Health Effects Of Electric and Magnetic Fields: Overview Of Research Recommendations

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We developed a series of articles concerning epidemiologic research on potential health effects of electric and magnetic fields. Our goal was to identify methodological issues that have arisen through past studies of cancer, reproduction, and neurobehavioral outcomes in order to suggest strategies to extend knowledge. Following an overview of relevant physics and engineering principles, cancer epidemiology of electric and magnetic fields is discussed separately with a focus on epidemiologic methods and cancer biology, respectively. Reproductive health studies, many of which focus on exposure from video display terminals are then summarized, followed by an evaluation of the limited literature on neurobehavioral outcomes, including suicide and depression. Methodological issues in exposure assessment are discussed, focusing on the challenges in residential exposure assessment and interpretation of wire configuration codes. An overview offers recommendations for priorities across these topic areas, emphasizing the importance of resolving the question of wire codes and childhood cancer. Collectively, these articles provide an array of observations and suggestions regarding the epidemiologic literature, recognizing the potential benefits to science and public policy. — Environ Health Perspect 101(Suppl 4):71–72 (1993).

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Introduction

The scientific literature on potential health effects of electric and magnetic fields has evolved haphazardly, like many research pursuits. The origins of the epidemiologic evidence can be traced to studies of neuropsychological symptoms in Soviet electrical workers in the 1960s (1,2), with an important study of power lines and childhood cancer published by Wertheimer and Leeper in 1979 (3). Through the 1980s, the pace and scope of epidemiologic research accelerated to the point that there are now perhaps a dozen major ongoing epidemiologic studies focused on cancer and a smaller number addressing reproduction and neuropsychological function.

In an attempt to conceptualize and organize better the evolving evidence, we have developed a series of articles. The intent was not to review comprehensively the past research or to draw specific conclusions for decision-making purposes, but rather to focus on the frontiers of existing knowledge and make recommendations for how to extend those frontiers. Some degree of subjectivity is required to abstract the important observations from the literature and make recommendations about which of the many possible approaches is most likely to advance our understanding. Individual authors undoubtedly have different priorities about what would constitute an exciting discovery, but we all share an interest in the fundamental questions of whether exposures to power-frequency electric and magnetic fields affect human health in clinically important ways.

Overview of Articles

To orient readers unfamiliar with the physics and engineering aspects of electric and magnetic fields, the articles begin with Kaune's "Introduction to Power-Frequency Electric and Magnetic Fields" (4). This defines the key concepts, identifies principal sources of electric and magnetic fields and the levels of exposure typically encountered, analyzes how these fields affect humans, and describes the technology available for environmental measurements. The shielding of electric but not magnetic fields by biological tissues is noted, with some discussion of the processes by which the weak fields of concern might induce biological effects.

Two chapters are devoted specifically to the study of cancer in relation to electric and magnetic field exposure. In "Epidemiologic Studies of Electric and Magnetic Fields and Cancer: Strategies for Extending Knowledge" (5), I focus on epidemiologic design and analysis issues that are in need of examination and improvement. The recommendation is made for two specific efforts concerning residential exposures and cancer: a comprehensive evaluation of sources and patterns of individual magnetic field exposures to identify exposure sources most worthy of study and to clarify the role of "wire codes" (based on power lines outside the residence) as an exposure source, and an examination of the sociology and geography of wire codes to evaluate confounding or selection bias or the possibility that wire codes influence cancer through mechanisms other than magnetic fields. Studies of occupational electric and magnetic field exposure would benefit from additional surveys of exposure patterns in diverse industrial settings and from additional empirical evidence on the patterns of cancer risk in relation to those exposures.

Stevens considers "Biologically Based Epidemiologic Studies of Electric Power and Cancer" (6), in which he relates the indirect evidence from studies of DNA transcription and translation, calcium balance in cells, and pineal production of melatonin to modern concepts of cancer biology. The potential role of electric and magnetic fields in the carcinogenic process is examined in the context of a two-stage model for carcinogenesis, consisting of mutation of DNA and cell growth. Integration of laboratory evidence with this model of carcinogenesis leads to the following recommendations: a) given a number of points at which electric and magnetic fields might operate, exposures over a broad time period should be considered; b) effects on calcium balance encourage studies of acute nonlymphocytic leukemia; c) influences on pineal function suggest studies of hormone-dependent cancers (female breast, prostate) be conducted in conjunction with an evaluation of other influences on pineal function; and d) alteration of calcium homeostasis might lead to oxidative stress, which encourages study of...
the interactive role of radiation and other agents that induce oxidative stress.

Shaw and Croen’s article on “Human Adverse Reproductive Outcomes and Electromagnetic Field Exposure: Review of Epidemiologic Studies” (7) systematically reviews the epidemiologic evidence from exposures in residences, workplaces, and to specific electrical devices such as electric blankets and video display terminals. Serious methodological deficiencies exist in many of the studies, especially those examining exposures other than video display terminals, so that research directions cannot be articulated with a high degree of specificity and confidence. Nonetheless, recommendations are made for: a) addressing the suggestion from laboratory studies of a possible adverse effect on growth by studying selected congenital anomalies, intrauterine growth retardation, and chromosomally normal spontaneous abortions; b) consideration of paternal residential exposure in relation to reproductive outcomes; and c) application to reproductive health outcomes of the exposure assessment methods for residential and occupational settings previously applied to cancer, ideally incorporating diverse sources of exposure.

“Neurobehavioral Effects of Power Frequency Electromagnetic Fields” by Paneth (8) summarizes the evidence for potential adverse effects on a number of indices of neurological and psychological parameters. The unique challenges of studying behavior and cognition include the problem of laboratory artifacts, the subtlety and transience of many outcomes of interest, and the strong influence of social factors. The literature on neurobehavioral testing of experimentally exposed subjects, assessments of occupationally exposed workers, and the studies associating residential exposure with suicide are reviewed. Laboratory evidence suggesting effects on calcium efflux does not generate specific predictions, whereas the potential role of electric and magnetic fields in pineal function and circadian rhythms points directly toward depression as a plausible outcome. Thus, the recommendation is made that prospective studies of occupational exposure and depression be conducted, rather than pursuing additional studies of cognition in occupationally exposed groups, for which the results have been largely negative, or studying depression in relation to residential exposures, for which the social class influences would be difficult to remove.

Kaune summarizes the key issues regarding ascertainment of exposure in “Assessing Human Exposure to Power-Frequency Electric and Magnetic Fields” (9). Occupational exposures have been inferred largely from job titles. Residential exposure sources are reviewed, with a focus on the rationale for wire codes and spot measurements as indicators of long-term exposure. Recommendations are made for: a) development of job-exposure matrices for occupational exposure assessment based on direct measurements of workers in different occupational groups; b) evaluation of the ability of wiring codes and spot measurements to predict long-term historical exposure; c) an examination of exposures that are predicted by wire codes; d) an assessment of the contribution of residential and nonresidential exposures to total exposure; e) study of long-term temporal variation in residential exposure; and f) consideration of alternate exposure metrics associated more closely with wire code than is average magnetic field.

Sieniawski offers his perspective on “Problems and Priorities in Epidemiologic Research on Human Health Effects Related to Wiring Code and Electric and Magnetic Fields” (10). He argues that the most pressing need is to verify the finding that wire codes are associated with childhood cancer because that possibility is the dominant basis for public concern. This could be achieved by reexamining data from past studies as well as by launching additional case–control studies that are responsive to concerns about control selection and incorporate measured fields and appliance exposures. Additional efforts are recommended for: a) reexamination of completed studies of wire codes and childhood cancer, b) new studies to examine the reported association between wire codes and childhood cancer, c) methodological research to evaluate the relation of wire codes to measured fields and indicators of historical exposure, d) occupational studies of cancer, e) documentation of exposure patterns in workers outside the electric utility industry, f) animal carcinogenicity studies, g) a broad survey of residential exposure and ecological studies of cancer, h) study of neurobehavioral effects, i) reproductive health studies focusing on residential wire codes primarily and other sources secondarily, and j) studies of adult cancer in relation to nonoccupational exposure, with items a to f of higher priority and g to j of lower priority. Current impediments to the conduct of environmental epidemiology are noted, with the suggestion that large-scale monitoring systems are needed.

In all chapters, the authors were encouraged to express their own take on the literature and avoid the noncommittal tone of many previous committee recommendations. Neither the individual articles nor the summary represents a consensus but, rather, the product of individual work and critical responses to the ideas at several steps along the way. As a result, these chapters offer perspectives with which the reader may well disagree, but because the underlying assumptions that lead to the recommendations are provided, the debate itself should be a productive one. There was a consensus among Working Group members, however, about the basic premise that the research area is important (in part, because the public has decided that it is) and that well-designed and carefully conducted epidemiologic research will be beneficial to scientists and those concerned with the formulation of public policy on this issue.

REFERENCES

1. Asanova TP, Rakov AI. The state of health of persons working in the electric field of outdoor 400 and 500 kV switchyards. Gig Tr Prof Zabol 10:50–52 (1966).
2. Danilin VA, Voronin AK, Modorskii VS. The state of health of personnel working in high-voltage electric fields. Gig Tr Prof Zabol 13:51–52 (1969).
3. Wertheimer N, Leeper E. Electrical wiring configurations and childhood cancer. Am J Epidemiol 109:274–284 (1979).
4. Kaune WT. Introduction to power-frequency electric and magnetic fields. Environ Health Perspect 101(Supp 4):73–81 (1993).
5. Savitz DA. Epidemiologic studies of electric and magnetic fields and cancer: strategies for extending knowledge. Environ Health Perspect 101(Supp 4):83–91 (1993).
6. Stevens R. Biologically based epidemiologic studies of electric power and cancer. Environ Health Perspect 101(Supp 4):93–100 (1993).
7. Shaw GM, Croen L. Human adverse reproductive outcomes and electromagnetic field exposures: review of epidemiologic studies. Environ Health Perspect 101(Supp 4):107–119 (1993).
8. Paneth N. Neurobehavioral effects of power-frequency electromagnetic fields. Environ Health Perspect 101(Supp 4):101–106 (1993).
9. Kaune WT. Assessing human exposure to power-frequency electric and magnetic fields. Environ Health Perspect 101(Supp 4):121–133 (1993).
10. Sieniawski J. Problems and priorities in epidemiologic research on human health effects related to wiring code and electric and magnetic fields. Environ Health Perspect 101(Supp 4):135–141 (1993).