

Exposure to low-frequency electromagnetic fields — A health hazard?

by Bengt Knave, MD, Birgitta Floderus, PhD¹

During the 1970s there were continuous discussions on the possible health risks of power-frequency electric fields. Extensive research efforts failed to reveal any health hazards as a consequence of exposure to field strengths in the magnitude of those found in the vicinity of overhead high-voltage power lines. At the end of the 1970s and in the 1980s scientific interest has focused on power-frequency magnetic fields, especially their relationship to carcinogenesis. The reason for this interest is a number of epidemiologic reports presenting data indicative of an increase in the incidence of cancer among children and adults living in the vicinity of power distribution lines and among occupational groups with presumed exposure to low-frequency electromagnetic fields. Several reviews have been published on the possible health effects (eg, references 5, 10, 11). This extended abstract contains a brief comment on epidemiologic and experimental cancer studies and presents the current and projected epidemiologic Swedish studies.

In 1979, Wertheimer & Leeper (9) reported an excess of childhood cancer in residential areas near power-line distribution systems in Denver, Colorado. These authors found an association between childhood cancer and special wire configuration codings and postulated that this finding might be caused by exposure to the magnetic fields from these wiring systems. Some years later, Milham (4) reported an increase in leukemia in certain "electrical" occupations with presumed exposure to magnetic fields. These studies have been followed by others, in some of which the results have supported a possible association with magnetic field exposure. Of special interest is the case-referent study by Savitz et al (7) on residential exposure to magnetic fields and childhood cancer in which magnetic flux density measurements were carried out. In this study the lower limit of exposure was as low as 0.2 μ T.

Several studies have indicated an increase in leukemia, and, in some cases, brain tumors for certain "electrical" occupations with presumed exposure to magnetic fields. The list includes a wide variety of occupations, eg, electronic and electric-power engineers and technicians, electronic-equipment fitters and repairmen, miners, railway and subway engineers and

assistants, telephone operators, radio and telegraph operators, telephone and telegraph repairmen, furnace men, smelters, welders and flame-cutters, station operators, and linesmen in the electric-power industry. For many of these occupations with presumed exposure, we do not know whether there is, in fact, exposure to magnetic fields or not, and, if there is, which type and frequency of magnetic field is in question and whether or not there is exposure to other known carcinogens. For some occupations in the metal industry (furnace men and smelters) we do know that magnetic flux densities may be 10 000 times stronger than residential exposure. Major efforts are now being made in several countries to develop dosimeters for use in on-going epidemiologic studies.

The question can be asked of whether there is any experimental evidence of a relationship between magnetic fields and carcinogenesis. In 1986 Phillips et al (6) reported an increase in growth (clonogenicity) of cancer cells in soft agar after exposure to magnetic fields. An effort to replicate this finding was unsuccessful, however (2). Recently, increases in the intracellular enzyme ornithine decarboxylase (ODC), reported after exposure to 60-Hz low-energy electromagnetic fields, have been interpreted as possible indirect experimental evidence for the hypothesis that magnetic fields may serve as a tumor-promoting stimulus (1). A carcinogenic mechanism related to the pineal hormone melatonin has also been discussed (8). So far no whole-animal carcinogenicity studies have been performed. However, studies on rodents are being planned in several laboratories in America and Europe.

Current studies

Workers employed in the electric-power industry

Among workers definitely exposed to electromagnetic fields are linesmen and station operators in the electric-power industry. In 1981-1982 a prospective study of workers employed in these occupations was initiated, comprising 700 men newly employed at the start of the study. A 10-year follow-up is being carried out, including a health examination every third year. Data on, eg, reproductive history, electrocardiographic results, and different blood parameters are collected. Occupational hygiene is assessed and exposure to electromagnetic fields is measured with the dosimeter de-

¹ National Institute of Occupational Health, Solna, Sweden.

scribed by Lindh (3). Close collaboration with the occupational health services of the industries involved has been of great value for the study.

The same occupations — linesmen and station operators — are focused on in a study based on central registers (the National Medical Birth Register and the Register of Congenital Malformation). Subjects are identified from the censuses of 1960 through 1980, and long-term employment in the occupation is established. Reproductive data for the subjects are determined and compared to those of the general male working population. Factors such as number of children, the ratio of boys to girls, birth weights, and the occurrence of malformations will be examined.

Occupational groups with presumed exposure to electromagnetic fields

As previously mentioned, several studies — based on data from registers — have been performed for workers presumably exposed to electromagnetic fields. Such a study is currently being completed at the National Institute of Occupational Health. The Cancer Environment Register, ie, the linkage between the census of 1960 and the Cancer Register for 1961—1979, was used to determine the cancer incidence of different sites for 14 separate “electrical” occupations. The results are consistent with previous findings in that several of the occupational groups (10 of 13) showed a standardized mortality ratio above unity for acute myeloid leukemia. In addition, an increased incidence of cancer of the nervous system was found among women working in unspecified “electrical” occupations. A detailed report is being prepared.

The fact that exposure is being “presumed” in these studies is a major drawback. To obtain an understanding of the meaning of the occupational titles used, and to gain experience in measuring electromagnetic fields in the work environment, we initiated the study outlined below.

Step 1 entails the identification of industries that incorporate the different occupations in question and a recording of the number of persons within each occupational-industrial category. Some of the occupations occur in a great variety of industries, eg, electricians, electrical repairmen, and related electrical workers (12 different industries), while others are more homogeneous, eg, railway conductors and brakemen (one industry only). On the basis of this knowledge, about 30 workplaces were selected for the second step. For example, miners employed in the iron mines in northern Sweden were selected.

Step 2 includes (i) the direct measurement of electromagnetic fields and (ii) an interview to determine the prevalence of possible confounders (carcinogens), the electrical equipment used, and how these factors have changed over time. Measurements will cover a full shift and will be performed with the dosimeter developed by Lindh. Parallel measurements will be in-

cluded as new instruments become available. The study will be completed during the spring of 1988.

Projected studies

Leukemia and cancer of the central nervous system

Current evidence regarding an association between exposure to electromagnetic fields and cancer calls for further, more conclusive, studies. The problem of misclassification in previous studies has to be dealt with, and the problem of confounding factors must also be considered. Two extensive studies designed to minimize these sources of bias are presently being planned in Sweden. One will examine the relationship between cancer incidence and residential exposure to electromagnetic fields and will be conducted at the National Institute of Environmental Medicine. The other will concentrate on occupational exposure and will be performed at the National Institute of Occupational Health. Occupational exposure is particularly interesting, as the ranges of exposure will be much larger than those in the general environment and in dwellings.

The occupational exposure study will consist of two case-referent studies, and diseases to be considered are leukemia and cancer of the nervous system. Cases and referents will be limited to men 20 to 70 years of age at diagnosis. The numbers aimed at are 300 leukemia cases and 200 cases of cancer of the nervous system. A group of about 1 000 subjects will serve as referents. The selection of subjects will be based on the censuses and the Cancer Register. Diagnoses will be verified from pathology reports.

The prevalence of electromagnetic fields in the work environment is unknown, and therefore it is not apparent how the study base should be defined in order to maintain a certain power of the study. Bearing in mind that even very low levels of exposure have indicated an increased cancer risk, it seems reasonable to work with a wide study base, such as the working male blue-collar population (as opposed to a high-exposure base of “electrical” occupations). If 10 % of the referents can be classified as exposed, the numbers aimed at would give a 90 % power of detecting a two-fold relative risk ($\alpha = 0.05$, one-sided). Suitable criteria for the study base are currently being explored.

A questionnaire will be mailed to each subject or, if deceased, to a close relative. Questions on occupational history, including the identification of workplaces, residential exposure to electromagnetic fields, and the prevalence of potential confounders and modifiers, such as leisure-time activities, will be included.

Representatives at the subjects' workplaces will be contacted and requested to participate. Exposure to electromagnetic fields will be measured with personal dosimeters. In the absence of exposure, or in cases of highly intermittent exposure, single spot measurements will be performed. In addition, the job held, or previously held by the subject, will be analyzed with respect

to the occurrence of potential confounders, and an effort will be made to record important time-related changes, eg, in the electrical equipment used and the prevalence of carcinogenic agents. Data collection will be limited to about 1 500 workplaces. In principle, for both the cases and referents, place of work for the decade preceding the year of diagnosis will be selected.

The monitoring of electromagnetic fields will be based on 50-Hz dosimeters — developed in the United States and Canada — that are easy to carry. In addition, an instrument developed in our department will be used, which covers the frequencies 10 Hz—2 kHz, 1 nT—1 mT. Because of its weight, this instrument will be used for spot measurements only. As nothing is yet known about the impact of different frequencies, it is important to include this instrument also.

Summary

Several epidemiologic studies indicate an association between exposure to low-frequency electromagnetic fields and certain types of cancer. However, there is no solid evidence from current experimental studies to support the hypothesis of carcinogenicity. Further research is needed, and in the present extended abstract Swedish epidemiologic studies projected for the future are briefly outlined. The studies will be time-consuming and will involve high costs. However, we anticipate that within the next four years the approach described will contribute significantly to knowledge about the possible health hazards caused by electromagnetic fields.

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