

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

- RF 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 RF 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 RF 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.
- RF 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 RF 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) 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.

For further information, please contact Health Communications and Public Relations, WHO, Geneva. Telephone (41 22) 791 2532. Fax (41 22) 791 4858. 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.ch/>

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