

# Biological Effects of ELF on human body cells

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**Abstract**— Extremely low frequency electromagnetic radiation has received considerable attention recently as a possible threat to the health of persons living near high tension electric power lines, distribution substations, and even in close proximity to common household electric appliances. Results of epidemiological and laboratory research are examined to assess risks associated with magnetic fields generated by extremely low frequency electromagnetic sources. Health risks associated with such fields include a wide variety of ills ranging from disruption of normal circadian rhythms to childhood cancers. Risk assessment has been particularly difficult to determine in light of an ostensible lack of a dose-response relationship. Current media sensation fueled in part by an equivocal position adopted by the United States Environmental Protection Agency has contributed to the controversy. Recommendations for prudent avoidance of possible dangers are presented along with policy implications concerning health risks associated with magnetic fields.

**Index Terms**— electromagnetic radiation, ELF, biological effects, magnetic field, biochemical reaction, epidemiological, radiowaves.

## 1 INTRODUCTION

The Exposure to electromagnetic fields is not a new phenomenon. However, during the 20th century, environmental exposure to man-made electromagnetic fields has been steadily increasing as growing electricity demand, ever-advancing technologies and changes in social behaviour have created more and more artificial sources. Everyone is exposed to a complex mix of weak electric and magnetic fields, both at home and at work, from the generation and transmission of electricity, domestic appliances and industrial equipment, to telecommunications and broadcasting.

Tiny electrical currents exist in the human body due to the chemical reactions that occur as part of the normal bodily functions, even in the absence of external electric fields. For example, nerves relay signals by transmitting electric impulses. Most biochemical reactions from digestion to brain activities go along with the rearrangement of charged particles. Even the heart is electrically active - an activity that your doctor can trace with the help of an electrocardiogram.

Low-frequency electric fields influence the human body just as they influence any other material made up of charged particles. When electric fields act on conductive materials, they influence the distribution of electric charges at their surface. They cause current to flow through the body to the ground. Low-frequency magnetic fields induce circulating currents within the human body. The strength of these currents depends on the intensity of the outside magnetic field. If sufficiently large, these currents could cause stimulation of nerves and muscles or affect other biological processes.

Heating is the main biological effect of the electromagnetic fields of radiofrequency fields. In microwave ovens this fact is employed to warm up food. The levels of radiofrequency

The heating effect of radiowaves forms the underlying basis for current guidelines. Scientists are also investigating the possibility that effects below the threshold level for body heating occur as a result of long-term exposure. To date, no adverse health effects from low level, long-term exposure to radiofrequency or power frequency fields have been confirmed, but scientists are actively continuing to research this area.

## 2 BIOLOGICAL EFFECTS

Biological effects are measurable responses to a stimulus or to a change in the environment. These changes are not necessarily harmful to your health. For example, listening to music, reading a book, eating an apple or playing tennis will produce a range of biological effects. Nevertheless, none of these activities is expected to cause health effects. The body has sophisticated mechanisms to adjust to the many and varied influences we encounter in our environment. Ongoing change forms a normal part of our lives. But, of course, the body does not possess adequate compensation mechanisms for all biological effects. Changes that are irreversible and stress the system for long periods of time may constitute a health hazard.

An adverse health effect causes detectable impairment of the health of the exposed individual or of his or her offspring; a biological effect, on the other hand, may or may not result in an adverse health effect.

It is not disputed that electromagnetic fields above certain levels can trigger biological effects. Experiments with healthy volunteers indicate that short-term exposure at the levels present in the environment or in the home do not cause any apparent detrimental effects. Exposures to higher levels that might be harmful are restricted by national and international guidelines. The current debate is centred on whether long-term low level exposure can evoke biological responses and influence people's well being.

A look at the news headlines of recent years allows some insight into the various areas of public concern. Over the course of the past decade, numerous electromagnetic field sources have become the focus of health concerns, including power lines, microwave ovens, computer and TV screens, se-

fields to which people are normally exposed are very much lower than those needed to produce significant heating.

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curity devices, radars and most recently mobile phones and their base stations.

In response to growing public health concerns over possible health effects from exposure to an ever increasing number and diversity of electromagnetic field sources, in 1996 the World Health Organization (WHO) launched a large, multidisciplinary research effort. The International EMF Project brings together current knowledge and available resources of key international and national agencies and scientific institutions.

### 3 EFFECTS ON PREGNANCY

Many different sources and exposures to electromagnetic fields in the living and working environment, including computer screens, water beds and electric blankets, radiofrequency welding machines, diathermy equipment and radar, have been evaluated by the WHO and other organizations. The overall weight of evidence shows that exposure to fields at typical environmental levels does not increase the risk of any adverse outcome such as spontaneous abortions, malformations, low birth weight, and congenital diseases. There have been occasional reports of associations between health problems and presumed exposure to electromagnetic fields, such as reports of prematurity and low birth weight in children of workers in the electronics industry, but these have not been regarded by the scientific community as being necessarily caused by the field exposures (as opposed to factors such as exposure to solvents).

Some members of the public have attributed a diffuse collection of symptoms to low levels of exposure to electromagnetic fields at home. Reported symptoms include headaches, anxiety, suicide and depression, nausea, fatigue and loss of libido. To date, scientific evidence does not support a link between these symptoms and exposure to electromagnetic fields. At least some of these health problems may be caused by noise or other factors in the environment or by anxiety related to the presence of new technologies.

### 4 ELECTROMAGNETIC FIELDS AND CANCER

Despite many studies, the evidence for any effect remains highly controversial. However, it is clear that if electromagnetic fields do have an effect on cancer, then any increase in risk will be extremely small. The results to date contain many inconsistencies, but no large increases in risk have been found for any cancer in children or adults.

A number of epidemiological studies suggest small increases in risk of childhood leukemia with exposure to low frequency magnetic fields in the home. However, scientists have not generally concluded that these results indicate a cause-effect relation between exposure to the fields and disease (as opposed to artifacts in the study or effects unrelated to field exposure). In part, this conclusion has been reached because animal and laboratory studies fail to demonstrate any reproducible effects that are consistent with the hypothesis that fields cause or promote cancer. Large-scale studies are currently underway in several countries and may help resolve these issues.

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### 5 ELECTROMAGNETIC HYPERSENSITIVITY AND DEPRESSION

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The electromagnetic spectrum includes forms of energy ranging from cosmic rays and X-rays on the high frequency side to microwaves and electricity on the low frequency end [2] Hertz (Hz) is the term commonly used to describe frequency or the number of times per second that electromagnetic waves alternate. Extremely high frequency radiation such as X-rays and gamma rays are referred to as ionizing and are able to disrupt matter by stripping electrons from atoms. The current controversy focuses on the opposite end of the electromagnetic spectrum, extremely low frequency radiation (ELF).

ELF, which is defined as frequencies below 300 Hz, includes 60 Hz fields found in household electricity which had not been considered hazardous to health until the early 1970s. These fields are non-ionizing; they are too weak to disrupt molecular bonds leading to genetic damage in living cells. They are not capable of generating significant amounts of heat like microwaves or radar.[3],[4] Electric fields are directly related to the level of voltage, while magnetic fields are produced by the movement of the charge.(2) Both types of fields are produced by electric transmission and distribution lines

and the vast array of electric appliances ubiquitous in modern society.

The strength of electric fields is directly related to voltage, the higher the voltage, the stronger the electric field. Electric fields are easily blocked by normal building materials from which houses are constructed. Their strength decreases rapidly with distance from the source. The current controversy focuses not on electric fields but on magnetic fields which produce a series of force waves in concentric loops around electric currents.

## 6 EPIDEMIOLOGICAL EVIDENCE

An ideal study to determine the health impacts of electromagnetic radiation would have several characteristics. First, it would include a process for identifying the dosage, including both amount and intensity of exposure. Second, it would control for other exposures to potential illness risk factors such as chemical carcinogens or occupational exposures to electromagnetic radiation. It would follow a sufficient number of cases to allow for considerable statistical power. If it were a cohort study, it would have to follow an extremely large cohort for a sufficient period of time to allow for the development of malignancies potentially associated with electromagnetic radiation. Because of practical, real world considerations, none of the studies completed so far on electromagnetic radiation have met these criteria.

It is difficult, if not impossible, to determine the exposure received by any individual, since magnetic fields vary according to electric usage during different times of day and seasons of the year. Instead, most studies have substituted configuration of wires near the study site as a proxy measure. The accuracy of this measure is particularly suspect in studies of patients from three decades earlier. The low number of childhood cancer patients does not allow many studies, even those which indicate positive findings, to reach statistical significance. Finally, most of the epidemiological studies, to date, have used case control or retrospective cohort formats; no prospective cohort study has been attempted.

In a recent editorial, Monson [7] noted significant limitations associated with the case control format often including the absence of actual measures of electromagnetic fields (EMF) or empirical assessments of exposure to secondary sources of EMF, and biased reporting or incomplete histories related to self-reports of exposure. Retrospective cohort designs, while less likely to suffer from recall bias, still do not adequately address the problem of providing actual measures of EMF exposure. Monson concluded there was a need for prospective cohort studies to examine the relationships between EMF and adverse health effects.

A chance observation in 1974 by Wertheimer led to an intense investigation of possible health effects associated with electromagnetic radiation generated by 60 Hz power lines. Wertheimer was investigating clustering among addresses of childhood leukemia deaths in Denver when she noticed that a large number of the victims' homes had been located near electrical transformers and distribution substations. This prompted the first of several epidemiological investigations into the possible association between residential electromag-

netic field exposure and the occurrence of childhood cancers.

Wertheimer and Leeper conducted a case-control study of 344 children who had died of childhood cancer in Colorado between 1950 and 1973.(8) Proximity to electric distribution lines was assessed and elevated cancer risks were indicated for residents of higher exposure dwellings. A dose response relationship was noted with greatest risk associated with length of residence in high exposure homes. Compared to children from low exposure homes, those dwelling in high exposure environments were two to three times as likely to have developed leukemias, lymphomas, or cancers of the central nervous system.

This study suffered from several weaknesses including the difficulty of accurately assessing exposure levels, since magnetic fields vary greatly with the levels of electric power usage and with distance from their source and may be produced by a variety of electric appliances within the home. Risk assessment was based on an electric distribution wire coding scheme assigned by the researchers without any type of blinding. Power line configurations proved, in later studies, not to be strongly correlated with magnetic field strength. In the Wertheimer study, actual magnetic field measurements were never conducted within the homes.

Several studies have attempted to replicate Wertheimer and Leeper's results. Six additional case control studies have been performed examining the association between magnetic fields in homes of persons diagnosed with cancer compared to controls without cancer. The results have been mixed and inconclusive. Two studies found no increased risk for cancer related to magnetic fields.[11]. Three studies found an increased risk that did not reach statistical significance. The best designed study was conducted by Savitz, Wachtel, Barnes, John, and Tvrdik in Denver. These researchers studied a different group of children diagnosed with cancer than those examined by Wertheimer and Leeper in their original study. Exposure levels were assessed using wire configuration codes and magnetic field measurements within homes wherever possible. Results from this study, though not statistically significant, confirmed Wertheimer and Leeper's findings. Savitz and colleagues estimated that children from high exposure homes were 1.5 times more likely to develop cancer than were children from low exposure homes, a lower chance than that posited by Wertheimer and Leeper. It has been noted that as the rigor of these studies has increased the relative risks for cancer have tended to decrease.

Several case control studies have been published recently reporting on the association between electric appliances (primarily electric blankets) in the home and risk for a variety of cancers. Verreault et al found little or no risk for testicular cancer related to the use of electric blankets. Savitz et al reported a weak, positive association between both prenatal and postnatal exposure to electric blankets and childhood cancers. These researchers felt their results warranted further study on the effects of magnetic field exposure produced by electric appliances. Vera et al.(19) found that electric blanket use was not generally associated with an increased risk for postmenopausal breast cancer. They also suggested a need for further research based on their finding that the most frequent users of electric blankets had slightly increased risks for breast cancer.



Researchers in all three studies advised caution in interpreting results due to the absence of actual EMF measurements for which self-report levels of exposure had been substituted.

Over two dozen studies have examined the effects of occupational exposure to electromagnetic fields on the development of a variety of cancers, primarily leukemias. Eighteen studies have indicated a significant increased risk of leukemia, while 11 have shown an association with brain tumors. As the experimental designs for occupational studies have grown more rigorous controlling for other carcinogenic risk factors such as chemical exposures, the relative risks for cancers associated only with electromagnetic fields have decreased.

## 7 OTHER HEALTH HAZARDS

Both animal and human studies on the effects of ELF electromagnetic fields have shown a decrease in the secretion of pineal melatonin, a hormone which stimulates the daily cycle of sleep and wakefulness, the circadian rhythm. Research on the effects of electromagnetic fields on reproduction have produced mixed and equivocal results. Studies of chicken eggs and miniature swine have indicated slight possibilities of abnormal development, while other studies have shown no measurable effects.

Wertheimer and Leeper examined the relationship between the use of electric blankets or electrically heated water beds and pregnancy outcomes and found increased levels of miscarriage, birth defects, and low birthweights in those pregnancies where the mothers used the electrical appliances. A variety of methodological problems including small sample size and the possibility that elevated temperature. Fulton, JP, Cobb, S, Preble, et al. Electrical wiring configurations and childhood leukemia in Rhode Island. *American J Epid*, 111:292-296, 1980. e was the etiological agent have interfered with extrapolation from these data.

## 8 CONCLUSION

The current media attention related to extremely low frequency magnetic fields has produced a mixture of beneficial and detrimental effects. The Environmental Protection Agency fueled the controversy by equivocating on whether to declare electromagnetic fields carcinogenic; EPA has even been accused of deliberately impeding the release of data fearing that the public might misinterpret EPA reports. Many popular magazines and local television news reports have focused attention on the potential health hazards associated with electromagnetic fields. Some reports have not been balanced presentations of research findings. The typical scenario involves elementary schools in the shadow of high voltage transmission lines. Paul Brodeur's book, *Currents of Death: Power Lines, Computer Terminals, & the Attempt to Cover Up Their Threat to Your Health*, purports to chronicle the dangers associated with electromagnetic fields and to describe

an alleged cover-up by the electric utility industry. Like so many popular media health related messages, there is a basic core of facts embedded in an alarmist package which tends to generate hysteria among the public.

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