

# **NIEHS REPORT on**

## **Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields**

Prepared in Response to the 1992 Energy Policy Act  
(PL 102-486, Section 2118)

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NIH Publication No. 99-4493  
Supported by the NIEHS/DOE

## **Executive Summary**

### **Introduction**

Electrical energy has been used to great advantage for over 100 years. Associated with the generation, transmission, and use of electrical energy is the production of weak electric and magnetic fields (EMF). In the United States, electricity is usually delivered as alternating current that oscillates at 60 cycles per second (Hertz, Hz) putting fields generated by this electrical energy in the extremely low frequency (ELF) range.

Prior to 1979 there was limited awareness of any potential adverse effects from the use of electricity aside from possible electrocution associated with direct contact or fire from faulty wiring. Interest in this area was catalyzed with the report of a possible association between childhood cancer mortality and proximity of homes to power distribution lines. Over the next dozen years, the U.S. Department of Energy (DOE) and others conducted numerous studies on the effects of ELF-EMF on biological systems that helped to clarify the risks and provide increased understanding. Despite much study in this area, considerable debate remained over what, if any, health effects could be attributed to ELF-EMF exposure.

In 1992, the U.S. Congress authorized the Electric and Magnetic Fields Research and Public Information Dissemination Program (EMF-RAPID Program) in the Energy Policy Act (PL 102-486, Section 2118). The Congress instructed the National Institute of Environmental Health Sciences (NIEHS), National Institutes of Health and the DOE to direct and manage a program of research and analysis aimed at providing scientific evidence to clarify the potential for health risks from exposure to ELF-EMF. The EMF-RAPID Program had three basic components: 1) a research program focusing on health effects research, 2) information compilation and public

outreach and 3) a health assessment for evaluation of any potential hazards arising from exposure to ELF-EMF. The NIEHS was directed to oversee the health effects research and evaluation and the DOE was given the responsibility for overall administration of funding and engineering research aimed at characterizing and mitigating these fields. The Director of the NIEHS was mandated upon completion of the Program to provide a report outlining the possible human health risks associated with exposure to ELF-EMF. This document responds to this requirement of the law.

This five-year effort was signed into law in October 1992 and provisions of this Act were extended for one year in 1997. The Program ended December 31, 1998. The EMF-RAPID Program was funded jointly by Federal and matching private funds and has been an extremely successful Federal/private partnership with substantial financial support from the utility industry. The NIEHS received \$30.1 million from this program for research, public outreach, administration and the health assessment evaluation of ELF-EMF. In addition to EMF-RAPID Program funds from the DOE, the NIEHS contributed \$14.5 million for support of extramural and intramural research including long-term toxicity studies conducted by the National Toxicology Program.

### **NIEHS Conclusion**

The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects (including increased cancers in animals) have been reported. No indication of increased leukemias in experimental animals has been observed.

The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real-life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given the weak magnitude of these increased risks, some other factor or common source of error could explain these findings. However, no consistent explanation other than exposure to ELF-EMF has been identified. Epidemiological studies have serious limitations in their ability to demonstrate a cause and effect relationship whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to ELF-EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but it cannot completely discount the epidemiological findings.

The NIEHS concludes that ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in

the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern.

The interaction of humans with ELF-EMF is complicated and will undoubtedly continue to be an area of public concern. The EMF-RAPID Program successfully contributed to the scientific knowledge on ELF-EMF through its support of high quality, hypothesis-based research. While some questions were answered, others remain. Building upon the knowledge base developed under the EMF-RAPID Program, meritorious research on ELF-EMF through carefully designed, hypothesis-driven studies should continue for areas warranting fundamental study including leukemia. Recent research in two areas, neurodegenerative diseases and cardiac diseases associated with heart rate variability, have identified some interesting and novel findings for which further study is ongoing.

## **Background**

### **Program Oversight and Management**

The 1992 Energy Policy Act created two committees to provide guidance and direction to this program. The first, the Interagency Committee (IAC), was established by the President of the United States and composed of representatives from the NIEHS, the DOE and seven other Federal agencies with responsibilities related to ELF-EMF. This group receives the report from the NIEHS Director and must prepare its own report for Congress. The IAC had responsibility for developing a strategic research agenda for the EMF-RAPID Program, facilitating interagency coordination of Federal research activities and communication to the public and monitoring and evaluating the Program.

The second committee, the National EMF Advisory Committee (NEMFAC), consisted of representatives from public interest groups, organized labor, state governments and industry. This group was involved in all aspects of the EMF-RAPID Program providing advice and critical review to the DOE and the NIEHS on the design and implementation of the EMF-RAPID Program's activities.

### **ELF-EMF Health Effects Research**

The EMF-RAPID Program's health effects research initiative relied upon accepted principles of hazard identification and risk assessment to establish priorities. All studies supported by the NIEHS and the DOE under this program were selected for their potential to provide solid, scientific data on whether ELF-EMF exposure represents a human health hazard, and if so, whether risks are increased under exposure conditions in the general population. Research efforts did not focus on epidemiological studies (i.e. those in the human population) because of time constraints and the number of ongoing, well-conducted studies. The NIEHS health effects research program focused on mechanistic, cellular and laboratory studies in the areas of neurophysiology, behavior, reproduction, development, cellular research, genetic research, cancer and melatonin. Mechanistic, cellular and laboratory studies are part of the overall criteria used to determine causality in interpreting epidemiological studies. In this situation, the most cost-effective and efficient use of the EMF-RAPID Program's research funds was clearly for

trying to clarify existing associations identified from population studies. The DOE research initiatives focused on assessment of exposure and techniques of mitigation.

The EMF-RAPID Program through the combined efforts of the NIEHS and the DOE radically changed and markedly improved the quality of ELF-EMF research. This was accomplished by providing biological and engineering expertise to investigators and emphasizing hypothesis-driven, peer-reviewed research. Four regional facilities were also set-up where state-of-the-art magnetic field exposure systems were available for in-house and outside investigators to conduct mechanistic research. The EMF-RAPID Program through rigorous review and use of multi-disciplinary research teams greatly enhanced the understanding of the interaction of biological systems with ELF-EMF.

### **Information Dissemination and Public Outreach**

The EMF-RAPID Program provided the public, regulated industry and scientists with useful, targeted information that addressed the issue of uncertainty regarding ELF-EMF health effects. Two booklets, a question and answer booklet on ELF-EMF and a layman's booklet addressing ELF-EMF in the workplace, were published. A telephone information line for ELF-EMF was available where callers could request copies of ELF-EMF documents and receive answers to standard questions from operators. The NIEHS also developed a web-site for the EMF-RAPID Program where all of the Program's documents are on-line and links are available to other useful sites on ELF-EMF. Efforts were made to include the public in EMF-RAPID Program activities through sponsorship of scholarships to meetings; holding open, scientific workshops; and setting aside a two-month period for public comment and review on ELF-EMF and the workshop reports. In addition, the NIEHS sponsored attendance of NEMFAC members at relevant scientific meetings and at each of the public comment meetings.

### **Health Risk Assessment of ELF-EMF Exposure**

In preparation of the NIEHS Director's Report, the NIEHS developed a process to evaluate the potential health hazards of ELF-EMF exposure that was designed to be open, transparent, objective, scholarly and timely under the mandate of the 1992 Energy Policy Act. The NIEHS used a three-tiered strategy for collection and evaluation of the scientific information on ELF-EMF that included: 1) three science review symposia for targeted ELF-EMF research areas, 2) a working group meeting and 3) a period of public review and comment. Each of the three symposia focused on a different, broad area of ELF-EMF research: mechanistic and cellular research (24-27 March 1997, Durham, NC), human population studies (12-14 January 1998, San Antonio, TX) and laboratory human and clinical work (6-9 April 1998, Phoenix, AZ). These meetings were aimed at including a broad spectrum of the research community and the public in the evaluation of ELF-EMF health hazards, identifying key research findings and providing opinion on the quality of this research. Discussion reports from small discussion groups held for specific topics were prepared for each meeting.

Following the symposia, a working group meeting (16-24 June 1998, Brooklyn Park, MN) was held where a scientific panel reviewed historical and novel evidence on ELF-EMF and determined the strength of the evidence for human health and biological effects. Stakeholders and the public attended this meeting and were given the opportunity to comment during the process. The Working Group conducted a formal, comprehensive review of the literature for research areas identified from the symposia as being important to the assessment of ELF-EMF-

related biological or health effects. Separate draft documents covering areas of animal carcinogenicity, animal non-cancer findings, physiological effects, cellular effects, theories and human population studies (epidemiology studies) in children and adults for both occupational and residential ELF-EMF exposures were rewritten into a single book. The Working Group characterized the strength of the evidence for a causative link between ELF-EMF exposure and disease in each category of research using the criteria developed by the International Agency for Research on Cancer (IARC).

The IARC criteria fall into four basic categories: sufficient, limited, inadequate and evidence suggesting the lack of an effect. After critical review and discussion, members of the Working Group were asked to determine the categorization for each research area; the range of responses reflected the scientific uncertainty in each area. A majority of the Working Group members concluded that childhood leukemia and adult chronic lymphocytic leukemia from occupational exposure were areas of concern. For other cancers and for non-cancer health endpoints, the Working Group categorized the experimental data as providing much weaker evidence or no support for effects from exposure to ELF-EMF.

Following the Working Group Meeting, the NIEHS established a formal review period for solicitation of comments on the symposia and Working Group reports. The NIEHS hosted four public meetings (14-15 September 1998, Tucson, AZ; 28 September, Washington, DC; 1 October 1998, San Francisco, CA; and 5 October 1998, Chicago, IL) where individuals and groups could voice their opinions; the meetings were recorded and transcripts prepared. In addition, the NIEHS received 178 written comments that were also reviewed in preparation of this report. The remarks that NIEHS received covered many areas related to ELF-EMF and provided insight about areas of concern on behalf of the public, researchers, regulatory agencies and industry.