Electric Power Lines

Questions and Answers on Research into Health Effects

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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 electric and magnetic fields (EMF) produced by power lines and other electrical devices cause health effects.

The purpose of this pamphlet is to answer some common questions that the Bonneville Power Administration (BPA) 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. We then describe how BPA is addressing public concerns raised by these studies. Some important information about electrical safety follows. The last section tells you how to obtain more detailed information about the health and safety issues summarized in this pamphlet.

Amount of
technical
detail

Note to readers:

This publication contains a moderate level of technical detail. See page 38 for other BPA publications on this subject.

MASTER

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BACKGROUND INFORMATION

Electric Power Basics

This pamphlet uses six basic electrical terms—*conductor*, *current*, *voltage*, *load*, *power*, and *circuit*. The *conductor* is the wire 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 more 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 alternating current (AC) transmission lines operating at voltages of 115 kV, 230 kV, and 500 kV (1 kV or kilovolt = 1000 volts). BPA also operates one of only six direct current (DC) transmission lines in the U.S.

Utilities use lower-voltage *distribution lines* to bring power from substations to homes and busi-

Electrical Terms

- Voltage:** Electrical pressure, the potential to do work. Measured in volts (V) or in kilovolts (kV). 1 kV = 1000 volts.

- Current:** The movement of electric charge (e.g. electrons). Measured in Amperes (A).

- Power:** The product of volts and current. Measured in watts (W). In the above example:

$$120 \text{ V} \times 1 \text{ A} = 120 \text{ W}$$

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

$$240 \text{ V} \times 0.5 \text{ A} = 120 \text{ W}$$

- Conductor:** Material that will carry electric current.

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

Familiar Comparisons

Hose connected to an open faucet but with the nozzle turned off.

Hose connected to an open faucet and with the nozzle turned on.

Low pressure and large hose.

High pressure and small hose.

Same water output

Good conductor: open hose.

Poor conductor: kinked hose.

nesses. Distribution lines operate at voltages such as 25 kV and 12 kV. These levels are further reduced to 120/240 V when the power gets to homes and businesses.

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.

QUESTIONS AND ANSWERS

Q What are electric and magnetic fields (EMF)?

DC magnetic field around a bar magnet.

A 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, 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.

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

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 extremely-low-frequency (ELF) range. ELF includes frequencies below 3,000 Hz.

In general, the higher the frequency, the greater the amount of energy in the field. 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 14).

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.

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.

Q *Doesn't the earth produce EMF?*

A Yes, the earth produces EMF which are mainly DC. 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. Although this is stronger than typical electric power magnetic fields, DC fields do not create currents in objects in the same way that AC fields do (see page 14).

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

A Electric fields close to transmission lines are much stronger than the fields found 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 (page 9).

Some appliances also produce both 60-Hz and higher-frequency fields. For example, video displays such as TV sets and video display terminals

(VDTs) used with computers produce radio-frequency fields (10-30 kHz) as well as ELF fields. Some typical EMF levels for power lines and magnetic fields for some appliances are shown on page 9. Appliance electric fields are usually less than 100 V/m at 30 cm (1 ft.) from the appliance.

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 EMF exposures?*

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 now available that can be carried or worn by a person to record magnetic field exposures automatically. The figure on page 10 is an example of data collected with one of

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

"AVERAGES"

There are two common ways of describing 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.

Typical EMF for Transmission Lines and Magnetic Fields for Appliances

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 was close to an appliance. During the rest of the day, spikes occurred when the person drove or walked under power lines, or was close to office appliances.

Random sample of the magnetic field exposure of a BPA employee over a 24-hour period. This person works in an office with a computer and lives in a house by a "very low current configuration" power line (see page 11).

Some studies have used these automatic gaussmeters to measure human exposure to magnetic fields (see page 11). 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 11, there is much individual variation among homes.

Magnetic Field Exposures Measured by Gaussmeters Worn for 2 Days 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 page 16).

SOURCE: Bracken 1993

Q *Are there any regulations for 60-Hz EMF?*

A In the U.S., there are no Federal health regulations specifically for 60-Hz EMF. A professional society, the American Conference of Governmental Industrial Hygienists (ACGIH), has developed "Threshold Limit Values" for EMF at 30 kHz and below (which includes 60 Hz). These guidelines (shown below) are for use by industrial hygienists in occupational settings.

Occupational Threshold Limit Values for 60-Hz EMF (ACGIH)

Electric Field:

Occupational exposures should not exceed:

25 kV/m (from 0 Hz to 100 Hz).

Prudence dictates the use of protective devices (e.g. suits, gloves, insulation) in fields above 15 kV/m.

For workers with cardiac pacemakers:

Maintain exposure at or below 1 kV/m.

Magnetic Field:

Routine occupational exposure should not exceed:

10 G (10,000 mG).

For workers with cardiac pacemakers, field should not exceed:

1 G (1,000 mG).

SOURCE: ACGIH 1991

At least six states have set standards for transmission line electric fields; two of these also have standards for magnetic fields (see page 13). The two state magnetic field standards (New York and Florida) are basically 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 occupational and residential environments (see table below).

State Transmission Line EMF Standards and Guidelines

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 ^c (max. load) 200 mG ^b (max. load) 250 mG ^c (max. load) ^d
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	---	100 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 EMF Guidelines

Exposure	Electric Field	Magnetic Field
Occupational:		
Whole working day	10 kV/m	5 G (10,000 mG)
Short term	30 kV/m	50 G (100,000 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)
Source: IRPA / INIRC 1990		

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 right, 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 area between cells.

Currents due to 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 25). In most cases, however, it is not clear how EMF actually produce these demonstrated effects.

Strong electric fields, such as those found beneath large transmission lines, can also cause hair on your exposed head or arms to vibrate at 60 Hz. This is felt by some people as a tingling sensation. EMF from transmission lines can also cause nuisance shocks from voltages created by EMF on objects (see page 36).

A person standing in an electric field (blue lines) showing induced current (white dashed lines).

A person standing in a magnetic field (blue lines) showing induced current (white dashed lines).

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

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

Epidemiologists want to find out whether some factor may be a cause of a particular disease. They often conduct **case-control** studies to try and answer their questions. The basic steps in a case-control study are summarized in the table below.

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 both short-term epidemics such as outbreaks of food-poisoning, and long-term diseases like cancer and heart disease. Results of these studies are reported in terms of statistical associa-

How Epidemiologists Conduct Case-Control Studies

The Process:

1. A list of people with a particular disease is assembled. These are the **cases**.
2. A list is assembled of people who are similar to the cases, but who do not have the disease. They are the **controls**.
3. The numbers of cases and controls who were *previously* exposed to factor X is estimated. This is often one of the most difficult parts of the study because exposures have often occurred many years in the past.
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 *higher* ratio, there is a **positive association**, and factor X *may* be a cause of the disease. If the cases have a *lower* exposure ratio than the controls, there is a **negative association**. This would suggest that factor X may help protect people from the disease.

Examples:

Here are some examples of possible outcomes of a study of some factor X involving 180 cancer cases and 180 controls:

If 60 cases were exposed to factor X and 120 were not exposed, the case exposure ratio = $60 \div 120 = 0.50$. If 60 controls were also exposed, the control exposure ratio is also 0.50. Dividing the case exposure ratio by the control ratio gives the **odds ratio (OR)**, sometimes called **relative risk** ($0.50 \div 0.50 = 1.00$).

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.

Now suppose 80 cases were exposed (ratio = 0.80), and 60 controls were exposed (ratio = 0.50). The OR is $0.80 \div 0.50 = 1.60$. 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 a 60% increased risk of having cancer.

Even when the OR is above 1.00, calculations must be done to see whether it is **statistically significant** (more than just chance). For example, one study of factor X could find an OR of 1.60, which is also statistically significant. Another study of factor X could find an OR of say 1.90, which is not statistically significant, i.e., it could have been due to chance. This could happen if the second study were based on a smaller number of cases and controls which increased the variability in the data.

tions between various factors and disease. Ultimately, the challenge is to discover whether the results indicate a true causal association. Often, supplemental data are needed from studies of laboratory animals before scientists conclude that some factor is a cause of a disease.

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 17), 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. Exposure to magnetic fields was identified 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 11).

A second study in Denver in 1988, and one in Los Angeles in 1991, also found significant associations between living near high-current power lines and childhood cancer. However, in these two studies the association was not significant when measured magnetic fields were used in the analysis.

A study in Denver in 1979 first reported that children with cancer were more likely to live near high-current distribution lines.

On average, about 1 in 10,000 children develops cancer each year. If power lines doubled the risk of cancer, then, depending on level of exposure, about 2 in 10,000 children exposed to power lines would be expected to develop cancer each year.
(NY Powerline Science Panel 1987)

Summary of Residential Power-Line Cancer Studies

Author	Location	Study Results	Other Findings
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 = 0.30	CNS Tumors OR = 3.70*
Savitz et al. '88	Denver, CO	OR = 1.54	All Cancer OR = 1.53*
Coleman et al. '89	U.K.	OR = 1.70	Not Studied
Lin & Lu '89	Taiwan	OR = 1.31	All Cancer OR = 1.30
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 = 2.00	
Feychting & Ahlbom '93	Sweden	OR = 3.80*	All Cancer OR = 1.30
Olsen et al. '93	Denmark	OR = 1.50	All Cancer OR = 5.60*
Petridou et al. '93	Greece	OR = 1.19	Not Studied
Verkasalo '93	Finland	SIR = 1.60	All Cancer SIR = 1.50, CNS Tumors in Boys, SIR = 4.20*
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 = 0.80	Not Studied
Coleman et al. '89	U.K.	OR = 0.90	Not Studied
Youngson et al. '91	U.K.	Leukemia & Lymphoma OR = 1.29	
Feychting & Ahlbom '92	Sweden	OR = 1.00 (Leukemia Subtypes OR = 1.70)	
Schreiber et al. '93	The Netherlands	No Cases	All Cancer SMR = 85, Hodgkins Disease SMR = 469

Notes: This table is intended to summarize briefly some of the often-cited results of the residential cancer studies. The full papers should be consulted for details (see *References* section).

Abbreviations:

OR = Odds Ratio (see page 15). An OR of 1.00 means no increased or decreased risk.

SMR = Standardized Mortality Ratio. An SMR of 100 means no increased or decreased risk.

SIR = Standardized Incidence Ratio. An SIR of 1.00 means no increased or decreased risk.

CNS = Central nervous system

O/E = Observed number of cases divided by the expected number of cases.

* This means that the number is statistically significant (greater than expected by chance).

† For nonsolid tumors, which includes leukemias and lymphomas

Studies in Sweden, Finland, and Denmark also found increased cancer risks for children living near transmission lines. To date, 7 of 13 studies (page 17) found statistically significant associations between various types of childhood cancer and power lines. Two of seven studies of adults found significant associations between cancer and power lines. Although studies are often characterized this way, the diverse studies can't simply be "added up" this way (see margin notes on page 21). Several more studies of people living near power lines are still underway or are planned throughout the world.

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

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

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 1.50 for calculated fields of 1 to 2.9 mG (based on four leukemia cases), and 3.80 for fields above 3 mG (based on seven cases). The trend for increasing risk with increasing field strength was statistically significant.
- ┌ For homes within 50 m (164 ft.) of transmission lines (6 cases) relative risk for child leukemia was 2.90 and it was on the borderline of statistical significance.
- ┌ Excess leukemia risks were confined to one-family homes, and there were no elevated risks for other types of child cancers.
- ┌ There were no statistically significant elevated cancer risks for adults.
- ┌ Control for possible effects of air pollution and socioeconomic status did not change study results.

SOURCE: Feychting & Ahlbom 1992,1993

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 risks above were based on very small numbers of cases (see summary on page 18). For adults, no statistically significant elevated cancer risks were found.

The Swedish researchers concluded that their study provides additional evidence for a possible link between magnetic fields and childhood 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 magnetic field levels existing around the time the cancers were diagnosed. Others are skeptical because of the small numbers of cancer cases, and because no cancer association was seen with present-day magnetic field levels.

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?).

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, 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.

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 risks of cancer?*

A Several studies have reported increased cancer risks for jobs involving work around electrical equipment. To date it is not clear whether these risks are caused by EMF or other factors. A brief report published in 1982 was one of the first to suggest that electrical workers have an increased risk of leukemia compared to other occupations. The study was based on death certificates from Washington state, and included workers in 10 occupations

assumed to have elevated exposure to EMF. Since this study, at least 38 studies have reported statistically significant increased risks for various types of cancer in occupational groups exposed to EMF (see table below).

Summary of Results by Cancer Type in Studies of Electrical Workers

Cancer Type	Significant Increased Risks	No Significant Increased Risks	Totals*
Leukemia	21	19	40
Brain Cancer	12	14	26
Male Breast Cancer	2	5	7
Other Cancers	12	17	29
Totals	47	55	102

* Many studies included more than one cancer type, so the total number of studies is about 66 rather than 102. Of these 66 studies, about 38 reported increased risks (i.e., at least one risk above 1.00 that was statistically significant).

SOURCE Summary based on studies included in national reviews listed on page 44, with newer individual studies added.

Notes about the table above:

Study results are presented in very general terms. The studies can't be "added up" this way to reach some conclusion about health effects. This is because many types of studies are included. Also, many studies that reported no "significant" risks, *did* report elevated risks (above 1.00). The risks were not significant possibly because of small sample sizes. For studies included as significant, some found only one or a few significant risks out of several that were studied. When a large number of risks is calculated, some can be "significant" due to chance.

Relative risk levels in these studies are mostly less than 2.00, and the possible influence of other factors such as chemicals has not been ruled out. At least 28 other studies did not find any significant cancer risks in electrical workers. In most of the studies in the table above, EMF were not measured. Instead, "electrical" job titles were used as indicators of assumed elevated exposure to EMF.

A recent study provided some information on EMF exposures for various electrical workers. As shown in the table on page 22, electrical workers in Los

EMF Exposures of Workers in Los Angeles and Seattle

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

SOURCE: Bowman et al. 1992

Occupations included in the "electrical worker" category in the table on the left:

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

Angeles and Seattle do have higher EMF exposures than non-electrical workers. The Los Angeles electrical workers also had a 29% increase in leukemia, but there was no association between leukemia and magnetic field exposures among jobs within the group (no "dose-response" trend).

A recent electrical worker study in the U.S. involved 36,000 workers at a large utility in California (Sahl et al., 1993). Some elevated risks for leukemia of less than 2.00 were found, but they weren't statistically significant. No consistent evidence of an association between measured magnetic fields and cancer was found in this study. Two large studies of electrical workers using combined data from several large utilities are underway. These studies may help clarify whether or not EMF increase the risk of cancer in workers.

What have governmental reviews concluded about EMF and cancer?

As of fall 1993, most recent reviews have concluded that the existing evidence does not show that

EMF cause cancer. These include national reviews by: an Advisory Board to the U.S. Environmental Protection Agency, National Radiological Protection Board of the United Kingdom, Danish Ministry of Health, French National Institute of Health and Medical Research, and reviews sponsored by the states of California, Texas, Connecticut, Illinois, and Colorado.

In Sweden, a government agency concluded that, based on results of the recent study in that country

Some Quotes from National EMF 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)

“ ... the epidemiologic findings that have been reviewed provide no firm evidence of the existence of a carcinogenic hazard from exposure [to EMF] ... the findings to date can be regarded only as sufficient to justify formulating a hypothesis for testing by further investigations. ”
(U.K. National Radiological Protection Board 1992)

“ ... the Finnish and 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. ”
(Danish Ministry of Health 1993)

“ ... the epidemiologic results presently available do not permit the exclusion of a role for magnetic fields in the incidence of leukemia, particularly in children. New investigations are necessary to confirm or deny this role. ”
(French National Institute of Health and Medical Research 1993)

“ ... the Board will act on the assumption that there is a connection between power frequency magnetic fields and childhood cancer, when preparing regulation on electrical installations. ”
(Swedish National Electric Safety Board 1993)

(see page 18), it is *assumed* that a causal link exists between magnetic fields and childhood leukemia. The Swedish government is studying possible magnetic field regulations and other actions that may be adopted. In nearby Denmark, a government agency concluded there was no *scientific* reason for standards for high-current lines.

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

A Although not as numerous as the cancer studies, several epidemiologic studies have looked for effects of EMF on general health, reproduction, suicide and depression, and hypersensitivity. Most numerous are the studies involving possible effects on reproduction.

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, Sweden developed guidelines, which have been adopted by several makers of monitors (right).

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. Some studies have also investigated the possibility that certain sensitive individuals may experience allergic-type reactions to EMF.

Swedish VDT Guidelines	
Freq. Range	Magnetic Field
5 Hz to 2 kHz	2.5 mG
2 kHz to 400 kHz.....	0.25 mG

At 50 cm (20 inches)

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.

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 (see summary below). 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 very specific laboratory conditions were needed for them to be detected. It is also not clear how EMF actually cause these effects.

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 page 45

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)

Laboratory studies to date have not answered questions about possible human health effects. These studies are, however, providing clues about how EMF interact with basic biological processes. The cell membrane may be an important site of interaction with induced currents from EMF.

Q *What about effects on the hormone melatonin?*

A Melatonin is a hormone produced mainly 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, night-time 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 effect of electric fields on melatonin. Also, melatonin levels were not affected in sheep raised for nearly a year in the EMF directly beneath a BPA 500-kV transmission line. The Midwest Research Institute has begun a new study aimed at determining whether 60-Hz magnetic fields affect melatonin levels in humans. See page 27 for more on melatonin.

Q *Are more studies of EMF being done?*

A Yes, worldwide, there are about 200 studies underway or planned involving magnetic and/or electric fields. 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

EMF studies are being done in at least 22 countries.

Melatonin

What is it ?

The daily secretion of the hormone melatonin by the pineal gland is driven by a natural generator in the brain. Light regulates the generator so that melatonin secretion by the pineal matches the day-night cycle.

Noon Midnight Noon Midnight Noon Midnight

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, significant effects may occur in reproduction.

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 be related to irregularities in the melatonin rhythm.

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 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

Two studies found that 60-Hz magnetic fields reduced melatonin levels in hamsters. Exposure to the field occurred for only 15 minutes during the light period.

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 is under way to see whether magnetic fields affect melatonin in people under laboratory conditions. A study in Seattle is attempting to see whether breast cancer in women is related to EMF.

government agencies and by private organizations, including electric utilities and appliance manufacturers.

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 will be supported by both Federal and matching private funds. The program is being coordinated by the U.S. Department of Energy and the National Institute of Environmental Health Sciences.

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 11). As discussed above, with the exception of Sweden, government health or safety organizations worldwide have generally not assumed or concluded that EMF cause cancer or other health effects. 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.

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 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 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:

1. Become well-informed about the EMF issue by reading and talking with people from a variety of sources.
2. Find out about the EMF levels produced by the particular transmission line you are interested in. (You may be far enough away from the line so that EMF levels are very low--see page 9.)
3. Try to place EMF in perspective with other potential and real health risks that are important to you (see BPA publication number 4 listed on page 38 for information on various risks).

Q *What can be done to limit EMF exposures?*

A While scientific research is ongoing, there are a number of ways that individuals and organizations can reduce 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 debating whether or not EMF are a hazard to health, it is not clear how much should be done at this time to reduce exposures. Below are some ways to reduce exposures to EMF.

General Ways to Reduce Exposures to EMF		
✓ Increase distance from the source.	Moving your bedside clock a short distance can greatly reduce the field level.	
✓ Design source to shield device help	New transmission lines and some appliances are designed to produce lower field levels.	
✓ Reduce time spent in field	Don't spend time in high fields if you don't have to. Some people use an electric blanket to warm up the bed, then unplug it before going to bed.

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 1987-88 BPA conducted a review of how the agency was dealing with the EMF issue. As a result, in 1988 BPA adopted interim guidelines on EMF (see page 31). These included a provision that EMF exposures of employees and the public should not be increased if practical alternatives can be found.

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

BPA's right-of-way management practice was revised in 1990 to reflect 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 increasing interest in EMF, BPA adopted revised guidelines on EMF in 1992.

Summary of BPA Interim Guidelines on EMF

Because of public concern and scientific uncertainty about EMF, in 1988 BPA adopted *interim guidelines* for addressing EMF issues. The guidelines were revised in 1992, and they will be reviewed approximately every 2 years. The full guidelines can be found in BPA publication number 4 listed on page 38. Below is a summary.

- It is not reasonable to adopt numerical health standards for EMF at this time. BPA will be consistent with EMF standards adopted by states in our service area to the maximum extent practicable.
 - BPA will continue to support research efforts dealing with EMF issues.
 - For new transmission facilities, EMF exposure shall be a major decision factor, and we will attempt to keep EMF exposures as low as reasonably achievable.
 - Where practical alternatives exist, public and employee exposure to EMF should not be increased.
 - BPA employees will be kept informed on current research, and ways will be explored to reduce EMF exposures on the job.
 - BPA will continue to inform and involve the public in decisions and issues involving EMF produced by BPA transmission facilities.
-

Exposure to EMF is now considered a major factor that BPA evaluates when new transmission lines and substations are proposed. As a general goal, we attempt to keep new EMF exposures as low as reasonably achievable.

Q *What would BPA do if EMF were found to be hazardous to human health?*

A This would depend on the nature of the hazard and on how the hazard determination was made. For example, a Federal health or environmental agency could direct other agencies such as BPA to adopt specific EMF health standards, guidelines, or mitigation plans. Similarly, BPA could be directed to take specific actions as a result of Federal Executive Office Orders, or as a result of Federal legislation dealing with EMF. It is also possible that the U.S. Department of Energy could take actions regarding EMF.

Significant BPA decisions about EMF which might involve major modifications of the existing transmission system, or could cause expansions of existing rights-of-way, could require following procedures of the National Environmental Policy Act (NEPA). NEPA provides BPA's customers and citizens in the Northwest with a formal opportunity to assist BPA in developing and evaluating alternative courses of action. Concern about EMF is a societal issue, and BPA is committed to involving the public in policy discussions about this issue.

Are EMF a health hazard ?

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 9. 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 39). If the line that you are interested in is not owned by BPA, you should 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. For information on these meters, contact BPA or your local utility.

Several companies make small meters that measure power-frequency magnetic fields.

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

A As a source of comparison with the magnetic field in your home, see the figure below. It summarizes spot measurements of magnetic fields made in the center of each room in about 700 homes throughout the U.S. Because the measurements were made away from appliances, they reflect the magnetic field in homes caused by power lines and electrical grounding currents. In about 90% of the homes, the all-room median magnetic field was less than 2 mG. Only 5% of the homes had median magnetic fields greater than 2.72 mG.

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 serious electric shocks if a person or anything he or she 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 “arc” over 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 (see page 38).

For safety purposes, buildings should never be located within transmission line rights-of-way. If a homeowner is not sure where the edge of the right-of-way is, he or she 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 39 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 were to touch the fence, you could receive an annoying shock, much like the shock you can get from touching a door knob after walking across a rug. To prevent nuisance shocks, metal fences, gutters, buildings, or other such equipment near transmission lines are grounded if they pose a problem.

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

Grounded fence Insulated person

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).

Insulated fence Grounded person

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.

Vehicle Grounded person

Lines are designed to have lower EMF levels where many vehicles are expected (like parking lots) to prevent nuisance shocks when touching cars and trucks. (Most tires are actually partially conductive which prevents vehicles from being fully insulated from ground.)

FOR MORE INFORMATION

From BPA:

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

1. ***Living and Working 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.

Level of
technical
detail:

Low

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*** (107 pp.)

This book contains detailed information about all types of biological and environmental effects of both AC and DC transmission lines.

High

Copies of BPA publications may be ordered by calling BPA's document request line, 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 at 800-622-4519.

Or, call the nearest BPA Area or District Office:

Portland	(503) 230-4558
Eugene	(503) 465-6952
Seattle	(206) 553-4130
Spokane	(509) 353-2567
Missoula	(406) 329-3060
Walla Walla	(509) 527-6213
Idaho Falls	(208) 523-2706
Boise	(208) 334-9137
Washington, DC	(202) 586-5640

Information From Other Sources:

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

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

Publications on EMF are available for sale from:

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 beginning on page 41 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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News about EMF issues and research can also be found in these monthly publications:

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