17) or the Sham group (n = 17). We employed a double-blind repeated-measures design consisting of three 5 min experimental periods. The chest region of each individual in the EMF group was exposed to 50 Hz, 28  $\mu$ T, linear polarized, continuous EMF during the EMF exposure period. HR and HRV data were recorded continuously by using a photoplethysmography sensor. Within-subject statistical analysis indicated a significant HR deceleration in both the EMF and Sham groups. However, the standard deviation of the NN intervals (SDNN), root mean square of successive differences (RMSSD), low-frequency (LF), and high-frequency (HF) powers increased only in the EMF group and remained stable in the Sham group. We also compared the same HRV indices measured during the EMF and Sham periods between the two experimental groups. The between-subject analysis results demonstrated significantly higher SDNN, RMSSD, LF, and HF values in the EMF group than in the Sham group. The LF/HF ratio did not change significantly within and between groups. On the basis of these results, we concluded that short-term exposure of the chest region to ELF-EMF could potentially enhance parasympathetic predominance during the resting condition.