ELECTRIC AND MAGNETIC FIELDS (EMF): THE BASICS

Electric charges are present in all matter, but most objects are electrically neutral because positive and negative charges are present in equal numbers. When the balance of electric charges is altered, electrical effects are experienced, such as the attraction between a comb and our hair or the drawing of sparks after walking on a synthetic rug in the wintertime. The voltage on an electrical wire is caused by electric charges that can exert forces on other nearby charges, and this force is called an "electric field" (E). When charges move they produce an electric current that can exert forces on other electric currents, and this force between electric currents is called a "magnetic field" (M). Together, electric and magnetic fields are called EMF.

EMF exists wherever electricity is produced or used, and EMF surrounds any electrical appliance or wire that is conducting electricity. Everyone is exposed to these fields at home when you turn on a lamp, e-mail a friend, or use an electric oven or microwave to cook your dinner. In all likelihood, you're surrounded by EMF from electrical equipment in your workplace, too.

The electric power we use daily is a 60 Hertz (Hz) alternating current, meaning that electric charges move back and forth 60 times a second. We use "EMF" in this fact sheet in reference to these 60 Hz fields, called "extremely low frequency" or "power frequency" fields. These are distinct from the much higher frequency fields associated with radio and TV waves, and cell phone signals.

What are electric and magnetic fields?

Electric fields are created by voltage – the higher the voltage, the stronger the field. Anytime an electrical appliance is plugged in, even if it isn't on, an electric field is created in its vicinity. But these fields are easily blocked by walls, trees, and even your clothes and skin, and the farther away you move from the source of the electric field, the weaker it becomes. Moving even a few feet away from an appliance makes a big difference in the strength of the field that you're exposed to. Electric fields are measured in kilovolts per meter (kV/m).

Magnetic fields, measured in milliGauss (mG), are produced by electric current and only exist when an electric appliance is turned on – the higher the current, the greater the magnetic field. As with electric fields, the strength of a magnetic field dissipates rapidly as you move away from its source. However, unlike electric fields that are easily blocked by ordinary materials, magnetic fields do not interact with and are not affected by walls and clothes and other barriers.

Research studies on the biological effects of EMF often focus on magnetic fields because they are not blocked by ordinary materials and because power line magnetic fields can create weak electric currents in the body by a process called "induction."

Induced currents from 60 Hz EMF produced by power lines or home appliances are weaker than the natural currents found in the body, such as those from the electrical activity generated by your brain or your heart. Such induced currents are also much weaker than the currents you might experience from a mild electric shock.

Why are you calling them electric and magnetic fields instead of electromagnetic fields? Is there a difference?

These terms are often used interchangeably, and both electric and magnetic fields from power lines and electromagnetic fields may be abbreviated as EMF. However, there are important differences between low frequency power line EMF and higher frequency radio waves.

The frequency (i.e., the rate of time variation) of fields produced by the generation, transmission and use of electricity – typical of most household and office appliances and power lines – are low, and electric and magnetic fields exist separately. At higher frequencies, such as with radio or TV signals, the fields are interrelated, and are more accurately described by the term "electromagnetic." Radio and TV electromagnetic waves are meant to transmit away from the antenna and carry radio frequency energy to the receiver. The EMF from power lines is too low in frequency to carry any significant energy away, and the electric power stays on the utility lines.

Thus, the EMF from power lines should not be called radiation or emissions. More importantly, neither power line

EMF nor radio frequency electromagnetic waves should be confused with ionizing radiation, such as X-rays. Because of its dramatically higher frequency, ionizing radiation (like X-rays) has enough energy to alter chemical bonds and damage biological molecules, something that lower frequencies in the electromagnetic spectrum (power lines, radio, TV, and infrared) cannot do.

What are some of the things in my home and at work that produce EMF?

Anything that generates, distributes or uses electricity creates electric and magnetic fields. Figure 1 is a list of some appliances and machines commonly found in homes or offices and the magnetic field levels found nearby.

We also encounter a wide variety of EMF in other ways – natural and man-made. The earth's atmosphere creates slowly varying electric fields, and thunderstorms produce very intense electric fields that are occasionally discharged by a lightning bolt. The earth's core produces a steady magnetic field, as can easily be demonstrated with a compass needle which points to magnetic north. This magnetic field has a strength of about 550 mG.

Magnetic fields from the earth or from small magnets exert forces on electric currents or on other magnetic objects, as when a compass needle points toward a nearby magnet. Magnetic fields are common in our lives. Many children's toys contain magnets and many of us use refrigerator magnets, generating fields of about 100,000 to 500,000 mG.

An increasingly common diagnostic procedure, magnetic resonance imaging (MRI), uses fields of about 20,000,000 mG. If you were to spin a magnet at a rate of 60 times a second, you would get an alternating magnetic field like the fields produced by power lines.

How can I find out what EMF levels I'm exposed to at home and at work?

You can monitor your daily exposure to magnetic fields by wearing a personal exposure meter (called a magnetometer or gauss meter) or by keeping one close to you. This is the most accurate way to measure your true exposure to magnetic fields during the course of your normal activities. Other meters can be put in a location – like your kitchen or home office – to measure typical EMF levels in that spot. This type of measurement isn't an accurate measure of personal exposure, however, because it doesn't take into account your distance from the source of the fields or the amount of time you might spend in that place. Contact your local electric service provider. Most utilities offer a free measurement service to customers to measure magnetic fields in their homes or businesses.

Figure 1. Typical 60 Hz magnetic field levels from some common home appliances

	MAGNETIC FIELD 6 INCHES FROM APPLIANCE (mG)	MAGNETIC FIELD 2 FEET AWAY (mG)
Electric shaver	100	–
Vacuum cleaner	300	10
Electric oven	9	–
Dishwasher	20	4
Microwave oven	200	10
Hair dryer	300	–
Computers	14	2
Fluorescent lights	40	2
Copy machines	90	7
Garbage disposals	80	2

Source: National Institute of Environmental Health Services / National Institutes of Health: EMF Associated with the Use of Electric Power

What are 'typical' residential exposures to magnetic fields?

Exposure levels vary from individual to individual and from home to home, but a study by the Electric Power Research Institute (EPRI) puts the background levels of power line magnetic fields in the typical U.S. home at between 0.5 mG and 4 mG with an average of 0.9 mG. Levels rise the closer you get to the source of the field. Most people are exposed to greater magnetic fields at work than in their homes. See Figure 1.

What EMF levels are found near transmission lines?

All transmission lines produce EMF. The fields are the strongest directly under the lines and drop dramatically the farther away you move. These magnetic fields will change with the amount of electricity flowing on the line that varies with the time of day and the season of the year. Contact your local utility to find out EMF information about a particular transmission line near you.

Do underground lines reduce EMF levels?

Yes. Because magnetic fields are not shielded by ordinary materials, burying power lines won't keep the fields from passing through the ground. In fact, underground lines can produce higher levels of magnetic fields directly above the line at ground level because these lines are located closer to you (5 feet below) compared to overhead lines (25 to 30 feet above). However, the strength of the magnetic field from underground lines falls away more quickly to the side with distance than from overhead lines because of the way the lines are built.

Compared to overhead lines, underground lines are significantly more expensive to install (up to 10 to 20 times more expensive), more difficult to repair and can have greater environmental impacts because of the disturbance of the soil to install the underground lines. Since recent research results provide no conclusive connection between EMF exposure and health effects, burying lines isn't a reasonable alternative.

Are there state or federal standards for EMF exposure?

There are no federal standards limiting residential or occupational EMF exposure. Several states have set standards for the allowed level of magnetic fields from new power lines.

The EMF levels produced by appliances vary from manufacturer to manufacturer and model to model. The designs of many newer model appliances, in general, often produce lower fields than older models. An example is electric blankets where new blankets produce much lower fields than those produced 20 years ago. There is no federal certification program on EMF levels so beware of advertisements on appliances making claims of federal government certification of low or zero EMF levels.

Do exposures to power line EMF affect my health?

This issue has been studied for more than 40 years by government and scientific institutions all over the world. The balance of scientific evidence indicates that exposure to EMF does not cause disease. (See the sources and useful links section of this fact sheet for more information on studies about EMF and health.)

Does EMF interfere with pacemakers or other medical devices?

High levels of power line EMF can interfere with a pacemaker's ability to sense normal electrical activity in the heart. Most often, the electric circuitry in a pacemaker might detect the interference of an external field and direct the pacemaker to fire in a regular, life-preserving mode. This isn't considered hazardous and is actually a life-preserving default feature. There have been cases with dual-chamber pacemakers triggering inappropriate pacing before the life-preserving mode takes over. Newer pacemakers have been designed to be less susceptible to this type of interference.

The American Conference of Governmental Industrial Hygienists (ACGIH) issued guidelines for EMF exposure for workers with pacemakers or implantable defibrillators. Maximum safe exposure for workers with these medical devices at 60 Hz (the frequency of most transmission lines) is 1 G (1,000 mG) for magnetic fields and 1 kV/m for electric fields. Non-electronic metallic implants (artificial limbs, screws, pins, etc.) can be affected by high magnetic fields like those produced by MRI devices but are generally unaffected by the lower magnetic fields produced by most other sources.

How can I reduce my exposure to EMF?

If you wish to reduce EMF levels in your vicinity you can do so by recognizing that your exposure is determined by the strength of the magnetic fields given off by things around you, your distance from the source of the field and how much time you spend in the field. Creating distance between yourself and the sources of EMF is the easiest way to reduce exposure. Standing back – even an arm's length away – from appliances that are in use is a simple first step. Remember, EMF decreases dramatically with distance. This is more feasible with some appliances than with others, but the following simple recommendations will help you reduce your EMF exposure at home:

- Move motor-driven electric clocks or other electrical devices away from your bed.
- Be aware that electric motors change electricity into mechanical energy by using magnetic fields, so any motorized appliance (e.g., hairdryers, shavers, fans, vacuum cleaners, air conditioners) will produce magnetic fields.
- Stand away from operating appliances that use a lot of electricity.
- Sit a few feet away from the TV and at least an arm's length from the computer screen. Liquid crystal or plasma displays (LCDs), however, produce very low levels of EMF compared to the older cathode-ray tube (CRT) displays.
- Limit the time you're exposed to a magnetic field by turning appliances, like computer monitors, off when you're not using them.

Sources and useful links

The following are links to more information and studies on EMF:

- The National Institute of Environmental Health Services (NIEHS) offers information on a variety of EMF topics. In June of 2002 they prepared EMF: Electric and Magnetic Fields Associated with the Use of Electric Power, Questions and Answers. This booklet, along with other helpful links, can be found at www.niehs.nih.gov/health/topics/agents/emf/.
- American Cancer Society: Power Lines, Electrical Devices and Extremely Low Frequency Radiation https://www.cancer.org/cancer/cancer-causes/radiation-exposure/extremely-low-frequency-radiation.html
- Public Service Commission of Wisconsin: Electric & Magnetic Fields https://psc.wi.gov/Documents/Brochures/EMF.pdf
- Minnesota Public Utilities Commission: A White Paper on Electric and Magnetic Field (EMF) Policy and Mitigation Options https://mn.gov/eera/web/project-file?legacyPath=/opt/documents/EMF%20White%20Paper%20-%20MN%20Workgroup%20Sep%202002.pdf

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