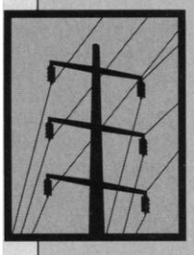
Is There an EMF-Cancer Connection?

The question of whether electromagnetic fields pose a health risk is being taken seriously by an increasing number of researchers, but don't throw out your electric hair dryer just yet



Are power lines and electric blankets hazardous to your health? There are scientists on both sides of the increasingly public debate over the biological effects of electromagnetic fields. Each camp can point to research supporting its position, but what does the evidence really say? Science *now begins a series of three articles examining that evidence. This first one looks at the epidemiological research that is searching for a link between electromagnetic fields and cancer; the second will deal with the cell and animal studies; and the third will consider policy questions and the politics behind the research.*

LIKE MOST SCIENTISTS 10 YEARS AGO, David Carpenter was skeptical of claims that exposure to electromagnetic radiation could promote cancer. But that was before he directed a $5-million project to test those claims with epidemiological and laboratory studies. Now Carpenter, who is the dean of the school of public health at the State University of New York in Albany, doesn't think it's such a crazy idea anymore. "I think there is sufficient evidence to really raise some red flags here," he says.

Although many of the researchers who study this controversial field disagree with Carpenter about the red flags, there has been an undeniable shift in attitude toward electromagnetic fields (EMFs) and their purported health effects. In the 1970s, it seemed absurd that EMFs—which are generated by anything electric, from power lines to household appliances—could be hazardous, even in the tiniest degree. Now it's a legitimate open question.

Much of the rethinking has been prompted by a series of epidemiological studies. Over the past 11 years, a number of researchers have found increased risk of cancer among children who live close to power lines or among men whose jobs expose them to unusually high levels of EMFs. This epidemiological work, which has been highly publicized, has created a great deal of public concern about EMFs.

In Alexandria, Virginia, for instance, the city council has tried to force the local electric company to remove aboveground power lines that run very close to homes in the city's densely packed historic district. Hillsborough County in Florida is fighting the construction of a high-power transmission line on the grounds that the magnetic fields it generates are too intense to be considered safe. In Seattle, a Boeing Company employee sued to be compensated for leukemia that he claimed was caused by on-the-job exposure to EMFs; the claim was denied, but lawyers see many more such lawsuits in the future.

A widely read magazine—*The New Yorker*—has published several sensationalistic articles by a journalist who has made the EMF issue into a personal crusade. And newspapers, television newscasts, and radio talk shows have gotten into the act, worrying their audience members. Meanwhile, a report from the Environmental Protection Agency assessing the possible health effects of EMFs is due out in final form in a few weeks; the draft version of the report labeled EMFs as "a possible, but not proven, cause of cancer." And a bill that would set federal standards for EMF exposures has been introduced in Congress.

How good is the evidence that is generating all this concern? It is, in a word, inconclusive. The half dozen childhood leukemia studies are somewhat contradictory, for instance, and researchers have generally found no increased risk at all among adults living close to power lines. The data do seem to imply that men working in electrical jobs, such as electricians and telephone linemen, are at higher risk of brain tumors and other cancers, but EMFs may not be to blame. Many of these workers have been exposed to chemical carcinogens, such as benzene, that could explain the extra risk.

"It needs to be resolved," says Patricia Buffler, director of the Epidemiological Research Unit at the University of Texas Medical Center in Houston. Buffler, who says she is not persuaded that EMFs are a health hazard, nevertheless believes that epidemiologists need to do another round of studies to resolve the ambiguities in the data.

One of the complications facing epidemiologists is that nearly everyone in the industrialized world is exposed to electromagnetic radiation in one form or another. Created by moving electric charges, electromagnetic radiation propagates outward from any object that carries an electrical current and contains two components that behave quite differently: an electric field and a magnetic field. The electric component pushes or pulls charged particles, such as ions, in the direction of the field; the magnetic component acts on moving charged particles and pushes them perpendicular to their direction of motion.

In terms of possible health effects, the two components have an even more important distinction. An electric field is easily screened—only a tiny part makes it through the walls of a house or even through skin—but magnetic fields travel right through most matter without losing strength.

The EMFs that most people come in contact with are quite weak. The magnetic field generated by an overhead power line or a video terminal, for instance, is normally only a few milligauss, or about 1% of the earth's magnetic field. And although the electric field directly below a high-tension power line can be as much as 10 kilovolts per meter, the corresponding field induced inside the body will be only about 1 millivolt per meter—no bigger than the electric fields naturally generated by some cells.

These facts, more than any other, initially persuaded scientists that EMFs must be safe. How could such seemingly insignificant magnetic and electric fields be dangerous?

So in 1979 when Nancy Wertheimer and Ed Leeper first reported a correlation between childhood cancer and high EMF exposure from power lines, almost no one believed it. Wertheimer and Leeper had performed a case-control study in which they compared the EMF exposures of 344 children in Colorado who died of cancer from 1950 to 1973 with those of an approximately equal number of controls—children born at the same time as the cancer victims but who did not get cancer. The researchers concluded that children from high-exposure homes were two to three times as likely as those from low-exposure homes to develop cancer, particularly leukemia, lymphomas, and nervous system tumors.

It was a nearly unbelievable result, and other researchers didn't have to look too hard to find reasons to doubt it. The study's major weakness was that Wertheimer and Leeper had not actually measured the EMFs that the children were exposed to. They had merely estimated them according to what types of electric power lines ran near the homes. (Such lines carry anywhere from 115 volts to several hundred kilovolts, depending on their function in the distribution system; most lines near homes are no more than 35 kilovolts.) Moreover, this "wire coding" was not even done blind: The two researchers knew which homes had the cancer cases and which had the controls. "Everyone expected that the Wertheimer study's flaws were fatal," Carpenter recalls.

That certainly was Carpenter's expectation. He first got involved in EMF research in 1980 when he was asked to direct a series of EMF studies paid for by New York power companies and administered by the state health department. Carpenter asked David Savitz at the University of Colorado Medical School to try to replicate the Denver study, expecting that the new research would come up negative.

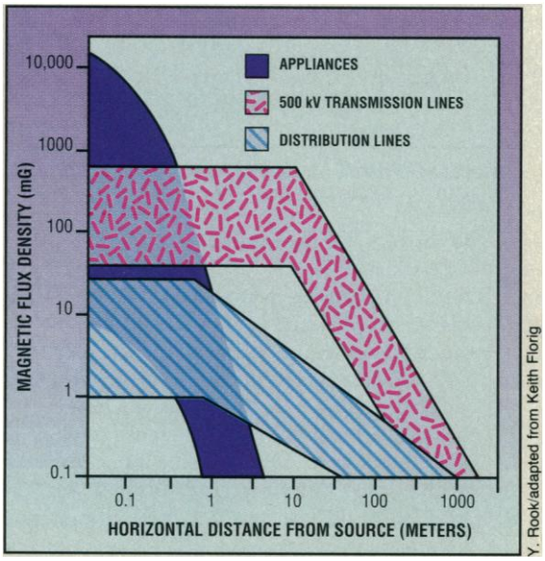
Instead, Savitz essentially replicated the Wertheimer-Leeper results. From a case-control analysis of 356 childhood cancer cases in the Denver area between 1976 and 1983, he calculated a risk ratio of about 1.5—that is, children with high exposure to power line EMFs were about 1½ times as likely to develop cancer as children with very low exposure. Although Savitz's calculated risks were lower than those of Wertheimer and Leeper, his thoroughness gave the results greater weight. For example, Savitz performed statistical analyses to make sure his results were not skewed by such possible confounding factors as socioeconomic class or mothers smoking during pregnancy. "It was that study," Carpenter remembers, "that caused me and most of the panel members [overseeing the New York State studies] to change our position."

In addition to the Wertheimer-Leeper and the Savitz work, four other studies have looked for correlations between EMFs and childhood cancer—with mixed results. One found no increased risks at all for children living close to power lines; another found increased risks of nervous system cancers and lymphomas, but a decreased risk for leukemia; two others found higher risks for various cancers, but the numbers were not statistically significant.

Each of these reports has a variety of flaws. All, for instance, included relatively small numbers of children, and therefore the statistical power of the results is low. But the major shortcoming is that no one has found a consistent dose-response relationship between cancer rates and EMF exposures. If a little electromagnetic radiation is bad, then more should be worse, but that doesn't emerge from the data. One study, for instance, found a higher cancer risk in homes where the average magnetic field was lower.

A related problem is finding a correlation between cancer risk and measured—as opposed to estimated—EMF exposures. Even the well-regarded study by Savitz, for instance, found an increased risk in high-exposure homes as rated by wire coding, but a weaker or absent relationship between cancer rates and EMF exposures as determined by spot measurements in the home.

This is not a fatal flaw, Savitz says. He argues that because electrical usage varies widely from day to day and even hour to hour, long-term EMF exposure may be more accurately estimated by looking at the types of power lines near a home than by taking a one-time measure of the EMFs in or near that house. Still, he says, the question won't be settled until the data show a better correlation between dose and effect.



Magnetic field exposure *varies according to distance and type of equipment.*

That information could soon be provided by John Peters at the University of Southern California, who is putting the finishing touches on a case-control study of 230 childhood leukemia victims in the Los Angeles area between 1980 and 1987. In it he will compare cancer rates with 24-hour records of actual EMF exposures in the homes as well as with exposures obtained by spot measurements and those estimated by wire coding. In addition to the EMF measurements, Peters says he has collected information on "everything else we can think of" that might cause or promote cancer in an effort to rule out other possible causes if an increased risk appears. He plans to report the results at an October meeting sponsored by his funding agent, the Electric Power Research Institute. Meanwhile, he is keeping his findings under wraps.

Although a majority of the studies of childhood cancer and EMF exposure have found at least some correlation, those looking at adults living close to power lines have generally been negative. In 1982, Wertheimer and Leeper claimed to have found increased cancer rates among adults living in various parts of Colorado who were exposed to higher than average doses of EMFs. But several other studies since then have found little or nothing. And that's hard to explain. Why should EMFs increase the risk of childhood cancer while having little or no effect on adult cancer? One possible explanation is that it is much more difficult to separate out EMFs from other risk factors for adults than for children, but no one really knows.

In contrast to the uncertainty about residential EMF exposures, the picture that emerges from occupational studies is sharp. Again and again, epidemiologists have found that workers in various electrical jobs have higher risks for various types of cancer, particularly brain and nervous system cancers as well as leukemias. In a recently finished case-control study in the Los Angeles area, for instance, Susan Preston-Martin and Wendy Mack at the University of Southern California found that men who had worked for 10 years or more in a variety of electrical occupations had a ten times greater chance of getting brain cancer than men in the control group. "Employment in these occupations is definitely conferring some type of risk," Mack says, but "we don't know whether EMFs are to blame."

The problem, she explains, is that electrical workers may be exposed to things besides electric and magnetic fields that could be causing the increased cancer risk. In the past, electricians have worked with organic solvents, such as benzene, that are known to cause cancer. So it's premature to single out EMFs as the culprit.

And proving a dose-response relationship here has been just as tough as in the case of EMFs and childhood cancer. One widely noted study, performed by Genevieve Matanoski of Johns Hopkins University, did find a dose-response relationship for cancers in male New York Telephone employees from 1976 to 1980. Matanoski measured the average magnetic field exposure among

different types of employees and found that cable splicers had by far the largest doses, followed by central office employees and then installation and repair workers.

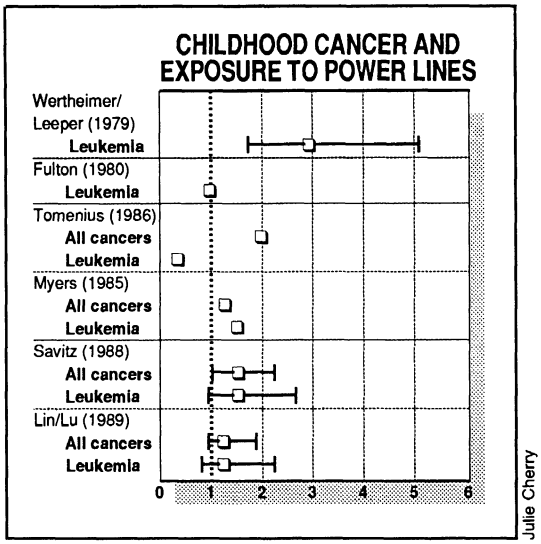
When she compared cancer rates among the various types of employees, she found an ominous result: Cable splicers were nearly twice as likely to contract all types of cancer as company employees who did not work on telephone lines, with the risks for leukemia and lymphomas being particularly high. Among central office workers, who are exposed to short, intense fields from telephone switching machinery, the rates of several cancers were unusually high, although not as high as for the cable splicers. The central office workers were more than three times as likely to get prostate cancer and more than twice as likely to get oral cancer as co-workers who were less exposed. And there were two cases of male breast cancer, a disease so rare that no cases at all would be expected among a group as small as the one Matanoski studied.

That suggestive finding by Matanoski was supported by a study announced in June by David Thomas of the Hutchinson Cancer Research Institute in Seattle, Washington. In a case-control study of 250 male breast cancer patients, Thomas found a strong correlation with jobs that involved exposure to EMFs. He calculated that men whose jobs involved some exposure to EMFs were nearly twice as likely to have breast cancer as those men with no exposure, and men likely to have the highest exposures—electricians, utility linemen, and power plant workers—had six times the risk of developing breast cancer as men who worked in occupations with no EMF exposure.

But other studies have found no evidence of a dose response for EMF exposure. A 1987 report by Terry Thomas at the National Cancer Institute found an increased risk of brain cancer among electrical workers, but apparently not as a result of their EMF exposure. When Thomas removed those cases who had been exposed to lead, soldering fumes, and organic solvents, the risk for brain cancer among the remaining workers was much less than that for the general population.

More recently, Joe Bowman at the University of Southern California finished a dose-response analysis of a 1985 study in which Neal Pearce of the Wellington School of Medicine in New Zealand found an increased risk for leukemia among electricians and radio and television repairers and assemblers in New Zealand. Bowman measured the average magnetic field exposures for the various occupations and found no dose response. Welders, for example, had the highest exposure to electromagnetic fields but no leukemia cases. Although the low numbers of cases limit the study's statistical power, it is "a strike against the hypothesis that all EMFs cause cancer," Bowman says.

Individually, the various epidemiological studies can each be challenged on one ground or another, but as a group they have a rough consistency that is harder to ignore. The cancers linked with EMF exposure are usually leukemia, lymphomas, and nervous system cancers, and the risk rates comparing exposed with unexposed persons are usually on the order of two or three.



Increased risk? *Most studies find risk ratios between 1 and 2 for childhood cancer.*

Savitz, who is now at the University of North Carolina, has performed a meta-analysis on leukemia among electrical workers in which he combined and analzyed the data from 11 occupational studies, some negative and some positive. He found that as a group the studies imply a small but unmistakable effect. For a wide range of occupations that involve some EMF exposure, the risk for developing leukemia was 1.2 times that of the general population.

If the increased risk is real, Savitz says, the calculated risk ratios almost certainly understate the size of the effect. The occupational studies, for instance, usually judge how much EMF exposure a person had over his career by relying on job titles. This imprecise approach must certainly lead to a great deal of misclassification, which will tend to bias the results toward a lower risk.

On the other hand, some researchers suspect that better studies, particularly those looking at childhood cancer, might find little or no risk from EMFs. Buffler at the University of Texas Medical Center points out that as the studies have improved, the risk ratios have tended to get smaller. This is particularly evident when comparing the Wertheimer-Leeper work with the Savtiz results. This pattern argues against the existence of a much larger risk that is waiting to be identified, she says.

And even if the effect is real, EMFs are clearly not as dangerous to the general population as smoking, for instance. Electricity usage has doubled several times in the last 40 years—and with it, probably, the average exposure to EMFs—but there has been no corresponding giant upsurge in childhood leukemia, or any of the other cancers suggested by the epidemiological work. If the implications of the Savitz study are true, then roughly 15% of childhood cancers are due to power line exposure, and Carpenter thinks it's reasonable to guess that another 15 to 25% could be caused by appliances. But if 30 to 40% of childhood cancers are caused by EMFs, there should have been a big jump in these cancers over the last 40 years. Epidemiologists don't agree on exactly how much cancer rates have changed over time, but it would be hard for them to miss something this large.

Scientists would also like to understand the biological processes by which EMF exposure might lead to cancer. Laboratory investigations have shown that EMFs can indeed elicit some effects in cells, including changes in hormone levels, in protein synthesis, and in ion flow across cell membranes. But so far this research has not produced a "smoking gun"—there is no clear laboratory evidence that EMFs either cause or promote cancer. Without such evidence, most researchers are reluctant to pin the carcinogen label on EMFs based on the somewhat ambiguous epidemiology studies.

What is needed, researchers say, is more research, and that is coming. Two or three epidemiological studies, including Peters', are scheduled to be released in the next couple of months, and several large projects are under way which won't be finished for 2 or 3 years. This next generation of research will include several improvements over its predecessors. The studies will in general be much larger—large enough to provide some real statistical power—and they will take into account what researchers have learned in the past few years about measuring EMF exposures. "If the next wave of studies doesn't answer the question," says Bowman at the USC, where several of the studies are being done, "it probably won't be decided by epidemiological means."

■ **ROBERT POOL**

ADDITIONAL READING

I. Nair, G. Morgan, H. K. Florig, *Biological Effects of Power Frequency Electric and Magnetic Fields* (Office of Technology Assessment, Washington, DC, 1989).