

Questions and Answers about EMF

Electric and Magnetic Fields Associated with the Use of Electric Power

Human Health Studies

EPIDEMIOLOGY

Q. How do scientists study possible effects of EMFs on people?

A. They use a type of research called epidemiology-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 in terms of statistical associations between various factors and disease. The challenge is to discover whether the statistical results indicate a true causal association. This includes assessing possible effects of other factors "confounders" that could affect study results. A "statistically significant" finding is one in which researchers are 95% confident that an association exists. However, a statistically significant finding does not necessarily prove a cause-effect association. Usually, supplemental data are needed from studies of laboratory animals before scientists can conclude that a given factor is a cause of disease.

The language of epidemiology can appear, to the uninitiated, more precise than it actually is. An odds ratio (see example below) is an estimate. Epidemiologists must calculate, along with the odds ratio, the range over which they are confident that this estimate is reliable. Sample size is a key factor in this calculation. The smaller the sample, the less reliable the information.

How Epidemiologists Conduct Case-Control Studies	
The Process	Examples
1. A list of people with a particular disease is assembled. These are the cases.	Here are some examples of possible outcomes of a study of a potential risk factor X, based on 300 cancer cases and 300 controls:
2. A list is assembled of people who are similar to the cases, but who do not have the disease. They are the controls.	If 71 cases were exposed to factor X and 229 were not exposed, the case exposure ratio = $71/229 = 0.31$. 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 ($0.31/0.31 = 1.00$). 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.
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.	
4. The exposure ratio of the cases is compared to that 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	Now suppose 110 of the total 300 cases were exposed (ratio = $110/190 = 0.58$), and 71 controls were exposed (ratio = 0.31). The OR is $0.58/0.31 = 1.87$. 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%

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.

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). 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 = 1.00, it is not statistically significant because of the small numbers of exposed subjects.

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

A. To date, 14 studies have analyzed a possible association between proximity to power lines and various types of childhood cancer. Of these, eight have reported positive associations between proximity to power lines and some form(s) of cancer. Four of the 14 studies showed a statistically significant association with leukemia.

The first study to report an association between power lines and cancer was conducted in 1979 in Denver by Dr. Nancy Wertheimer and Ed Leeper. They found that children who had died from cancer were 2 to 3 times more likely to have lived within 40 m (131 ft) of a high-current power line than were the other children studied. 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 the magnetic fields produced by the power lines. The estimate was based on the size and number of power line wires and the distance between the power lines and the home (p. 34).

A second Denver study in 1988, and a 1991 study in Los Angeles, also found significant associations between living near high-current power lines and childhood cancer incidence. The L.A. study found an association with leukemia but did not look at all cancers. The 1988 Denver study found an association with all cancer incidence. When leukemia was analyzed separately, the risk was elevated but not statistically significant. In neither of these two studies were the associations found to be statistically significant when magnetic fields were measured in the home and used in the analysis. Studies in Sweden (1992) and Mexico (1993) have found increased leukemia incidence for children living near transmission lines. A 1993 Danish study, like the 1988 Denver study, found an association for incidence of all childhood cancers but not specifically leukemia. A Finnish study found an association with central nervous system tumors in boys. Eight studies have examined risk of cancer for adults living near power lines. Of these, two found significant associations with cancer. The following chart summarizes results from studies involving cancer in people living near power lines.

Summary of Residential Power-Line Cancer Studies			
Study	Location	Leukemia	Other Cancers
Child Cancer Studies			
Wertheimer & Leeper '79	Denver	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	OR = 1.54	All Cancer OR = 1.53*
Coleman et al. '89	U.K.	OR = 1.50	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	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*
Fajardo-Gutiérrez et al. '93	Mexico	OR = 2.63*	Not Studied
Adult Cancer Studies			
Wertheimer & Leeper '82	Denver	OR = 1.00	All Cancer OR = 1.28*
McDowall '86	U.K.	SMR = 143	Lung Cancer SMR = 215*
Severson et al. '88	Seattle	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	
Eriksson & Karlsson '92	Sweden	Not studied	Multiple Myeloma OR = 0.94
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
<p>Note: This table is intended to summarize briefly some of the selected, often-cited results of the residential cancer studies; consult the full papers for details (see <i>References</i>, p. 56). OR = Odds Ratio (see p. 10). 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. * The number is statistically significant (greater than expected by chance), p. 11. † For nonsolid tumors, which includes leukemias and lymphomas.</p>			

Although often characterized this way, these diverse studies can't simply be "added up" to determine weight of evidence or to reach a conclusion about health effects because many types of studies are included in these lists. Also, many studies that reported no statistically significant elevations in risk did report elevated risks (above 1.00). The risks in some cases may not be reported as "significant" because of small sample sizes. For studies included as significant, some found only one or a few significant risks out of several that had been calculated. When many risks are calculated, some can be "significant" due to chance. It is also worth noting that studies which report positive associations tend to receive more publicity than do studies which find no association.

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 risk calculations were based on very small numbers of cases (see summary box, next page).

The Swedish researchers concluded that their study provides additional evidence for a possible link between magnetic fields and childhood leukemia. However, scientists have expressed differing opinions about this study. Some scientists believe the study is important because it is based on magnetic field levels presumed to have existed 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 measured in the home.

There are about 70 new cases of childhood leukemia per year in Sweden. The National

Electrical Safety Board of Sweden estimates that if, as this study suggests, living near overhead transmission lines increases a child's risk of developing leukemia, then approximately two children per year in Sweden would develop leukemia as a result of living near such power lines.

Information on adult cancer incidence was also collected and analyzed in the Swedish study. Researchers reported in 1994 that adults with the highest cumulative exposure (over 15 years) to power-line EMFs were twice as likely to develop acute or chronic myeloid leukemia as were less exposed adults. Although the total number of cases was small, which made the results of borderline statistical significance, the study provides some evidence for an association between exposure to magnetic fields from power lines and acute and chronic myeloid leukemia in adults.

Summary of Swedish Residential Cancer Study	
<ul style="list-style-type: none"> • Cancer cases (from 1960-85) and controls were 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. • No cancer association was found with present-day in-home magnetic field measurements. 	<ul style="list-style-type: none"> • For homes within 50 m (164 ft) of transmission lines (six cases), relative risk for childhood leukemia was 2.90, which was on the borderline of statistical significance. • Excess leukemia risks were found only in one-family homes. There were no elevated risks for other types of child cancers. • Control for possible effects of air pollution and socioeconomic status did not change study results. • Adults with highest cumulative exposures to power-line EMFs had twice the risk of developing acute or chronic myeloid leukemia. <p style="text-align: right;">Source: Feychting & Ahlbom 1992, 1993.</p>

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

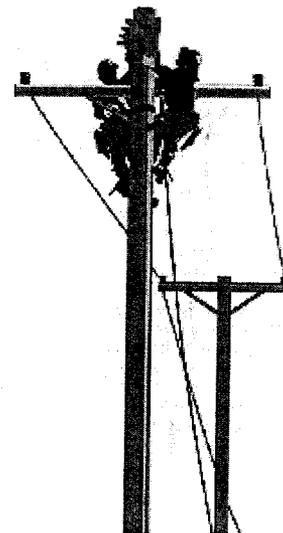
A. Scientists call unusual occurrences of cancer in an area or in time a "cancer cluster". In some cases, a cancer cluster has served as an early warning of a health hazard. For most reports of cancer clusters, however, the cause is never determined, or the perceived cluster is not really an unusual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

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 EMFs or by other factors. A report published in 1982 by Dr. Samuel Milham was one of the first to suggest that electrical workers have a higher risk of leukemia than do workers in other occupations. The Milham study was based on death certificates from Washington state and included workers in 10 occupations assumed to have elevated exposure to EMFs. A subsequent study by Milham, published in 1990, reported elevated levels of leukemia and lymphoma among workers in aluminum smelters, which use very large amounts of electrical power.



About 50 studies have now reported statistically significant increased risks for several types of cancer in occupational groups presumed to have elevated exposure to EMFs. Relative risk levels in these studies are mostly less than 2, and the possible influence of other factors such as chemicals has not been ruled out. At least 30 other studies did not find any significant cancer risks in electrical workers. Most of the earlier occupational studies did not include actual measurements of EMF exposure on the job. Instead, they used "electrical" job titles as indicators of assumed elevated exposure to EMFs. Recent studies, however, have included extensive EMF exposure assessments.

A report published in 1992 by Dr. Joseph Bowman and colleagues provided some information about actual EMF exposures of various electrical workers. As shown in the table below, electrical workers in Los Angeles and Seattle did have higher EMF exposures than nonelectrical workers.

For this study, the category "electrical workers" included electrical engineering technicians, electrical engineers, electricians, power line and cable workers, power station operators, telephone line workers, TV and radio repairmen, and welders and 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
Nonelectrical	5.5 V/m	10.6 V/m	1.7 mG	4.1 mG

Source: Bowman et al. 1992

In a further analysis published in July 1994, Dr. Stephanie London, Bowman, and others found a weakly positive trend for increased leukemia risk in relation to exposure to magnetic fields among electrical workers in Los Angeles County. These results were consistent with findings from studies based on job title alone that electrical workers may be at slightly increased risk of leukemia.

A 1993 study (Sahl et al.) of 36,000 electrical workers at a large utility in California found no consistent evidence of an association between measured magnetic fields and cancer. Some elevated risks for lymphoma and leukemia were observed, but they were not statistically significant. A 1992 study of Swedish workers (Floderus et al.) found an association between average EMF exposure and chronic lymphocytic leukemia but not acute myeloid leukemia. There was some evidence of increasing risk with increasing exposure. The Floderus study also reported an increase in brain tumors among younger men whose work involved relatively high magnetic field exposure.

Results of a major study of electrical workers in Canada and France were reported in early 1994. The research team, led by Dr. Gilles Theriault, looked at 4151 cancer cases in 223,292 workers from two utilities in Canada and one in France. Workers with more than the median cumulative magnetic field exposure (31mG) had a significantly higher (up to three times higher) risk of developing acute myeloid leukemia. Workers who had the greatest exposures to magnetic fields had twelve times the expected rate of astrocytomas (a type of brain tumor), but according to the authors, this finding "suffered from serious statistical limits" and was based on a small number of cases (five) in the highest exposure category. In the analysis of median cumulative magnetic field exposure, no significant elevated risks were found for the other 29 types of cancer studied.*

There were inconsistencies in results among the three utilities and no clear indication of a dose-response trend. The authors concluded, therefore, that their results did not provide definitive evidence that magnetic fields were the cause of the elevated risks found in leukemia and brain cancer. However, they observed as "noteworthy" the fact that despite the enormous number of analyses done, the only two types of cancer for which a significant association with EMF was found (leukemia and brain cancer) were among the three for which an association had been hypothesized, based on previous studies.

In another major study involving more than 138,000 utility workers (Savitz et al. 1995), the authors concluded that the results "do not support an association between occupational magnetic field exposure and leukemia, but do suggest a link to brain cancer."

*A later analysis reported an association between exposure to short bursts of extremely high magnetic fields and increased risk of lung cancer.

Q. Is there any evidence that EMF exposure increases the risk of breast cancer?

A. There is some epidemiological evidence for an association between EMF exposure and breast cancer, but studies have also reported evidence to the contrary.

A 1994 study (Loomis et al.) examined death records of female workers and found that women employed in electrical occupations were slightly more likely to have died of breast cancer than were other working women. However, because the study could not control for factors such as diet, fertility, and family history (which are known to affect breast cancer risk), the results are considered to be preliminary, not conclusive. A 1994 Norwegian study reported an excess risk of breast cancer among female radio and telegraph operators aboard ships. A 1993 Danish study found no association between occupational EMF exposure and female breast cancer. Several studies have reported an increased risk of breast cancer among men employed in EMF-related occupations. However, the 1994 study

of electrical workers in Canada and France reported no such association.

Several large-scale studies are now under way in the United States and in other countries to see if women living in homes with higher EMF exposures have an increased risk of developing breast cancer. The reason for the recent interest in EMFs and breast cancer has less to do with epidemiology than with biology-laboratory evidence concerning the role of EMFs and melatonin in the development and suppression of breast cancer (see p. 24).

Q. If EMFs 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 (right), EMF exposures have probably not increased in the same way. Changes in the way that buildings are wired and in the way electrical appliances are made have in some cases resulted in lower magnetic field levels. 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 because of better treatment. Incidence rates (numbers of new cases), however, have tended to increase for unknown reasons. Reliable data on incidence rates only became available beginning in the early 1970s.) Incidence rates can reflect changes in exposures to various environmental agents, and they are also 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 effect of EMFs 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 EMFs?

A. Several epidemiologic studies have looked for EMF effects on pregnancy outcomes and general health. Various EMF sources have been studied for possible association with miscarriage risk: power lines and substations, electric blankets and heated water beds, electric cable ceiling heat, and computer monitors or video display terminals (VDTs). Some studies have correlated EMF exposure with higher than expected miscarriage rates; others have found no such correlation. Epidemiologic studies have revealed no evidence of an association between EMF exposure and birth defects in humans.

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. Results of these studies have been mixed. Some studies have also investigated the possibility that certain sensitive individuals may experience allergic-type reactions to EMFs, known as "electrosensitivity."

One preliminary report released in 1994 has suggested a possible link between occupational EMF exposure and increased incidence of Alzheimer's disease. This study also found a higher incidence of Alzheimer's disease among tailors and dressmakers. At the time this booklet was produced, the research related to Alzheimer's had not been peer-

reviewed or published.

On to Biological Studies...

Back to Contents...

[Factsheets and Pamphlets](#)

[Facts About Environment-Related Diseases and Health Risks](#)

NIEHS welcomes your comments and suggestions. Please send them to:

WebCenter

(webcenter@niehs.nih.gov)

Page created: 27 Jan 98

Last revision: 30 Oct 98

[NIEHS Home
Page](#)

[NIH Home
Page](#)