Electric Power Lines

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Questions and Answers on Research into Health Effects

June 1995

MASTER

BONNEVILLE
POWER ADMINISTRATION

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INTRODUCTION

Most people know that electric power lines, like the wiring in our homes, can cause serious electric shocks if we're not careful. Many people also want to know whether the EMF (electric and magnetic fields) produced by power lines and other electrical devices affect our health. Although no adverse health effects of electric power EMF have been confirmed, there is continued scientific uncertainty about this issue. Research on EMF is ongoing throughout the world.

Amount of
technical detail

Moderate

Note to readers:

This publication contains a moderate level of technical detail. See page 43 for other BPA publications on this subject.

The purpose of this booklet is to answer some common questions that the BPA (Bonneville Power Administration) receives about the possible effects of power lines on health.

BPA is the Pacific Northwest's Federal electric power marketing agency.

First, some basic electrical terms are defined, and electric and magnetic fields are described. Next, answers are given to several questions about recent scientific studies. Some important information about electrical safety follows. We then describe how BPA is addressing public concerns about potential health effects of power lines. The last section tells you how to obtain more detailed information about the health and safety issues summarized in this booklet.

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BPA Electric Power Lines Q&A

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1

BACKGROUND INFORMATION

Electric Power Basics

This section uses six basic electrical terms—*conductor*, *current*, *voltage*, *load*, *power*, and *circuit*. The *conductor* is the wire that you see between power poles or towers; it carries the electricity. *Current* is the movement of electrons in the conductor (right). *Voltage* is the electric force that causes current in a conductor. *Load* is the electric power needed by homes and businesses. When a conductor energized with voltage is connected to a load, a *circuit* is completed and current will flow. Electrical terms are summarized on page 3 in a comparison with familiar examples involving water.

Electric Power Facilities

There are two basic types of power lines: transmission lines and distribution lines. *Transmission lines* are high-voltage power lines. The high voltage allows electric power to be carried efficiently over long distances from electrical generation facilities to substations near urban areas. BPA uses mostly AC (alternating current) transmission lines operating at voltages of 115 kV, 230 kV, 345 kV and 500 kV (1 kV or kilovolt = 1000 volts). BPA also operates one of only six DC (direct current) transmission lines in the U.S.

Utilities use lower-voltage *distribution lines* to bring power from substations to businesses and homes. Primary distribution lines operate at voltages from about 4 kV to 25 kV. These levels are

Electrical Terms

- **Voltage** is electrical pressure, the potential to do work. It is measured in volts (V) or in kilovolts (kV). 1 kV = 1000 volts.

- **Current** is the movement of electric charge (electrons). It is measured in Amperes (A).

- **Power** is the product of volts and current. It is measured in watts (W). In the above example:

$$120 \text{ V} \times 0.5 \text{ A} = 60 \text{ W}$$

You can raise the voltage and lower the current and produce the same power:

$$240 \text{ V} \times 0.25 \text{ A} = 60 \text{ W}$$

- **Conductor** is material that will carry electric current.

Excellent conductor:	Copper
Fair conductor:	Human body
Non-conductor (an insulator):	Rubber

Familiar Comparisons

A hose connected to an open faucet, but with the nozzle turned off.

A hose connected to an open faucet, and with the nozzle turned on.

Low pressure and a large hose.

High pressure and a small hose.

Same water output.

A good conductor: open hose.

A poor conductor: kinked hose.

further reduced to 120/240 V (secondary distribution) when the power gets to homes and businesses. In many areas, new distribution lines are constructed with buried cables. In most areas, however, transmission lines are not buried because of high construction costs, and reliability concerns.

Electrical substations serve many functions in controlling and transferring power on an electrical system. Several different types of equipment may be present, depending on the functions of the particular substation. For example, transformers change the high voltages used by transmission lines to the lower voltages used by distribution lines. Circuit breakers are used to turn lines on and off. The figure below shows how these facilities fit together in an electric power system.

Typical Distribution Line

QUESTIONS AND ANSWERS

Q What are electric and magnetic fields (EMF)?

Power lines, electrical wiring, and appliances all produce AC electric and magnetic fields. EMF are invisible lines of force that exist in the area surrounding any electrical device. The DC magnetic field from a magnet (left) can be shown by sprinkling iron filings around a magnet placed on a sheet of paper.

Electric and magnetic fields have different properties from each other, and possibly different ways of causing biological effects. Therefore, at times it is useful to talk about the two fields separately. The two fields are compared below.

The DC magnetic field around a bar magnet.

Magnetic Fields	Electric Fields
<p>1. Produced by current.</p> <p>Lamp plugged in and turned on. Current now produces a magnetic field, also.</p>	<p>1. Produced by voltage.</p> <p>Lamp plugged in but turned off. Voltage produces an electric field.</p>
<p>2. Measured in gauss (G) or tesla (T). 1 milligauss (mG) = 0.1 microtesla (μT) 1 milli (m) = 1 thousandth micro (μ) = 1 millionth</p>	<p>2. Measured in volts per meter (V/m) or in kilovolts per meter (kV/m). 1 kV = 1000 V</p>
<p>3. Not easily shielded (weakened) by most material.</p>	<p>3. Easily shielded (weakened) by conducting objects like trees and buildings.</p>
<p>4. Reduced in strength with increasing distance from the source.</p>	<p>4. Reduced in strength with increasing distance from the source.</p>

Example:
100 V on wire
100 V/m between wire and ground
Ground, 0 V

Q How do electric power EMF compare to other types of fields?

A The electromagnetic spectrum (right) covers an enormous range of frequencies which are expressed in hertz (Hz) (cycles per second). Electric power (60 Hz in North America, 50 Hz elsewhere) is in the ELF (extremely-low-frequency) range. ELF includes frequencies below 3,000 Hz.

It is important to note that as the frequency increases, the amount of energy in the field also increases. Microwave frequency fields can have enough energy to cause heating in conducting material. Still higher frequencies like X-rays cause ionization: breaking of molecular bonds that damages genetic material. In comparison, ELF fields have very low energy levels which do not cause heating or ionization. However, AC fields, including those in the ELF range, do create weak electric currents in conducting objects, including people and animals (see page 15).

Some points about the figure on the right:

Frequency is shown in hertz (Hz). 1 Hz = 1 cycle per second.
(Note that 10^4 means $10 \times 10 \times 10 \times 10 = 10,000$ Hz, etc.)
kHz = kilohertz = 1,000 Hz, MHz = megahertz = million Hz

As frequency goes up, wavelength gets shorter, and more energy is transferred to objects similar in size to the wavelength.

Examples:

Source	Frequency	Wavelength
Power line	60 Hz	5,000 km (3,100 miles)
Microwave oven	2,450 MHz	12.2 cm (4.8 in.)

Earth's DC electric field comes from thunderstorms.

Earth's DC magnetic field comes from currents in the earth.

Appliances vs. Lines

When you are about 1.2 m (48 in.) from appliances, the average magnetic field is usually less than 1 mG. For transmission lines, the magnetic field typically does not decrease to below 1 mG until you are about 50–90 m (164–300 ft.) or more from the line (see pages 8–9).

Q *Doesn't the earth produce EMF?*

A Yes, the earth produces EMF which are mainly DC (also called static fields). Electric fields are produced by thunderstorm activity in the atmosphere. Near the ground the DC electric field averages less than 200 V/m. Much stronger fields occur directly beneath electrical storms.

Magnetic fields are thought to be produced by electric currents flowing deep in the earth. The earth acts like a large magnet. The DC magnetic field averages around 500 mG. This number is larger than typical AC electric power magnetic fields, but DC fields do not create currents in objects in the way that AC fields do (see page 15).

Q *How do EMF from transmission lines and appliances compare?*

A Electric fields close to transmission lines are much stronger than the fields near electrical appliances. However, remember that electric fields are reduced in strength greatly by objects like buildings, trees, and vehicles. Magnetic fields very close to electrical appliances are often stronger than the fields directly beneath power lines. However, appliance fields decrease in strength with distance more quickly than do power line fields (see pages 8–9).

Some appliances also produce both 60-Hz and higher-frequency fields. For example, video displays, such as TV sets and video monitors used with computers, produce radio-frequency fields (10–30 kHz) as well as ELF fields. Typical 60-Hz mag-

netic fields for some appliances are shown in the box below. Fields for most other appliances are within the range shown for these examples. Appliance electric fields are usually less than 100 V/m at 30 cm (1 ft.) from the appliance. Typical levels of EMF for transmission lines are shown on page 9.

60-Hz Magnetic Fields for Some Appliances

Magnetic Fields Measured At Two Distances From Appliances on the Left

		27 cm (10.5 in)		1.17 m (46 in)
485 Microwave Ovens Measured (Outside 60-Hz field, not inside the oven)		Maximum 263.9 mG Median 36.9 mG Minimum 0.9 mG	⇒	Maximum 17.2 mG Median 2.1 mG Minimum 0.2 mG
118 Analog Clocks Measured		Maximum 41.2 mG Median 14.8 mG Minimum 1.8 mG	⇒	Maximum 3.2 mG Median 0.3 mG Minimum 0.0 mG
383 Electric Ranges Measured		Maximum 28.6 mG Median 9.0 mG Minimum 0.5 mG	⇒	Maximum 6.2 mG Median 0.3 mG Minimum 0.0 mG
343 Color TVs Measured		Maximum 18.6 mG Median 7.0 mG Minimum 0.4 mG	⇒	Maximum 1.4 mG Median 0.4 mG Minimum 0.02 mG
95 Digital Clock/ Clock-Radios Measured		Maximum 5.7 mG Median 1.3 mG Minimum 0.3 mG	⇒	Maximum 1.3 mG Median 0.2 mG Minimum 0.0 mG

SOURCE: Zaffanella 1993

Typical Levels of EMF for Transmission Lines *

115 kV Line		Approx. Edge of Right-of-way 15 m (50 ft.) 30 m (100 ft.) 61 m (200 ft.) 91 m (300 ft.)				
Electric Field (kV/m)	1.0	0.5	0.07	0.01	0.003	
Mean Mag. Field (mG)	29.7	6.5	1.7	0.4	0.2	
230 kV Line		Approx. Edge of Right-of-way 15 m (50 ft.) 30 m (100 ft.) 61 m (200 ft.) 91 m (300 ft.)				
Electric Field (kV/m)	2.0	1.5	0.3	0.05	0.01	
Mean Mag. Field (mG)	57.5	19.5	7.1	1.8	0.8	
500 kV Line		Approx. Edge of Right-of-way 20 m (65 ft.) 30 m (100 ft.) 61 m (200 ft.) 91 m (300 ft.)				
Electric Field (kV/m)	7.0	3.0	1.0	0.3	0.1	
Mean Mag. Field (mG)	86.7	29.4	12.6	3.2	1.4	

Magnetic Field From a 500-kV Transmission Line Measured on the Right-of-way Every 5 Minutes for 1 Week

Electric fields from power lines are relatively stable because line voltage doesn't change very much. Magnetic fields on most lines fluctuate greatly as current varies in response to changing loads. The graph on the left is an example of how the magnetic field varied during 1 week for one 500-kV transmission line. Magnetic fields must be described statistically in terms of averages, maximums, etc. The magnetic fields above are means calculated for 321 BPA lines for 1990 annual mean loads. During peak loads (about 1% of the time) magnetic fields are about twice as strong as the mean levels above.

* These are typical EMF at 1 m (3.3 ft.) above ground for various distances from BPA lines. They are for *general information*. For information about a specific BPA line, see page 44. For other lines, contact the utility that operates the line.

Q *How strong are the EMF from electric power substations?*

A In general, the strongest EMF around the outside of a substation come from the power lines entering and leaving the station. The equipment within the station typically does not produce large EMF beyond the substation fence. The strength of the EMF from transformers decreases rapidly with increasing distance, in a way similar to that of household electrical appliances.

Q *What are some typical exposures to EMF?*

A First, "exposure" must be defined. Scientists are still uncertain about the best way to do this. One problem is that we are usually exposed to EMF from a large number of sources every day. Should exposure be an *average* of the time spent in these fields, or is it important to know how much time we spend in high fields above certain levels?

Several kinds of small meters are available that can be carried or worn by a person to record magnetic field exposures automatically. The figure on page 11 is an example of data collected with one of these meters. It shows the magnetic field measured every 24 seconds over a 24-hour period. For this person, field exposure at home was very low. The occasional spikes (short exposures to high fields) occurred when the person drove or walked under power lines, or was close to appliances in the home or office.

The strength of the EMF from electrical transformers weakens rapidly with distance, as it does from electrical appliances.

"AVERAGES"

There are two common ways to describe a middle value in a sample of measurements:

Mean = The sum of all measurements in a sample divided by the number of measurements.

Median = The middle measurement in a sample arranged in order of size. There are as many measurements larger than the median as there are smaller.

The median is useful for data with some very high or very low measurements.

The figure below is a random sample of the magnetic field exposure for one person over a 24-hour period. This person works in an office with a computer, and lives in a house with all electric appliances, and electric heat. The only power line nearby is the line that serves the house. Thus, it is a "very low current configuration" house (see page 12).

Some studies have used these recording gaussmeters to measure human exposure to magnetic fields (see page 12). These studies tend to show that appliances and building wiring contribute to the low-level background magnetic field exposure that most people receive. People living close to large power lines tend to have higher overall field exposures. However, as shown on page 12, there is much individual variation among homes.

Example of 24-Hour Magnetic Field Exposure

Magnetic Field Exposures Measured by Gaussmeters Worn by People Living Near Various Types of Power Lines

The five categories below were used to estimate magnetic field exposures in some studies of cancer in people living near power lines (see pages 17–20).

SOURCE: Bracken 1994

Q Are there any standards for 60-Hz EMF?

A In the U.S., there are no Federal health standards specifically for 60-Hz EMF. A professional society, the American Conference of Governmental Industrial Hygienists (ACGIH), has developed "Threshold Limit Values" for EMF which include 60 Hz (below). These are guidelines for use by industrial hygienists in occupational settings. They are not a line between safe and unsafe EMF levels.

Occupational Threshold Limit Values for 60-Hz EMF (ACGIH)	
Electric Field	Magnetic Field
<p>Occupational exposures should not exceed:</p> <p>25 kV/m (from 0 Hz to 100 Hz).</p> <p>Prudence dictates the use of protective devices (e.g. suits, gloves, insulation) in fields above 15 kV/m.</p> <p>For workers with cardiac pacemakers: Maintain exposure at or below 1 kV/m.</p>	<p>Routine occupational exposure should not exceed the following ceiling value :</p> <p>10 G (10,000 mG).</p> <p>For workers with cardiac pacemakers, the field should be maintained at or below:</p> <p>1 G (1,000 mG).</p> <p style="text-align: right;">SOURCE: ACGIH 1994</p>

At least six states have set standards for transmission line electric fields; two of these also have standards for magnetic fields (see page 14). The two state magnetic field standards (New York and Florida) are based on the maximum fields that existing lines in those states produce under maximum load-carrying conditions. Interim guidelines on limits of exposure to 50/60-Hz EMF have been developed by the International Commission on Non-Ionizing Radiation Protection. These limits

are based on *established* effects of EMF (e.g., nerve stimulation), and they are much higher than EMF levels found typically in most occupational and residential environments (see table below).

State Standards and Guidelines for Transmission Line EMF				
State	Electric Field		Magnetic Field	
	On R.O.W.	Edge R.O.W.	On R.O.W.	Edge R.O.W.
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 to 230 kV ^b For 500-kV lines ^c For 500-kV lines on certain existing R.O.W. ^d Maximum for highway crossings ^e Maximum for private road crossings R.O.W. = Right-of-way				

International Commission on Non-Ionizing Radiation Protection		
Exposure (50/60 Hz)	Electric Field	Magnetic Field
Occupational:		
Whole working day	10 kV/m	5 G (5,000 mG)
Short term ^a	30 kV/m	50 G (50,000 mG)
For limbs	—	250 G (250,000 mG)
General Public:		
Up to 24 hours per day	5 kV/m	1 G (1,000 mG)
Few hours per day	10 kV/m	10 G (10,000 mG)
^a For electric fields of 10-30 kV/m, field strength (kV/m) x hours of exposure should not exceed 80 for the whole working day. Whole-body exposure to magnetic fields up to 2 hours per day should not exceed 50 G.		
		Source: IRPA / INIRC 1990

A person standing in a vertical electric field (blue lines) showing the pattern of the induced body current (white dashed lines).

A person standing in a vertical magnetic field (blue lines) showing the pattern of the induced body current (white dashed lines).

Most of the 60-Hz current occurs between the cells.

Q *What happens when I am exposed to EMF?*

A AC fields create weak electric currents in the bodies of people and animals. This is one reason why there is a potential for EMF to cause biological effects. As shown on the left, currents from electric and magnetic fields are distributed differently within the body. The amount of this current, even if you are beneath a large transmission line, is extremely small: millionths of an ampere. The current is too weak to penetrate cell membranes, so the current is present mostly in the small spaces between the cells.

Currents from 60-Hz EMF are weaker than natural currents in the body—such as those from the electrical activity of the brain and heart. Some scientists argue that it is, therefore, impossible for EMF to have any important effects. Other scientists point to results of some studies which show that biological effects can be caused by exposure to EMF (see page 29). In most cases, however, it is not clear how EMF actually produce these demonstrated effects. Some scientists believe that the weak induced currents may stimulate some of the receptors which are located on the surface of cells.

Strong electric fields, such as those found beneath large transmission lines, can cause hair on your exposed head or arms to vibrate at 60 Hz. This is felt as a tingling sensation by some people.

EMF from transmission lines can also cause nuisance shocks from voltages created by EMF on objects like metal fences, and vehicles (page 39).

Q How do scientists study possible effects of power lines on people?

A They use a type of research called **epidemiology**. Epidemiology is the study of patterns and possible causes of diseases in human populations. Epidemiologists study short-term epidemics such as outbreaks of food poisoning, and long-term diseases such as cancer and heart disease. Results of these studies are reported as statistical associations between various risk factors and a disease. The

Epidemiologists want to find out whether some factor may be a cause of a particular disease. One common type of study that they conduct is the case-control study. The basic steps in a case-control study are summarized in the box below.

How Epidemiologists Conduct Case-Control Studies

The Process	Examples
<p>1 A list of people with a particular disease is assembled. These are the cases.</p> <p>2 A list is assembled of people who are similar to the cases, but who do not have the disease. They are the controls.</p> <p>3 The numbers of cases and controls who were <i>previously</i> exposed to factor X are estimated. This is often one of the most difficult parts of the study because exposures have often occurred many years in the past.</p> <p>4 The exposure ratio of the cases is compared to the exposure ratio of the controls. If the ratios are the same, there is no association between factor X and the disease. If cases have a <i>higher</i> ratio, there is a positive association, and factor X <i>may</i> be a cause of the disease. If the cases have a <i>lower</i> exposure ratio than the controls, there is a negative association. This would suggest that factor X may help protect people from the disease.</p>	<p>Here are examples of results of a study of some potential risk factor X, based on 300 cancer cases and 300 controls:</p> <p>If 71 cases were exposed to factor X, and 229 were not exposed, the case exposure ratio = $71 \div 229 = 0.31$. If 71 controls were also exposed, the control exposure ratio is also 0.31. Dividing the case exposure ratio by the control ratio gives the odds ratio (OR), sometimes called relative risk ($0.31 \div 0.31 = 1.00$). An OR of 1.00 means the odds that the cases were exposed to factor X was the same as for the controls. Therefore, in the example, there is no association between factor X and cancer.</p> <p>Now suppose 110 cases were exposed (ratio = $110 \div 190 = 0.58$), and 71 controls were exposed (ratio = 0.31). The OR is $0.58 \div 0.31 = 1.87$. If the OR is above 1.00, there is a positive association between factor X and the disease. With certain assumptions, this means that, in the example, people exposed to factor X had an 87% increased risk of having cancer.</p> <p>Even when the OR is above 1.00, calculations must be done to see whether it is statistically significant (the probability the result is from chance is only 5% or less). In the example, the OR of 1.87 is statistically significant. Suppose another study was done also with 300 cases and 300 controls. In this study, however, there were only 11 exposed cases and 6 exposed controls. Although the OR = 1.90, it is not statistically significant because of the small numbers of exposed subjects. See page 17 for more on statistical significance.</p>

Statistical Significance

To estimate sampling variability, 95% confidence intervals are calculated. For positive associations a risk is statistically significant if the lower limit of the interval is greater than unity, e.g., greater than 1.00. The box on the right shows how small numbers of exposed subjects can result in wide confidence intervals, and nonsignificant results. A risk that is not statistically significant, especially one that does not have a narrow confidence interval around 1.00, may still indicate a real risk, but scientists have much less confidence that it does.

challenge is to discover whether the results indicate a true causal association. This includes assessing possible effects of other factors (*confounders*) that could affect study results. A statistically significant finding does not necessarily mean a cause-effect association. Usually, supplemental data are needed from studies of laboratory animals before scientists conclude that some factor is a cause of a disease.

A 1979 study in Denver by Wertheimer and Leeper first reported that children who died from cancer were more likely to have lived within about 40 m (131 ft.) of high-current distribution lines.

Q What have the studies of cancer in people living near power lines found?

A Several studies have reported positive associations between cancer and power lines (see page 18), but a causal association has not been established. The first study to report an association between power lines and cancer was done in Denver in the late 1970s. The study found that children who had died from cancer were two to three times more likely to have lived near high-current distribution lines compared to children who did not have cancer.

Summary of Residential Power Line Cancer Studies

Study	Location	Leukemia	Other Cancers
Child Cancer Studies			
Wertheimer & Leeper '79	Denver, CO	OR = 2.35*	All Cancer OR = 2.22*
Fulton et al. '80	Rhode Island	OR = 1.09	Not Studied
Tomenius '86	Sweden	OR = 0.3	CNS Tumors OR = 3.7*
Savitz et al. '88	Denver, CO	OR = 1.54 ^o	All Cancer OR = 1.53*, Brain OR=2.04*
Coleman et al. '89	U.K.	OR = 1.5	Not Studied
Lin & Lu '89	Taiwan	OR = 1.31	All Cancer OR = 1.30 ^o
Myers et al. '90	U.K.	OR = 1.14 [†]	All Cancer OR = 0.98
London et al. '91	Los Angeles, CA	OR = 2.15*	Not Studied
Lowenthal et al. '91	Australia	O/E = 2.0	
Feychting & Ahlbom '93	Sweden	OR = 3.8*	All Cancer OR = 1.3
Olsen et al. '93	Denmark	OR = 1.5	Leukemia+CNS+Lymphoma OR = 5.6*
Petridou et al. '93	Greece	OR = 1.19	Not Studied
Verkasalo '93	Finland	SIR = 1.6	All Cancer SIR = 1.5, CNS Tumors in Boys, SIR = 4.2*
Fajardo-Gutiérrez et al. '93	Mexico	OR = 2.63*	Not Studied
Preston-Martin et al. '94	Los Angeles, CA	Not studied	Brain Tumors OR = 1.6 [§]
Lin and Lee '94	Taiwan	SIR = 1.49*	Not Studied
Adult Cancer Studies			
Wertheimer & Leeper '82	Denver, CO	OR = 1.00	All Cancer OR = 1.28*
McDowall '86	U.K.	SMR = 143	Lung Cancer SMR = 215*
Severson et al. '88	Seattle, WA	OR = 0.79	Not Studied
Coleman et al. '89	U.K.	OR = 0.9	Not Studied
Youngson et al. '91	U.K.	Leukemia & Lymphoma OR = 1.29 ^o	
Eriksson & Karlsson '92	Sweden	Not studied	Multiple Myeloma OR = 0.94
Schreiber et al. '93	The Netherlands	No Cases	Hodgkins Disease SMR =469
Shore et al. '93	East/Central U.S.	OR = 1.0	(Acute myeloid leukemia OR = 1.0)
Feychting & Ahlbom '94	Sweden	OR = 1.5 ^o	(Acute myeloid leukemia OR = 2.3 ^o)
<p>Notes: This table is intended to summarize briefly some of the selected, often-cited results of the residential cancer studies. The full papers should be consulted for details (see <i>References</i>, pages 47–49).</p> <p>Abbreviations:</p> <p>OR = Odds Ratio (see page 16), an OR of 1.00 means no increased or decreased risk</p> <p>SMR = Standardized Mortality Ratio, an SMR of 100 means no increased or decreased risk</p> <p>SIR = Standardized Incidence Ratio, an SIR of 1.00 means no increased or decreased risk</p> <p>CNS = Central nervous system</p> <p>O/E = Observed number of cases divided by the expected number of cases</p> <p>* The number is statistically significant (greater than expected by chance), see page 17</p> <p>^o The number is on the borderline of statistical significance</p> <p>[†] For nonsolid tumors, which includes leukemias and lymphomas</p> <p>[§] OR for highest 24-hour magnetic field exposure. For homes with underground lines, OR = 3.8*.</p>			

Child Cancer Rates

For children in the U.S. ages 14 and under, about 14 out of 100,000 develop some form of cancer each year from all causes. About one-third of these are leukemias. During 1995, it is estimated that there will be about 8,000 new cases of child cancer in the U.S., and about 1,600 child deaths from cancer.

(Sources: National Cancer Institute 1992, American Cancer Society 1995)

Adult Cancer Rates

The incidence of cancer increases with age. For instance, in the U.S. for people ages 25–29, there are about 53 new cancer cases per 100,000 people per year. For ages 55–59, the rate is about 804 per 100,000. Leukemia and brain cancer are relatively rare cancer types. For the two age groups mentioned, leukemia incidence rates are 2 and 16 per 100,000, and for brain cancer the rates are about 3 and 12, per 100,000, respectively. (Source: National Cancer Institute 1992)

Exposure to magnetic fields was suggested as a possible factor in this finding. Magnetic fields were not measured in the homes. Instead, the researchers devised a substitute method to estimate magnetic fields from power lines based on (1) the size and number of power line wires, and (2) distance of power lines from the home (see page 12).

A second study in Denver in 1988, and one in Los Angeles in 1991, also found significant associations between living near high-current-configuration power lines and childhood cancer. However, in these two studies the associations were not significant when measured magnetic fields were used in the analyses. Studies in Sweden, Finland, Denmark, and Mexico, found increased cancer risks for children living near high-voltage transmission lines.

To date, 9 of 16 studies found at least one statistically significant association between various types of childhood cancer and power lines (page 18). Two of nine studies of adults found significant associations between cancer and power lines. Studies are often characterized this way, but they are so diverse, they can't simply be "added up" in this manner (see the upper sidebar on page 23).

Q *What about the Swedish cancer study of people living near transmission lines?*

A In late 1992, researchers in Sweden reported results of a study of cancer in people living near high voltage transmission lines. The Swedish study generated a great deal of interest among scientists, the public, and the news media. Relative risk for

leukemia increased in Swedish children who lived within 50 m (164 ft.) of a transmission line. The risk was found also to increase progressively as the calculated average annual 50-Hz magnetic field increased in strength. However, the estimated risks were based on very small numbers of cases (see summary below). For adults, elevated risks were found for myeloid leukemia.

The Swedish researchers concluded that their study provides some evidence for a possible link between magnetic fields and leukemia. However, differing opinions have been expressed by scientists about the study. For example, some scientists believe that the study is important because it is based on calculated magnetic fields existing around the time the cancers were diagnosed. Others are skeptical because of the small numbers of cancer cases, and because no statistically significant association was seen between cancer and measured magnetic fields.

Nordic Studies

Researchers in Sweden, Finland, and Denmark combined the results of their transmission line studies. The combined relative risk for child leukemia was 2.1, and it was statistically significant. This was based, however, on only 13 total cases. No significant risks were found for lymphoma, or for nervous system tumors. (Ahlbom et al. 1993)

Summary of Swedish Residential Cancer Study

- Cancer cases (from 1960–85) and controls selected from the 500,000 people who had lived on property within 300 m (984 ft.) of 220- and 400-kV lines.
- Magnetic field exposure was estimated by: 1) in-home measurements, 2) dwelling distance from lines, and 3) calculated average annual magnetic field before, and near time of cancer diagnosis.
- The relative risk of child leukemia was 1.5 for calculated fields of 1 to 2.9 mG (based on four leukemia cases), and 3.8 for fields above 3 mG (based on seven cases). The latter risk and the trend for increasing risk with increasing field strength, were statistically significant.
- For homes within 50 m (164 ft.) of transmission lines (six cases) relative risk for child leukemia was 2.9, and it was on the borderline of statistical significance.
- Excess child leukemia risks were confined to one-family homes, and there were no elevated risks for other types of child cancers.
- For adults with cumulative exposure ≥ 2 mG (16 cases) relative risk was 2.3 for myeloid leukemia, and it was on the borderline of statistical significance.
- Control for possible effects of air pollution and socioeconomic status did not change the study results.

SOURCE: Feychting and Ahlbom 1993,1994

Q *How do the cancer risks associated with power lines compare to risks from other factors?*

A The sizes of the risks reported in the power line studies (see page 18) are similar to the small to moderate-sized risks reported for a variety of other potential environmental cancer risk factors. An example of a very large risk factor is smoking, which can increase a smoker's risk of dying of lung cancer by 22 times or more compared to people who have never smoked. This is also an example of a risk that people accept voluntarily. People are less likely to accept even small involuntary risks, especially when they involve children.

Excess Cancers

The box below shows odds ratios (relative risks). These numbers alone don't tell you how many actual excess leukemia cases might occur. To estimate this, you need to know the leukemia rate, which is about 3-4 new cases per year per 100,000 children under age 15. If some factor such as "high" EMF actually doubled the risk, then about 3-4 additional (excess) cases would be expected per year in 100,000 children exposed to high EMF.

The box below gives some examples of odds ratios (see page 16) for childhood leukemia reported for several factors. These data are all from the case-control study in Denver headed by David Savitz, which was primarily directed toward studying the possible effects of power lines on childhood cancer.

Summary of Child Leukemia Risks From a Study in Denver, CO

* The odds ratio is statistically significant (greater than expected by chance)

◊ The odds ratio is on the borderline of statistical significance

SOURCES: See page 53

Q

Are there high cancer rates in some neighborhoods close to electric power facilities?

A

Scientists call unusual occurrences of cancer in an area or in time a "cancer cluster." In some cases, a cancer cluster has served as an early warning of a health hazard. For most reports of cancer clusters, however, the cause is never determined, or the perceived cluster is not really an unusual occurrence.

Concerns have been raised about seemingly high numbers of cancers in some neighborhoods, and schools close to electric power facilities. In recent years, at least three state health departments have studied apparent cancer clusters near electric power facilities.

A Connecticut study involved five cases of brain and central nervous system cancers in people living near an electrical substation. The local rates for these types of cancer were found to be no different from state-wide rates. Examination of cancer rates at various distances from the substation also failed to show evidence of clustering. In North Carolina, several cases of brain cancer were identified in part of a county that included an electric-power-generating plant. An investigation showed that brain cancer rates in the county, however, were actually lower than state-wide rates. Among staff at an elementary school near transmission lines in California, 13 cancers of various types were identified. Although this was twice the expected rate, the state investigators concluded that the cancers could have occurred by chance alone.

Cancer cases (x's below) in a city may show patterns which appear to be "clusters." They may seem to suggest a common environmental cause. Usually such patterns are just due to chance. Delineation of a cluster is subjective (where do you draw the circles?).

CLUSTERS

As an analogy, think about how an uncommon family name might be distributed at homes located throughout a city. Would it be unusual to find neighborhoods where two or three unrelated families with this same last name live in the same small area? Statistically, this may be shown to be expected due just to chance. While four or more such families may be very unlikely due to chance, this does not mean that it is impossible. One possible cause (other than chance) for some such "name clusters" is that the families are part of the same ethnic group and they choose to live close together. For perceived neighborhood cancer clusters, however, health agencies generally never find a common environmental cause. It is also apparent that the definition of a "cluster" depends on how large an area (neighborhood) is included.

Q**Do electrical workers have higher cancer risks?****A**

A report in 1982 by Milham was one of the first to suggest that electrical workers have an increased risk of leukemia compared to other occupations. About 57 studies have since reported statistically significant elevated cancer risks for jobs involving work around electrical equipment. Relative risks in these studies are mostly less than 2.0. At least 36 other studies of electrical workers did not find any statistically significant cancer risks (see sidebar).

Positive and Negative Studies

Studies that reported statistically significant risks are often called "positive studies." Some of these found only one or a few significant risks out of many that were calculated. When a large number of risks is calculated, some can be significant due to chance. Positive studies also tend to be published, and publicized more often than negative studies (those that did not find statistically significant risks). Many negative studies did report elevated risks, but they were not significant, in some cases possibly because of small sample sizes. It can, therefore, be misleading to characterize studies as either positive or negative.

In most of the studies of electrical workers, EMF were not actually measured. Recent studies, summarized on page 24, have provided some information on exposures for various electrical workers. As shown in the table below, electrical workers in Los Angeles and Seattle did have higher exposures to EMF than did non-electrical workers. The Los Angeles electrical workers also had elevated risks for leukemia, especially for chronic myeloid leukemia (London et al.). Studies of electrical workers in Sweden (Floderus et al.) and in Denmark (Guénel et al.) also reported elevated risks for leukemia, but they found opposite risks for brain cancer. The

Occupations included in the "electrical" category in the table on the right:

Electrical engineering techs.
Electrical engineers
Electricians
Power line & cable workers
Power station operators
Telephone line workers
TV & radio repairmen
Welders & flame cutters

EMF Exposures of Workers in Los Angeles and Seattle

Job Type	Mean Electric Field		Mean Magnetic Field	
	Los Angeles	Seattle	Los Angeles	Seattle
Electrical	19.0 V/m	51.2 V/m	9.6 mG	27.6 mG
Non-electrical	5.5 V/m	10.6 V/m	1.7 mG	4.1 mG

SOURCE: Bowman et al. 1992

Recent Electrical Worker Cancer Studies with Exposure Assessments

Study/Location	Leukemia	AML	CLL	Brain Cancer	Astrocytoma ^a	Other Cancers
Armstrong et al. '94 Canada-France ^b	0.80	1.02	2.98	1.90	6.26	Lung cancer = 3.11*
Floderus et al. '93 Sweden ^c	1.7	0.9	3.7*	1.2	1.1,1.5	—
Guénel et al. '93 Denmark ^d	1.64*	—	—	0.69	—	Breast cancer = 1.36
London et al. '94 Los Angeles, CA ^e	1.4 [◇]	—	0.8	—	—	CML = 2.3*
Sahl et al. '93 CA ^f	1.10, 1.30	—	—	0.65	—	Lymphoma = 1.02
Savitz and Loomis '95, U.S. ^g	0.65	0.82	1.08	2.56*	—	Total cancer = 1.12 [◇]
Thériault et al. '94 Canada-France ^h	1.54 [◇]	3.15*	1.48	1.95	12.29*	Total cancer = 1.01

NOTES: This table summarizes some of the results of recent studies emphasized by authors of those studies. The full papers should be consulted for details (see *References*, page 50). For most of the studies the numbers are odds ratios (OR) or relative risks (RR), and for Guénel they are the observed / expected (O/E). A value of 1.0 means no increased or decreased risk, 2.0 is a doubling of risk, and 0.5 means the risk is reduced by 1/2 (see page 16).

AML = Acute myeloid leukemia

CLL = Chronic lymphoid leukemia

CML = Chronic myeloid leukemia

* The risk is statistically significant (greater than expected by chance), see page 17

◇ The risk is on the borderline of statistical significance

^a A type of brain cancer

^b Exposure was to presumed pulsed high frequency electromagnetic fields (ORs are for the 10% highest exposed)

^c ORs for the job held longest during the 10 years prior to cancer diagnosis for the 10% most highly exposed jobs

^d O/E for men with continuous magnetic field exposure

^e OR for jobs with the highest percent of workday exposure above 25 mG

^f OR for the highest exposure score (fraction above 50 mG)

^g RR for highest cumulative magnetic field exposure for past 2–10 years

^h ORs for leukemia and for total cancer are for magnetic field exposure $\geq$ median, brain cancer ORs are for the 10% most highly exposed

Confounders

These are factors that could mask a true association between EMF and cancer, or could lead to a false indication that EMF are associated with cancer. Suppose that electrical workers had high exposure to a chemical that causes cancer, and is also strongly associated with EMF exposure. The chemical, not EMF, could be the real cause of cancer among such workers. Confounders for EMF have not been ruled out, but several of the electrical worker studies listed on page 24 considered, and found no evidence of confounding by chemicals or by other factors.

Conclusions

These are some conclusions about electrical worker studies from the paper published in 1995 by Savitz and Loomis:

"There is no obvious, coherent explanation for the discrepancies among the major studies of occupational magnetic fields...."

"Firm conclusions regarding whether magnetic fields cause cancer, based on our study alone or on the entire literature, are not yet possible."

Danish study also found an elevated risk for breast cancer, but it was not statistically significant. Three earlier studies found statistically significant breast cancer risks for male electrical workers, and three studies reported this result for female workers.

One of the largest studies looked at cancer cases in over 223,000 workers from two utilities in Canada and one in France (Thériault et al.). There were statistically significant elevated risks for one type of leukemia, and for one type of brain cancer. There were inconsistencies in results among the three utilities in the study, and no clear indication of a dose-response trend. For nearly 30 other types of cancer, no significant elevated risks were found. A follow-up study (Armstrong et al.) found an elevated risk for lung cancer for presumed exposure to high frequency pulsed electromagnetic fields.

A study of 36,000 workers at a large utility in California (Sahl et al.) found no consistent evidence for an association between cancer and magnetic fields. A study of 139,000 workers at five large utilities in the U.S. (Savitz and Loomis) found statistically significant elevated risks for brain cancer in the highest magnetic field exposure category. Except for electricians, magnetic field exposure was not associated with leukemia. For workers with 20 or more years employment in jobs involving magnetic field exposure, risk for all cancers combined was elevated 19 percent and it was statistically significant. Compared to the general population, the utility workers had lower cancer risks. This is an expected finding in occupational studies called the "healthy worker effect."

Q *What have governmental reviews concluded about EMF and cancer?*

A A large number of government-sponsored reviews of research on EMF and cancer have been done in the U.S., and in several other countries. Representative quotes from some of these reviews are shown in the box below, and more are referenced on page 51. The reviews basically reached the same conclusion that existing scientific evidence does not establish that EMF cause or promote cancer. Many of the reviews acknowledged, however, that the issue should not be dismissed, and more research is needed. The reviewers differed in how they charac-

Quotes on EMF and Cancer From Some Government Reviews

"... some of the epidemiological evidence is suggestive of an association between surrogate measurements of magnetic-field exposure and certain cancer outcomes.... [lack of sufficient data] prevents the inference of cancer causality from these associations at this time."

U.S. EPA Science Advisory Board 1991

"It has not been scientifically established that magnetic fields of extremely low frequency initiate or promote cancer or have any other harmful effects on humans. However, it has not been scientifically established that such fields are not harmful."

Advisory Panel to Australian Minister of Health 1992

"Thus, at present, there is no persuasive biological evidence that ELF electromagnetic fields can influence any of the accepted stages in carcinogenesis. There is no clear basis from which to derive a meaningful assessment of risk, nor is there any indication of how any putative risk might vary with exposure."

U.K. NRPB Advisory Group on Non-ionizing Radiation 1994

"... the Danish and the Swedish study support the hypothesis of previous studies that children living near high-current plants have an increased frequency of cancer, but the results do not exclude the possibility that the association might be due to chance."

Expert Group on Non-ionising Radiation, The Danish Ministry of Health 1993

"In conclusion, the epidemiologic results presently available do not permit the exclusion of a role for magnetic fields in the incidence of leukemia, particularly for children. New investigations are necessary to confirm or deny this role."

French Institute of Health and Medical Research 1993

"The existing epidemiological data cannot be used to support any definite conclusions as to whether exposure to electromagnetic fields increases the cancer-risk in any organ system....However, the possibility of there being a link between exposure and risk cannot be ruled out; especially with regard to child leukaemia."

Working Group Under the Swedish National Board of Health and Welfare 1995

Leukemia in Sweden

In Sweden there are about 70 new cases of childhood leukemia each year from all causes. If transmission line magnetic fields do increase the risk of leukemia, then these lines could be responsible for about one or two of these cases each year. This is according to estimates by researchers and agencies in Sweden. There could also be additional cases caused by magnetic fields from distribution lines, and from electrical appliances, but no estimates of these cases were made.

terize the potential for EMF to be involved in the cancer process, and in whether they believe any precautionary actions should be taken at this time to reduce exposures to EMF.

Attention has been focused on Sweden since 1992 when the National Electrical Safety Board assumed that a causal link exists between magnetic fields and childhood leukemia for purposes of preparing regulations. However, in 1994 the Board concluded that there is insufficient knowledge on magnetic field effects to set numerical field standards. The Board did endorse reasonable cost measures to limit public exposures to magnetic fields. In Denmark, an agency also concluded that there was no scientific reason to set numerical standards for power lines. Other measures are also taken in that country to limit field exposures from power facilities.

Q *If EMF really do cause or promote cancer, shouldn't cancer rates have increased along with the increased use of electricity?*

A Not necessarily. Although use of electricity has increased greatly over the years (left), it is not known how human exposures to EMF may have changed during this time. Changes in how modern buildings are wired, and in the way that some electrical appliances are designed, have resulted in lower magnetic fields from these sources.

U.S. Per Capita Electricity Sales From 1950-1991

Source: Kujawa et al. 1992

Rates for various types of cancer have shown both increases and decreases through the years. For example, mortality rates (deaths) for the two most common cancers in children have decreased be-

cause of better treatment and survival (right). Incidence rates (numbers of new cases), however, have increased for unknown reasons. (Reliable data on incidence rates only became available beginning in the early 1970s.) Incidence rates can reflect changes in various exposures, and they are affected by changes in how cancers are diagnosed and reported.

The effect of a major cancer risk factor, like smoking, is evident in the historic lung cancer rates. The possible effects of EMF would be mixed with those of many other factors having small or moderate risks to certain segments of the population. The individual contribution of these factors would be difficult to separate in the overall cancer rates.

Q Besides cancer, what other kinds of effects have been reported in epidemiologic studies involving EMF?

A Several epidemiologic studies have looked for effects of EMF on general and mental health, reproduction, and hypersensitivity. Most numerous are studies of possible effects on reproduction. (See the sidebar on page 29 for a summary of a new study.) Sources of EMF exposure in the reproduction studies included power lines and substations, electric blankets and heated water beds, electric cable ceiling heat, and VDTs (video display terminals). Although evidence is weak for effects from VDTs, guidelines developed in Sweden (right) have been adopted by several makers of video monitors.

VDT Guidelines From Two Swedish Organizations

Limits for magnetic fields in the 5 Hz to 2 kHz range:

At 50 cm (20 in.) 2.5 mG (MPR-II)

At 30 cm (12 in.) 2 mG (TCO)

Sources: MPR-II, SWEDAC 1990. TCO 1994.

EMF and Reproduction

A comprehensive study of 60-Hz magnetic field exposure during pregnancy was published in early 1995. Bracken and associates at Yale University studied birthweight, and intrauterine growth retardation for about 3,000 women. Magnetic field exposures during pregnancy were estimated for electric blankets, heated water beds, VDTs, and power lines. The researchers found that the women's exposures to these sources, did not affect the reproductive outcomes in the study. A similar study from California is also expected to be published in 1995.

Several studies looked at the overall health of high-voltage electrical workers, and a few looked at the incidence of suicide or depression in people living near transmission lines. One recent study involved occupational magnetic field exposure and Alzheimer's disease. Several studies have also investigated the possibility that certain sensitive individuals may experience allergic-type reactions to EMF.

Recent reviews have assessed the kinds of EMF research listed above. Typically, the reviews conclude that many of the studies have methodological problems such as small sample sizes. To date, there is only weak evidence that EMF cause the type of health problems described above.

Cancer

Laboratory studies have shown that it is unlikely that EMF can *initiate* the cancer process. Some studies suggest, however, that power-frequency EMF may *promote* development of certain existing cancers.

Q *What kinds of effects of EMF have been reported in laboratory studies?*

A Several kinds of biological effects have been reported in studies of electric and/or magnetic fields (page 30). A biological effect is a measurable change in some biological factor. It may or may not have any bearing on health. Overall, effects attributed to EMF have been small, and difficult to reproduce. Very specific laboratory conditions are usually needed for effects of EMF to be detected. It is not known how EMF actually cause these effects.

The associations between cancer and magnetic fields reported in epidemiologic research, have prompted the initiation of many laboratory studies. The laboratory studies, however, have also produced mixed results. Some recent studies were

presented at the 1994 annual review meeting on EMF research (see page 52). Three research groups reported that magnetic fields had no effect on development of lymphoma in mice, on leukemia in rats, or on skin cancer in opossums. Another group, however, reported that magnetic fields promoted development of mammary tumors in rats. Several laboratory studies of magnetic fields and cancer are still underway, and many more are planned.

Laboratory studies to date have not answered questions about possible human health effects. These studies do provide clues about how EMF interact with basic biological processes. The cell membrane may be an important site of interaction with weak induced currents from EMF. Because these induced currents have such extremely low energy levels, scientists are still trying to identify possible mechanisms to explain how these biological interactions could occur.

Some Reported Effects of 60-Hz EMF in Laboratory Studies

Decrease in bone fracture-healing rate (E)

Avoidance of strong fields (E)

Decrease in the hormone melatonin (E,M)

Changes in stress hormones (E)

Field detection (E)

Slowing of human heart rate (E,M)

Changes in human brain activity (E,M)

Source: Laboratory references listed on pages 52-53

Changes in tumor development (E,M)

Changes in white blood cell counts (E)

Temporary effect on growth (E,M)

Changes in behavior tests (E,M)

Changes in biorhythms (E,M)

Changes in functions of cells and tissues (E,M)

(E = electric field, M = magnetic field)

Melatonin and Cancer

One reason scientists are interested in melatonin is that it could help explain results of some EMF epidemiological studies. Melatonin seems to have a natural ability to slow the growth of some cancers, including breast cancer. If power-frequency EMF can affect melatonin in humans, this could be a mechanism to explain results of some EMF studies.

Q *What about effects of EMF on the hormone melatonin?*

A Melatonin is a hormone produced at night by the pineal, a small gland in the brain. In the 1980s, scientists found that in rats exposed to 60-Hz electric fields, nighttime melatonin levels were reduced greatly. Other studies have since reported that both AC and DC magnetic fields can also affect melatonin levels. Recent studies, however, have not been able to confirm the large effect of electric fields on melatonin. Also, melatonin levels were not affected in sheep raised for nearly a year in the EMF beneath a BPA 500-kV transmission line.

The Midwest Research Institute studied melatonin in two groups of 30 and 40 men exposed to 60-Hz magnetic fields in a laboratory setting. There was no consistent evidence that nighttime melatonin levels were affected by exposure to fields of 10 or 200 mG for up to 7 hours. (The fields were switched on and off rapidly during this period.)

Q *Are more studies of EMF being done?*

A Yes, worldwide, there are over 200 studies of EMF underway or planned. These include epidemiologic, laboratory, environmental, and engineering studies. Many of these involve some aspect of cancer development. These studies are sponsored by Federal and local government agencies, and by private organizations, including electric utilities and appliance manufacturers. The Electric Power Research Institute in Palo Alto, CA has managed the single largest EMF research program.

EMF studies are being done in at least 22 countries.

Melatonin

The nightly secretion of the hormone **melatonin** by the pineal gland is driven by a circadian rhythm generator in the brain. Light regulates the generator so that melatonin secretion by the pineal matches the day-night cycle. (Melatonin is also found in many species without a pineal, such as insects, plants, and even one-celled organisms.)

Melatonin levels are very low during the day, and increase rapidly at night. The secretion corresponds to the length of the night. This provides biological information about the time of day, and the time of year.

What does it do ?

Regulation of seasonal breeding

Wildlife and many domestic species such as sheep breed only at certain times of the year. Melatonin provides the animals' reproductive system with the necessary time-of-year information. If melatonin patterns are altered, the timing of reproduction can be affected.

Regulation of circadian rhythms

Melatonin helps regulate daily biological rhythms such as the sleep-wake cycle. It also appears to influence mood and behavior. Some types of depression, and "jet lag" may result when melatonin secretion is out of sync with the day-night cycle.

Tumor suppression

Melatonin seems to have an anti-tumor effect. In some studies, breast cancer in women was associated with low levels of melatonin. Some animal and cell studies also found that melatonin helps reduce the growth of tumors.

What affects it ?

Under certain conditions, night-time melatonin can be depressed by light, stress, alcohol, and EMF.

Laboratory rats

Studies in the 1980s first reported that 60-Hz electric fields reduced greatly pineal melatonin in rats. Newer studies have not been able to repeat these findings. Some studies have reported that 50/60-Hz magnetic fields affect melatonin, but other studies did not find this effect.

Hamsters

A single 15-minute exposure to a 60-Hz magnetic field 2-hours before lights out, reduced nighttime melatonin in hamsters. Melatonin was not affected, however, after 3 weeks of daily 15-minute exposures to the field.

Sheep

A study found no effects of EMF on melatonin in sheep raised beneath a BPA 500-kV transmission line in Oregon. There were also no effects on reproductive cycles, however, a possible effect on the immune system was found.

Humans

One study suggested melatonin was affected in certain women using specially made electric blankets. A study of men exposed to magnetic fields in a laboratory found no consistent effects of the field on melatonin. A study in Seattle is attempting to see whether breast cancer in women is related to EMF.

EMF RAPID

The national program is called The Electric and Magnetic Fields Research and Public Information Dissemination (EMF RAPID) Program. The program receives guidance from the National EMF Advisory Committee. Members come from public advocacy groups, organized labor, state governments, academia, and industry. The National Academy of Sciences will also evaluate research conducted under the program.

The 1992 *National Energy Policy Act* included a provision for a 5-year, \$65-million program of research and information dissemination on EMF. The program is supported by both Federal and matching voluntary private funds. The program is being coordinated by the U.S. Department of Energy, and the National Institute of Environmental Health Sciences.

The first 21 awards for research under the national program were announced in September 1994. The awards cover laboratory studies that extend for 1 to 4 years. Awards for five engineering studies were announced in early 1995. Contractors conducting research under the program come from universities, national laboratories, and private research institutes and firms. A report on the first results of the EMF Rapid program is expected in 1997.

Q *Is it safe to live close to a transmission line?*

A Living close to a transmission line can increase your overall exposure to EMF (see page 12). As discussed on pages 26–27, with the exception of Sweden, government health or safety organizations worldwide have not assumed or concluded that EMF cause cancer or other health effects.

American Medical Association comments on EMF:

"Findings of studies are inconsistent in terms of whether a risk exists, what conditions might be related to exposures, and risk magnitude. Positive studies indicate, for the most part, that the associated relative risks are low."

"Yet, without stronger evidence there is no problem, it would be unwise to dismiss the possibility that electromagnetic fields have adverse health effects."

(Council on Scientific Affairs 1994)

It is generally acknowledged that several studies have reported increased cancer risks, especially for children living close to high-current power lines.

Although these studies suggest potential risks, scientists do not yet know whether EMF, other factors, or methodological problems are responsible for the findings of these studies (see sidebar).

It is possible that future studies will provide sufficient information to establish whether or not EMF are a hazard to human health. The newer studies may also show that factors other than EMF were responsible for effects reported in earlier studies. It is also quite possible that, even with more research, there will be no scientific resolution to the EMF issue in the near future.

The answer to this question, therefore, involves: (1) a great deal of judgment about the meaning of existing scientific evidence, (2) speculation about the possible results of future studies, and (3) individual perceptions and values about the relative importance of various potential health risks.

During this period of uncertainty, there are some things that you can do to help answer this question:

- ✓ Become well-informed about the EMF issue by reading and talking with people from a variety of sources.
- ✓ Find out about the EMF produced by the particular transmission line that you are interested in. You may be far enough away from the line so that EMF are very low—see page 9.
- ✓ Try to place EMF in perspective with other potential, and real health risks that are important to you (see pages 21, and 53 for more information on risks).

?

2 mG Magnetic Fields

Some studies report higher cancer risks associated with prolonged exposure to power line magnetic fields of 2–3 mG and above. Other studies found no increased risks. There are no state or Federal health standards for 60-Hz magnetic fields that define any safe or unsafe field levels.

Burying Power Lines

By burying a power line, the electric field above ground is essentially eliminated. The soil does not affect the magnetic field. However, by insulating the wires and bringing them closer together, some field cancellation occurs. This can cause the magnetic field from buried transmission lines to decrease in strength much more quickly with distance, compared to typical overhead lines. For transmission voltages, buried lines typically are very expensive to construct and to maintain compared to overhead lines.

Q

What can be done to limit exposures to EMF?

A

While scientific research is ongoing, there are a number of ways that individuals and organizations can limit exposures to EMF if they choose to do so. Some methods entail little or no cost, while others could be very expensive. Because scientists are still trying to determine whether EMF are hazardous to health, there are widely differing opinions about the need for actions at this time to limit exposures (see references on pages 54 and 55).

BPA, like many utilities, routinely looks for reasonable low-cost ways to minimize EMF, when new electric power facilities are designed and located. The box below shows general ways that individuals, and organizations can limit exposures to EMF.

General Ways to Limit Exposures to EMF
Increase distance from the source.	<p>If you use an electric analog clock by your bed or desk, moving it a short distance can greatly reduce the field. Or, you can use a digital clock (see page 8).</p>

Design source to shield or cancel field.	<p>Some new transmission lines, and some appliances such as video monitors and electric blankets are designed to produce lower field levels.</p>

Reduce time spent in field.	<p>Don't spend time in high fields if you don't have to. Some people use an electric blanket to warm up the bed, they then unplug it before going to bed.</p>

Q *How can I find out how strong the EMF are where I live or work?*

A You can get a general idea about magnetic field levels around various kinds of electrical appliances from the figure on page 8. Also, page 9 shows typical EMF at various distances from BPA transmission lines. If you want more specific information about EMF from a particular BPA transmission line, contact your nearest BPA office (see page 44). If the line that you are interested in is not owned by BPA, contact the utility that operates the line.

If you want to make your own field measurements, there are several companies that sell gaussmeters which measure 60-Hz magnetic fields. Some of these meters will also measure electric fields.

There are detailed procedures available that explain how gaussmeters work, and how to make and understand magnetic field measurements. See page 54 for more information about gaussmeters.

Several companies make small meters that measure power-frequency magnetic fields. The type shown here is called a three-axis meter (see sidebar).

Gaussmeters

There are two basic types of instruments for measuring 60-Hz magnetic fields (commonly called gaussmeters). *Three-axis* meters are the easiest to use but they also cost the most (about \$200 on up). These meters give a single reading that automatically combines the three spatial components of the field. *Single-axis* meters cost less, but they are not as easy to use. You must rotate the meter, or a coil attached to the meter, to find the maximum field each time you make a measurement.

Q How does the magnetic field throughout my home compare to other homes?

A As a comparison with the magnetic field throughout your home, see the figure below. It summarizes spot measurements of magnetic fields made in the center of rooms in 992 homes throughout the U.S. The measurements were made away from electrical appliances, so they primarily reflect the fields from outside distribution lines, and electrical grounding sources. The all-room mean magnetic field for all homes was 0.9 mG. Only 15% of the homes had mean magnetic fields greater than 2.1 mG.

Field Exposure

The study of 992 homes was not designed to measure people's actual exposure to magnetic fields. Instead, it focused on identifying internal and external sources of these fields in the home. Your exposure to magnetic fields depends on how much time you spend near various sources, and on the strength of the fields produced by the sources (see pages 7–12).

POWER LINES AND SAFETY

The previous questions and answers dealt with possible *health* effects of EMF. When electric utilities refer to *safety* near power lines, they mean prevention of electric shocks which could seriously injure or kill people or animals. Safety hazards are well understood and they are managed in two basic ways: (1) by designing lines to minimize public exposure to these hazards, and (2) by educating people who live or work near the lines about safety hazards.

People can live safely around power lines so long as care is taken. BPA and local utilities must be careful about how and where lines are built and maintained. BPA designs and builds transmission lines in accordance with the *National Electrical Safety Code*. The code specifies how far transmission line conductors must be from the ground or from adjacent buildings or trees. BPA usually determines how wide its *rights-of-way** must be on the basis of those safe clearance distances.

* The right-of-way is a strip of land for which a utility acquires permanent rights which allow the utility to build, operate, and maintain its transmission lines safely and reliably. These rights enable the utility to keep the right-of-way clear of trees, structures, and fire hazards that could compromise the safety of employees and the public.

The *National Electrical Safety Code* alone cannot guarantee complete safety. People must be careful around power lines. These lines can cause lethal electric shocks if anything a person is carrying (such as an irrigation pipe or a ladder) comes too close to the line. If this happens, the high voltage on the line can cause the electricity to jump through the air to the nearby object; you would be seriously injured or killed. A BPA booklet, *Living and Working Around High-Voltage Power Lines*, describes safe practices near power lines (page 43).

For safety reasons, BPA does not allow buildings to be located within transmission line rights-of-way. If you are not sure where the edge of the right-of-way is, you should check with the utility, planning department, or zoning department before starting to build anything close to a transmission line. A publication from BPA, called *Landowner's Guide to Use of BPA Rights-of-way*, may be helpful in learning about rights-of-way. (See page 44 on how to obtain BPA publications.)

Q *Can I receive shocks from objects near transmission lines?*

A Yes, AC lines create voltages on nearby conducting objects—anything from trees and fences to people and animals. One effect associated with large transmission lines (usually with voltages greater than 230 kV) is the “nuisance shock.” For instance, suppose a voltage were created on wire fencing mounted on dry wood posts (insulating it from the ground). If you touched the fence, you could get an

annoying or painful shock, much like the shock you can get from touching a door knob after walking across a rug. To prevent these shocks, metal fences, gutters, buildings, or other such permanent objects near transmission lines are grounded if they pose a problem. You can also receive nuisance shocks from touching a vehicle if it is parked close to a transmission line. However, measures are taken to reduce this possibility (see figure below).

Typical Situations Where Nuisance Shocks Can Occur From Voltages on Objects Near Transmission Lines

<p>Grounded fence Insulated person</p>	<p>A person standing on dry gravel or wearing rubber boots may feel a tingling sensation when touching a grounded metal object (like a wire fence attached to metal posts).</p>
<p>Insulated fence Grounded person</p>	<p>A person wearing leather shoes (especially on wet ground) could get a painful shock by touching a large metal object (like a fence on dry wood posts). Such objects are routinely grounded if they pose a shock hazard. Some metal posts connected to the fence can correct the problem.</p>
<p>Vehicle Grounded person</p>	<p>Lines are designed to have lower EMF levels where many vehicles are expected (like parking lots) to reduce nuisance shocks when touching cars and trucks. (Most tires are actually partially conductive which prevents vehicles from being fully insulated from ground.)</p>

Q *What is BPA doing about the EMF issue?*

A BPA has been reviewing and conducting research on EMF since the mid-1970s. Because of public concern and scientific uncertainty, in 1988 BPA conducted a review of how the agency was dealing with the EMF issue. As a result, in late 1988 BPA adopted interim guidelines on EMF. These included a guideline that EMF exposures would be considered in the design and location of new transmission facilities.

BPA's right-of-way management practice was revised in 1990 in response to public concerns over EMF. BPA no longer encourages new uses of its transmission rights-of-way which might increase public exposure to EMF. Such uses include parks, playgrounds, and parking lots.

Because of continued interest in EMF the BPA guidelines were revised in 1992, and again in 1995. The 1995 guidelines are shown on page 42. BPA will continue to closely follow developments involving EMF, and we will review the guidelines as appropriate.

BPA transmits electric power from Federal hydroelectric dams in the Pacific Northwest.

BPA Guidelines on EMF (February 1995)

ISSUE: There continues to be significant uncertainty about the potential health effects from electric and magnetic fields. Scientists and others do not agree on how to interpret the available information, and public concern is sincere.

RESPONSE: BPA believes the concerned public and its employees need to know about and understand the EMF issue.

DESIRED RESULTS: BPA is recognized as a credible source of information on EMF and a utility responsive to public concern and to changes in the science.

To implement its **STRATEGY** on EMF, BPA adopts the following **GUIDELINES** governing its practices with regard to electric and magnetic fields.

- 1 Staffing:** Maintain a high level of professional knowledge and internal capability in the area of EMF.
- 2 Communication:**
 - Create, gather and share educational information on EMF. Communicate respectfully, sincerely and responsibly with employees and the public.
 - Inform and involve affected customers and the public in BPA project development.
 - Explore with employees ways to reduce exposures in carrying out their jobs.
- 3 Research:** Support research and development associated with EMF and transmission facilities that directly relates to accomplishing BPA's desired results.
- 4 Transmission Facilities:**
 - Consider EMF as an important factor with other design and siting factors for new and upgraded transmission facilities. BPA will take reasonable low-cost steps to minimize field exposure for these facilities while taking into account operation and maintenance considerations.
 - Consider modifying existing facilities upon request and at no cost to BPA. System reliability, operation, maintenance, and safety should not be adversely affected, and there should be no adverse impact on others.
- 5 Participate with Others:** Participate with professional entities, the scientific community, utilities, governmental bodies and others in the development of the EMF issue.
- 6 Evaluation:** Monitor and evaluate EMF activities and make decisions based upon the value of the results.

FOR MORE INFORMATION

From BPA

If you want to learn more about health and safety concerns related to transmission lines, the publications below are available from BPA.

Level of
technical
detail:

Low

1 *Living and Working Safely Around High-Voltage Power Lines* (9 pp.)

This short booklet tells you about the safety precautions you should take when you are around a high-voltage line. It deals primarily with ways to prevent electric shock.

2 *What We Know (and don't know) About EMF* (brochure)

If you want a short summary of the health issues associated with electric and magnetic fields, you will find it in this publication.

Low

3 *Health, Safety and New Electric Power Facilities* (9 pp.)

This brochure describes how BPA considers health and safety issues when new electric power facilities are planned.

Moderate

4 *Electrical and Biological Effects of Transmission Lines: A Review*

This book contains detailed information about all types of biological and environmental effects of both AC and DC transmission lines. (Next edition available in early 1996.)

High

Copies of BPA publications can be ordered from BPA's document request line, call 800-622-4520. You will reach a recorded message. Please ask for the documents you want by name.

If you would like to speak with someone, please call our toll-free public involvement line which is 800-622-4519.

(From outside the U.S., call 503-230-3478.)

If you have questions about a specific BPA transmission line, please contact your nearest local BPA office:

Boise	(208) 334-9137
Eugene	(503) 465-6863
Idaho Falls	(208) 523-2706
Portland	(503) 230-3478
Missoula	(406) 329-3060
Olympia	(360) 753-9070
Seattle	(206) 216-4272
Spokane	(509) 353-2568
Vancouver	(360) 418-8618
Walla Walla	(509) 527-6206
Washington, DC	(202) 586-5640

Information From Other Sources

Federal

The U.S. Environmental Protection Agency (EPA) provides free publications on EMF, contact:

EPA Public Information Center
Washington, D.C. 20460 (202-260-7751)

EPA also manages an EMF information line:
call 800-363-2383 (in Washington DC, 484-1803)

Information on EMF is also available from the National Institute for Occupational Safety and Health:
call 800-356-4674

Information on EMF and on the national EMF program (EMF *RAPID*) can be obtained from these two agencies:

U.S. Department of Energy, call 202-586-5575,

National Institute of Environmental Health Sciences, call 919-541-5085.

Nonfederal

Publications on EMF are available for sale from several nonfederal sources:

**Carnegie Mellon
University**
Dept. of Engineering
and Public Policy, P
Attention: EMF
129 Baker Hall
Pittsburgh, PA 15213
(412-268-2670)

Culver Company
316 Merrimac Street
Newburyport, MA
01950
(800-428-5837)

Edison Electric Institute
Washington, DC
(202-508-5424)

**Electric Power Research
Institute** Palo Alto, CA
(510-934-4212)

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The references are grouped by the major topics covered in this publication. Most of these should be available in technical libraries such as at universities, or medical schools. If you need to see a particular reference and you can't find it at the library, you may want to call BPA's toll-free public involvement line at 800-622-4519. Ask to speak with an EMF specialist. The specialist may be able to help you obtain the reference.

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- Environmental Science and Technology*, Volume 27, Number 1, 1993.
- Land Use & Environment Forum*, Volume 3, Number 4, 1994.

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This publication was prepared through work of the *BPA Biological Studies Task Team*. This team was formed in 1974 to conduct an ongoing review of information on electrical and biological effects of transmission lines. Comments or questions about this publication can be directed to:

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DOE/BP-2081
Third printing, revised
June 1995
1.5M

Printed on recycled paper