Electric and Magnetic Fields

measurements and possible effect on human health — what we know and what we don't know in 2000

This factsheet has a moderate level of technical detail and is intended for those with an interest in science. For more information see our Website at http://www.dhs.ca.gov/ps/deodc/ehib/.

INTRODUCTION

Our daily use of electricity is taken for granted, yet scientific and public concern has arisen about possible health effects from electric and magnetic fields (EMF) that are created by the use of electricity. Because of this concern, the California Public Utilities Commission authorized a statewide research, education and technical assistance program on the health aspects of exposure to magnetic fields and asked the Department of Health Services to manage it. Even though both electric and magnetic fields are present with the use of electrical power, interest and research have focused on the effects of 50 and 60 Hertz (Hz) magnetic fields, called "power frequency" fields, from sources such as power lines, appliances and wiring in buildings. This is because it is known that magnetic fields are difficult to shield and because early scientific studies showed a possible relationship between human exposure to certain magnetic field sources and increased rates of cancer.

Even now, scientists are not sure if there are health risks from exposure to 50 and 60 Hz magnetic fields, or if so what is a "safe" or "unsafe" level of exposure. People frequently ask about EMF risk when they are choosing where to live. This choice should include consideration of proven risks of the location, such as the possibility of earthquake, flooding, or fire, or the presence of traffic, radon, or air pollution. To some people even limited evidence for a possible EMF risk weighs heavily in their decisions. For others, different considerations take precedence. There really is no one right answer to these questions because each situation is unique.

The California EMF Program developed this fact sheet to give an overview of the present state of knowledge and provide a basis for understanding the current limitations on the ability of science to resolve questions about the possible health risks of magnetic field exposure. This paper describes electric and magnetic fields, high field sources and how to interpret field measurements once they are made. It includes discussions of the controversy about possible health effects, as well as current California state policy and what the government is doing to address public concern.

WHAT ARE ELECTRIC AND MAGNETIC FIELDS OR "EMF"

Before man-made electricity, humans were exposed only to the magnetic field of the earth, electric fields caused by charges in the clouds or by the static electricity of two objects rubbing together, or the sudden electric and magnetic fields caused by lightning. Since the advent of commercial electricity in the last century we have been increasingly surrounded by man-made EMF generated by our power grid (composed of powerlines, other electrical equipment, electrical wiring in buildings, power tools, and appliances) as well as by higher frequency sources such as radio and television waves and, more recently, cellular telephone antennas.

EMF: Invisible lines of force

Wherever there is electricity, there are also electric and magnetic fields, invisible lines of force created by the electric charges. Electric fields result from the strength of the charge while magnetic fields result from the *motion* of the charge, or the current. Electric fields are easily shielded: they may be weakened, distorted or blocked by conducting objects such as earth, trees, and buildings, but magnetic fields are not as readily blocked. Electric charges with opposite signs (positive and negative) attract each other, while charges with the same sign repel each other. The forces of attraction and repulsion create electric fields whose strength is related to "voltage" (electrical pressure). These forces of attraction or repulsion are carried through space from charge to charge by the electric field. The electric field is measured in volts per meter (V/m) or in kilovolts per meter (kV/m). A group of charges moving in the same direction is called an "electric current." When charges move they create additional forces known as a "magnetic field." The strength of a magnetic field is measured in "gauss" (G) or "tesla" (T), while the electric current is measured in "amperes" (amps). The strength of both electric and magnetic fields decrease as one moves away from the source of these fields.

Fields vary in time

An important feature of electric and magnetic fields is the way they vary in time. Fields that are steady with respect to direction, rate of flow, and strength are called "direct current" (DC) fields. Others, called "alternating current" (AC) fields, change their direction, rate of flow, and strength regularly over time. The magnetic field of the earth is DC because it changes so little in one year that it can be considered constant. However, the most commonly used type of electricity found in power lines and in our homes and work places is the AC field. AC current does not flow steadily in one direction, but moves back and forth. In the U.S. electrical distribution system it reverses direction 120 times per second or "cycles" 60 times per second (the direction reverses twice in one complete cycle). The rate at which the AC current flow changes direction is expressed in "cycles per second" or "Hertz" (Hz). The power systems in the Untied States operate at 60 Hz, while 50 Hz is commonplace elsewhere. This fact sheet focuses on "power frequency" 60 Hz fields and not the higher frequency fields generated by sources such as cellular phone antennas.

Describing magnetic fields

The concentration of a chemical in water can be described by citing a single number. Unlike chemicals, alternating electric and magnetic fields have wave-like properties and can be described in several different ways, like sound. A sound can be loud or soft (strength), high or low-pitched (frequency), have periods of sudden loudness or a constant tone, and can be pure or jarring. Similarly, magnetic fields can be strong or weak, be of high frequency (radio waves) or low frequency (powerline waves), have sudden increases ("transients") or a constant strength, consist of one pure frequency or a single dominant frequency with some distortion of other higher frequencies ("harmonics"). It is also important to describe the direction of magnetic fields in relation to the flow of current. For instance, if a magnetic field oscillates back and forth in a line it is "linearly polarized." It may also be important to describe how a field's direction relates to other physical conditions such as the earth's static magnetic fields.

MEASURING MAGNETIC FIELDS AND IDENTIFYING THE SOURCES OF ELEVATED FIELDS

Measuring magnetic field strength

The strength or intensity of magnetic fields is commonly measured in a unit called a Gauss or Tesla by magnetic field meters called "gaussmeters." A milligauss (mG) is a thousandth of a gauss, and a microtesla (uT) is a millionth of a tesla (one milligauss is the same as 0.1 microtesla). The magnetic field strength in the middle of a typical living room measures about 0.7 milligauss or 0.07 microtesla. As noted above, the strength of the magnetic field is only one component of the mixture that characterizes the field in a particular area. Measuring only magnetic field strength may not capture all the relevant information any more than the decibel volume of the music you are playing captures the music's full impact. The main health studies to date have only measured magnetic field strength directly or indirectly and assessed its association with disease. Some scientists wonder if the weak association between measured magnetic fields and cancer in these studies might appear stronger if we knew which aspect of the EMF mixture to measure. Other scientists wonder if any such aspect exists.

Where are we exposed to 60 Hz EMF?

There are "power frequency" electric and magnetic fields almost everywhere we go because 60 Hz electric power is so widely used. Exposure to magnetic fields comes from many sources, like high voltage "transmission" lines (usually on metal towers) carrying electricity from generating plants to communities and "distribution" lines (usually on wooden poles) bringing electricity to our homes, schools, and work places. Other sources of exposure are internal wiring in buildings, currents in grounding paths (where low voltage electricity returns to the system in plumbing pipes), and electric appliances such as TV monitors, radios, hair dryers and electric blankets. Sources with *high voltage* produce strong electric fields, while sources with *strong currents* produce strong magnetic fields. The strength of both electric and magnetic fields weakens with increasing distance from the source (table 1). Magnetic field strength falls off more rapidly with distance from "point" sources such as appliances than from "line" sources (powerlines). The magnetic field is down to "background" level (supposed to be no greater than that found in nature) 3-4 feet from an appliance, while it reaches background level around 60-200 feet from a distribution line and 300-1000 feet from a transmission line. Fields and currents that occur at the same place can interact to strengthen or weaken the total effect. Hence, the strength of the fields depends not only on the distance of the source but also the distance and location of other nearby sources.

Table 1. Examples of magnetic field strengths at particular distances from appliance surfaces.

	MILLIGAUSS (mG) at 1 foot	at 3 feet
aquarium pump	0.35-18.21	0.01-1.17
band saw	0.51-14.24	0.05-0.75
can opener	7.19-163.02	1.30-6.44
clock	0.34-13.18	0.03-0.68
clothes iron	1.66-2.93	0.25-0.37
coffee machine	0.09-7.30	0-0.61
computer monitor	0.20-134.7	0.01-9.37
copier	0.05-18.38	0-2.39
desktop light	32.81	1.21
dishwasher	4.98-8.91	0.84-1.63
drill press	0.21-33.33	0.03-8.35
fax machine	0.16	0.03
food processor	6.19	0.35
garbage disposal	2.72-7.79	0.19-1.51
microwave oven	0.59-54.33	0.11-4.66
mixer	0.49-41.21	0.09-3.93
portable heater	0.11-19.60	0-1.38
printer	0.74-43.11	0.18-2.45
portable fan	0.04-85.64	0.03-3.12
radio	0.43-4.07	0.03-0.98
range	0.60-35.93	0.05-2.83
refrigerator	0.12-2.99	0.01-0.60
scanner	2.18-26.91	0.09-3.48
sewing machine	3.79-7.70	0.35-0.45
tape player	0.13-6.01	0.01-1.66
television	1.80-12.99	0.07-1.11
toaster	0.29-4.63	0.01-0.47
vacuum cleaner	7.06-22.62	0.51-1.28
VCR	0.19-4.63	0.01-0.41
vending machine	0.46-5.05	0.02-0.59

Source: L. Zaffanella, School Exposure Assessment Survey, California EMF Program, interim results, November, 1997.

Identifying sources of elevated magnetic fields

Sometimes fairly simple measurements can identify the external or internal sources creating elevated magnetic fields. For example, turning off the main power switch of the house can rule out sources from use of power indoors. Magnetic field measurements made at different distances from powerlines can help pinpoint them as sources of elevated residential magnetic fields. Often, however, it takes some detective work to find the major sources of elevated magnetic fields in or near a home. Currents in grounding paths (where low voltage electricity returns to the system in plumbing pipes) and some common wiring errors can lead to situations in which source identification is difficult and requires a trained technician. It is almost always possible to find and correct the sources of elevated magnetic fields when they are due to faulty electrical wiring, grounding problems, or appliances such as lighting fixtures.

60 Hz magnetic field exposure during a typical day

Exposure assessment studies of adults who wore measurement meters for a 24- to 48-hour period suggest that the average magnetic field level encountered during a typical 24 hours is about 1 mG. About 40% of magnetic field exposures found in homes come from nearby powerlines, while 60% come from other sources such as stray currents running back to the electrical system through the grounding on plumbing and cables, current "loops" due to incorrect internal wiring in the home, and brief exposure to appliances and electrical tools.

Magnetic field survey of homes in the San Francisco Bay Area

The California Department of Health Services surveyed homes in the San Francisco Bay Area in the mid-1990s. In this study, magnetic field measurements were taken in the middle of the bedroom, family room and kitchen and at the front door of these homes under normal power conditions (any appliances or electrical devices turned on at the onset of the measurement period were left on). As shown in table 2, about half the houses in the Bay Area had an average level below 0.71 mG and 90 percent had average levels below 1.58 mG.

Magnetic fields generated by current flowing through wires can be reduced

Two wires with current flowing in opposite directions create magnetic fields going in opposite directions. If the wires are placed close together and have currents of similar magnitude the magnetic fields cancel each other. This principle is often used to lower magnetic fields. For example, an underground distribution cable has a "hot" line (carrying current to the user) and a "neutral" line (carrying it away) that generate low magnetic fields when they are placed close together. The underground cables can

Table 2. Distribution of average magnetic field strength of San Francisco Bay Area homes.

homes below average field strength	736 homes measured [1]
10%	0.43 mG
25%	0.54 mG
50%	0.71 mG
75%	0.98 mG
90%	1.58 mG

Source: Lee, G., California Exposure Assessment study (preliminary findings). California EMF Program. 1996.

be placed close together because it is possible to insulate them heavily to prevent arcing. Overhead powerlines cannot be placed this close together because of the weight of the needed insulation and the need for worker safety. For most distribution and transmission lines, however, California utilities use three-wire or four-wire systems. The current in these lines alternates in strength and direction in slightly different phases (not alternating completely together). It is sometimes possible to optimize these phase differences so that the magnetic fields from the wires cancel each other.

What can we say about a measurement once we have it?

A concerned person would like to know if the measurements found in his or her home are "safe" or "unsafe." Right now, most scientists do not feel that the data are solid enough to make predictions about the health risks of magnetic field strength. When magnetic field exposure (or its estimate) increases there is no evident orderly increase of a health risk. The highest level of magnetic field strength measured in homes is below the intensity found in almost all the cellular and animal experiments that have produced subtle biological effects. This makes scientists and policy makers reluctant to set health-based standards for magnetic field exposures. However, it is possible to find out how measurements in your home compare to other homes and if these measurements are "typical" or not. The information in tables 1 and 2 may be helpful in deciding if your home is typical.

Dose-response relationship

A special problem in the study of health effects of environmental factors is how to measure exposure in a way that adequately reflects the true amount of the person's exposure to the substance being studied. This true amount is called the "dose." With cigarette smoke and toxic chemicals, there is a positive relationship between the size (or strength) of the dose and the adverse health effect it produces: the higher the dose, the greater the effect. With magnetic fields, however, some laboratory evidence suggests that this is not always the case, and very confusing relationships have been seen. Biological effects or changes appear at strengths of certain levels, disappear at higher levels, only to appear again at still higher levels. Varying the frequency (speed of alternation), for example from 60 Hz to 120 Hz, shows similar "effect windows" of magnetic fields. To complicate things further, some laboratory experiments have shown an effect with intermittent ("pulsed") exposures, others with "spikes" or transients, and still others with continuous exposure. There is some evidence that the orientation of alternating fields in relation to the direction of the earth's static magnetic field is also important in making a biological effect. Generally, the effects observed are only biological *changes* that may or may not translate into true health effects.

Limitations of direct magnetic field measurements

Those human health studies investigating the relationship of magnetic field exposure and cancer measured magnetic fields using one-time, short-term measures (i.e., for 24 hours) of one area such as the bedroom, or one-time spot measurements (i.e., for one minute) in several different rooms of the participants' homes. It was assumed that these home measurements adequately estimate a person's total exposure. However, these measures can not be used to assess the biological importance of the length of exposure, the number of times there are high exposures, or the presence of other components of the field such as harmonics. Also, field intensity (strength) varies at different times of day and different seasons, depending on electricity use. Dinnertime readings are often higher than readings in the middle of the night. In addition, an area measure may not reflect a personal exposure that is dependent on the amount of time a person spends in the area measured.

CONTROVERSY ABOUT POSSIBLE HEALTH EFFECTS

The controversy about EMF health effects derives from: 1) the fact that many scientists believe powerline magnetic fields emit little energy and are therefore too weak to have any effect on cells; 2) the inconclusive nature of laboratory experiments; and 3) the fact that epidemiological studies of people exposed to high EMF are inconclusive.

1. Weak fields may have too little energy to cause biological effects

The electromagnetic spectrum covers a large range of frequencies (expressed in cycles per second or Hertz). The higher the frequency, the greater the amount of energy in the field. X-rays have very high frequencies, and are able to ionize molecules and break chemical bonds, which damages genetic material and can eventually result in cancer and other health disorders. High frequency microwave fields have less energy than x-rays, but still enough to be absorbed by water in body tissues, heating them and possibly resulting in burns. Radio frequency fields from radio and TV transmitters are another step weaker than microwaves. Although they alternate millions of times per second, they can't ionize molecules and can only heat tissues close to the transmitter. Electric power fields (50 and 60 Hz) have much lower frequencies than even radio waves and hence emit very low energy levels that do not cause heating or breakage of bonds. They do create electrical currents in the body, but in most cases these currents are much weaker than those normally existing in living organisms. For these reasons, many scientists argue that it is unlikely that 60 Hz power frequency magnetic fields at the strengths commonly found in the environment have any physical or biological effects on the body.

2. Inconsistent laboratory results

As stated above, 60 Hz power frequency magnetic fields do create weak electric currents in the bodies of people and animals. In the mid-1970s a variety of laboratory studies in cell cultures and whole animals demonstrated that these fields produce biological changes when applied in intensities of hundreds or thousands of milligauss. Some scientists observed effects at lower strengths, but average daily personal exposure is only about 1 mG. Biological effects that seem to be attributable to magnetic fields are subtle and difficult to reproduce. These studies are continuing in an effort to understand how magnetic fields affect living tissue. Some laboratory scientists have found that magnetic fields can produce changes in the levels of specific chemicals the human body makes (such as the hormone melatonin), as well as changes in the functioning of nerve cells and nervous systems of other animals. However, the jury is still out as to whether this type of change can lead to any increased risk to human health.

In the mid-1990s, scientists conducted a series of EMf animal studies. Most of these studies showed little or no association between EMF and cancer or adverse reproductive effects. This convinced some scientists that EMF's were harmless. However, others pointed out that the animals' EMF exposures in these studies might not adequately capture some aspect of EMF exposure that could have biological effects on humans.

3. Inconclusive epidemiological studies

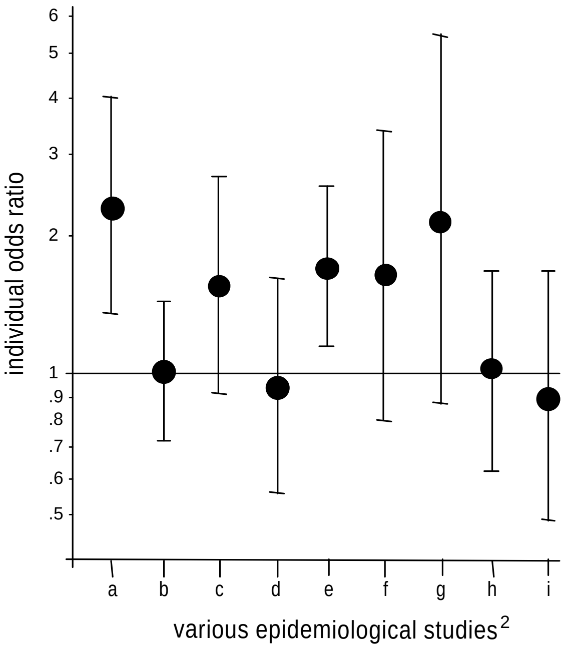
Epidemiology examines the health of groups of people, and epidemiological studies make statistical comparisons about how often diseases occur in "exposed" and "non-exposed" groups. Studies in which the disease rate is higher for the exposed group than non-exposed (said to have "positive" results) do not necessarily show a direct cause for disease, but rather indicate that there is some sort of relationship between exposure and disease. Most epidemiological studies of magnetic fields have been of two types. One kind focused on children with cancer to see whether their home magnetic field measurements were higher or if they were more likely to live in homes with overhead powerlines carrying high current than a comparable group of children without cancer. The other type of study looked at rates of death and disease of adults assumed to be heavily exposed to magnetic fields at work, with exposure often indirectly assessed by using job titles, to determine if their rates were higher than adults assumed to be working in low magnetic field environments.

Childhood cancer studies

Public concern has arisen because of media reports about epidemiological studies that showed an association between childhood cancer and proximity to high current-carrying overhead powerlines. In 1996, a special committee of the National Research Council (NRC) made a careful review of 11 epidemiological studies examining the relationship between childhood leukemia and residential proximity to this type of powerlines.[1] For these studies, a child's exposure to magnetic fields was estimated three ways. First, the type and proximity of powerlines ("wire codes") near the child's home was assessed. Those houses with lines nearby with the potential to carry high current were classified as "high current configuration" and were assumed to have higher magnetic field levels (due to higher current) than houses near lower current configuration powerlines (figure 2). Second, exposure was estimated by measurements of magnetic fields taken in the child's home at the time of the study—often many years after diagnosis of their cancer. And third, exposure was approximated by estimating what the home magnetic field levels were right after the children were diagnosed, using line distance from the house and past utility records of current flow in the lines during the appropriate time period.

The NRC made a statistical summary and comparison of these eleven studies. They concluded that children living in high current configuration houses are 1.5 times as likely to develop childhood leukemia than children in other homes. Despite this conclusion, the NRC was a unable to explain this elevated risk and recommended that more research be done to help clarify the issue. One reason for this uncertainty is that wire-code classification assumes that houses with high wire-codes have higher magnetic field levels than low wire-code houses, but high wire-codes may also be a proxy for some type of exposure besides magnetic fields that is not yet understood. For example,

Figure 1. Summary of results of power line distance ("wire code") and childhood leukemia studies.



a Wertheimer N, 1979.
b Fulton JP, 1979.
c Savitz DA, 1988.
d Coleman M, 1989.
e London SJ, 1991.
f Feycting M, 1993.
g Fajardo-Gutierrez AJ, 1993.
h Petridou ED, 1993.
i Linet MS, 1997.

high wire-code houses tend to have higher traffic density nearby, resulting in higher air pollution levels. However, traffic density seems to be an unlikely explanation for the wire-code association found in these studies.

In 1997, the NRC statement seemed to be contradicted by the findings of Dr. M. S. Linet of the National Cancer Institute in a large epidemiological study[1i]. Her researchers estimated exposure to magnetic fields in two ways, wire-codes as defined above (based on distance of different types of powerlines near the home) and home area measurements. The study found no association between living in high wire-code houses and childhood leukemia. On the other hand, the study found that children living in houses with high average magnetic field levels did have higher rates of cancer in general.

The EMF RAPID Program Working Group statement on childhood leukemia

In 1998, a working group of experts gathered by the federal EMF RAPID program (see "Governmental Regulation," below) reviewed the research on the possible health risks associated with EMF. A majority felt that the epidemiology studies of childhood leukemia provide enough evidence to classify EMF as a "possible human carcinogen," meaning they think it *might* cause cancer. This does not mean that it definitely causes cancer, however. The working group's findings are published in a report posted on the program's Web site (see address below).

If real, how important would this risk of childhood leukemia be?

Each year an average of six cases of leukemia are diagnosed per 100,000 children. Six percent of American houses are near high-current-carrying powerlines.[2] If the epidemiological association is correct that means that in such houses there would be three additional cases of leukemia among 100,000 children due to the effects of EMF from the nearby powerlines. (This is almost the increased risk of lung cancer of an adult nonsmoker who lives in a smoking household.) Among the 500,000 children in California who live nearest high-current-carrying powerlines there could be a theoretical 15 extra cases of leukemia each year compared to the number of cases if they lived further away. In California, we regulate chemicals whose typical exposures generate a theoretical *lifetime* risk of one per 100,000. An added risk of three sick children per 100,000 per *year* is larger than this. From an individual's point of view, this risk, if real, would be small: 99,991 out of 100,000 children would *not* get leukemia each year.

Occupational studies

The occupational studies looking at magnetic field exposure and various health outcomes show mixed results. Occupations assumed to have higher than normal magnetic field levels included electricians, telephone linemen, electric welders, electronic technicians, utility workers, electrical engineers and sewing machine operators. In general, but not always, workers of these occupations were more likely to have higher rates of brain tumors, leukemia, testicular tumors and male breast cancer than expected. A particular brain tumor (astrocytoma) occurred more often among men who worked for many years in jobs with high estimated exposure levels such as electricians, linemen, and electrical engineers.[3] A large study of Canadian and French utility workers found an association between estimated high magnetic field exposures based on area measures of certain occupations and myeloid leukemia, a rare type of blood cancer.[4] On the other hand, another large study found no increase in mortality from brain tumors, leukemia or other cancers among electrical workers with estimated high magnetic field exposure over many years.[5] Differences among study results may exist simply because the studies used different study populations and methods for estimating high occupational magnetic field exposure. Also, these surrogate measures estimating high occupational magnetic field levels could be proxies for other types of exposure at work besides magnetic fields.

Comparing the scientific evidence on magnetic fields to that of environmental tobacco smoke

There are regulations in place protecting us from environmental tobacco smoke. They are based on the strength of its association with disease and the consistent epidemiological evidence for it. What's the difference between this evidence and that for magnetic fields? First, no magnetic field epidemiological study has found an association with disease that is as strong as that implicating a two-pack-a-day smoking habit. The strength of the association found for leukemia in electric train engineers, who are exposed to magnetic fields of hundreds of milligauss all day long, is no stronger than the strength of the association relating residential magnetic field levels (generally less than 10 mG) to childhood leukemia. Second, there is no laboratory evidence about magnetic field exposure that is as convincing as that for lung cancer and smoking—magnetic field animal studies have been inconsistent. These differences make scientists much more cautious about interpreting the magnetic field epidemiology as dangerous than the environmental tobacco smoke epidemiology.

GOVERNMENTAL REGULATION

State regulations

Lack of understanding has kept scientists from recommending any health-based regulations. Despite this, several states have adopted regulations governing transmission line-generated magnetic fields at the edge of the "right-of-way" ("ROW," the area immediately surrounding powerlines left clear for access for maintenance and repairs) because of concern about the risk of electric shock from strong electric fields present in these areas (table 3). All current regulations relate to transmission lines; none govern distribution lines, substations, appliances or other sources of electric and magnetic fields.

The California Department of Education requires minimum distances between new schools and the edge of transmission line rights-of-way. The setback guidelines are: 100 feet for 50-133 kV lines, 150 feet for 220-230 kV lines, and 350 feet for 500-550 kV lines. Once again, these were not based on specific biological evidence, but on the rationale that the electric field drops to background levels at the specified distances.

The California Public Utilities Commission (CPUC), upon the recommendation of a Consensus Group composed of citizens, utility representatives, union representatives, and public officials, recommended that the state's investor-owned utilities carry out "no and low cost EMF avoidance measures" in construction of new and upgraded utility projects. This means that 4% of the total project cost is allocated to mitigation measures if these measures will reduce magnetic field strength by at least 15%. The strategy is to address public concern and cope with potential but uncertain risks until a policy based on scientific fact can be developed. The CPUC also followed the Consensus Group's recommendation to establish the research, education and technical assistance programs of the California EMF Program under the guidance of the California Department of Health Services. It is expected to provide information that will be useful to those responsible for making public policy in the future.

Table 3. Transmission line EMF standards and guidelines adopted by certain states for utilities' rights-of-way (ROW).

STATE	ELECTRIC FIELD on ROW	ELECTRIC FIELD edge, ROW	MAGNETIC FIELD edge, ROW
Florida	8 kV/m[a] 10 kV/m[b]	2 kV/m	150 mG[a] (max load) 200 mG[b] (max load) 250 mG[c] (max load)
Minnesota	8 kV/m		
Montana	7 kV/m[d]	1 kV/m	
New Jersey		3 kV/m	
New York	11.8 kV/m 11 kV/m[e] 7 kV/m[d]	1.6 kV/m	200 mG (max load)
Oregon	9 kV/m		

[a]for lines of 69-230 kV
[b]for 500 kV lines
[c]for 500 kV lines on certain existing ROW
[d]maximum for highway crossings
[e]maximum for private road crossings
Source: *Questions and Answers About EMF*. National Institute of Environmental Health Sciences and U.S. Department of Energy, 1995.

Federal efforts

At the Federal level, the Federal Energy Policy Act of 1992 included a five-year program of electric and magnetic field (EMF) Research and Public Information Dissemination (EMF-RAPID). The EMF-RAPID Program asked these questions: Does exposure to EMF produced by power generation, transmission, and use of electric energy pose a risk to human health? If so, how significant is the risk, who is at risk, and how can the risk be reduced?

In 1998, a working group of experts gathered by the EMF-RAPID Program met to review the research that has been done on the possible health risks associated with EMF. This group reviewed all of the studies that have been done on the subject, and then voted on whether they believed that exposure to EMF might be a health risk. They then published a report describing their findings. A majority of the scientists on this working group voted that the epidemiology studies of childhood leukemia and residential EMF exposures provide enough evidence to classify EMF as a "possible human carcinogen."[6] This means that, based on the evidence, these researchers believe that it is possible that EMF causes childhood leukemia, but they are not sure. About half of the group's members thought that there is also some evidence that workplace exposure to EMF is associated with chronic lymphocytic leukemia in adults. The group also concluded that there was not enough evidence to determine whether EMF exposure might cause other diseases.[6]

The EMF-RAPID Program released its final report to Congress in 1999. This report explains the program's findings, including the results of its working group and many research projects. The final report states that "the NIEHS believes that there is weak evidence for possible health effects from [power frequency] ELF-EMF exposures, and until stronger evidence changes this opinion, inexpensive and safe reductions should be encouraged."7 (page 38) The report specifically suggests educating power companies and individuals about ways to reduce EMF exposure, and encouraging companies to reduce the fields created by appliances that they make, when they can do so inexpensively[7] (page 38). For more information on the EMF-RAPID program or to look at these reports, contact the EMF-RAPID Program, National Institute of Environmental Health Sciences, National Institutes of Health, P.O. Box 12233, Research Triangle Park, North Carolina 27709, or visit their Web site at http://www.niehs.nih.gov/emfrapid. When ordering a copy of the final report, refer to NIH publication number 99-4493.

CONCLUSION

Public concern about possible health hazards from the delivery and use of electric power is based on data that give cause for concern, but which are still incomplete and inconclusive and in some cases contradictory. A good deal of research is underway to resolve these questions and uncertainties. Until we have more information, you can use "no and low cost avoidance" by limiting exposure when this can be done at reasonable cost and with reasonable effort, like moving an electric clock a few feet away from a bedside table or sitting further away from the computer monitor. Table 1 shows how quickly fields fall off as one moves away from appliances—they virtually disappear at 3-5 feet. You might stop using an electric appliance you do not really need. You may also consider home testing, which can identify faulty electrical wiring that can produce shock hazards and current code violations as well as elevated magnetic fields. In California, the investor-owned utilities are required by the CPUC to provide magnetic field measurement at no charge to their customers. So far, in the absence of conclusive scientific evidence, there is no sufficient basis for enacting laws or regulations to limit people's exposure to EMF, so it is up to individuals to decide what avoidance measures to take, based on the information available.

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