Media centre

Electromagnetic fields and public health: mobile phones

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Key facts

- Mobile phone use is ubiquitous with an estimated 6.9 billion subscriptions globally.
- The electromagnetic fields produced by mobile phones are classified by the International Agency for Research on Cancer as possibly carcinogenic to humans.
- Studies are ongoing to more fully assess potential long-term effects of mobile phone use.
- WHO will conduct a formal risk assessment of all studied health outcomes from radiofrequency fields exposure by 2016.

Mobile or cellular phones are now an integral part of modern telecommunications. In many countries, over half the population use mobile phones and the market is growing rapidly. In 2014, there is an estimated 6.9 billion subscriptions globally. In some parts of the world, mobile phones are the most reliable or the only phones available.

Given the large number of mobile phone users, it is important to investigate, understand and monitor any potential public health impact.

Mobile phones communicate by transmitting radio waves through a network of fixed antennas called base stations. Radiofrequency waves are electromagnetic fields, and unlike ionizing radiation such as X-rays or gamma rays, can neither break chemical bonds nor cause ionization in the human body.

Exposure levels

Mobile phones are low-powered radiofrequency transmitters, operating at frequencies between 450 and 2700 MHz with peak powers in the range of 0.1 to 2 watts. The handset only transmits power when it is turned on. The power (and hence the radiofrequency exposure to a user) falls off rapidly with increasing distance from the handset. A person using a mobile phone 30–40 cm away from their body – for example when text messaging, accessing the Internet, or using a “hands free” device – will therefore have a much lower exposure to radiofrequency fields than someone holding the handset against their head.

In addition to using "hands-free" devices, which keep mobile phones away from the head and body during phone calls, exposure is also reduced by limiting the number and length of calls. Using the phone in areas of good reception also decreases exposure as it allows the phone to transmit at reduced power. The use of commercial devices for reducing radiofrequency field exposure has not been shown to be effective.

Mobile phones are often prohibited in hospitals and on airplanes, as the radiofrequency signals may interfere with certain electro-medical devices and navigation systems.

Are there any health effects?

A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use.

Short-term effects

Tissue heating is the principal mechanism of interaction between radiofrequency energy and the human body. At the frequencies used by mobile phones, most of the energy is absorbed by the skin and other superficial tissues, resulting in negligible temperature rise in the brain or any other organs of the body.

A number of studies have investigated the effects of radiofrequency fields on brain electrical activity, cognitive function, sleep, heart rate and blood pressure in volunteers. To date, research does not suggest any consistent evidence of adverse health effects from exposure to radiofrequency fields at levels below those that cause tissue heating. Further, research has not been able to provide support for a causal relationship between exposure to electromagnetic fields and self-reported symptoms, or “electromagnetic hypersensitivity”.

Long-term effects

Epidemiological research examining potential long-term risks from radiofrequency exposure has mostly looked for an association between brain tumours and mobile phone use. However, because many cancers are not detectable until many years after the interactions that led to the tumour, and since mobile phones were not widely used until the early 1990s, epidemiological studies at present can only assess those cancers that become evident within shorter time periods. However, results of animal studies consistently show no increased cancer risk for long-term exposure to radiofrequency fields.

Several large multinational epidemiological studies have been completed or are ongoing, including case-control studies and prospective cohort studies examining a number of health endpoints in adults. The largest retrospective case-control study to date on adults, Interphone, coordinated by the International Agency for Research on Cancer (IARC), was designed to determine whether there are links between use of mobile phones and head and neck cancers in adults.

The international pooled analysis of data gathered from 13 participating countries found no increased risk of glioma or meningioma with mobile phone use of more than 10 years. There are some indications of an increased risk of glioma for those who reported the highest 10% of cumulative hours of cell phone use, although there was no consistent trend of increasing risk with greater duration of use. The researchers concluded that biases and errors limit the strength of these conclusions and prevent a causal interpretation.

Based largely on these data, IARC has classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B), a category used when a causal association is considered credible, but when chance, bias or confounding cannot be ruled out with reasonable confidence.

While an increased risk of brain tumors is not established, the increasing use of mobile phones and the lack of data for mobile phone use over time periods longer than 15 years warrant further research of mobile phone use and brain cancer risk. In particular, with the recent popularity of mobile phone use among younger people, and therefore a potentially longer lifetime of exposure, WHO has promoted further research on this group. Several studies investigating potential health effects in children and adolescents are underway.

Exposure limit guidelines

Radiofrequency exposure limits for mobile phone users are given in terms of Specific Absorption Rate (SAR) – the rate of radiofrequency energy absorption per unit mass of the body. Currently, two international bodies [1, 2] have developed exposure guidelines for workers and for the general public, except patients undergoing medical diagnosis or treatment. These guidelines are based on a detailed assessment of the available scientific evidence.

WHO'S response

In response to public and governmental concern, WHO established the International Electromagnetic Fields (EMF) Project in 1996 to assess the scientific evidence of possible adverse health effects from electromagnetic fields. WHO will conduct a formal risk assessment of all studied health outcomes from radiofrequency fields exposure by 2016. In addition, and as noted above, the International Agency for Research on Cancer (IARC), a WHO specialized agency, has reviewed the carcinogenic potential of radiofrequency fields, as from mobile phones in May 2011.

WHO also identifies and promotes research priorities for radiofrequency fields and health to fill gaps in knowledge through its research agendas.

WHO develops public information materials and promotes dialogue among scientists, governments, industry and the public to raise the level of understanding about potential adverse health risks of mobile phones.

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[1] International Commission on Non-Ionizing Radiation Protection (ICNIRP). *Statement on the "Guidelines for limiting exposure to time-varying electric, magnetic and electromagetic fields (up to 300 GHz)"*, 2009.

[2] Institute of Electrical and Electronics Engineers (IEEE). *IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz*, IEEE Std C95.1, 2005.

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Related link

Interphone study on mobile phone use and brain cancer risk [pdf 176kb]

The International Electromagnetic Fields Project

Electromagnetic fields: base stations and wireless technologies

Electromagnetic fields: electromagnetic hypersensitivity

WHO research agenda for electromagnetic fields

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ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH

The International EMF Project

Recent years have seen an unprecedented increase in the number and diversity of sources of electric and magnetic fields (**EMF**) used for individual, industrial and commercial purposes. Such sources include television, radio, computers, mobile cellular phones, microwave ovens, radars and equipment used in industry, medicine and commerce.

All these technologies have made our life richer and easier. Modern society is inconceivable without computers, television and radio. Mobile phones have greatly enhanced the ability of individuals to communicate with each other and have facilitated the dispatch of emergency medical and police aid to persons in both urban and rural environments. Radars make air travelling much safer.

At the same time, these technologies have brought with them concerns about possible health risks associated with their use. Such concerns have been raised about the safety of cellular mobile telephones, electric power lines and police speed-control "radar guns". Scientific reports have suggested that exposure to electromagnetic fields emitted from these devices could have adverse health effects, such as cancer, reduced fertility, memory loss, and adverse changes in the behaviour and development of children. However, the actual level of health risk is not known, although for certain types of EMF, at levels found in the community, it may be very low or non-existent.

There is also confusion about the biological effects of *non-ionizing* radiations (e.g radio waves, microwaves, etc.) versus *ionizing* radiations such as X-rays and gamma rays.

The conflict between concerns about possible health effects from exposure to EMF and the development of electricity supply and telecommunications facilities have led to considerable economic consequences. For example, electrical utilities in many countries have had to divert high voltage transmission lines around populated areas and even halt their construction. The installation of base stations for mobile telephone systems has been delayed or has met opposition from the public because of concerns that the RF emissions from these base stations might cause cancer in children. In the United States, for example, 85% of the total number of base stations needed have yet to be constructed.

Measures to significantly reduce electric and magnetic fields in the environment, below what is now commonly accepted, are costly. It has been estimated that concerns about EMF and health are now costing the United States economy alone some **US$1 billion** annually. However, if unacceptable health risks do occur, costly prevention measures will be required.

In May 1996, in response to growing public health concerns in many Member States over possible health effects from exposure to an ever-increasing number and diversity of EMF sources, the World Health Organization (WHO) launched an international project to assess health and environmental effects of exposure to electric and magnetic fields, which became known as **the International EMF Project**.

The International EMF Project brings together current knowledge and available resources of key international and national agencies and scientific institutions in order to arrive at scientifically-sound recommendations for health risk assessments of exposure to **static** and **time varying electric** and **magnetic fields in the frequency range 0-300 GHz.** This range includes **static** (**O Hz**), **extremely low frequency** (**ELF, >0 - 300 Hz**), **intermediate frequencies** (**IF, 300 Hz - 10 MHz**) and **radio-frequency fields** (**RF, 10 MHz - 300 GHz**).

This Project has been devised to provide authoritative and independent peer-review of the scientific literature, and identify and fill gaps in scientific knowledge by establishing protocols for the conduct of research using compatible and comparable methodologies, and by encouraging more focused research that should lead to better health risk assessments in the EMF domain. The International EMF Project:

- reviews the scientific literature on biological effects of EMF exposure;
- identifies gaps in knowledge requiring research that will improve health risk assessments;
- encourages a focused agenda of high quality EMF research;
- formally assesses health risks of EMF exposure after the required research is completed;
- encourages internationally acceptable uniform standards;
- provides information on risk perception, risk communication, risk management; and,
- advises national programmes and non-governmental institutions.

An **International Advisory Committee** (**IAC**), consisting of representatives of international organizations, independent scientific institutions and national governments supporting the Project, provides oversight. All activities are coordinated and facilitated by the WHO Secretariat.

International organizations supporting and participating in the Project include (in alphabetical order): European Commission (**EC**); International Agency for Research on Cancer (**IARC**); International Commission on Non-Ionizing Radiation Protection (**ICNIRP**); International Electrotechnical Commission (**IEC**); International Labour Office (**ILO**); International Telecommunication Union (**ITU**); North Atlantic Treaty Organization (**NATO**) and United Nations Environment Programme (**UNEP**).

The scientific work is conducted by **ICNIRP** and independent **WHO scientific collaborating institutions**, including National Radiological Protection Board (UK), Bundesamt für Strahlenschutz (Germany), Karolinska Institute (Sweden), Food and Drug Administration (USA), National Institute of Environmental Health Sciences (USA), National Institute of Occupational Safety and Health (USA), National Institute for Environment Studies (Japan).

Over 40 national governments have contributed to or are interested in the activities of the Project.

Scientific activities of the International EMF Project include review meetings to arrive at health risk assessments for various types of electromagnetic fields and their specific application. Independent expert groups, using accepted assessment criteria, review the literature on biological effects of EMF. These reviews are timed to allow needed research to be completed so that the results can be included in the publications on health risk assessments.

The International EMF Project will publish documents on risk perception, risk communication and risk management in order to improve communications among those concerned, including an increasingly sceptical public and workforce, about possible health risks of EMF exposure. For more information, see the Internet site of the International EMF Project at http://www.who.int/emf

As a result of the International EMF Project, a number of monographs are expected to be published by WHO in the Environmental Health Criteria series. They will address the health effects of exposure to RF, ELF and static fields, as well as risk perception, communication and management, and public and occupational health policy.

It is expected that the Project will facilitate the development of universally acceptable standards on limits of human exposure to EMF, standards on the measurement and compliance of EMF emissions for various devices, and a better understanding on how best to communicate information to the public and workers on possible risks from EMF exposure.

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ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH

Physical Properties and Effects on Biological Systems

Natural and many human-made sources generate electromagnetic energy in the form of electromagnetic waves. These waves consist of oscillating electric and magnetic fields which interact differently with **biological systems** such as cells, plants, animals, or human beings. In order to better understand these interactions, it is essential to be familiar with the physical properties of the waves which make up the electromagnetic spectrum.

Electromagnetic waves can be characterized by their **wavelength**, **frequency**, or **energy**. The three parameters are interrelated. Each influences the effect the field may have on a biological system.

- The **frequency** of an electromagnetic wave is simply the number of oscillations which passes a fixed point per unit of time. It is measured in cycles per second, or *hertz*. One cycle per second equals one **hertz** (**Hz**). Large divisions commonly used to describe radio frequency (RF) fields include the **kilohertz** (**kHz**), or one thousand cycles per second; the **megahertz** (**MHz**), one million cycles per second; and the **gigahertz** (**GHz**), one billion cycles per second.
- **The shorter the wavelength, the higher the frequency**. The middle of the AM broadcast band, for example, has a frequency of one million hertz (1 MHz) and a wavelength of about 300 metres. Microwave ovens use a frequency of 2.45 billion hertz (2.45 GHz) and a wavelength of 12 centimetres.
- An electromagnetic wave consists of very small packets of energy called **photons**. The energy in each packet or photon is directly proportional to the frequency of the wave: **The higher the frequency, the larger the amount of energy** in each photon.

How electromagnetic waves affect biological systems is determined partly by the intensity of the field and partly by the amount of energy in each photon.

Electromagnetic waves at low frequencies are referred to as **"electromagnetic fields"** and those at very high frequencies are called **"electromagnetic radiations"**. According to their frequency and energy, electromagnetic waves can be classified as either "**ionizing radiations**" or "**non-ionizing radiations**" (**NIR**).

- **Ionizing radiations** are extremely high frequency electromagnetic waves (X-rays and gamma rays), which have enough photon energy to produce **ionization** (create positive and negative electrically charged atoms or parts of molecules) by breaking the atomic bonds that hold molecules in cells together.
- **Non-ionizing radiations (NIR)** is a general term for that part of the electromagnetic spectrum which has photon energies too weak to break atomic bonds. They include **ultraviolet (UV) radiation, visible light, infrared radiation, radiofrequency** and **microwave fields, extremely low frequency (ELF) fields,** as well as **static electric and magnetic fields.**
- **Even high intensity NIR cannot cause ionization in a biological system.** NIR, however, have been shown to produce other biological effects, for instance, by

heating, altering chemical reactions or inducing electrical currents in tissues and cells.

Electromagnetic waves may produce **biological effects** which may **sometimes**, but **not always**, lead to **adverse health effects**. It is important to understand the difference between the two:

- **A biological effect** occurs when exposure to electromagnetic waves causes some noticeable or detectable physiological change in a biological system.
- **An adverse health effect** occurs when the biological effect is outside the normal range for the body to compensate, and thus leads to some detrimental health condition.

Some biological effects can be innocuous, such as the body's reaction of increasing blood flow in the skin in response to slightly greater heating from the sun. Some effects can be advantageous, such as the feeling of warmth of direct sunshine on a cool day, or can even lead to positive health effects, such as the sun's role in helping the body produce vitamin D. However, some biological effects lead to adverse health effects, such as the pain of sunburn or skin cancer.

The International EMF Project of the World Health Organization is addressing the health concerns raised about exposure to radiofrequency (RF) and microwave fields, intermediate frequencies (IF), extremely low frequency (ELF) fields, and static electric and magnetic fields. These electromagnetic fields can produce different biological effects that may lead to health consequences.

Intermediate frequency (IF) and Radiofrequency (**RF**) **fields** are known to produce **heating and the induction of electrical currents.** Other less established biological effects have also been reported**.**

- **Fields** at frequencies **above** about **1 MHz** primarily cause **heating** by moving ions and water molecules through the medium in which they exist. Even very low levels of energy produce a small amount of heat, but this heat is carried away by the body's normal thermoregulatory processes without the person noticing it.
- A number of studies at these frequencies suggest that **exposure to fields too weak to cause heating** may have adverse health consequences, including cancer and memory loss. Identifying and encouraging coordinated research into these open questions is one of the major objectives of the **International EMF Project.**
- **Fields** at frequencies **below about 1 MHz** primarily induce electrical charges and currents which can stimulate cells in tissues such as nerves and muscles. Electrical currents already exist in the body as a normal part of the chemical reactions involved in living. If fields induce currents significantly exceeding this background level in the body, there is a possibility of adverse health consequences.

Extremely Low Frequency (**ELF) electric and magnetic fields.** The primary action in biological systems by these fields is the **induction of electrical charges and currents**. This mechanism of action is unlikely to explain the health effects, such as cancer in children, reported to occur from exposure to "environmental" levels of ELF fields.

- **ELF electric fields** exist whenever a charge (voltage) is present, regardless of whether any current is flowing. Almost none of the electric field penetrates into the human body. At very high field strengths they can be perceived by hair movement on the skin. However, some studies suggest that exposure to low levels of these fields is associated with an increased incidence of childhood cancer or other health consequences. Other studies do not. **The International EMF Project** is recommending that more focused research be conducted to improve health risk assessments.
- **ELF magnetic fields** exist whenever an electric current is flowing. They easily

penetrate the human body without any significant attenuation. Some epidemiological studies have reported associations between ELF fields and cancer, especially in children, but others have not. Research on effects of low-level (environmental) ELF fields is currently underway, including that monitored and encouraged by the **International EMF Project**.

Static electric and magnetic fields. While the primary action in biological systems by these fields is the **induction of electrical charges and currents**, other effects have been established to occur that could potentially lead to adverse health consequences, but only at very high field strengths.

- **Static electric fields** do not penetrate into the body, but can be perceived by skin hair movement. Except for electrical discharges from strong static electric fields, they do not seem to have significant health effects.
- **Static magnetic fields** have virtually the same strength inside the body as outside. Very intense static magnetic fields can alter blood flow or change normal nerve impulses. But such high field strengths are not found in everyday life. However, there is insufficient information about the effects of long-term exposure to static magnetic fields at levels found in the working environment.

Safety Standards: In order to ensure that human exposure to EMF should not have adverse health effects, that man-made EMF generating devices are safe and their use does not electrically interfere with other devices, various international guidelines and standards are adopted. Such standards are developed following reviews of all the scientific literature by groups of scientists who look for evidence of consistently reproduced effects with adverse health consequences. These groups then recommend guidelines for standards for action by the appropriate national and international bodies. A non-governmental organization, formally recognised by WHO in the field of NIR protection, is the **International Commission on Non-Ionizing Radiation Protection** (ICNIRP). **ICNIRP** has established international guidelines on human exposure limits for all electromagnetic fields, including ultraviolet (UV) radiation, visible light and infrared radiation, as well as RF fields and microwaves.

Electromagnetic waves are generated by natural, but mostly by human-made sources. Their spectrum includes both **ionizing** and **non-ionizing radiations** (**NIR**).

Ionizing radiations (X-rays and gamma rays) have enough energy to create positive and negative electrically charged atoms or parts of molecules by breaking the atomic bonds that hold molecules in cells together. This effect is called **ionization**.

Even high intensity **NIR cannot cause ionization** in the biological system. NIR, however, have been shown to produce other biological effects, for instance, by heating, altering normal chemical reactions or inducing electrical currents in tissues.

The International EMF Project of the World Health Organization deals with the health effects of **static**, **extremely low frequency** (**ELF**), **intermediate frequencies (IF)** and **radiofrequency** (**RF**) **electromagnetic fields** (**0-300 GHz**).

Electromagnetic waves of different frequencies interact differently with **biological systems,** such as cells, plants, animals, or human beings. The extent they affect biological systems depends partly on their **intensity** and partly on the **amount of energy in photons.**

Biological effects produced by electromagnetic waves may sometimes, but **not always, lead to adverse health effects**.

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ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH

Health Effects of Radiofrequency Fields

This Fact Sheet is based on the Environmental Health Criteria 137 "Electromagnetic Fields (300 Hz to 300 GHz), World Health Organization, Geneva, 1993, and the report of the Scientific Review under the auspices of the International EMF Project of the World Health Organization, Munich, Germany, November 1996.

Radiofrequency (**RF**) **fields** are part of the electromagnetic spectrum. For the purpose of the International EMF Project, such fields are defined as those within the frequency range **10 MHz** (or 10 000 kHz) and **300 GHz**. Natural and human-made sources generate RF fields of different frequency.

Common sources of RF fields include: FM radio (30 - 300 MHz), mobile telephones, television broadcast, microwave ovens, medical diathermy (0.3 - 3 GHz), radar, satellite links, microwave communications (3 -30 GHz) and the sun (3 -300 GHz).

RF fields are **non-ionizing radiations** (**NIR**). Unlike X-rays and gamma rays, they are much too weak to break the bonds that hold molecules in cells together and, therefore, produce ionization. RF fields may, however, produce different effects on biological systems such as cells, plants, animals, or human beings. These effects depend on **frequency** and **intensity** of the RF field. By no means, will all of these effects result in adverse health effects.

RF fields above 10 GHz are absorbed at the skin surface, with very little of the energy penetrating into the underlying tissues.

- The basic dosimetric quantity for RF fields above 10 GHz is the **intensity** of the field measured as **power density** in watts per square metre (**W/m^2**) or for weak fields in milliwatts per square metre (**mW/m^2**) or microwatts per square metre (m**W/m^2**).
- For adverse health effects, such as eye cataracts and skin burns, to occur from exposure to RF fields above 10 GHz, power densities **above 1000 W/m^2** are needed. Such densities are not found in everyday life. They do exist in very close proximity to powerful radars. Current exposure standards preclude human presence in this areas.

RF fields between 10 MHz and 10 GHz penetrate exposed tissues and produce **heating** due to **energy absorption** in these tissues. The depth of penetration of the RF field into the tissue depends on the frequency of the field and is greater for lower frequencies.

- **Energy absorption** from RF fields in tissues is measured as a **specific absorption rate** (**SAR**) within a given tissue mass. The unit of **SAR** is **watts per kilogram** (**W/kg**). **SAR** is the basic dosimetric quantity for RF fields **between about 1 MHz and 10 GHz**.

- An **SAR** of at least **4 W/kg** is needed to produce adverse health effects in people exposed to RF fields in this frequency range. Such energies are found tens of meters away from powerful FM antennas at the top of high towers, which makes these areas inaccessible.
- **Most adverse health effects** that could occur from exposure to RF fields between 1 MHz and 10 GHz are consistent with responses to **induced heating**, resulting in rises in tissue or body temperatures **higher than 1C**.
- **Induced heating** in body tissues may provoke various **physiological** and **thermoregulatory responses**, including a decreased ability to perform mental or physical tasks as body temperature increases. Similar effects have been reported in people subject to heat stress: for example, those working in hot environments or suffering a prolonged fever.
- Induced heating may affect **the development of a fetus. Birth defects** would occur only if the temperature of the fetus is raised by **2-3C** for hours. Induced heating can also affect **male fertility** and lead to the induction of **eye opacities** (cataracts).
- **It is important to emphasize that most RF studies conducted at frequencies exceeding 1 MHz, examined the results of acute exposure to high levels of RF fields - an exposure that is not normally found in everyday life.**

Other effects on the body from exposure to **low-intensity RF fields**, present in the living environment, have been reported. But, either they have not been confirmed by other laboratory studies, or their health implications are unknown. However, these studies have raised important health concerns about an increased risk of cancer. It is for this reason that they are being monitored and evaluated under the **International EMF Project**.

Exposure to RF fields and cancer: Current scientific evidence indicates that exposure to RF fields is unlikely to induce or promote cancers.

- **Cancer studies using animals have not provided convincing evidence for an effect on tumour incidence.** A recent study found that RF fields, similar to those used in mobile telecommunications, increased the incidence of cancer among genetically engineered mice that were exposed near (0.65m) an RF transmitting antenna. Further studies will be carried out to determine the relevance of these results to cancer in human beings.
- Many epidemiological (**human health**) studies have addressed possible links between exposure to RF fields and excess risk of cancer. To date these studies do not provide enough information to allow a proper evaluation of human cancer risk from RF exposure because the results of these studies are inconsistent. This can be explained by differences in the design, execution and interpretation of these studies, including the identification of populations with substantial RF exposure and retrospective assessment of such exposure. The International EMF Project is encouraging coordinated research in this area.

Exposure to low-levels of RF fields, too low to produce heating, has been reported to alter the electrical activity of the brain in cats and rabbits by changing calcium ion mobility. This effect has also been reported in isolated tissues and cells. Other studies have suggested that RF fields change the proliferation rate of cells, alter enzyme activity or affect the genes in the DNA of cells. However, these effects are not well established, nor are their implications for human health sufficiently well understood to provide a basis for restricting human exposure.

Electromagnetic interference and other effects: Mobile telephones, as well as many other electronic devices in common use, can cause electromagnetic interference in other electrical equipment. Therefore, caution should be exercised when using mobile telephones around sensitive electromedical equipment used in hospital intensive care units. Mobile telephones can, in rare instances, also cause interference in certain other medical devices, such as cardiac pacemakers and hearing aids. Individuals using such devices should contact their doctor to determine the susceptibility of their products to these effects.

RF fields from **natural sources** have very low power densities. RF intensity from **the sun** - the primary natural source - is **less than 0.01 mW/m^2**. **Human-made sources,** which emit the majority of RF fields found in the immediate environment, can be divided into those found in **the community, home, and workplace**:

- **Community**: Most RF fields found in the environment are due to commercial **radio** and **TV broadcasting**, and from **telecommunications facilities**. RF exposure from telecommunications facilities is generally less than from radio or TV broadcasting. A study conducted in the Unites States found that, **in large cities**, **the average background** RF levels were **about 50 μ W/m^2**. About 1% of people living in large cities are exposed to RF fields **exceeding 10 mW/m^2**. Higher RF field levels can occur in areas located close to transmitter sites or radar systems.
- **Home**: RF sources in the home include microwave ovens, mobile telephones, burglar alarms, video display units and TV sets. Microwave ovens that could potentially be the source of very high RF levels, are covered by product performance standards which limit the amount of microwave leakage. Overall, the RF field background from household appliances is low, and of the order of **a few tens of μ W/m^2**.
- **Workplace**: Relatively high levels of exposure to RF fields can occur to workers in the **broadcasting**, **transport** and **communications industries** when they work **in close proximity** to RF transmitting antennas and radar systems. An important subset of these workers are **military personnel**. Stringent regulations controlling the civil and military use of RF fields exist in most countries.

Safety Standards: To ensure that devices emitting RF are safe and their use does not interfere with other devices, international standards are adopted. Exposure limits for RF fields have been developed by the **International Commission on Non-Ionizing Radiation Protection** (**ICNIRP**) - a nongovernmental organization formally recognized by WHO. ICNIRP guidelines were developed following reviews of all the peer-reviewed scientific literature, including thermal and non-thermal effects. **The RF field limits are well above the levels found in the living environment**. The standards are based on evaluations of biological effects that have been established to have health consequences. The objective of the International EMF Project is to determine if the biological effects reported from exposure to RF fields at low levels have any adverse health consequences. If such consequences were found, this may result in a reevaluation of the limits of human exposure.

Exposure to RF fields may cause **heating** in body tissues. Heating is the primary interaction of RF fields at high frequencies, above about 10 MHz.

A scientific review by WHO, held under the International EMF Project (Munich, November, 1996), concluded that, **from the current scientific literature**, **there is no convincing evidence that exposure to RF shortens the life span of humans, induces or promotes cancer**.

However, the same review also stressed that **further studies are needed to draw a more complete picture of health risks, especially about possible cancer risk from exposure to low-levels of RF exposure**.

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ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH

PUBLIC PERCEPTION OF EMF RISKS

Technological progress in the broadest sense of the word has always been associated with various hazards and risks, both perceived and real. The industrial, commercial and household application of electromagnetic fields (EMF) is no exception.

Throughout the world, the general public is concerned that exposure to EMF from such sources as high voltage power lines, radars, mobile telephones and their base stations could lead to adverse health consequences, especially in children. As a result, the construction of new power lines and mobile telephone networks has met with considerable opposition in some countries.

In response to these public concerns shared by many governments, the World Health Organization (WHO) has established the International EMF Project to evaluate the biological effects and assess possible health risks from EMF exposure. Over 40 countries and 6 international organizations are currently involved in the Project.

Recent history has shown that lack of knowledge about health consequences of technological advances may not be the sole reason for social opposition to innovations. Disregard for differences in risk perception that are not adequately reflected in communications among scientists, governments, industry and the public, is also to blame. It is for this reason that risk perception and risk communication in relation to EMF are also covered by the International EMF Project.

Health Hazard and Risk: In trying to understand people's perception of risk, it is important to distinguish between a health hazard and a health risk. A ***hazard*** can be an object or a set of circumstances that can potentially harm a person's health. ***Risk*** is the likelihood (or probability) that a person will be harmed by a particular hazard.

- **Every activity you can think of has an associated risk. Travelling may result in a car accident, or a plane or train crash. Staying at home may not protect you from an earthquake. Living in general is associated with many risks. There is no such thing as a zero risk.**
- **A car is a potential health hazard. Driving a car is a risk. The higher the speed, the more risky is the driving.**
- **The same is true for EMF-emitting sources. Under certain circumstances, EMF can be potentially hazardous, and the risk to a person's health depends on the level of exposure.**

Perception of risk: A number of factors influence a person's decision to take a risk or reject it. People usually perceive risks as negligible, acceptable, tolerable, or unacceptable, and compare them with the benefits, which should outweigh the risk by a significant margin. These perceptions can depend on people's age, sex, cultural and educational backgrounds.

- **Many young people, for example, find the risk of sky diving as acceptable. Many older people do not since they perceive it as too dangerous and,**

therefore, unacceptable.

The nature of the risk can lead to different perceptions. Surveys have found that the following pairs of characteristics of a situation generally affect risk perception. The first member of the pair tends to increase while the second one decreases the magnitude of the perceived risk:

- ***Involuntary vs. voluntary exposure.* This is an important factor in risk perception, especially for EMF-emitting sources. People who do not use mobile telephones perceive the risk as high from the relatively low radio-frequency (RF) fields emitted from mobile telephone base stations. However, mobile telephone users generally perceive as low the risk from the much more intense RF fields from their voluntarily-chosen handsets.**
- ***Lack of personal control vs. feeling of control over a situation.* If people do not have any say about installation of power lines and mobile telephone base stations, especially near their homes, schools or play areas, they tend to perceive the risk from such EMF facilities as being high.**
- ***Familiar vs. unfamiliar.* Familiarity with the situation, or a feeling of understanding of the technology, helps reduce the level of the perceived risk. The perceived risk increases when the situation or technology, such as the EMF technology, is new, unfamiliar, or hard-to-comprehend. Perception about the level of risk can be significantly increased if there is an incomplete scientific understanding about potential health effects from a particular situation or technology.**
- ***Dread vs. not dreaded*. Some diseases and health conditions, such as cancer, severe and lingering pain and disability, are more feared than others. Thus, even a small possibility of cancer, especially in children, from EMF exposure receives significant public attention.**
- ***Unfairness vs. fairness*. If people are exposed to RF fields from mobile telephone base stations, but do not have a mobile telephone, or if they are exposed to the electric and magnetic fields from a high voltage transmission line that does not provide power to their community, they consider it unfair and are less likely to accept any associated risk.**

In the case of people who do not own a mobile telephone, for example, exposure to RF fields from mobile telephone base stations may be perceived as a high risk for the following reasons:

- **People are faced with an involuntary exposure to RF fields;**
- **It is unfair because the installation of these base stations exposes the whole community to RF fields while only the few mobile telephone users benefit;**
- **There is a lack of control over expansion of such networks into communities;**
- **Mobile telephone technology is unfamiliar and incomprehensible to most people;**
- **There is insufficient scientific information to precisely assess health risks; and**
- **There is a likelihood that this technology could cause a dreaded disease such as cancer.**

Communities feel they have a right to know what is proposed and planned with respect to the construction of EMF facilities that might affect their health. They want to have some control and be part of the decision-making process.

Unless an effective system of public information and communications among scientists, governments, the industry and the public is established, new EMF technologies will be mistrusted and feared.

The development of EMF technologies should be matched by appropriate and coordinated research into their potential consequences for health. This is one of the most important objectives of the International EMF Project established by WHO.

For further information, please contact the Office of Press and Public Relations, WHO, Geneva. Telephone (41 22) 791 2599. Fax (41 22) 791 4858. Email: info@who.int

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Fact Sheet N201

July 1998

ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH

VIDEO DISPLAY UNITS (VDUs)

Over 30 years have passed since the introduction of mass-produced video display units (VDUs) into the workplace. These machines are also called video display terminals (VDTs) and most commonly take the form of computer screens. The rapid proliferation of computers has lead to a large increase in VDU use in both the workplace and at home. It is estimated that by the year 2000, 60% of the North American workforce will be using VDUs and more than 150 million units will be in service worldwide.

What are VDUs?

A VDU is essentially a television-type monitor that displays information received from a computer rather than from a broadcast signal for television. The typical VDU creates images in a large evacuated cathode-ray tube (CRT) by directing a beam of high-energy electrons from the cathode onto a special phosphor-coated, glass screen. This coating emits light when struck by the fast-moving electrons. The electron beam creates the image from computer signals that control coils, at the back of the CRT, that sweep the electrons in the vertical and horizontal directions. These coils are called vertical and horizontal deflection coils. The electronic circuitry used to create the image gives rise to static electric and magnetic fields, as well as low and high frequency electromagnetic fields.

Radiation and Fields

Almost the entire electromagnetic spectrum is included in the electric and magnetic fields and optical radiation produced by VDUs. The optical radiation emitted includes long-wavelength ultraviolet (UV), visible, and infrared (IR) radiation. Visible light forms the image that the VDU is intended to produce. IR appears as heat dissipated by the unit. Very small amounts of UV are emitted from the tube, much less than that coming through the window on a winter's day.

Electric and magnetic fields are emitted in three different frequency ranges. The horizontal deflection coils emit fields operating predominantly in the frequency range 15-35 kHz. Extremely low frequency (ELF) fields at 50 or 60 Hz come from the power supply, transformers and the vertical deflection coils. Finally, weak signals at higher radio frequencies (RF) come from the VDU's interior electronic circuitry and signals received from the computer.

Static electric fields are also present, particularly when there is low humidity, from the build-up of electric charge by electrons striking the front of the screen. In addition, high frequency sound or ultrasound radiation, possibly detected as a high pitch noise, is emitted from various VDU components, mostly by the horizontal deflection circuits.

Very low-energy X-rays are produced inside the CRT, but the glass screen is thick enough to completely absorb them before they escape from the VDU.

Health Concerns

When first introduced into the workplace, VDUs were suggested as the cause of many health complaints, for example, headaches, dizziness, tiredness, cataracts, adverse pregnancy outcomes and skin rashes. Many scientific studies were conducted to determine if electromagnetic fields (EMF) could have any health consequence. WHO and other agencies have reviewed factors, including indoor air quality, job-related stress and ergonomic issues, such as posture and seating while using a VDU. These studies (see below) have suggested that the work environment, and not EMF emissions from VDUs, may be a determining factor of possible health effects associated with VDU use. A brief review of the scientific findings follows:

Adverse Pregnancy outcomes

Suggestions that working with a VDU could affect the outcome of a pregnancy arose in the late 1970s, when several "clusters of adverse pregnancy outcomes" were noticed in Australia, Europe and North America. These clusters were groups of pregnant women who worked with VDUs and who seemed to experience an unusually high occurrence of spontaneous abortion ("miscarriage") or birth of malformed children. This led to many epidemiological and animal studies being conducted in North America and Europe. Taken as a whole, these studies have failed to demonstrate any effect on reproductive processes due to EMF emitted from VDUs. Studies have suggested, however, that if there are effects on reproduction, they may be related to other work factors, such as job stress.

Effects on the eye

Cataracts and other eye diseases were not found to have any link with VDU work. Glare and reflections from VDU screens have been identified as a source of eye strain and headaches in extreme circumstances.

Effects on the Skin

An excess of symptoms such as skin rashes or itching has been studied, particularly in Scandinavian countries. However, they could not link these symptoms to EMF emissions from VDUs. Laboratory tests conducted on people with these symptoms showed their symptoms were not a result of any EMF exposure.

Other Factors

Researchers have studied various factors related to the indoor work environment. These include indoor air quality, room temperature, eye fatigue caused by improper illumination, and ergonomically improper workstations. Some individuals have experienced headaches or dizziness, and musculo-skeletal discomfort. These are largely preventable if proper work environment and ergonomic measures are introduced for working with VDUs. Such measures include designing equipment, lighting and other aspects of the environment to encourage proper posture and to reduce muscular and eye strain and other stress-producing tensions.

The above conclusions are in agreement with reviews conduced by the International Commission on Non-Ionizing Radiation Protection *(ICNIRP),* the International Labour Office (ILO) and WHO.

Protective Measures

Fear of adverse health effects from EMF emitted by VDUs has led to a proliferation of products supposedly offering protection from any adverse effects of these fields and radiation. These include special aprons, screen shields or "radiation absorbing" devices for use with VDUs. These items have no protective effect whatsoever on VDU emissions. Even those that do reduce emissions are of no practical value, since the EMF fields and radiation are only a very small fraction of exposure limits permitted in national and international standards. Except for screens that reduce glare (causing eyestrain), protective devices are not recommended by WHO. Use of protective devices to reduce EMF emissions is also not recommended by the ILO.

Where Can I Find More Information?

WHO's International EMF Project has a home page with links to the WHO Fact Sheets on various aspects of EMF exposure and health. The home page also provides further information on the Project, publications and its scientific and public information activities. You can access the WHO EMF home page at: http://www.who.int/emf/.

The following references can provide a more in-depth treatment of this subject:

- *Visual Display Terminals and Workers' Health*, WHO Offset Publication No. 99, World Health Organization, Geneva 1987. (Gives particular attention to non-radiation induced disorders such as eyestrain and musculo-skeletal injuries.)
- *Electromagnetic Fields 300 Hz - 300 GHz*, WHO Environmental Health Criteria No. 137, World Health Organization, Geneva 1993. (Comprehensive review of the physics and biological effects of electromagnetic fields emitted by VDUs.)

Visual Display Units: Radiation Protection Guidance, Occupational Safety and Health Series No. 70, International Labour Office, Geneva, 1994. (Succinct, recent overview of the issues.)

- Matthes, R. editor: *Non-Ionizing Radiation: Proceedings of the Third International Non-Ionizing Radiation Workshop*, Baden, Austria, ICNIRP, 1996. (Contains a series of papers on NIR protection, including VDUs.)

For further information, please contact the Office of the Spokesperson, WHO, Geneva. Tel (+41 22) 791 2599, Fax (+41 22) 791 4858. Email: inf@who.int. All WHO Press Releases, Fact Sheets and Features as well as other information on this subject can be obtained on Internet on the WHO home page http://www.who.int/

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Electromagnetic fields and public health: extremely low frequency (ELF)

Everyone is exposed to a complex mix of electromagnetic fields (EMF) of different frequencies that permeate our environment. Exposures to many EMF frequencies are increasing significantly as technology advances unabated and new applications are found.

While the enormous benefits of using electricity in everyday life and health care are unquestioned, during the past 20 years the general public has become increasingly concerned about potential adverse health effects of exposure to electric and magnetic fields at extremely low frequencies (ELF). Such exposures arise mainly from the transmission and use of electrical energy at the power frequencies of 50/60 Hz.

The World Health Organization (WHO) is addressing the associated health issues through the International Electromagnetic Fields Project. Any health consequence needs to be clearly identified and appropriate mitigation steps taken if deemed necessary. Present research results are often contradictory. This adds to public concern, confusion and lack of confidence that supportable conclusions about safety can be reached.

The purpose of this Fact Sheet is to provide information about ELF field exposure and its possible impacts on health within the community and the workplace. Information comes from a WHO review of this subject and other recent reviews by eminent authorities.

ELF electric and magnetic fields

Electromagnetic fields consist of electric (E) and magnetic (H) waves travelling together, as shown in the diagram below. They travel at the speed of light and are characterised by a frequency and a wavelength. The frequency is simply the number of oscillations in the wave per unit time, measured in units of hertz (1 Hz = 1 cycle per second), and the wavelength is the distance travelled by the wave in one oscillation (or cycle).

ELF fields are defined as those having frequencies up to 300 Hz. At frequencies this low, the wavelengths in air are very long (6000 km at 50 Hz and 5000 km at 60 Hz), and, in practical situations, the electric and magnetic fields act independently of one another and are measured separately.

Electric fields arise from electric charges. They govern the motion of other charges situated in them. Their strength is measured in units of volt per metre, (V/m), or kilovolt per metre (kV/m). When charges accumulate on an object they create a tendency for like or opposite charges to be repelled or attracted, respectively. The strength of that tendency is characterised by the **voltage** and is measured in units of volt, (V). Any device connected to an electrical outlet, even if the device is not switched on, will have an associated electric field that is proportional to the voltage of the source to which it is connected. Electric fields are strongest close the device and diminish with distance. Common materials, such as wood and metal, shield against them.

Magnetic fields arise from the motion of electric charges, i.e. a **current.** They govern the motion of moving charges. Their strength is measured in units of ampere per metre, (A/m) but is usually expressed in terms of the corresponding magnetic induction measured in units of tesla, (T), millitesla (mT) or microtesla (μT). In some countries another unit called the gauss, (G), is commonly used for measuring magnetic induction (10,000 G = 1 T, 1 G = 100 μT, 1 mT = 10 G, 1 μT = 10 mG). Any device connected to an electrical outlet, when the device is switched on and a current is flowing, will have an associated magnetic field that is proportional to the current drawn from the source to which it is connected. Magnetic fields are strongest close to the device and diminish with distance. They are not shielded by most common materials, and pass easily through them.

Sources

Naturally occurring 50/60 Hz electric and magnetic field levels are extremely low; of the order of 0.0001 V/m, and 0.00001 µT respectively. Human exposure to ELF fields is primarily associated with the generation, transmission and use of electrical energy. Sources and typical upper limits of ELF fields found in the community, home and workplace are given below.

Community: Electrical energy from generating stations is distributed to communities via high voltage transmission lines. Transformers are used to lower the voltage for connections to residential distribution lines that deliver the energy to homes. Electric and magnetic fields underneath overhead transmission lines may be as high as 12 kV/m and 30 µT respectively. Around generating stations and substations, electric fields up to 16 kV/m and magnetic fields up to 270 µT may be found.

Home: Electric and magnetic fields in homes depend on many factors, including the distance from local power lines, the number and type of electrical appliances in use in the home, and the configuration and position of household electrical wiring. Electric fields around most household appliances and equipment typically do not exceed 500 V/m and magnetic fields typically do not exceed 150 µT. In both cases, field levels may be substantially greater at small distances but they do decrease rapidly with distance.

Workplace: Electric and magnetic fields exist around electrical equipment and wiring throughout industry. Workers who maintain transmission and distribution lines may be exposed to very large electric and magnetic fields. Within generating stations and substations electric fields in excess of 25 kV/m and magnetic fields in excess of 2 mT may be found. Welders can be subjected to magnetic field exposures as high as 130 mT. Near induction furnaces and industrial electrolytic cells magnetic fields can be as high as 50 mT. Office workers are exposed to very much smaller fields when using equipment such as photocopying machines and video display terminals.

Health effects

The only practical way that ELF fields interact with living tissues is by inducing electric fields and currents in them. However, the magnitude of these induced currents from exposure to ELF fields at levels normally found in our environment, is less than the currents occurring naturally in the body.

Electric Field Studies: Available evidence suggests that, apart from stimulation arising from electric charge induced on the surface of the body, the effects of exposures of up to 20 kV/m are few and innocuous. Electric fields have not been shown to have any effect on reproduction or development in animals at strengths over 100 kV/m.

Magnetic Field Studies: There is little confirmed experimental evidence that ELF magnetic fields can affect human physiology and behaviour at field strengths found in the home or environment. Exposure of volunteers for several hours to ELF fields up to 5 mT had little effect on a number of clinical and physiological tests, including blood changes, ECG, heart rate, blood pressure, and body temperature.

Melatonin: Some investigators have reported that ELF field exposure may suppress secretion of melatonin, a hormone connected with our day-night rhythms. It has been suggested that melatonin might be protective against breast cancer so that such suppression might contribute to an increased incidence of breast cancer already initiated by other agents. While there is some evidence for melatonin effects in laboratory animals, volunteer studies have not confirmed such changes in humans.

Cancer: There is no convincing evidence that exposure to ELF fields causes direct damage to biological molecules, including DNA. It is thus unlikely that they could initiate the process of carcinogenesis. However, studies are still underway to determine if ELF exposure can influence cancer promotion or co-promotion. Recent animal studies have not found evidence that ELF field exposure affects cancer incidence.

Epidemiological Studies: In 1979 Wertheimer and Leeper reported an association between childhood leukaemia and certain features of the wiring connecting their homes to the electrical distribution lines. Since then, a large number of studies have been conducted to follow up this important result. Analysis of these papers by the US National Academy of Sciences in 1996 suggested that residence near power lines was associated with an elevated risk of childhood leukaemia (relative risk RR=1.5), but not with other cancers. A similar association between cancer and residential exposure of adults was not seen from these studies.

Many studies published during the last decade on occupational exposure to ELF fields have exhibited a number of inconsistencies. They suggest there may be a small elevation in the risk of leukaemia among electrical workers. However, confounding factors, such as possible exposures to chemicals in the work environment, have not been adequately taken into account in many of them. Assessment of ELF field exposure has not correlated well with the cancer risk among exposed subjects. Therefore, a cause-and-effect link between ELF field exposure and cancer has not been confirmed.

NIEHS Panel: The US National Institute of Environmental Health Sciences (NIEHS) has completed its 5-year RAPID

Program.The RAPID Program replicated and extended studies reporting effects with possible health implications, and conducted further studies to determine if indeed there was any health consequence from ELF field exposure. In June 1998, NIEHS convened an international Working Group to review the research results. NIEHS's international panel concluded, using criteria established by the International Agency for Research on Cancer (IARC), that ELF fields should be considered as a "possible human carcinogen".

"Possible human carcinogen" is the weakest of three categories ("possibly carcinogenic to humans", "probably carcinogenic to humans" and "is carcinogenic to humans") used by IARC to classify scientific evidence on potential carcinogens. IARC has two further classifications of scientific evidence: "is not classifiable" and "is probably not carcinogenic to humans", but the NIEHS Working Group considered there was enough evidence to eliminate these categories.

"Possible human carcinogen" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals. Thus **the classification is based on the strength of scientific evidence, not on the strength of carcinogenicity or risk of cancer from the agent.** Thus, "possible human carcinogen" means limited credible evidence exists suggesting that exposure to ELF fields may cause cancer. While it cannot be excluded that ELF field exposure causes cancer from available evidence, further focused, high quality research is now needed to resolve this issue.

The decision of the NIEHS Working Group was based mainly on the appearance of consistency in epidemiological studies suggesting residence near power lines resulted in an apparently higher risk of leukaemia in children. Support for this association was found in studies relating childhood leukaemia incidence to proximity to power lines and to magnetic fields measured for 24 hours in homes. Furthermore, the Working Group also found limited evidence for an increased occurrence of chronic lymphocytic leukaemia in the occupational setting.

International EMF Project

WHO's International EMF Project has been established to work towards resolving the health issues raised by EMF exposure. Scientific reviews have been conducted and gaps in knowledge identified. This has resulted in a research agenda for the next few years that will ensure better health risk assessments can be made. A formal task group meeting to assess the results is scheduled by IARC in 2001. WHO will then adopt IARC's conclusions and complete an assessment of non-cancer health risks in 2002.

International Standards

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published guidelines on exposure limits for all EMF. The guidelines provide adequate protection against known health effects and those that can occur when touching charged objects in an external electric field. Limits of EMF exposure recommended in many countries are broadly similar to those of ICNIRP, which is a non-governmental organization (NGO) formally recognised by WHO and a full partner in the International EMF Project. It will reassess its guidelines once the EMF Project has completed new health risk assessments.

Protective Measures

Large conducting objects such as metal fences, barriers or similar metallic structures permanently installed near high voltage electrical transmission lines should be grounded. If such objects are not grounded, the power line can charge them to a sufficiently high voltage that a person who comes into close proximity or contact with the object can receive a startling and uncomfortable shock. A person may also receive such a shock when touching a car or bus parked under or very near high voltage power lines.

General public: Since current scientific information is only weakly suggestive and does not establish that exposure to ELF fields at levels normally encountered in our living environment might cause adverse health effects, there is no need for any specific protective measures for members of the general public. Where there are sources of high ELF field exposure, access by the public will generally be restricted by fences or barriers, so that no additional protective measures will be needed.

Workers: Protection from 50/60 Hz electric field exposure can be relatively easily achieved using shielding materials. This is only necessary for workers in very high field areas. More commonly, where electric fields are very large, access of personnel is restricted. There is no practical, economical way to shield against ELF magnetic fields. Where magnetic fields are very strong the only practical protective method available is to limit of personnel.

EMF Interference

Strong ELF fields cause electromagnetic interference (EMI) in cardiac pacemakers or other implanted electromedical devices. Individuals using these devices should contact their doctor to determine their susceptibility to these effects. WHO urges manufacturers of these devices to make them much less susceptible to EMI.

Office workers may see image movement on the screen of their computer terminal. If ELF magnetic fields around the terminal are greater than about 1 μT (10 mG) this can cause interference with the electrons producing the image on the screen. A simple solution to this problem is to relocate the computer to another part of the room where the magnetic fields are below 1 μT. These magnetic fields are found near cables that provide electric power to office or apartment buildings, or around transformers associated with power supplies to buildings. The fields from these sources are generally well below the levels that cause any health concern.

Noise, Ozone and Corona

Noise in the form of a buzzing or humming sound may be heard around electrical transformers or high voltage power lines producing corona (see below). While the noise may be annoying, there are no EMF health consequences associated with these sounds.

Electrical devices such as photocopiers or any device using a high voltage to function may produce ozone, a colourless gas having a pungent smell. Electrical discharges in the air convert oxygen molecules into ozone. While people may easily smell the ozone, the concentrations produced around photocopiers and similar devices are well below health standards.

Corona or electrical discharges into the air are produced around high voltage power lines. It is sometimes visible on a humid night or during rainfall and can produce noise and ozone. Both the noise levels and ozone concentrations around power lines have no health consequence.

What should be done while research continues?

One of the objectives of the International EMF Project is to help national authorities weigh the benefits of using EMF technology against the detriment should any adverse health effects be demonstrated, and decide what protective measures, if any, may be needed. It will take some years for the required research to be completed, evaluated and published by WHO. In the meantime, WHO recommends:

- Strict adherence to existing national or international safety standards: Such standards, based on current knowledge, are developed to protect everyone in the population.
- Simple protective measures: Fences or barriers around strong ELF sources help preclude unauthorised access to areas where national or international exposure limits may be exceeded.
- Consultation with local authorities and the public in siting new power lines: Obviously power lines must be sited to provide power to consumers. Despite the fact that ELF field levels around transmission and distribution lines are not considered a health risk, siting decisions are often required to take into account aesthetics and public sensibilities. Open communication and discussion between the electric power utility and the public during the planning stages can help create public understanding and greater acceptance of a new facility.
- An effective system of health information and communication among scientists, governments, industry and the public can help raise general awareness of programmes to deal with exposure to ELF fields and reduce any mistrust and fears.

References for further reading

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ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH RADARS AND HUMAN HEALTH

Radar systems detect the presence, direction or range of aircraft, ships or other, usually moving objects. This is achieved by sending pulses of high frequency electromagnetic fields (EMF). Invented some 60 years ago, radar systems have been widely used for navigation, aviation, national defence and weather forecasting. Their primary objective is individual and collective safety and protection.

People who live or routinely work around radars have expressed concerns about long-term adverse effects of these systems on health, including cancer, reproductive malfunction, cataracts and changes in behaviour or development of children. A recent example has been the alleged increase in testicular cancer in police using speed control hand-held radar "guns".

It is important to distinguish between perceived and real dangers that radars pose, as well as to understand the rational behind existing international standards and protective measures used today.

EMF Emissions: Radars usually operate at radio frequencies (RF) between 300 MHz and 15 GHz. They generate EMFs that are called RF fields. RF fields within this part of the electromagnetic spectrum are known to interact differently with human body.

RF fields **below 10 GHz** (to 1 MHz) penetrate exposed tissues and produce ***heating*** due to ***energy absorption***. The depth of penetration depends on the frequency of the field and is greater for lower frequencies. **Absorption** of RF fields in tissues is measured as *a **s**pecific **a**bsorption **r**ate* (**SAR**) within a given tissue mass. The unit of SAR is *watts per kilogram* (**W/kg**). **SAR** is the quantity used to measure the "dose" of RF fields **between about 1 MHz and 10 GHz**.

- *An **SAR** of at least **4 W/kg** is needed to produce known adverse health effects in people exposed to RF fields in this frequency range.*

RF fields **above 10 GHz** are absorbed at the skin surface, with very little of the energy penetrating into the underlying tissues. The basic dosimetric quantity for RF fields **above 10 GHz** is *the intensity of the field* measured as ***power density*** in watts per square metre (**W/m2**) or for weak fields in milliwatts per square metre (**mW/m2**) or microwatts per square metre (µ**W/m2**).

- Exposure to RF fields above 10 GHz at power densities **over 1000 W/m2** are known to produce adverse health effects, such as eye cataracts and skin burns.

Human Exposure: The power that radar systems emit varies from a few milliwatts (police traffic control radar) to many kilowatts (large space tracking radars). However, a number of factors significantly reduce human exposure to RF generated by radar systems, often by a factor of at least 100:

- Radar systems send electromagnetic waves in pulses and not continuously. This makes the average power emitted much lower than the peak pulse power.
- Radars are directional and the RF energy they generate is contained in beams that are very narrow and resemble the beam of a spotlight. RF levels away from the main beam fall off rapidly. In most cases, these levels are *thousands of times lower* than in the main beam.
- Many radars have antennas which are continuously rotating or varying their elevation by a nodding motion, thus constantly changing the direction of the beam.
- Areas, where dangerous human exposure may occur are normally inaccessible to unauthorized personnel.

Radar Sources: Some of the common types of radars encountered in daily life include:

Air traffic control radars are used to track the location of aircraft and to control their landing at airports. They are generally located at elevated positions where the beam is inaccessible to persons on the ground. Typical air traffic control radars can have peak powers of 100 kW or more, but average powers of a few hundred watts. Under normal operating conditions, these systems pose no hazard to the general public.

Weather radars are often co-located with air traffic control radars in remote areas at airports. They operate at higher frequencies but generally have lower average and peak powers. As with air traffic control radars, under normal conditions, they pose no hazards to the general public.

Military radars are numerous and vary from very large installations, which have large peak (1 MW or greater) and average powers (kW), to small military fire control radars, typically found on aircraft. Large size radars often evoke concern in communities living around them. However, because its power is radiated over a large surface area, the power densities associated with these systems vary between 10 and 100 W/m^2 within the site boundary. Outside the site boundary RF field levels are usually unmeasurable without using sophisticated equipment. However, small military fire control radars on aircraft can be hazardous to ground personnel. These units have relatively high average powers (kW) and small area antennas, making it possible to have power densities up to 10 kW/m^2. Members of the general public would not be exposed to these emissions because during ground testing of radars access to these areas by all personnel is prohibited. The military also use most other types of radars described below.

Marine radars can be found on small pleasure boats to large ocean going vessels. Peak powers of these systems can reach up to 30 kW, with average powers ranging from 1 to 25 W. Under normal operating conditions, with the antenna rotating, the average power density of the higher power systems within a metre of the antenna is usually less than 10 W/m^2. In accessible areas on most watercraft, these levels would fall to a few percent of present public RF exposure standards.

Speed Control Radars are hand-held by police in many countries. The average output power is very low, a few milliwatts, and so the units are not considered hazardous to health, even when used in very close proximity to the body.

Possible Health Effects: Most studies conducted to date examined health effects other than cancer. They probed into physiological and thermoregulatory responses, behavioural changes and effects such as the induction of lens opacities (cataracts) and adverse reproductive outcome following acute exposure to relatively high levels of RF fields. There are also a number of studies that report non-thermal effects, where no appreciable rise in temperature can be measured.

Cancer-related studies: Many epidemiological studies have addressed possible links between exposure to RF and excess risk of cancer. However, because of differences in the design and execution of these studies, their results are difficult to interpret. A number of national and international peer review groups have concluded that there is no clear evidence of links between RF exposure and excess risk of cancer. WHO has also concluded that there is no convincing scientific evidence that exposure to RF shortens the life span of humans, or that RF is an inducer or promoter of cancer. However, further studies are necessary.

Thermal effects: RF fields have been studied in animals, including primates. The earliest signs of an adverse health consequence, found in animals as the level of RF fields increased, include reduced endurance, aversion of the field and decreased ability to perform mental tasks. These studies also suggest adverse effects may occur in humans subjected to whole body or localized exposure to RF fields sufficient to increase tissue temperatures by greater than 1° C. Possible effects include the induction of eye cataracts, and various physiological and thermoregulatory responses as body temperature increases. These effects are well established and form the scientific basis for restricting occupational and public exposure to RF fields.

Non-thermal effects: Exposure to RF levels too low to involve heating, (i.e., very low SARs), has been reported by several groups to alter calcium ion mobility, which is responsible for transmitting information in tissue cells. However, these effects are not sufficiently established to provide a basis for restricting human exposure.

Pulsed RF fields: Exposure to very intense pulsed RF fields, similar to those used by radar systems, has been reported to suppress the startle response and evoke body movements in conscious mice. In addition, people with normal hearing have perceived pulse RF fields with frequencies between about 200 MHz and 6.5 GHz. This is called the *microwave hearing effect*. The sound has been variously described as a buzzing, clicking, hissing or popping sound, depending on the RF pulsing characteristics. Prolonged or repeated exposure may be stressful and should be avoided where possible.

RF shocks and burns: At frequencies less than 100 MHz, RF burns or shock may result from charges induced on metallic objects situated near radars. Persons standing in RF fields can also have high local absorption of the fields in areas of their bodies with small cross sectional areas, such as the ankles. In general, because of the higher frequencies that most modern radar systems operate, combined with their small beam widths, the potential for such effects is very small.

Electromagnetic interference: Radars can cause electromagnetic interference in other electronic equipment. The threshold for these effects are often well below guidance levels for human exposure to RF fields. Additionally, radars can also cause interference in certain medical devices, such as cardiac pacemakers and hearing aids. If individuals using such devices work in ***close proximity*** to radar systems they should contact manufacturers to determine the susceptibility of their products to RF interference.

Ignition of flammable liquids and explosives: RF fields can ignite flammable liquids and explosives through the induction of currents. This is a rare occurrence, and normally of most concern where there is a large concentration of radars, such as on board a naval ship where measures are taken to prevent such effects.

International Standards: Exposure limits for RF fields are developed by international bodies such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP is a non-governmental organization formally recognised by WHO. The Commission uses health risk assessments developed in conjunction with WHO to draft their guidelines on exposure limits. The ICNIRP guidelines protect against all *established* RF health effects and are developed following reviews of all the peer-reviewed scientific literature, including reports on cancer and non-thermal effects. Environmental RF levels from radars, in areas normally accessible to the general public, are at least 1,000 times below the limits for continuous public exposure allowed by the ICNIRP guidelines, and 25,000 times below the level at which RF exposure has been established to cause the earliest known health effects.

Protective Measures: The aim of protective measures is to eliminate or reduce human exposure to RF fields below acceptable limits. An extensive program of measurement surveys, hazard communication, coupled with effective protective measures, is required around all radar installations. In most countries, comprehensive documentation is prepared, including an environmental impact statement, before a radar system can be constructed.

Following construction of the radar facility, site surveys should be performed to quantify RF field levels in the area. While extremely high RF field levels can be measured directly in front of a radar, in most cases levels in public areas are not easily measurable. In order to prevent both workers and the general public from entering areas where the RF levels are above the limits, both engineering and administrative controls are used.

- Engineering controls include interlocks, electronic means to exclude the radar pointing in certain areas, and shielding.
- Administrative controls include audible and visible alarms, warning signs, and restriction of access through barriers, locked doors, or limiting access time to radar.

When engineering and administrative controls do not suffice, workers should use personal protective equipment to ensure compliance with exposure standards. Conductive suits, gloves, safety shoes and other types of personal protective equipment for RF fields are now commercially available.

- They should be used with great care, since the attenuation properties of the material used to make this protective equipment can vary dramatically with frequency. Only when the attenuation properties of the equipment is known at the frequency in question can they be used reliably.
- Special care should be exercised with RF safety glasses since any metal may enhance local fields by acting as a receiving antenna.
- There are no exposure situations where members of the general public need to use protective equipment for RF fields from radars.
- In recent years, clothing and other materials have appeared on the consumer market claiming to have RF shielding properties, and directing their claims to

"sensitive" members of the general population, such as pregnant women. The use of these types of products is unnecessary and should be discouraged. They offer no effective RF shielding, and there is no need for these devices.

Human exposure to EMF emitted by radar systems is limited by international standards and protective measures, which were adopted on the basis the currently available scientific evidence. In summary:

- *RF fields cause molecules in tissue to vibrate and generate heat. Heating effects could be expected if time is spent directly in front of some radar antennas, but are not possible at the environmental levels of RF fields emanating from radar systems.*
- *To produce any adverse health effect, RF exposure above a threshold level must occur. The known threshold level is the exposure needed to increase tissue temperature by at least 1oC. The very low RF environmental field levels from radar systems cannot cause any significant temperature rise.*
- *To date, researchers have not found evidence that multiple exposures to RF fields below threshold levels cause any adverse health effects. No accumulation of damage occurs to tissues from repeated low level RF exposure.*
- *At present, there is no substantive evidence that adverse health effects, including cancer, can occur in people exposed to RF levels at or below the limits set by international standards. However, more research is needed to fill certain gaps in knowledge*

For more information, see http://www.who.int/emf/

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Fact sheet N° 263
October 2001

Electromagnetic fields and public health: extremely low frequency fields and cancer

In 1996, the World Health Organization (WHO) established the International Electromagnetic Fields (EMF) Project to address the health issues associated with exposure to EMF. The EMF Project is currently reviewing research results and conducting risk assessments of exposure to static and extremely low frequency (ELF) electric and magnetic fields. WHO plans to conduct an evaluation of all health effects from ELF field exposure in 2002-3.

Whenever electricity is conducted through transmission lines, distribution lines or is used in appliances, both electric and magnetic fields exist close to the lines or appliances. The power frequency used is 50 or 60 Hz. Use of electric power has become part of everyday life. However, questions have been raised as to whether these and other ELF fields are carcinogenic.

The International Agency for Research on Cancer (IARC) -- a specialized cancer research agency of WHO -- has recently concluded the first step in WHO's health risk assessment process by classifying ELF fields with respect to the strength-of-the-evidence that they could cause cancer in humans.

This Fact Sheet updates findings of recent reviews on the health effects of static and ELF electric and magnetic fields conducted by IARC (June 2001), by the Health Council of the Netherlands (May 2001), and by an expert Advisory Group of the National Radiological Protection Board in the United Kingdom (AGNIR) (March 2001).

IARC evaluation

In June 2001, an expert scientific working group of IARC reviewed studies related to the carcinogenicity of static and ELF electric and magnetic fields. Using the standard IARC classification that weighs human, animal and laboratory evidence, ELF magnetic fields were classified as **possibly carcinogenic to humans** based on epidemiological studies of childhood leukaemia. Evidence for all other cancers in children and adults, as well as other types of exposures (i.e. static fields and ELF electric fields) was considered not classifiable either due to insufficient or inconsistent scientific information.

"Possibly carcinogenic to humans" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals.

This classification is the weakest of three categories ("is carcinogenic to humans", "probably carcinogenic to humans" and "possibly carcinogenic to humans") used by IARC to classify potential carcinogens based on published scientific evidence. Some examples of well-known agents that have been classified by IARC are listed below:

Classification	Examples of agents
Carcinogenic to humans	Asbestos
(usually based on strong evidence of carcinogenicity in humans)	Mustard gas
	Tobacco (smoked and smokeless)
	Gamma radiation

Probably carcinogenic to humans	Diesel engine exhaust
(usually based on strong evidence of carcinogenicity in animals)	Sun lamps
	UV radiation
	Formaldehyde
Possibly carcinogenic to humans	Coffee
(usually based on evidence in humans which is considered credible, but for which other explanations could not be ruled out)	Styrene
	Gasoline engine exhaust
	Welding fumes
	ELF magnetic fields

Do ELF fields cause cancer?

ELF fields are known to interact with tissues by inducing electric fields and currents in them. This is the only established mechanism of action of these fields. However, the electric currents induced by ELF fields commonly found in our environment are normally much lower than the strongest electric currents naturally occurring in the body such as those that control the beating of the heart.

Since 1979 when epidemiological studies first raised a concern about exposures to power line frequency magnetic fields and childhood cancer, a large number of studies have been conducted to determine if measured ELF exposure can influence cancer development, especially leukaemia in children.

There is no consistent evidence that exposure to ELF fields experienced in our living environment causes direct damage to biological molecules, including DNA. Since it seems unlikely that ELF fields could **initiate** cancer, a large number of investigations have been conducted to determine if ELF exposure can **influence** cancer promotion or co-promotion. Results from animal studies conducted so far suggest that ELF fields do not initiate or promote cancer.

However, two recent pooled analyses of epidemiological studies provide insight into the epidemiological evidence that played a pivotal role in the IARC evaluation. These studies suggest that, in a population exposed to **average** magnetic fields in excess of 0.3 to 0.4 µT, twice as many children might develop leukaemia compared to a population with lower exposures. In spite of the large number data base, some uncertainty remains as to whether magnetic field exposure or some other factor (s) might have accounted for the increased leukaemia incidence.

Childhood leukaemia is a rare disease with 4 out of 100,000 children between the age of 0 to 14 diagnosed every year. Also average magnetic field exposures above 0.3 or 0.4 µT in residences are rare. It can be estimated from the epidemiological study results that less than 1% of populations using 240 volt power supplies are exposed to these levels, although this may be higher in countries using 120 volt supplies.

The IARC review addresses the issue of whether it is feasible that ELF-EMF pose a cancer risk. The next step in the process is to estimate the likelihood of cancers in the general population from the usual exposures and to evaluate evidence for other (non-cancer) diseases. This part of the risk assessment should be finished by WHO in the next 18 months.

International guidelines

International guidelines on exposure limits for all EMF have been developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) - a non-governmental organization (NGO) in official relations with WHO and a partner in WHO's International EMF Project. While the ICNIRP guidelines for EMF exposure are based on comprehensive reviews of all the science, the limits are intended to prevent health effects related to short-term acute exposure. This is because ICNIRP considers the scientific information on potential carcinogenicity of ELF fields insufficient for establishing quantitative limits on exposure.

Some national responses

Regulatory policies for agents classified as possible carcinogens vary by country and by particular agent. The carcinogenic evaluation and classification of an agent by IARC does not automatically trigger a national regulatory response. While gasoline exhaust and coffee have been classified as possible human carcinogens, there has been a significant response by government to reduce gasoline engine exhausts, but there has not been any effort to limit intake of coffee.

In response to increasing public concern over health effects from EMF exposure, several countries have established their own scientific reviews prior to the IARC evaluation. Already in 1998, a working group examining the issue for the US National Institute of Environmental Health Sciences (NIEHS) classified ELF magnetic fields as possibly carcinogenic to humans. The US government agency has since recommended "passive regulatory action", described as continued information and education of the public and encouraging power utilities to voluntarily reduce exposure to people where possible.

In the United Kingdom, an Advisory Group on Non-Ionising Radiation recently reported to the National Radiological Protection Board (NRPB) on the topic of power frequency EMF and the risk of cancer (AGNIR, 2001). It concluded that while the evidence is currently not strong enough to justify a firm conclusion that EMF fields cause leukaemia in children, the possibility remains that intense and prolonged exposures to magnetic fields can increase the risk of leukaemia in children. Further, they provided research recommendations. The Health Council of the Netherlands, a major scientific advisory body of the Netherlands government, reached similar conclusions.

WHO's response

While the classification of ELF magnetic fields as possibly carcinogenic to humans has been made, it remains possible that there are other explanations for the observed association between exposure to ELF magnetic fields and childhood leukaemia. In particular, issues of selection bias in the epidemiological studies and exposure to other field types deserve to be rigorously examined and will likely require new studies. WHO therefore recommends a follow-up, focused research programme to provide more definitive information. Some of these studies are currently being undertaken and results are expected over the next 2-3 years.

WHO's EMF Project aims to help national authorities balance the benefits of electrical technology against possible health risks, and to help them decide what protective measures may be needed. It is especially difficult to suggest protective measures for ELF fields because we do not know what field characteristic might be involved in the development of childhood leukaemia and therefore need to be reduced, or even if it is the ELF magnetic fields that are responsible for this effect. One approach is to have voluntary policies that aim to cost-effectively reduce exposure to ELF fields. This has been discussed in the WHO Backgrounder issued March 2000.

Some precautionary measures are outlined below:

- **Government and industry**: These entities should be cognisant of the latest scientific developments and should provide the public with balanced, clear and comprehensive information on potential EMF risks, as well as suggestions for safe and low cost ways to reduce exposures. They should also promote research that will lead to better information from which assessments of health risk can be made.
- **Individuals**: Members of the general public might choose to reduce their EMF exposure by minimizing the use of certain electrical appliances or by increasing distance to the sources that can produce relatively high fields.
- **Consultation with local authorities, industry and the public when siting new power lines**: Obviously power lines must be sited to provide power to consumers. Siting decisions are often required to take into account aesthetics and public sensibilities. However, siting decisions should also consider ways to reduce peoples' exposure.
- **An effective system of health information and communication** among scientists, governments, industry and the public is needed to help raise general awareness of programmes to deal with exposure to ELF fields and reduce any mistrust and fears.

Further reading

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Fact sheet N° 296
December 2005

Electromagnetic fields and public health
Electromagnetic Hypersensitivity

As societies industrialize and the technological revolution continues, there has been an unprecedented increase in the number and diversity of electromagnetic field (EMF) sources. These sources include video display units (VDUs) associated with computers, mobile phones and their base stations. While these devices have made our life richer, safer and easier, they have been accompanied by concerns about possible health risks due to their EMF emissions.

For some time a number of individuals have reported a variety of health problems that they relate to exposure to EMF. While some individuals report mild symptoms and react by avoiding the fields as best they can, others are so severely affected that they cease work and change their entire lifestyle. This reputed sensitivity to EMF has been generally termed “electromagnetic hypersensitivity” or EHS.

This fact sheet describes what is known about the condition and provides information for helping people with such symptoms. Information provided is based on a WHO Workshop on Electrical Hypersensitivity (Prague, Czech Republic, 2004), an international conference on EMF and non-specific health symptoms (COST244bis, 1998), a European Commission report (Bergqvist and Vogel, 1997) and recent reviews of the literature.

What is EHS?

EHS is characterized by a variety of non-specific symptoms, which afflicted individuals attribute to exposure to EMF. The symptoms most commonly experienced include dermatological symptoms (redness, tingling, and burning sensations) as well as neurasthenic and vegetative symptoms (fatigue, tiredness, concentration difficulties, dizziness, nausea, heart palpitation, and digestive disturbances). The collection of symptoms is not part of any recognized syndrome.

EHS resembles multiple chemical sensitivities (MCS), another disorder associated with low-level environmental exposures to chemicals. Both EHS and MCS are characterized by a range of non-specific symptoms that lack apparent toxicological or physiological basis or independent verification. A more general term for sensitivity to environmental factors is Idiopathic Environmental Intolerance (IEI), which originated from a workshop convened by the International Program on Chemical Safety (IPCS) of the WHO in 1996 in Berlin. IEI is a descriptor without any implication of chemical etiology, immunological sensitivity or EMF susceptibility. IEI incorporates a number of disorders sharing similar non-specific medically unexplained symptoms that adversely affect people. However since the term EHS is in common usage it will continue to be used here.

Prevalence

There is a very wide range of estimates of the prevalence of EHS in the general population. A survey of occupational medical centres estimated the prevalence of EHS to be a few individuals per million in the population. However, a survey of self-help groups yielded much higher estimates. Approximately 10% of reported cases of EHS were considered severe.

There is also considerable geographical variability in prevalence of EHS and in the reported symptoms. The reported incidence of EHS has been higher in Sweden, Germany, and Denmark, than in the United Kingdom, Austria, and France. VDU-related symptoms were more prevalent in Scandinavian countries, and they were more commonly related to skin disorders than elsewhere in Europe. Symptoms similar to those reported by EHS individuals are common in the general population.

Studies on EHS individuals

A number of studies have been conducted where EHS individuals were exposed to EMF similar to those that they attributed to the cause of their symptoms. The aim was to elicit symptoms under controlled laboratory conditions.

The majority of studies indicate that EHS individuals cannot detect EMF exposure any more accurately than non-EHS individuals. Well controlled and conducted double-blind studies have shown that symptoms were not correlated with EMF exposure.

It has been suggested that symptoms experienced by some EHS individuals might arise from environmental factors unrelated to EMF. Examples may include “flicker” from fluorescent lights, glare and other visual problems with VDUs, and poor ergonomic design of computer workstations. Other factors that may play a role include poor indoor air quality or stress in the workplace or living environment.

There are also some indications that these symptoms may be due to pre-existing psychiatric conditions as well as stress reactions as a result of worrying about EMF health effects, rather than the EMF exposure itself.

Conclusions

EHS is characterized by a variety of non-specific symptoms that differ from individual to individual. The symptoms are certainly real and can vary widely in their severity. Whatever its cause, EHS can be a disabling problem for the affected individual. EHS has no clear diagnostic criteria and there is no scientific basis to link EHS symptoms to EMF exposure. Further, EHS is not a medical diagnosis, nor is it clear that it represents a single medical problem.

Physicians: Treatment of affected individuals should focus on the health symptoms and the clinical picture, and not on the person's perceived need for reducing or eliminating EMF in the workplace or home. This requires:

- a medical evaluation to identify and treat any specific conditions that may be responsible for the symptoms,
- a psychological evaluation to identify alternative psychiatric/psychological conditions that may be responsible for the symptoms,
- an assessment of the workplace and home for factors that might contribute to the presented symptoms. These could include indoor air pollution, excessive noise, poor lighting (flickering light) or ergonomic factors. A reduction of stress and other improvements in the work situation might be appropriate.

For EHS individuals with long lasting symptoms and severe handicaps, therapy should be directed principally at reducing symptoms and functional handicaps. This should be done in close co-operation with a qualified medical specialist (to address the medical and psychological aspects of the symptoms) and a hygienist (to identify and, if necessary, control factors in the environment that are known to have adverse health effects of relevance to the patient).

Treatment should aim to establish an effective physician-patient relationship, help develop strategies for coping with the situation and encourage patients to return to work and lead a normal social life.

EHS individuals: Apart from treatment by professionals, self help groups can be a valuable resource for the EHS individual.

Governments: Governments should provide appropriately targeted and balanced information about potential health hazards of EMF to EHS individuals, health-care professionals and employers. The information should include a clear statement that no scientific basis currently exists for a connection between EHS and exposure to EMF.

Researchers: Some studies suggest that certain physiological responses of EHS individuals tend to be outside the normal range. In particular, hyper reactivity in the central nervous system and imbalance in the autonomic nervous system need to be followed up in clinical investigations and the results for the individuals taken as input for possible treatment.

What WHO is doing

WHO, through its International EMF Project, is identifying research needs and co-ordinating a world-wide program of EMF studies to allow a better understanding of any health risk associated with EMF exposure. Particular emphasis is placed on possible health consequences of low-level EMF. Information about the EMF Project and EMF effects is provided in a series of fact sheets in several languages www.who.int/emf/.

FURTHER READING

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World Health Organization

Fact sheet N° 299
March 2006

Electromagnetic fields and public health
Static electric and magnetic fields

Technologies using static fields are increasingly being exploited in selected industries, such as medicine with magnetic resonance imaging (MRI), transportation systems that use direct current (DC) or static magnetic fields and high-energy physics research facilities. As the field strength of the static field increases, so does the potential for a variety of interactions with the body.

The International EMF Project of the World Health Organization (WHO) has recently reviewed the health implications of high static field exposure and highlighted the importance of public health protection for medical staff and patients (particularly children and pregnant women) and workers in industries producing high field magnets (Environmental Health Criteria, 2006).

SOURCES

Electric and magnetic fields are generated by phenomena such as the Earth's magnetic field, thunderstorms, and the use of electricity. When such fields do not vary with time they are referred to as static and have a frequency of 0 Hz.

In the atmosphere, static electric fields (also referred to as electrostatic fields) occur naturally, in fair weather, and especially under thunderclouds. Friction can also separate positive and negative charges and generate strong static electric fields. Their strength is measured in units of volt per metre, (V/m), or kilovolt per metre (kV/m). In daily life we may experience spark discharges with grounded objects or hair rising as a result of friction, for example from walking on a carpet. The use of DC electricity is another source of static electric fields, e.g. rail systems using DC, and televisions and computer screens with cathode ray tubes.

A static magnetic field is measured in units of ampere per metre, (A/m) but is usually expressed in terms of the corresponding magnetic induction measured in units of tesla, (T) or millitesla (mT).The natural geomagnetic field varies over the Earth's surface between about 0.035 - 0.07 mT and is perceived by certain animals that use it for orientation. Man-made static magnetic fields are generated wherever DC currents are used, such as in electric trains or industrial processes such as aluminium production and in gas welding. These can be more than 1000 times stronger than the Earth's natural magnetic field.

Recent technological innovations have led to the use of magnetic fields up to 100 000 times stronger than the Earth's magnetic field. They are used in research and in medical applications such as MRI that provides three-dimensional images of the brain and other soft tissues. In routine clinical systems, scanned patients and machine operators can be exposed to strong magnetic fields in the range of 0.2 - 3 T. In medical research applications, higher magnetic fields, up to about 10 T, are used for whole body patient scanning.

For static electric fields, few studies have been carried out. The results to date suggest that the only acute effects are associated with body hair movement and discomfort from spark discharges. Chronic or delayed effects of static electric fields have not been properly investigated.

HEALTH EFFECTS

For static magnetic fields, acute effects are only likely to occur when there is movement in the field, such as motion of a person or internal body movement, such as blood flow or heart beat. A person moving within a field above 2 T can experience sensations of vertigo and nausea, and sometimes a metallic taste in the mouth and perceptions of light flashes. Although only temporary, such effects may have a safety impact for workers executing delicate procedures (such as surgeons performing operations within MRI units).

Static magnetic fields exert forces on moving charges in the blood, such as ions, generating electrical fields and currents around the heart and major blood vessels that can slightly impede the flow of blood. Possible effects range from minor changes in heartbeat to an increase in the risk of abnormal heart rhythms (arrhythmia) that might be life-threatening (such as ventricular fibrillation). However, these types of acute effects are only likely within fields in excess of 8 T.

It is not possible to determine whether there are any long-term health consequences even from exposure in the millitesla range because, to date, there are no well-conducted epidemiological or long-term animal studies. Thus the carcinogenicity of static magnetic fields to humans is not at present classifiable (IARC, 2002).

INTERNATIONAL STANDARDS

Exposure to static magnetic fields has been addressed by the International Commission on Non-Ionizing Radiation Protection (see: www.icnirp.org). For occupational exposure, present limits are based on avoiding the sensations of vertigo and nausea induced by movement in a static magnetic field. The recommended limits are time-weighted average of 200 mT during the working day for occupational exposure, with a ceiling value of 2 T. A continuous exposure limit of 40 mT is given for the general public.

Static magnetic fields affect implanted metallic devices such as pacemakers present inside the body, and this could have direct adverse health consequences. It is suggested that wearers of cardiac pacemakers, ferromagnetic implants and implanted electronic devices should avoid locations where the field exceeds 0.5 mT. Also, care should be taken to prevent hazards from metal objects being suddenly attracted to magnets in field exceeds 3 mT.

WHO'S RESPONSE

WHO has been active in the evaluation of health issues raised by exposure to electromagnetic fields (EMF) in the frequency range from 0 to 300 GHz. The International Agency for Research on Cancer (IARC) evaluated the carcinogenicity of static fields in 2002, and the WHO International EMF Project has recently conducted a thorough health risk assessment of these fields (Environmental Health Criteria, 2006) where gaps in knowledge have been identified. This has resulted in a research agenda for the next few years to inform future health risk assessments (www.who.int/emf). WHO recommends a review of standards when new evidence from the scientific literature becomes available.

WHAT CAN NATIONAL AUTHORITIES DO?

While there are huge benefits to be gained from use of static magnetic fields, particularly in medicine, possible adverse health effects from exposure to them must be properly evaluated so that the true risks and benefits can be assessed. It will take some years for the required research to be completed. In the meantime, WHO recommends that national authorities set up programmes to protect both the public and workers from possible adverse effects of static fields. In the case of static electric fields, since the main effect is discomfort from electric discharges to the body, it is sufficient to provide information on exposure to large electric fields and how to avoid them.

In the case of static magnetic fields, because the level of information on possible long-term or delayed effects of exposure is currently insufficient, cost-effective precautionary measures may be justified to limit the exposure of workers and the public. WHO recommends that authorities take the following measures:

- Adopt international science-based standards to limit human exposure.
- Take protective measures for the industrial and scientific use of magnetic fields by keeping a distance from fields that may pose a significant risk, by enclosing the fields, or by applying administrative controls such as staff education programs.
- Consider licensing magnetic resonance imaging (MRI) units having field strengths exceeding 2 T, in order to ensure that protective measures are implemented.
- Fund research to fill the large gaps in knowledge regarding the safety of people.
- Fund MRI units and databases to collect health information on exposure of workers and patients.

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Related links

- Electromagnetic fields

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Fact sheet N° 304
May 2006

Electromagnetic fields and public health
Base stations and wireless technologies

Mobile telephony is now commonplace around the world. This wireless technology relies upon an extensive network of fixed antennas, or base stations, relaying information with radiofrequency (RF) signals. Over 1.4 million base stations exist worldwide and the number is increasing significantly with the introduction of third generation technology.

Other wireless networks that allow high-speed internet access and services, such as wireless local area networks (WLANs), are also increasingly common in homes, offices, and many public areas (airports, schools, residential and urban areas). As the number of base stations and local wireless networks increases, so does the RF exposure of the population. Recent surveys have shown that the RF exposures from base stations range from 0.002% to 2% of the levels of international exposure guidelines, depending on a variety of factors such as the proximity to the antenna and the surrounding environment. This is lower or comparable to RF exposures from radio or television broadcast transmitters.

There has been concern about possible health consequences from exposure to the RF fields produced by wireless technologies. This fact sheet reviews the scientific evidence on the health effects from continuous low-level human exposure to base stations and other local wireless networks.

Health concerns

A common concern about base station and local wireless network antennas relates to the possible long-term health effects that whole-body exposure to the RF signals may have. To date, the only health effect from RF fields identified in scientific reviews has been related to an increase in body temperature (> 1 ° C) from exposure at very high field intensity found only in certain industrial facilities, such as RF heaters. The levels of RF exposure from base stations and wireless networks are so low that the temperature increases are insignificant and do not affect human health.

The strength of RF fields is greatest at its source, and diminishes quickly with distance. Access near base station antennas is restricted where RF signals may exceed international exposure limits. Recent surveys have indicated that RF exposures from base stations and wireless technologies in publicly accessible areas (including schools and hospitals) are normally thousands of times below international standards.

In fact, due to their lower frequency, at similar RF exposure levels, the body absorbs up to five times more of the signal from FM radio and television than from base stations. This is because the frequencies used in FM radio (around 100 MHz) and in TV broadcasting (around 300 to 400 MHz) are lower than those employed in mobile telephony (900 MHz and 1800 MHz) and because a person's height makes the body an efficient receiving antenna. Further, radio and television broadcast stations have been in operation for the past 50 or more years without any adverse health consequence being established.

While most radio technologies have used analog signals, modern wireless telecommunications are using digital transmissions. Detailed reviews conducted so far have not revealed any hazard specific to different RF modulations.

Cancer: Media or anecdotal reports of cancer clusters around mobile phone base stations have heightened public concern. It should be noted that geographically, cancers are unevenly distributed among any population. Given the widespread presence of base stations in the environment, it is expected that possible cancer clusters will occur near base stations merely by chance. Moreover, the reported cancers in these clusters are often a collection of different types of cancer with no common characteristics and hence unlikely to have a common cause.

Scientific evidence on the distribution of cancer in the population can be obtained through carefully planned and executed epidemiological studies. Over the past 15 years, studies examining a potential relationship between RF transmitters and cancer have been published. These studies have not provided evidence that RF exposure from the transmitters increases the risk of cancer. Likewise, long-term animal studies have not established an increased risk of cancer from exposure to RF fields, even at levels that are much higher than produced by base stations and wireless networks.

Other effects: Few studies have investigated general health effects in individuals exposed to RF fields from base stations. This is because of the difficulty in distinguishing possible health effects from the very low signals emitted by base stations from other higher strength RF signals in the environment. Most studies have focused on the RF exposures of mobile phone users. Human and animal studies examining brain wave patterns, cognition and behaviour after exposure to RF fields, such as those generated by mobile phones, have not identified adverse effects. RF exposures used in these studies were about 1000 times higher than those associated with general public exposure from base stations or wireless networks. No consistent evidence of altered sleep or cardiovascular function has been reported.

Some individuals have reported that they experience non-specific symptoms upon exposure to RF fields emitted from base stations and other EMF devices. As recognized in a recent WHO fact sheet "Electromagnetic Hypersensitivity", EMF has not been shown to cause such symptoms. Nonetheless, it is important to recognize the plight of people suffering from these symptoms.

From all evidence accumulated so far, no adverse short- or long-term health effects have been shown to occur from the RF signals produced by base stations. Since wireless networks produce generally lower RF signals than base stations, no adverse health effects are expected from exposure to them.

Protection standards

International exposure guidelines have been developed to provide protection against established effects from RF fields by the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998) and the Institute of Electrical and Electronic Engineers (IEEE, 2005).

National authorities should adopt international standards to protect their citizens against adverse levels of RF fields. They should restrict access to areas where exposure limits may be exceeded.

Public perception of risk

Some people perceive risks from RF exposure as likely and even possibly severe. Several reasons for public fear include media announcements of new and unconfirmed scientific studies, leading to a feeling of uncertainty and a perception that there may be unknown or undiscovered hazards. Other factors are aesthetic concerns and a feeling of a lack of control or input to the process of determining the location of new base stations. Experience shows that education programmes as well as effective communications and involvement of the public and other stakeholders at appropriate stages of the decision process before installing RF sources can enhance public confidence and acceptability.

Conclusions

Considering the very low exposure levels and research results collected to date, there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects.

WHO Initiatives

WHO, through the International EMF Project, has established a programme to monitor the EMF scientific literature, to evaluate the health effects from exposure to EMF in the range from 0 to 300 GHz, to provide advice about possible EMF hazards and to identify suitable mitigation measures. Following extensive international reviews, the International EMF Project has promoted research to fill gaps in knowledge. In response national governments and research institutes have funded over $250 million on EMF research over the past 10 years.

While no health effects are expected from exposure to RF fields from base stations and wireless networks, research is still being promoted by WHO to determine whether there are any health consequences from the higher RF exposures from mobile phones.

The International Agency for Research on Cancer (IARC), a WHO specialized agency, is expected to conduct a review of cancer risk from RF fields in 2006-2007 and the International EMF Project will then undertake an overall health risk assessment for RF fields in 2007-2008.

Further Reading

ICNIRP (1998) www.icnirp.org/documents/emfgdl.pdf
IEEE (2006) IEEE C95.1-2005 "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz"

Related links

- Base stations & wireless networks: Exposures & health consequences
- Fact sheet: Electromagnetic fields and public health: Electromagnetic Hypersensitivity
- WHO handbook on "Establishing a Dialogue on Risks from Electromagnetic Fields"
- 2006 WHO Research Agenda for Radio Frequency Fields [pdf 100kb]

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Fact sheet N° 322
June 2007

Electromagnetic fields and public health
Exposure to extremely low frequency fields

The use of electricity has become an integral part of everyday life. Whenever electricity flows, both electric and magnetic fields exist close to the lines that carry electricity, and close to appliances. Since the late 1970s, questions have been raised whether exposure to these extremely low frequency (ELF) electric and magnetic fields (EMF) produces adverse health consequences. Since then, much research has been done, successfully resolving important issues and narrowing the focus of future research.

In 1996, the World Health Organization (WHO) established the International Electromagnetic Fields Project to investigate potential health risks associated with technologies emitting EMF. A WHO Task Group recently concluded a review of the health implications of ELF fields (WHO, 2007).

This Fact Sheet is based on the findings of that Task Group and updates recent reviews on the health effects of ELF EMF published in 2002 by the International Agency for Research on Cancer (IARC), established under the auspices of WHO, and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 2003.

ELF field sources and residential exposures

Electric and magnetic fields exist wherever electric current flows - in power lines and cables, residential wiring and electrical appliances. **Electric** fields arise from electric charges, are measured in volts per metre (V/m) and are shielded by common materials, such as wood and metal. **Magnetic** fields arise from the motion of electric charges (i.e. a current), are expressed in tesla (T), or more commonly in millitesla (mT) or microtesla (μT). In some countries another unit called the gauss, (G), is commonly used (10,000 G = 1 T). These fields are not shielded by most common materials, and pass easily through them. Both types of fields are strongest close to the source and diminish with distance.

Most electric power operates at a frequency of 50 or 60 cycles per second, or hertz (Hz). Close to certain appliances, the magnetic field values can be of the order of a few hundred microtesla. Underneath power lines, magnetic fields can be about 20 μT and electric fields can be several thousand volts per metre. However, average residential power-frequency magnetic fields in homes are much lower - about 0.07 μT in Europe and 0.11 μT in North America. Mean values of the electric field in the home are up to several tens of volts per metre.

Task group evaluation

In October 2005, WHO convened a Task Group of scientific experts to assess any risks to health that might exist from exposure to ELF electric and magnetic fields in the frequency range >0 to 100,000 Hz (100 kHz). While IARC examined the evidence regarding cancer in 2002, this Task Group reviewed evidence for a number of health effects, and updated the evidence regarding cancer. The conclusions and recommendations of the Task Group are presented in a WHO Environmental Health Criteria (EHC) monograph (WHO, 2007).

Following a standard health risk assessment process, the Task Group concluded that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public. Thus the remainder of this fact sheet addresses predominantly the effects of exposure to ELF magnetic fields.

Short-term effects

There are established biological effects from acute exposure at high levels (well above 100 μT) that are explained by recognized biophysical mechanisms. External ELF magnetic fields induce electric fields and currents in the body which, at very high field strengths, cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system.

Potential long-term effects

Much of the scientific research examining long-term risks from ELF magnetic field exposure has focused on childhood leukaemia. In 2002, IARC published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans". This classification is used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals (other examples include coffee and welding fumes). This classification was based on pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 µT. The Task Group concluded that additional studies since then do not alter the status of this classification.

However, the epidemiological evidence is weakened by methodological problems, such as potential selection bias. In addition, there are no accepted biophysical mechanisms that would suggest that low-level exposures are involved in cancer development. Thus, if there were any effects from exposures to these low-level fields, it would have to be through a biological mechanism that is as yet unknown. Additionally, animal studies have been largely negative. Thus, on balance, the evidence related to childhood leukaemia is not strong enough to be considered causal.

Childhood leukaemia is a comparatively rare disease with a total annual number of new cases estimated to be 49,000 worldwide in 2000. Average magnetic field exposures above 0.3 µT in homes are rare: it is estimated that only between 1% and 4% of children live in such conditions. If the association between magnetic fields and childhood leukaemia is causal, the number of cases worldwide that might be attributable to magnetic field exposure is estimated to range from 100 to 2400 cases per year, based on values for the year 2000, representing 0.2 to 4.95% of the total incidence for that year. Thus, if ELF magnetic fields actually do increase the risk of the disease, when considered in a global context, the impact on public health of ELF EMF exposure would be limited.

A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them.

International exposure guidelines

Health effects related to short-term, high-level exposure have been established and form the basis of two international exposure limit guidelines (ICNIRP, 1998; IEEE, 2002). At present, these bodies consider the scientific evidence related to possible health effects from long-term, low-level exposure to ELF fields insufficient to justify lowering these quantitative exposure limits.

WHO's guidance

For high-level short-term exposures to EMF, adverse health effects have been scientifically established (ICNIRP, 2003). International exposure guidelines designed to protect workers and the public from these effects should be adopted by policy makers. EMF protection programs should include exposure measurements from sources where exposures might be expected to exceed limit values.

Regarding long-term effects, given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, the benefits of exposure reduction on health are unclear. In view of this situation, the following recommendations are given:

- Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure. Through the ELF risk assessment process, gaps in knowledge have been identified and these form the basis of a new research agenda.
- Member States are encouraged to establish effective and open communication programmes with all stakeholders to enable informed decision-making. These may include improving coordination and consultation among industry, local government, and citizens in the planning process for ELF EMF-emitting facilities.
- When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted.

Further reading

WHO - World Health Organization. Extremely low frequency fields. Environmental Health Criteria, Vol. 238. Geneva, World Health Organization, 2007.

IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing radiation, Part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. Lyon, IARC, 2002 (Monographs on the Evaluation of Carcinogenic Risks to Humans, 80).

ICNIRP - International Commission on Non-Ionizing Radiation Protection. Exposure to static and low frequency electromagnetic fields, biological effects and health consequences (0-100 kHz). Bernhardt JH et al., eds. Oberschleissheim, International Commission on Non-ionizing Radiation Protection, 2003 (ICNIRP 13/2003).

ICNIRP – International Commission on Non-Ionizing Radiation Protection (1998). Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz). Health Physics 74(4), 494-522.

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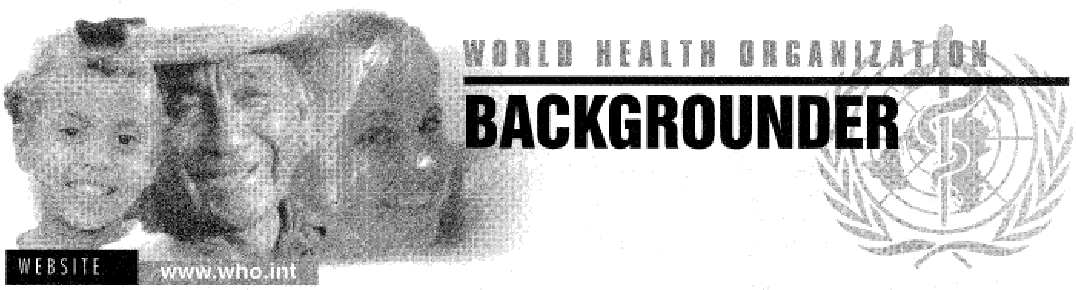

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ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH CAUTIONARY POLICIES

Potential health effects of man made electromagnetic fields (EMF) have been a topic of scientific interest since the late 1800s, and have received particular attention in the last 40 years. Common sources of these fields include power lines, household electrical wiring, appliances and motor driven instruments, computer screens, telecommunications and broadcast facilities, mobile telephones and their base stations.

Public exposure to EMF is regulated by a variety of voluntary and legal limits. The most important of these are international guidelines drafted by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) together with various national safety standards. Guidelines are designed to avoid all identified hazards, from short and long term exposure, with a large margin of safety incorporated into the limit values. Actual exposure levels are nearly always far below recommended limits.

Uncertainties about EMF

Assessment of potential health risks of EMF includes numerous uncertainties. In particular, a number of epidemiological studies suggest the existence of weak links between exposure to EMF and human disease. The studies involve a variety of diseases and exposure conditions. However, the largest body of evidence involves a possible increase in risk of leukaemia in children associated with exposure to electric and magnetic fields at power frequencies (50/60 Hz) in the home. Other scientific evidence, including a large number of animal studies, does not support this conclusion, and many of the epidemiology studies themselves suffer from problems including inadequate exposure assessment.

Expert committees that have reviewed this evidence have consistently found it to be too weak to be persuasive. For example, in 1997 the US National Research Council concluded, "the current body of evidence does not show that exposure to [power frequency electric or magnetic fields in the home] presents a human health hazard." Similarly, in its 1998 guidelines for EMF exposure, ICNIRP stated that the "results from the epidemiological research on EMF field exposure and cancer … are not strong enough to form a scientific basis for setting exposure guidelines." No major committee has concluded that a hazard actually exists from low-level fields. But clearly there is considerable scientific uncertainty as well as a high level of public apprehension about the issue.

Precautionary Policies

Throughout the world there has been a growing movement inside and outside of government to adopt "precautionary approaches" for management of health risks in the face of scientific uncertainty. As an international health agency, WHO does not normally advise national authorities to set policies that go beyond established knowledge. Yet within the declaration signed in London at the 1999 Third Ministerial Conference on Environment and Health, WHO was encouraged to take into account "the need to rigorously apply the Precautionary Principle in assessing risks and to adopt a more preventive, pro-active approach to hazards".

Several different policies promoting caution have been developed to address concerns about public, occupational and environmental health issues in the face of scientific uncertainty. These include:

- Precautionary Principle
- Prudent Avoidance
- ALARA (As Low As Reasonably Achievable)

The Precautionary Principle is a risk management policy applied in circumstances with a high degree of scientific uncertainty, reflecting the need to take action for a potentially serious risk without awaiting the results of scientific research.

For countries of the European Union, the Treaty of Rome states that "Community policy on the environment … shall be based on the precautionary principle." A recent instance of adoption of the Precautionary Principle is the European Commission's decision to ban beef from the United Kingdom, with a view to limiting the risk of transmission of bovine spongiform encephalopathy (BSE). The European Court of Justice ruled that this decision was justified:

In view of the seriousness of the risk and the urgency of the situation, and having regard to the objective of the decision, the Commission did not act in a manifestly inappropriate manner by adopting the decision, on a temporary basis and pending the production of more detailed scientific information

Where there is uncertainty as to the existence or extent of risks to human health, the Commission may take protective measures without having to wait until the reality or seriousness of those risks becomes apparent.

On 2 February 2000, the European Commission approved an important communication on the Precautionary Principle providing guidelines for the application of the Principle. According to this communication, measures based on the precautionary principle should be

- tailored to the chosen level of protection,
- non-discriminatory in their application, i.e. they should treat comparable situations in a similar way,
- consistent with similar measures already taken, i.e. they should be comparable in scope and nature to measures already taken in equivalent areas in which all scientific data are available,
- based on an examination of the potential benefits and costs of action or lack of action (including, where appropriate and feasible, an economic cost/benefit analysis),
- provisional in nature, i.e. subject to review in the light of new scientific data, and
- capable of assigning responsibility for producing the scientific evidence necessary for a more

comprehensive risk assessment.

In this definition, the Precautionary Principle is "risk-oriented", in that it requires an evaluation of risk research including cost-benefit considerations. It is clearly intended for use in drafting provisionary responses to potentially serious health threats, until adequate data are available for more scientifically based responses.

Prudent Avoidance was initially developed as a risk management strategy for power frequency EMF by Drs. Morgan, Florig and Nair at Carnegie Mellon University. In their 1989 report to the US Office of Technology Assessment these authors defined Prudent Avoidance as "taking steps to keep people out of fields by rerouting facilities and redesigning electrical systems and appliances". Prudence was defined as "undertaking those avoidance activities that carry modest costs".

Since 1989 Prudent Avoidance has evolved to mean taking simple, easily achievable, low cost measures to reduce EMF exposure, even in the absence of a demonstrable risk. The terms "simple", "easily achievable", and "low cost", however, lack precise meaning. Generally, government agencies have applied the policy only to new facilities, where minor modifications in design can reduce levels of public exposure. It has not been applied to require modification of existing facilities, which is generally very expensive.

Defined in this way, Prudent Avoidance prescribes taking low-cost measures to reduce exposure, in the absence of any scientifically justifiable expectation that the measures would reduce risk. Such measures are generally framed in terms of voluntary recommendations rather than in terms of fixed limits or rules.

Prudent Avoidance (not necessarily identified as such) has been adopted as policy in parts of the electrical sector in Australia, Sweden and a few US states (California, Colorado, Hawaii, New York, Ohio, Texas, and Wisconsin). In 1997 Australia adopted a policy of Prudent Avoidance with regard to new transmission lines, with measures described by the government as "general guidance" to be implemented "without undue inconvenience." Measures that can be taken at "modest cost" include routing power lines away from schools, and phasing power line conductors to reduce magnetic fields near their rights of way.

In the United States, no national body has explicitly recommended a policy of Prudent Avoidance for powerline fields. However, in its recent recommendations to the US Congress, the National Institute for Environmental Health Sciences (NIEHS) came close, by suggested that "the power industry continue its practice of siting power lines to reduce exposures and continue to explore ways to reduce the creation of magnetic fields around transmission and distribution lines without creating hazards. We also encourage technologies that lower exposures from neighbourhood distribution lines provided that they do not increase other risks, such as those from accidental electrocution and fire".

By contrast, in the cover letter to the NIEHS report to Congress, Kenneth Olden, Director of NIEHS, recommended instead "passive regulatory action" such as "educating both the public and the regulated community on means aimed at reducing exposure…". This recommendation is somewhat different from Prudent Avoidance in that it advocates educational measures, rather than taking actual measures to reduce exposure.

Prudent Avoidance has not been formally adopted in the US for regulation of communications or commercial broadcasting facilities. However, government agencies have made recommendations to the telecommunications industry that could be considered as forms of Prudent Avoidance. In 1999 the U.S. Food and Drug Administration (FDA) urged the mobile phone industry to design phones that minimize user exposure to RF fields to levels necessary for the device's function.

In Prudent Avoidance, as implemented by various countries, prudent refers to expenditures, not an attitude to risk. It does not imply setting exposure limits at an arbitrarily low level, and requiring that they be achieved regardless of cost, but rather adopting measures to reduce public exposure to EMF at modest cost. There is no requirement for assessment of potential health benefits.

ALARA is an acronym for As Low As Reasonably Achievable. It is a policy used to minimize known risks, by keeping exposures as low as reasonably possible, taking into consideration costs, technology, benefits to public health and safety and other societal and economic concerns. ALARA today is mainly used in the context of ionizing radiation protection, where limits are not set on the basis of a threshold, but rather on the basis of "acceptable risk". Under these circumstances, it is reasonable to minimize risk that can be presumed to exist even at levels below recommended limits, on the grounds that what constitutes "acceptable risk" can vary widely among individuals.

ALARA has not been applied to setting public policy related to exposure to EMF. Indeed, it is not an appropriate policy for EMF (either powerline or radiofrequency fields) in the absence of any expectation of risk at low exposure levels and given the ubiquity of exposure.

Precautionary Policies for EMF

Prudent Avoidance and other cautionary policies regarding EMF exposure have gained popularity among many citizens, who feel that they offer extra protection against scientifically unproven risks. However, such approaches are very problematic in their application. The chief difficulty is the lack of clear evidence for hazard from chronic exposure to EMF below recommended guidelines, or any understanding of the nature of a hazard should one exist. While the weight of evidence needed to trigger a cautionary policy is undoubtedly lower than that needed to set exposure guidelines, clearly a hazard must be identified and some understanding is needed of the conditions under which it is likely to be present.

Another difficulty is the ubiquity of EMF exposure in modern society, at highly variable levels and over wide frequency ranges. It is therefore difficult to create cautionary policies that have consistency and equity. For example, typical urban environments contain a multitude of radiofrequency transmitters, ranging from low power communications transmitters to very high power broadcast transmitters. It is difficult to envision a consistent and equitable cautionary policy that would minimize radiofrequency EMF exposures from cellular telephone base stations given the presence of far higher powered sources in the same urban area. Indeed, attempts to implement a cautionary policy for cellular telephone masts have typically been done on a piecemeal basis, with no attention to other (much stronger) sources of RF energy in the environment.

Implications for Guideline Limits

The above considerations suggest that a cautionary policy for EMF should be adopted only with great care and deliberation. The requirements for such a policy as outlined by the European Commission do not appear to be met in the case of either power or radio frequency EMF; however other related policies, such as Prudent Avoidance, may be justified.

A principle requirement is that such policies be adopted only under the condition that scientific assessments of risk and science-based exposure limits should not be undermined by the adoption of arbitrary cautionary approaches. That would occur, for example, if limit values were lowered to levels that bear no relationship to the established hazards or have inappropriate arbitrary adjustments to the limit values to account for the extent of scientific uncertainty.

It is possible to introduce cautionary policies without undermining science-based standards. In 1999, the New Zealand Government issued their RF exposure standards that follow the 1998 ICNIRP EMF guidelines. The Ministries of Health and Environment noted that it considered the basic restrictions and reference levels in its standard to "provide adequate protection". However, the Ministries noted that community concerns over RF exposure might be addressed by "…minimizing, as appropriate, RF exposure which is unnecessary or incidental to achievement of service objectives or process requirements, provided that this can be readily achieved at modest expense". This emphasis on reducing exposure at "modest expense" with no evidence of prospective health benefits or cost-benefit analysis, marks this policy as a form of prudent avoidance, not an application of the Precautionary Principle as outlined by the European Commission.

Other measures, not related to precautionary approaches, can help address public concerns, which typically arise when new electrical facilities are proposed. These might include public input or participation in decisions regarding siting of power lines, electrical substations or radiofrequency transmitters. In addition, individuals can choose to take whatever measures they feel are appropriate to their situation and circumstances. Such actions may include repositioning bedside electrical equipment, such as clock radios, or moving a child's bed to an area of the bedroom that has a lower magnetic field. Turning off electric blankets before going to bed may also be an option. People conducting extended mobile phone conversations could use an earphone-microphone headset (hands-free kit) and hold their mobile phone away from their bodies. Such actions should not be recommended by national authorities on health grounds but may be appropriate for individuals depending on their perception of the risks involved.

For further information, please contact WHO Office of Press and Public Relations, Geneva. Tel (4122) 791 2599, Fax (41 22) 791 4858. Email: inf@who.int. All WHO Press Releases, Fact Sheets and Features as well as other information on this subject can be obtained on Internet on the WHO home page http://www.who.int/ WHO's International EMF Project maintains an updated set of fact sheets giving information about all major sources of EMF exposure. Fact sheets on key issues have been translated into many languages and are available from WHO or on the Project home page at www.who.int/emf

International EMF Project
Information Sheet

February 2005

ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH
Intermediate Frequencies (IF)

Exposure to human-made electromagnetic fields (EMF) has increased over the past century. The widespread use of EMF sources has been accompanied by public debate about possible adverse effects on human health. As part of its charter to protect public health and in response to these concerns, the World Health Organization (WHO) established the International EMF Project to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz. The EMF Project encourages focused research to fill important gaps in knowledge and to facilitate the development of internationally acceptable standards limiting EMF exposure.

Public concerns have ranged from possible effects of exposure to extremely low frequency (ELF) electric and magnetic fields (e.g. electricity supply including power lines) having frequencies between 0 and 300 Hz to possible effects of exposure to radiofrequency (RF) fields (e.g. microwave ovens and broadcast and other radio-transmission devices including mobile phones) having frequencies in the range 10 MHz - 300 GHz. A large body of scientific research in these two frequency ranges now exists. For the purpose of this document, the intermediate frequency (IF) region of the EMF spectrum is defined as being between the ELF and RF ranges; 300 Hz to 10 MHz. A relatively small number of studies has been conducted on the biological effects or health risks of IF fields. This is due, in part, to the fact that fewer types of devices produce fields in this frequency range. But because these devices now have a high consumer and industrial market penetration, it is important to evaluate their impact on human health. This information sheet addresses the known health effects of IF fields, and offers recommendations for further study.

Sources
Common sources of IF fields can be found in the following settings:

- **Industry**: Dielectric heater sealers, induction and plasma heaters, broadcast and communications transmitters,
- **General public**: Domestic induction cookers, proximity readers, electronic article surveillance systems and other anti-theft devices, computer monitors and television sets,
- **Hospitals**: MRI systems, electromagnetic nerve stimulators, electro-surgical units, and other devices for medical treatment,
- **Military**: Power units, submarine communication transmitters and high frequency (HF) transmitters.

Except for medical diagnostic and treatment devices, levels of human exposure from IF devices normally fall below limits recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). However, workers in a few categories (e.g. operators of dielectric heater sealers and induction heaters, some military personnel and technicians working near high powered broadcast equipment) may be exposed to considerably higher levels of IF fields.

How EMF Affects the Human Body

Several mechanisms, both thermal and non-thermal, by which electromagnetic (primarily, electric) fields can interact with biological systems are well established. The limiting hazard will arise from the adverse effect (thermal or non-thermal) that has the lowest threshold under given exposure conditions. While strong fields in the upper IF range may cause *thermal damage* (a relatively slow process that requires tissue to be maintained at high temperatures for a given period of time), some of the most obvious hazards from acute exposure to electric currents in the body may occur through *membrane excitation***.** This non-thermal mechanism results from changes in membrane potential induced by external fields and occurs, for example, in the stimulation of peripheral nerves and muscle cells. Another mechanism is *electroporation*, which is the reversible or irreversible disruption of cell membranes when a field induces excessive electrical potentials across them. This can provoke tissue injury through electric shock, but is also being investigated for therapeutic purposes by using short electric field pulses to make human tissues more permeable to drugs.

External IF fields can induce these effects inside the human body but only at field strengths many times higher than typical environmental levels.

Reported Biological and Health Effects

Health benefits from electric and magnetic fields have been claimed since the 18th century, and pulsed EMFs in the IF range have found a place in modern medical practice for the treatment of bone healing and nerve stimulation and regeneration. However, concern has been expressed about possible health hazards associated with technology, both at home and in the workplace. These concerns include worker complaints of disturbances (e.g. swelling, prickling of fingers, headaches) and public anxiety about possible adverse health effects of IF fields from computer monitors and televisions. Types of research conducted so far have included:

- **Human studies**: Until now, most epidemiological studies concerning IF exposure have focused on *reproductive and ocular effects* from the use of computer monitors. Several major reviews have concluded that these, with their extremely weak IF fields, do not constitute a threat to human health and that they do not interfere with reproductive processes or pregnancy outcomes. Also, no association between such exposure and eye abnormalities has been established. A large study on female radio and telegraph operators showed a slight increased risk of *breast cancer*. However, this group of workers is also exposed to many other factors that could explain this increased risk. The high degree of biological variability and the multitude of EMF parameters make it difficult to reach firm conclusions about the significance of any of these studies for human health. Some of the most important health hazards due to IF sources relate to *indirect* action of EMF. For example, EMF produced by electronic anti-theft systems may interfere with implanted electronic medical devices (e.g. pacemakers, neurological stimulators).

- **Laboratory studies**: Few reported *cellular studies* using IF fields have shown independently-confirmed biological effects. Studies on mice have shown no morbidity, change in behaviour or lymphoma development with exposure to low-strength magnetic field signals in the kHz range. Although a few studies of effects on *reproduction and development* of mice, rats, and chick embryos and a few other studies suggest the possibility of minor skeletal anomalies; overall there is no clear evidence for increased malformations.

Compared to extremely low frequency fields (ELF, which includes AC power frequencies) and radio frequency fields (RF, which includes mobile phone communications), little research has been done of the effects of IF fields. The scientific evidence is not convincing that adverse health effects occur from exposure to IF fields normally found in the living and working environment. This conclusion is partly based on the studies conducted with IF fields but also on the fact that IF fields act on the body in a way similar to ELF and RF fields, depending on the frequency of the IF field.

International Standards

ICNIRP is an independent scientific commission formally recognized by WHO that has published guidelines on exposure limits for all EMF in the 0 to 300 GHz frequency range. Exposure guidelines in the IF range have been established from rigorous review of the scientific literature on possible adverse health effects and by extrapolating limits from the ELF and RF ranges, based on coupling of external fields with the body and assumptions about the frequency dependence of biological effects.

What Should Be Done?

The scientific evidence does not suggest any health risk from IF fields at exposures below the ICNIRP guideline levels. However, there is a need for more high quality research to address uncertainties in current knowledge. The following key areas have been identified for further research:

- **Epidemiological studies**: It is recommended that epidemiological studies be considered only if pilot studies demonstrate the feasibility of gathering high quality exposure data in appropriate highly exposed populations, thereby achieving adequate statistical power and identifying relevant health outcomes.
- **Exposure evaluation**: The degree and type of EMF exposure currently encountered in occupational and domestic settings need to be better characterized. Periodic checks must be made and documented in industrial and other occupational settings where IF fields are used, to ensure that the equipment is operating properly and that exposure guidelines are not exceeded.
- **Animal studies**: Future animal studies should attempt to use exposure conditions that are similar to human exposures from industrial and other sources, and also should explore higher exposure levels. If specific suspect pathways are identified, these studies could be supplemented by cell or tissue studies to clarify how IF fields affect organisms.
- **Biological interaction**: More comprehensive understanding of the biological interaction and hazard thresholds is required to refine exposure guidelines, particularly for pulsed fields or fields with complex waveforms.
- **Dosimetry**: Computer modelling techniques exist that enable the calculation of fields induced inside the bodies of people exposed to IF fields. The most advanced of these techniques employ anatomically realistic computational phantoms. Such methods are particularly appropriate in risk assessment and testing compliance of measured IF fields with exposure limits in a consistent manner. It is important that, where appropriate, female and child phantoms are also considered for use in such assessments.

What is the World Health Organization doing about the issue?

The WHO's International EMF Project has established a programme to review research results and conduct risk assessments of EMF exposure. It is developing public information materials, and bringing together standards groups world-wide in an attempt to harmonize approaches to the development of EMF exposure standards. Health risks from EMF exposure, including cancer, are being evaluated by WHO in collaboration with the International Agency for Research on Cancer (IARC) – the specialized cancer research agency of WHO – and by ICNIRP.

Further Reading

Bernhardt JH, McKinlay AF and Matthes R, editors: Possible health risk to the general public from the use of security and similar devices. Report to the European Commission Concerted Action QLK4-1999-01214, ICNIRP, 2002 (ICNIRP 12/2002).

Matthes R., van Rongen E., Repacholi M., editors: *Proceedings of the International Seminar on Health Effects of Exposure to Electromagnetic Fields in the Frequency Range 300 Hz to 10 MHz*, Maastricht, The Netherlands, ICNIRP, 1999 (ICNIRP 8/99).

Litvak E, Foster K R and Repacholi M H (2002): Health and safety implications of exposure to electromagnetic fields in the frequency range 300 Hz to 10 MHz. *Bioelectromagnetics* 23(1): 68-82.

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February 2005

ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH
Microwave Ovens

WHAT ARE MICROWAVES?
Microwaves are high frequency radio waves (radiofrequency fields) and, like visible radiation (light), are part of the electromagnetic spectrum. Microwaves are used primarily for TV broadcasting, radar for air and sea navigational aids, and telecommunications including mobile phones. They are also used in industry for processing materials, in medicine for diathermy treatment and in kitchens for cooking food.

Microwaves are reflected, transmitted or absorbed by materials in their path, in a similar manner to light. Metallic materials totally reflect microwaves while non-metallic materials such as glass and some plastics are mostly transparent to microwaves.

Materials containing water, for example foods, fluids or tissues, readily absorb microwave energy, which is then converted into heat. This Information Sheet discusses the operation and safety aspects of microwave ovens used in the home. More details about the nature of electromagnetic fields and health effects of radiofrequency and microwave fields are available in WHO Fact Sheets 182 and 183.

ARE MICROWAVE OVENS SAFE?
When used according to manufacturers' instructions, microwave ovens are safe and convenient for heating and cooking a variety of foods. However, several precautions need to be taken, specifically with regards to potential exposure to microwaves, thermal burns and food handling.

Microwave safety: The design of microwave ovens ensures that the microwaves are contained within the oven and can only be present when the oven is switched on and the door is shut. Leakage around and through the glass door is limited by design to a level well below that recommended by international standards. However, microwave leakage could still occur around damaged, dirty or modified microwave ovens. It is therefore important that the oven is maintained in good condition. Users should check that the door closes properly and that the safety interlock devices, fitted to the door to prevent microwaves from being generated while it is open, work correctly. The door seals should be kept clean and there should be no visible signs of damage to the seals or the outer casing of the oven. If any faults are found or parts of the oven are damaged, it should not be used until it has been repaired by an appropriately qualified service engineer.

Microwave energy can be absorbed by the body and produce heat in exposed tissues. Organs with a poor blood supply and temperature control, such as the eye, or temperature-sensitive tissue like the testes, have a higher risk of heat damage. However, thermal damage would only occur from long exposures to very high power levels, well in excess of those measured around microwave ovens.

Thermal safety: Burn injuries can result from handling hot items heated in a microwave oven, in the same way as items heated using conventional ovens or cooking surfaces. However, heating food in a microwave oven presents some peculiarities. Boiling water on a conventional stove allows steam to escape through bubbling action as the water begins to boil. In a microwave oven there may be no bubbles on the walls of the container and the water will super-heat and may suddenly boil. This sudden boiling may be triggered by a single bubble in the liquid or by the introduction of a foreign element such as a spoon. People have been severely burned by super-heated water.

Another peculiarity of microwave cooking relates to the thermal response of specific foods. Certain items with non-porous surfaces (e.g. hotdogs) or composed of materials that heat at different rates (e.g. yolk and white of eggs) heat unevenly and may explode. This can happen if eggs or chestnuts are cooked in their shells.

Food safety: Food safety is an important health issue. In a microwave oven, the rate of heating depends on the power rating of the oven and on the water content, density and amount of food being heated. Microwave energy does not penetrate well in thicker pieces of food, and may produce uneven cooking. This can lead to a health risk if parts of the food are not heated sufficiently to kill potentially dangerous micro-organisms. Because of the potential for uneven distribution of cooking, food heated in a microwave oven should rest for several minutes after cooking is completed to allow the heat to distribute throughout the food.

Food cooked in a microwave oven is as safe, and has the same nutrient value, as food cooked in a conventional oven. The main difference between these two methods of cooking is that microwave energy penetrates deeper into the food and reduces the time for heat to be conducted throughout the food, thus reducing the overall cooking time.

Only certain microwave ovens are designed to sterilize items (for example baby's milk bottles). The user should follow the manufacturer's instructions for this type of application.

Misconceptions: To dispel some misconceptions, it is important to realize that food cooked in a microwave oven does not become "radioactive". Nor does any microwave energy remain in the cavity or the food after the microwave oven is switched off. In this respect, microwaves act just like light; when the light bulb is turned off, no light remains.

HOW DO MICROWAVE OVENS WORK?

Domestic microwave ovens operate at a frequency of 2450 MHz with a power usually ranging from 500 to 1100 watts. Microwaves are produced by an electronic tube called a magnetron. Once the oven is switched on, the microwaves are dispersed in the oven cavity and reflected by a stirrer fan so the microwaves are propagated in all directions. They are reflected by the metal sides of the oven cavity and absorbed by the food. Uniformity of heating in the food is usually assisted by having the food on a rotating turntable in the oven. Water molecules vibrate when they absorb microwave energy, and the friction between the molecules results in heating which cooks the food.

Unlike conventional ovens, microwaves are absorbed only in the food and not in the surrounding oven cavity. Only dishes and containers specifically designed for microwave cooking should be used. Certain materials, such as plastics not suitable for microwave oven, may melt or burst into flames if overheated. Microwaves do not directly heat food containers which are designed for microwave cooking. These materials usually get warm only from being in contact with the hot food.

Oven manufacturers do not recommend operating an empty oven. In the absence of food, the microwave energy can reflect back into the magnetron and may damage it.

Microwave oven users should carefully read and comply with the manufacturer's instructions because new ovens vary widely in design and performance. While most modern ovens can tolerate some food packaging made of metal, oven manufacturers generally recommend not placing metal in the oven, particularly not close to the walls, as this could cause electrical arcing and damage the oven walls. Also, because metal reflects microwaves, food wrapped in metal foil will not be cooked, while food not in metal wrap may receive more energy than intended, causing uneven cooking.

INTERNATIONAL STANDARDS

Several countries, as well as the International Electrotechnical Commission (IEC), the International Committee on Electromagnetic Safety (ICES) of the Institute of Electrical and Electronics Engineers (IEEE) and the European Committee for Electrotechnical Standardization (CENELEC), have set a product emission limit of 50 watts per square metre (W/m^2) at any point 5 cm away from the external surfaces of the oven. In practice, emissions from modern domestic microwave ovens are substantially below this international limit, and have interlocks that prevent people being exposed to microwaves while the oven is on. Moreover, exposure decreases rapidly with distance; e.g. a person 50 cm from the oven receives about one one-hundredth of the microwave exposure of a person 5 cm away.

These product emission limits are defined for the purpose of compliance testing, not specifically exposure protection. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published guidelines on exposure limits for the whole EMF part of the spectrum. Exposure guidelines in the microwave range are set at a level that prevents any known adverse health effect. Exposure limits for workers and for the general public are set well below levels where any hazardous heating occurs from microwave exposure. The emission limit for microwave ovens mentioned above is consistent with the exposure limits recommended by ICNIRP.

WHAT THE WORLD HEALTH ORGANIZATION IS DOING

The World Health Organization (WHO), through the International EMF Project, has established a programme to review research results and conduct risk assessments of exposure to electromagnetic fields in the range from 0 to 300 GHz. Health risks from EMF exposure are being evaluated by WHO in collaboration with ICNIRP.

The EMF Project has a web site with links to WHO Fact Sheets on various aspects of EMF exposure and health and published in multiple languages (for more information, see http://www.who.int/docstore/peh-emf/publications/facts_press/fact_english.htm). The site also provides information on the Project, its publications and its scientific and public information activities.

International EMF Project
Information Sheet

February 2005

ELECTROMAGNETIC FIELDS AND PUBLIC HEALTH
Effects of EMF on the Environment

Levels of electromagnetic fields (EMF) from human-made sources have increased steadily over the past 50-100 years. Most EMF exposures come from increased use of electricity and new technologies. In the past decades, potential adverse effects from EMF exposure on human health have been an important topic of research. However, little has been published about the impact of EMF on the natural terrestrial and aquatic environment.

The World Health Organization (WHO) is addressing this issue through the International EMF Project. One of the Project's objectives is to provide advice to national authorities and others on EMF health and environmental effects and protective measures or actions if needed.

This information sheet summarizes the current scientific understanding on the effects of exposure to EMF fields on the living environment, across the electromagnetic spectrum in the frequency range 0-300 GHz. This range covers all frequencies that are emitted into the environment through use of EMF technology. Recommendations are also given for further research to fill gaps in knowledge needed to better assess EMF environmental impacts.

IS THERE REASON TO WORRY ABOUT ENVIRONMENTAL EFFECTS OF EMF?
Awareness of any environmental impacts of EMF is important to ensure the preservation of terrestrial and marine ecosystems, which form the basis for sustainable development. Protection of the environment and conservation of nature have become matters of great interest to the public, as well as to governments. Such interest is often expressed as concern over possible environmental impacts of large technology projects, such as dams, nuclear power plants, and radiofrequency transmitters. Several projects have been subject to public pressures on environmental grounds, with EMF being one but not necessarily the only issue. For example, a proposed high frequency (HF) radio transmitter for the Voice of America in Israel, which would have been the world's largest radio station, was blocked from construction on environmental grounds, in part related to concerns about potential effects of radio frequency fields on migrating birds.

Public concern about environmental exposure to EMF has ranged from claims of reduced milk production in cows grazing under power lines to damage to trees near high power radars. Such concerns might also affect the development of new technology: several plans have been proposed since the late 1960s for generating electric power in space by orbiting arrays of solar panels. Large amounts of electricity generated by such solar power satellites would be transmitted to sizeable antennas on the ground. In addition to overcoming technical difficulties, this and other new technologies would have to gain public acceptance.

SOURCES OF ENVIRONMENTAL EXPOSURE

Emissions from natural as well as artificial sources make up the EMF environment we live in. **Natural sources**, which include EMF radiation from the sun, the earth, the atmosphere including lightning discharges, account for only a small fraction of the overall EMF emissions in the 0-300 GHz frequency range. **Human-made sources** from major technologies have become an important component of the total EMF emissions into the environment. Relevant sources in the environment include:

- **FM Radio and TV Transmitters:** The strongest radio-frequency fields in most urban areas are associated with radio and TV broadcast services (for more information, see Fact Sheet 183). In urban areas, contributions from mobile phone base stations may reach similar amplitudes.
- **Radar:** Radar systems are used for a variety of tasks, ranging from navigation to aircraft and missile surveillance systems (for more information, see Fact Sheet 226). Wide-spread penetrations are expected from vehicle anti collision radar systems.
- **High Voltage Power Lines:** Power lines deliver electricity (usually at 50 or 60 Hz) and may span hundreds of kilometres (for more information related to their effects on human health, see the WHO Fact Sheets 205, 263).
- **Undersea Power Cables:** Undersea cables are used in Europe (especially in Scandinavia and Greece), Canada, Japan, New Zealand and the Philippines to transfer electric power across water. These sea cables usually conduct very large DC currents of up to a thousand amperes or more.

For most of these sources, substantial EMF only exist adjacent to the source, where they may exceed international guidelines for limiting exposure of people (ICNIRP, 1998). These areas are generally not accessible to the public but may be entered by fauna. Away from the EMF sources, the fields decrease rapidly to intensities below ICNIRP's exposure guidelines.

SUMMARY OF RELEVANT STUDIES

Animals

Most studies of EMF effects in animals have been conducted to investigate possible adverse health effects in humans. These are usually performed on standard laboratory animals used in toxicological studies, e.g. rats and mice, but some studies have also included other species such as like short-living flies for the investigation of genotoxic effects. The subject of this information sheet, however, is whether EMF can have harmful impacts on species of wild and domestic animals. Under consideration are:

- Species, in particular certain fish, reptiles, mammals and migratory birds, which rely on the natural (geomagnetic) static magnetic field as one of a number of parameters believed to be used for orientation and navigational cues
- Farm animals (e.g. swine, sheep or cattle) grazing under power lines (50/60 Hz) or in the vicinity of broadcasting antennas
- Flying fauna, such as birds and insects, which may pass through the main beam of high power radio-frequency antennas and radar beams or through high intensity ELF fields near power lines.

Studies performed to date have found little evidence of EMF effects on fauna at levels below ICNIRP's guideline levels. In particular, there were no adverse effects found on cattle grazing below power lines. However, it is known that flight performance of insects can be impaired in electric fields above 1kV/m, but significant effects have only been shown for bees when electrically conductive hives are placed directly under power lines. Un-insulated un-earthed conductors placed in an electric field can become charged and cause injury or disrupt the activity of animals, birds and insects.

Vegetation
Field studies of 50-60 Hz exposure to **plants and crops** have shown no effects at the levels normally found in the environment, nor even at field levels directly under power lines up to 765 kV. However, the variability of parameters associated with environmental conditions that affect plant growth (e.g. soil, weather) would likely preclude observation of any possible low-level effects of electric field exposure. Damage to **trees** is well known to occur at electric field strengths far above ICNIRP's levels due to corona discharge at the tips of the leaves. Such field levels are found only close to the conductors of very high voltage power lines.

Aquatic Life
Although all organisms are exposed to the *geomagnetic field*, marine animals are also exposed to natural *electric fields* caused by sea currents moving through the geomagnetic field. Electrosensitive fish, such as sharks and rays in oceans and catfish in fresh water, can orient themselves in response to very low electric fields by means of electroreceptive organs. Some investigators have suggested that human-made EMF from undersea power cables could interfere with the prey sensing or navigational abilities of these animals in the immediate vicinity of the sea cables. However, none of the studies performed to date to assess the impact of undersea cables on migratory fish (e.g. salmon and eels) and all the relatively immobile fauna inhabiting the sea floor (e.g. molluscs), have found any substantial behavioural or biological impact.

CONCLUSION
The limited number of published studies addressing the risk of EMF to terrestrial and aquatic ecosystems show little or no evidence of a significant environmental impact, except for some effects near very strong sources. From current in formation the exposure limits in the ICNIRP guidelines for protection of human health are also protective of the environment.

WHAT SHOULD BE DONE?
Environmental studies are needed since any adverse influence of EMF on plants, animals such as birds, and other living organisms, while important in their own right, could also ultimately impact on human life and health. However, much of the existing work in this area has been scattered in approach and uneven in quality. A co-ordinated research agenda that addresses the scientific issues raised by increasing environmental EMF levels does not exist. In view of the facts discussed above, there is no urgent need to give research priority to this field over other health topics. However, while there is a small but active research effort in this area, it would be informative to:

- design bio-effects research with **wildlife species** in mind and aimed at identifying their possible responses to new human-made sources of EMF energy. Appropriate choice of species for study is very important (e.g. birds since they can enter areas of high field strength),
- develop **environmental guidelines** for EMF exposure at different frequencies, drawing on information from well-performed studies. Such guidelines might resemble those developed for human health, but with appropriately adapted thresholds to ensure that EMF levels are below those producing adverse consequences in the environment,

WHERE CAN I FIND MORE INFORMATION?
The following references provide a more in-depth treatment of this subject:

- Matthes R., Bernhardt J., Repacholi M., editors: *Proceedings of the International Seminar on Effects of Electromagnetic Fields on the Living Environment*, Ismaning, Germany, ICNIRP, 2000 (ICNIRP 10/2000).

- Foster K. and Repacholi M. *Environmental Impacts of Electromagnetic Fields From Major Electrical Technologies.* EMF Project report: http://www.who.int/peh-emf/publications/reports/en/env_impact_emf_from_major_elect_tech_foster_repacholi.pdf
- Matthes R., Bernhardt J., McKinlay A., editors*: Guidelines on Limiting Exposure to Non-Ionizing Radiation*, ICNIRP, 1999 (ICNIRP 7/99). http://www.icnirp.org
- All WHO Fact Sheets are available at

  http://www.who.int/docstore/peh-emf/publications/facts_press/fact_english.htm