

Effect of electric and magnetic fields on biological systems

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ABSTRACT

Nowadays, due to the growth of science and technology in various fields and human intervention and application of electrical energy in everyday life have led to the fact that electric and magnetic fields are considered as one of the constituents of the environment and destructive effects of these waves have increased on the health of human and other creatures. In fact, these fields have harmful effects on biological structure of human tissues. In this study, the electromagnetic fields and the reduction of radiation were evaluated on animals and human.

Keywords: Electrical and magnetic fields, biological structure, environment, human health

INTRODUCTION

Electrical and magnetic pollution in the environment is considered as one of the most important ecological problems. Radio frequencies were essentially from radio transmitters and televisions before 1990 which were located in remote or high altitude areas. The expansion of telephone networks has led to a significant increase in electromagnetic pollution in cities and countries starting wireless communications. Pollution of these fields has been put on the agenda as a new threat with the rapid development, and in particular the increase in the number of devices operating with electric and magnetic fields. Electromagnetic pollution, which is received through high-pressure lines, mobile phones, radio waves, televisions and computers at home, creates an unhealthy atmosphere in life. The National Regulatory Research Institute (NRRI) has embraced the negative effects of electric and magnetic fields on general health as one of the most serious environmental problems. The electric current generates electric and magnetic fields around the transmitter. The combination of these fields is called electromagnetic field that their collision with each other perpendicular to their vector locations. An electromagnetic field is a concept that can be felt through its effects and

consequences [1]. Radio waves and microwaves are forms of electromagnetic energy [2]. Although the effects of magnetic fields on human organs are not understood accurately, research has shown that magnetic fields are more effective than electric fields. Electromagnetic waves damage the immune system by blocking signals sent from the brain to the cells. In experimental research conducted on laboratory animals under frequencies, energy levels and different exposure periods [1].

The effects of electromagnetic waves on biological environments are divided into thermal and non-thermal effects. The biological effects, which are caused by tissue heating by radio frequency energy, are often expressed as thermal effects. Exposure to high levels of radio frequency radiation may be harmful due to its ability to rapidly heat the biological tissue. Microwave ovens can obviously be used in the heating of the biological tissue and contact with a very high power radio frequency of almost 100 mW/cm².

Exposure to radio frequency energy in intensity values of 1 to 10 mW/cm² under certain conditions can lead to measurable heating of the biological tissue. The amount of this heating and its consequences depend

on several factors including radiation frequency, size, shape, direction of exposed object, duration of contact, environmental conditions and heat efficiency. Studies have indicated that environmental energy values of radio frequencies are much lower than the amount needed to create significant heating and increased body temperature. The electromagnetic wave frequency can also be important in determining energy absorption.

The quantity used to describe this absorption is called specific absorption rate (SAR) and usually expressed in watt per kilogram. Contact with radio frequency radiation in low quantities which create harmful biological and vague effects. Such effects are sometimes referred to as non-thermal effects [2]. At present, electromagnetic fields that are caused by human production are mainly created through cellular communication systems and radio transmitters. Special attention to the 900 MHz frequency which shows the GSM900 band frequency, the frequency that expanded in earth and is mostly used in the mobile system [3].

Electrical and magnetic radiation can have many effects on the body. The range of these effects varies from mild symptoms, such as redness of the skin, to serious and dangerous effects, such as cancer and death. These

effects are dependent on dose, the amount of radiation absorbed by the body, the type of radiation and the duration of the radiation.

The body tries to compensate for radiation damage, but sometimes damage is very intense. The biological effects of the radiation are divided into two groups. The first group involves exposing high doses of radiation over short periods of time which produces short-term effects. The second group involves exposure to low dose of radiation during long term periods which produces long-term chronic effects [3]. Beale in 1997 examined the effects of electromagnetic fields on mental and physical health in New Zealand. He stated that electromagnetic fields in 1940 which may have caused health problems.

Research on the biological and health effects of electromagnetic fields over the next decades was basically focused on high frequency transmitters, but the varied importance of lower frequencies for electrical power transmission was in 1970 when epidemiological research on leukemia in children showed that it is associated with magnetic fields of home power supply. It is now well-accepted that high levels of contact with maximum frequencies are dangerous. However, there is still ongoing debate about

the nature of the effects of relatively low contact values [3]. Galeev in 2000 investigated the effects of microwave radiation caused by cell phones on humans and animals. He believed that the biological effects of radiation from mobile phones depend on exposure time of radiation on human [4].

Biological effects of electric and magnetic fields of radiation

When the human body is exposed to electromagnetic radiation it absorbs the radiation, the effect of microwave absorption through parts of the body (water, blood) is very significant, such as the brain that contains almost 90% water. Effect where the movement of fluids is less, For example, eyes, brain, joints, heart and testicles is more [5]. Blood flow is one of the major mechanisms of the body to deal with the excessive heat [6].

Electric and magnetic fields have various risks. Some of these risks include:

Increased risk of cancer and tumor growth

Three research groups in Europe observed increased risk of brain tumors for people who have been using cell phones for 10 years. There is a relationship between the location of the tumor and the side of the head that

people kept their phone. Therefore, the risk of tumor is more for that side of the body which is exposed to more contact. One study also showed that the highest risk was in people who started using phones before the age of 20. It was found that using cell phones before the age of 20 increases the risk of brain tumor for all ages [7].

A study indicated that the head of adult people attracts 80% of the mobile phone radiation [6]. Excessive use of cell phones can cause cancer. Moreover, the use of mobile phones for more than 10 years creates a sustainable pattern of increased brain-glioma cancer risk and auditory nerve damage. There is increased risk for various types of cancers such as lymph node tumors, facial nerve tumors as well as skin, blood and breast cancers following the exposure radio radiation in long term [7].

The increased risk of salivary gland cancer has been reported which was directly affected by mobile phones. Researchers have found a worrying increase in the number of cases of malignant growth in glandular glands among cases of salivary gland cancers. Users under age 20 were more prone [8, 9].

Damage to DNA

Radio frequencies can lead to DNA damage. Electromagnetic radiation causes membrane

leakage due to the lack of calcium ions. Microwave radiation can interfere with the natural processes involved in DNA replication and modification by altering the molecular structure and damage to the DNA through free radical formation inside the cells. Free radicals destroy cells through damage to large molecules such as DNA, proteins, and membranes and lead to carcinogens.

Several reports have shown that electromagnetic field increases free radical activity in the cells [10, 11] through the fenton reagent [12]. Damage to the DNA is a mechanism for the progression of tumors and cancer. DNA damage in brain cells can affect neurological function and may lead to neurological diseases [5].

Melatonin reduction and sleep disorders

Roschke in 2005 examined the effects of electromagnetic fields released from communication devices on human sleep in Berlin. According to his study, the effect of exposure to electromagnetic fields on sleep has various reasons. Reports of sleep disorders were recorded by radio frequency electromagnetic fields and this led to speculation that the electromagnetic field may interfere with normal sleep patterns [13].

Sleep, blood pressure, heart rate, metabolic rate and thermal adjustment, hormone production, and immune system activity all have daily cycles which are regulated directly or indirectly via melatonin by voluntary system. Various studies have shown that exposure to electromagnetic radiation reduces melatonin levels in animals and humans.

When the amount of access to melatonin is interrupted, a wide range of disorders including sleep disorder, chronic fatigue, depression, cardiovascular, neurological and fertility diseases and ultimately death can occur. Melatonin reduction is also associated with increased DNA damage and increased risk of cancer, arthritis, schizophrenia, increased eye stress, renal failure, Parkinson's and Alzheimer's disease, abortions and increased risk of childhood leukemia [14]. According to research conducted by scientists, using mobile phones before going to bed and putting them near your head while sleeping causes the sleep process to slow down and also reduces it and followed by headache and depression. These findings are alarming especially for children, because they may lead to change in their mood and personality, hyperactivity symptoms such as depression, lack of concentration, and underestimation of scientific performance

[5,14]. The relationship between sleep disorder and exposure to radiation is shown in Figure 1. It was shown that the increase in

sleep disorder is proportional to exposure to radiation.

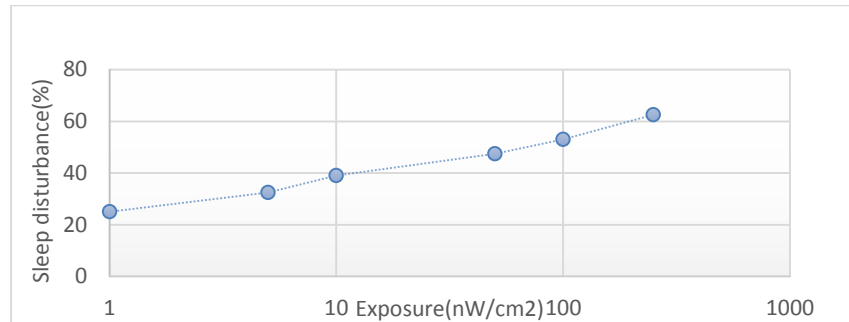


Figure 1: Relationship between the response rate for sleep disorder and exposure to radiation

The number of phone calls and short messages per day and the use of a combination of computers and mobile phones are associated with sleep disorders. The use of short message service is also associated with symptoms of depression [15].

Tinnitus and damage to ear

Tinnitus, ringing in the ear is a physiological illness of hearing a false voice has been reported among millions of mobile phone users worldwide [16]. Radiation emitted from cell phones may damage the function of the inner ear. Prolonged and excessive use of mobile phones for more than 4 years, and for periods longer than 30 min per day increases the risk of hearing loss, which is not a reversible problem.

Nowadays, many young people between the ages of 18 and 25 suffer from hearing impairment which physicians consider it to be due to the overuse of cell phones and other devices. Hearing problems occur because the hair cells in the inner ear that are damaged by radiation from the cell phone cannot be recovered. People who spend 2 to 3 h a day on cell phones develop a risk of relative deafness after 3 to 5 years. The problem begins with the pain in the ear that gradually rises in the form of ringing in the ear and eventually leads to loss of hearing [5].

Blood–brain barrier

The brain is protected by tight joints between the adjacent cells of the capillary walls by the blood-brain barrier. This barrier selectively allows nutrients to pass through the blood to the brain, but it does not permit the entry of

toxic substances. Experiments performed on young laboratory mice indicated that the electrical and magnetic frequencies can significantly increase the brain's barrier in animals and causes the albumin to leak from blood vessels to inappropriate places such as neurons, glial cells around the capillaries in the brain.

Neuronal damage may have no immediate consequences, but it could lead to a reduction in brain reserve and other neurological diseases. It should be noted that the blood–brain barrier and nerve cells are similar in mice and humans [5].

In another study, exposure to radiation emitted by the mobile phone for 2 h permanently damaged the blood brain barrier. In the autopsy 50 days later, it was observed that more than 2% of brain cells of animals including those cells of the brain that relate to learning, memory, and movement were damaged or destroyed [17]. It is known that the barrier is damaged in Parkinson and Alzheimer disease. Therefore, there is a risk that the damage to this protective barrier also damages the brain [5].

Releasing calcium ions from cell membrane

Studies have shown that weak magnetic fields eliminate the binding of calcium ions

to the membrane of living cells; makes it temporary holes and pores. The calcium ion intake into the cytocell acts as a metabolic stimulant which accelerates growth and recovery. However, It also increases tumor growth. The leakage of calcium ions into brain cells leads to inappropriate activity [18, 19].

Risk for children and pregnant women

Children are more vulnerable to radiation, because more energy is absorbed in children than adults due to the smaller size of their brain and head, the finer skin and bones, less blood cell volume, as well as the ability to direct more nerve cells and as a result, energy penetrates deeper. Tumors in the midbrain are more fatal than the temporal section. The proliferation of child cells is faster than the adult, which causes more lethal cancers. The immune system is not as advanced as adults, so that less effective in cancer growth [20].

Electromagnetic radiation induced by mobile phone is done in adults, 10-year-old and 5-year-old children.

For a younger child, the penetration of the beams is deeper, because their skin are thinner and still growing [21]. Brain tumors, as the largest cause of death among children, are now a substitute for leukemia. The risk of

brain cancer in children is more than adults [5].

A study indicated that children who live near the towers of radio and television stations had leukemia 2 times more than children who were more than 7 miles away from those stations [22]. Pregnant women and fetuses are both vulnerable, because radiation of radio frequency beams continuously affects fetal growth and cell proliferation. Microwave radiation can damage the wall of the embryo and membrane that prevents the passage of some materials from mother to fetus, and thus fetus preservation [23].

The relationship between the use of mobile phones during pregnancy and the probability of increased congenital abnormalities and behavioral problems in their children was observed in recent findings [24]. There has been a significant increase in the number of fetal and neonatal heart beats and a significant decrease in cardiac output in pregnant women exposed to the cell phone [25].

Irreversible infertility

Recent studies have confirmed that the waves emitted from mobile phones can greatly affect male fertility. It was reported a 30% sperm reduction by extreme cell phone users in addition to sperm damage. Also, radiation

of the cell phone can break DNA inside sperm cells which may cause mutations and cause cancer. Damage to sperm DNA can lead to genetic changes in later generations.

Studies on animals indicated that electromagnetic radiation may have a wide range of harmful effects on males [5]. It has been reported that rats that come in contact with cellular signals from the antenna, their reproduction is reduced. Mice were not able to produce children after 5 generations of radiation exposure. Therefore, the effect of radio frequency radiation can be transmitted from generation to generation [26].

Effect on vision

Frequent use of mobile phones can damage the visual system and cause melanoma [27]. Computational modeling and various experiments on animals indicated that microwave radiation like mobile frequencies can lead to chromosomal failure in retinal mucosal cells and increase the temperature inside the eye by prolonged exposure to radiation [28-30]. Increased temperature near the lens of the eye can lead to dimming of the lens and increase the risk of developing cataracts in humans [5].

Neurological diseases

Exposure to electric and magnetic fields is associated with diseases such as Alzheimer

disease, Parkinson disease and neuronal disease [31]. Moreover, microwave radiation may cause aggression in humans and animals [25]. People who live near radio stations are at risk of mental and nervous problems such as headache, memory loss, nausea, dizziness, tremor, muscle spasm, numbness, joint pain and muscle pain, leg pain, depression and

sleep disorders [32,33]. Severe reactions include sudden attacks, paralysis, insomnia and stroke.

Some of the results on the biological effects of electromagnetic waves on humans are given in the Table 1.

Table 1- Biological effects of electromagnetic waves on humans

Energy density ($\frac{\mu W}{cm^2}$)	Reported biological effects
10-5	Vulnerability of nervous system activity
10-4	Reduced visual acuity and memory impairment in children
100	26% decrease in blood insulin
8-0.2	Increased the risk of developing cancer in children under the influence of radiation
50	Reduced sleep by 18%
5.7-1.3	Increased the risk of developing cancer in adults under the influence of radiation
1.05-0.16	Infertility of mice under the influence of mobile phone radiation after five years

Energy density	Reported biological effects
$3-2 \frac{w}{kg}$	Accelerating the growth of breast and skin cancer
$400 \frac{mw}{kg}$	Significant increase in malignant tumors
$31.7 \frac{mw}{kg}$	Decreased appetite (eating and drinking)
$31.7 \frac{mw}{kg}$	The fragmentation of single and double strands of DNA from radiation

1.2 and 0.6 $\frac{w}{kg}$	Changes in brain due to mobile phone radiation
2.1-0.021 $\frac{mw}{kg}$	Changes in cell cycle and cell proliferation caused by mobile phone waves

Effects of electromagnetic radiation on mammals

Many studies have focused on the potential biological effects of electromagnetic fields on human health. Human beings frequently use wildlife as biological indicators to detect changes in ecosystems and mammals are important components [34].

Scientific evidence suggests that exposure to electromagnetic fields for a long time may affect the function of the immune system through effects on biological processes [4]. A stressed immune system may be more prone to infectious, bacterial, viral and parasitic infections [35].

Balmori in 2009 studied the effect of pollution caused by electromagnetic waves of telephone antennas on wildlife. In his research, he pointed out that life is affected by two factors of gravity and electromagnetism that these two forces play an important role in the activities of living organisms. Electromagnetic radiation is a

form of environmental pollution which can damage wildlife and telephone towers located in their areas of life create damage such as reducing natural defenses, reproductive problems, and reducing beneficial territory through the destruction of their habitats in the long run [21].

Studies in Germany showed that grazing of cows near towers is likely to result in stillbirth, spontaneous abortion, defective embryos, behavioral problems, and general health problems, while the movement of cows away from these towers improved their immediate health. Moreover, exposure of cattle to magnetic fields can lead to a decrease in milk production and reproductive problems [36].

Recently, a significant increase was discovered in cerebellar red blood cells which lived in the farm near one of the transmitter devices which is indicative of a genotypic effect of exposure to radiation [5]. Therefore, impairment of the sheep immune system, reproductive and reproductive problems in dogs and cats, anxiety in rabbits,

early death of domestic animals such as hamster and pigs living near the base stations have been observed.

In a study conducted on a colony of free-tailed bat, the number of bats decreased when several towers were located at 80 meters from the colony [5]. The activity of the bat is significantly reduced in the habitats exposed to the electromagnetic field. Electromagnetic radiation can cause abusive behavioral responses in bats [34].

Tomashevskaya and Navakatikian described a complex set of experiments that the behavioral disorder of the mice due to electromagnetic radiation at a low power density of about 0.1 mW/cm^2 was observed [37]. Microwave radiation causes aggression in people and animals like dogs. Central nervous system irritability in apes is affected by areas concentrated on the cerebellum. During a survey, frequencies below 50 Hz affected the behavior of the monkey [30].

In another study, limit for cataract production in rabbit eye lenses has been specified for 100 minutes [38]. A study was conducted in Greece which reported a progressive decrease in some of the newborn babies exposed to radio frequencies. Rats that were exposed to radiation became sterile after 5 generations.

It seems that the exposure time to radio frequency radiation plays an important role in its specific effects. Alternate calling showed a stronger effect than consecutive calls [25].

The effects in mice including lower body weight, delayed bone formation, and lower liver and brain weight were observed in mother [3].

Reducing the radiation from electric and magnetic fields

Efforts to combat the effects of electromagnetic fields and to limit radiation from them as well as prevention of potential damage to these fields were done for the first time during world war II. Since then, activity has begun to control the magnetic fields and discover and organize their effects in most developed and developing countries.

The results confirm that the electric and magnetic fields have had a dramatic effect on all aspects of the existence of living organisms. A more serious action must be considered by relying on relevant standards to inform people in order to control themselves with ways to reduce radiation and presence in these fields. Observance of international regulations and standards and the adoption of safety procedures to maintain health and protection against these fields are

some of the ways to reduce the pollution and the negative effects of exposure to electric and magnetic fields.

By following and considering the following principles, which are based on international standards such as INIRC, ICNIRP, NIOSH, ANSI, ICRP [2], effective scientific and practical steps can be taken to reduce radiation and pollution caused by electric and magnetic fields. Therefore, the most important ways and principles are:

- Identification and selection of the shortest path between source and destination of power transmission
- Full and proper monitoring of the implementation of the principles of safety and protection against electromagnetic radiation
- Use of proper and warning signs on magnetic field production or consumption devices
- Informing appropriately in order to avoid situations and situations which are harmful for electromagnetic field manufacturers
- Determining the areas where the dose level of electromagnetic fields is high
- Non-presence in electromagnetic fields except in unnecessary cases

- Identifying areas where entry into them is unacceptable for the general public or staff
- Applying the principles of protection against electromagnetic fields at work
- Observance of the principle of protection for electric control room equipment and other places where staffing is required
- Reduction in the surface of the field in all cases as much as possible
- Prevention of personnel to enter areas where the intensity of the field is high
- Preventing the construction of residential areas in the area of high pressure lines
- Establishing standards for manufacturers and importers of electrical equipment and generators of electromagnetic fields
- The familiarity of all employees with the regulations and standards of protection against electromagnetic fields
- Training all employees in electricity distribution network in terms of the potential hazards of electromagnetic fields
- Defining the principles of safety and protection against electromagnetic fields in the workplace in such a way

that these principles are always available to all

- Paying attention to the instructions on how to use electrical equipment and devices
- Preventing the repair and service of electromagnetic field generators and devices by ordinary and non-occupants
- Replacement of safety equipment that has been provided
- Equipping power distribution stations with tools for electromagnetic fields
- Providing reasonable warnings to offer an environment free of electromagnetic field pollutions that has a very important role in causing neurological disorders and behavioral abnormalities
- Organizing informational education classes on the hazards of electromagnetic fields. Organizing training courses related to job skills.
- Observing and maintaining the appropriate distance from field generators
- Performing periodic tests for all staff dealing with electromagnetic fields
- The use appropriate barriers or shields to keep all room and field generators up to the amount of

received doses below the standard level

- The permanent display and examination of the intensity of electromagnetic fields in power stations and distribution networks
- Minimizing radiation time and presence of people in electromagnetic fields
- Observing the maximum distance from sources of electromagnetic fields in unnecessary cases

Alzheimer: concerns of the present age

Alois Alzheimer, German psychologist and neuropsychologist, discovered the disease from a 50-year-old woman named August Dieter in 1901 and she introduced the disease the same year after her death. Most of the present articles have reported the causes of the disease. The effects of this disease are a sharp decrease in neurons in the brain and a decrease in synapse and also the creation of braided neurofibrils is one of the symptoms.

Symptoms of this disease are memory impairment, speech impairment and orientation, and problems in computing and behavior change. Imaging techniques include PET scan, MRI [39]. The disease begins at age 65 with symptoms and the prevalence is doubled every 5 years. The overall

prevalence is 2%. Alzheimer's disease is a progressive neurodegenerative disease and is one of the biggest causes of disorder which ultimately reduces memory and cognitive function.

The involvement of immune cells and the destruction of inner cells as well as the creation of malicious congestion called beta-amyloid and squeaky neurofibrils that the amyloids are created outside the cell, but neurofibrils are formed inside the cell. Most of these destructive tricks have been in the hippocampus and the amygdala. In general, all of these factors make behaviors unusual in behavior and disrupt various processes such as account, judgment, and memory which cause a problem in the patient social relationships [40].

The destructive function of microglia, antibodies, insulin, leptin, amylin, deficiency of fat soluble vitamins, fatty liver, ammonia vapor [41,42] are the causes of the disease. However, the most important causes from the viewpoint of researchers are the same two factors mentioned above.

The method of stem cells in this age is one of the new and innovative methods that has planted stem cells in a part of the brain and cause these cells to be transformed into neuronal cells, and they will be replaced in

places where neuronal cells are destroyed. This method is also very much appreciated and is looking forward to finding the right direction to treat Alzheimer [43].

One of the ways that has just been discussed in terms of outcome is the use of ultrasound waves which stimulates microglia by concentrating these waves on different tissues of the brain and they accelerate the process of decomposition of amyloid congestions. The method is based on the concentration of ultrasound waves on a part of the brain which ultimately stimulates the microglial lysosomes of the hippocampus region and this eventually leads to the decomposition and destruction of the amyloid digestive congestions. Approximately 75% of the amyloid congestions in the targeted areas are destroyed and the cognitive and behavioral performance of the experimental mice is improved in the tests. One of the most important points of this method is the occurrence and absence of inflammatory activity of microglia. This action leads to a better conclusion on the safety of macroglia.

In general, microgliaes did not exhibit any visible change. There was also no difference between the microglia of the control group and the test group in terms of size. All of

these factors have proven to be the result of this methodology.

CONCLUSION

The rapid development of science and technology has put different creatures under the radiation of a wide range of electromagnetic fields in the modern world. While the speed of electromagnetic waves has grown enormously and a significant number of people in the community deal with magnetic fields with higher intensity than usual in terms of working conditions or location of residence. Thus, determining the rules and regulations necessary to maintain the safety and health is one of the issues that should be considered in the relationship between the individual conditions, because the effects of carcinogenicity of magnetic fields on residents around power plants and power transmission lines have been established. These fields are not only felt vaguely, but they are felt in the form of severe buzzing of the ear, dizziness, changes in heart rate, intensified breathing, and annoying nervous stimuli. Due to the effects of these fields, the powerful balance of the nervous system and hormones will be weakened and activity of enzymes, cell division, neural conduction, blood and neoplasm, endocrine and metabolism, and even the function and

structure of the genital organ, especially gonads and sexual cells which are the site of genetic damage, may be influenced by this process.

However, according to studies and results obtained in the effects and hazards of magnetic fields on biological tissues of the human body, we can conclude that the risks of magnetic fields have become increasingly important in human and community health. Consequently, presence in magnetic fields is inevitable, it seems that practically effective scientific steps can be taken to increase public awareness, informing the practitioners, experts and drawing attention of the authorities in the field of environmental prevention management and reduction of illnesses, as well as reduction of the effects of magnetic fields on human health through the continuation of research and applied research about the effects and hazards of magnetic fields by the relevant organizations and centers, as well as the application and follow-up of coping strategies and emission reduction due to electromagnetic fields. It is hoped that we can see effective risks and challenges posed by magnetic fields with the use of new and up-to-date research and technologies, the principles and regulations of safety along with international standards.

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