

EXECUTIVE SUMMARY

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The National Institute for Occupational Safety and Health (NIOSH) convened a group of scientists on January 30-31, 1991, in Cincinnati, Ohio, to develop a national research strategy on the health effects of electromagnetic radiation on workers. The purpose of the workshop was to review current data and new findings regarding electric and magnetic fields which may have relevance for occupational exposures; to identify knowledge gaps that might be filled by directed research; and to recommend a national research agenda which, if implemented, would close the gaps and permit reliable recommendations for protecting workers. The workshop emphasized electric and magnetic fields at frequencies up to 1000 Hz, excluding static fields; and carcinogenic, reproductive, and neurologic health effects. Approximately 300 individuals attended the workshop, including 120 from governmental agencies, 35 from academia, 20 consultants, 25 from the health care field, 40 from general industry, 30 from utility companies, and 30 from research laboratories.

Five plenary papers were presented, each addressing a specific aspect of potential health effects from exposure to electric and magnetic fields, exposure assessments, or controls as they relate to workers. The five presentations covered:

- ◆ *In Vitro*/Cellular Mechanism Studies
- ◆ *In Vivo* Studies
- ◆ Epidemiologic Studies
- ◆ Exposure Assessments, and
- ◆ Methods for Reducing Exposures.

Panels of scientific experts in the five areas, using the information presented in the plenary papers, focused on the development of the national research agenda.

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These Proceedings, then, serve as a report to the Nation based on the interaction and discussions that occurred during the workshop. Dr. J. Donald Millar indicated in his introductory remarks at the workshop, that this document would provide a lasting record of the excellent plenary papers that were presented, and would focus research on the needs that were identified for worker protection. These Proceedings provide the reader with the following information:

- ◆ An executive summary which highlights the findings from the workshop.
- ◆ The five plenary papers which served as the basis for the panel discussions.
- ◆ The research recommendations which resulted from the panel deliberations.
- ◆ A glossary of terms that is useful for familiarizing the reader with the terminology that is used in this scientific field.
- ◆ Details on how to obtain a copy of the NIOSH bibliography that was provided to the participants of the workshop.

It should be noted that the initial terminology used to characterize the workshop (i.e., “electromagnetic radiation”) is more correctly referred to as “electric and magnetic fields (EMF).” Therefore, the title of these Proceedings and the terminology used in the section on Research Recommendations have been modified accordingly.

GENERAL FINDINGS

- ◆ **The frequency range initially identified (i.e., up to 1000 Hz, excluding static fields) is appropriate for a research agenda dealing with the workplace.**
- ◆ **There is uncertainty about the relationship between exposures to electric and magnetic fields and health outcomes.**

- ◆ **The health end points that were initially identified as most important (i.e., carcinogenic, reproductive and neurologic) remained so.** Other health end points that were discussed, but with less emphasis, dealt with immunologic and endocrine changes and cardiovascular effects. Specific subsets of the health end points are discussed in more detail in the section on Research Recommendations.

- ◆ **The scientific leadership role for protecting workers in the EMF arena is a NIOSH responsibility which goes beyond the conduct of the workshop.** NIOSH was charged with fulfilling this mandate by initiating the appropriate research within its own mission and by continuing to influence and interact with all involved parties (i.e., other Federal agencies, state and local agencies, industry, labor and academia). Of importance was the identified need to interact and coordinate activities with the Department of Energy, Environmental Protection Agency, Department of Defense, Food and Drug Administration, National Institute of Environmental Health Sciences and National Cancer Institute. These interactions should include an immediate and continuing translation of current knowledge to the occupational and environmental health community via NIOSH's dissemination mechanisms.

- ◆ **The need to transfer the results of research to occupational safety and health professionals, employers and workers through training and education programs is paramount to an overall prevention strategy.**

HIGHEST PRIORITY RESEARCH NEEDS

It was recognized that the identified research needs were not unusual for the occupational/environmental health field. However, for the specific EMF hazards under discussion (i.e., lower frequency fields), we are in the infancy of a research agenda when compared to other occupational/environmental hazards. Also, it was acknowledged

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that the research needs in the five areas that were compartmentalized for the purposes of the workshop are dependent and overlapping. But, there was a very clear consensus of what the highest priorities are for the research agenda. The highest priority research issue is to determine whether occupational exposure to electric and/or magnetic fields produces untoward health effects, and, if so, to determine not only the type(s) and level of exposure that will produce them but also ways to reduce exposure. In order to do this we need to accomplish the following:

- ◆ Determine the number of workers exposed; the industries and occupations where the exposures take place; and the extent and type of exposures (including identification and characterization of EMF sources, magnitude of the fields as a function of frequency, phase and duration).
- ◆ Establish standardized assessment protocols, including measurement techniques and performance criteria for instruments and dosimeters, plus standardized approaches for experimental and epidemiologic studies.
- ◆ Conduct experimental and epidemiologic studies directed at hypotheses-testing for *specific* health end points of interest, testing models, mechanism questions, and occupational groups to be studied. Standardized protocols and procedures, including specific quality assurance approaches, also must be developed for the experimental and epidemiologic studies.
- ◆ Conduct more long-term, definitive control technology research for reducing the identified exposures to acceptable levels .

This summary does not mean that the various components of experimental and epidemiologic research on “health effects” have to be conducted in sequence. However, it should be noted that without better exposure assessment tools for estimating dose and without

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better knowledge about workplace exposure levels and types of exposure, there will be limitations in the ability to interpret the health effects data. Also, the scenario presented here should not preclude implementing exposure reduction strategies that are now available and feasible.

SUMMARY OF RESEARCH NEEDS

The major research needs in each of the five program areas that were discussed at the workshop are highlighted below.

In Vitro/Cellular Mechanism Studies

- ◆ **Correlation of Exposure Parameters for *In Vitro* Studies with Potentially Harmful Exposures found in the Workplace**

A detailed occupational exposure assessment must be conducted by qualified individuals in order to provide EMF parameters for *In Vitro*/Cellular Mechanism Studies.

- ◆ **Development of Methods for Occupational Dosimetry which Reflect Exposures at the Cellular Level**

Appropriate methods for theoretical and experimental dosimetry should be developed and applied to permit accurate extrapolation of EMF exposure levels found in the workplace to exposure levels used in cellular studies.

- ◆ **Theoretical Studies and Models**

Theoretical studies and models are necessary because of the multitude of possible experimental exposures and parameters and other conditions which need to be defined prior to conducting definitive *In Vitro*/Cellular mechanism studies.

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◆ **Development of Reference Criteria for Experimental Design and EMF Field Characterization**

To reduce ambiguity and uncertainty in progressing toward a unified understanding of the biological actions of EMF, standardized criteria for conducting and reporting the results of *in vitro* studies must be encouraged.

◆ **Research Priorities for Health End Points**

The highest priority should be assigned to *in vitro* studies which help to define the nature of carcinogenic effects. Other targets for EMF occupationally induced adverse effects that should be investigated using *in vitro* methods include: the male and female reproductive systems, endocrine and neuroendocrine systems, alterations in fetal development, and non-cancer related aspects of immune system function. Regardless of the disease or system being investigated, the focus of *in vitro* research should be on:

- (a) mechanisms of interaction of EMF with biological systems
- (b) the consequences of those interactions, and
- (c) relationship to EMF-related diseases.

***In Vivo* Studies**

◆ **Conduct Studies with Scientific Rigor**

Reproducing the results of current research on *in vivo* effects has been difficult. Therefore, the first priority should be to improve the reproducibility and credibility of current and future research.

◆ **Characterize EMF Exposures**

There are many variables (e.g., exposure systems, EMF parameters, and exposures in relation to biological rhythms) that can be manipulated or controlled in *in vivo* experiments, and these must be well characterized and documented.

◆ **Characterize Critical Effects of EMF**

Establishment of critical effects on which to focus *in vivo* research is essential. This requires using scientifically accepted methods; stressing quality assurance procedures, etc; properly formulating and testing hypotheses; replicating key findings; exploring relationships between exposure and dose; and elucidating the mechanisms by which biological effects occur.

◆ **Neuroendocrine Dysfunction Produced by EMF**

Specific recommendations include characterizing neural, endocrine, and neuroendocrine responses; and studying behavioral effects, central nervous changes, sleep disturbances, and mood changes.

◆ **Definitive Studies of the Role of EMF in Carcinogenesis**

Specific recommendations include conducting *in vivo* tests of tumor initiation, promotion and progression with emphasis on leukemia, brain, and hormone-dependent tumors.

◆ **Reproductive and Developmental Effects of EMF**

Specific recommendations include studying shifts in patterns of development, maturation and degeneration of animal systems such as the nervous, reproductive and immune systems.

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◆ **Cardiovascular Effects of EMF**

Specific recommendations include conducting confirmatory studies in both humans and other animal species with emphasis on such phenomena as calcium ions and neurotransmitters.

Epidemiologic Studies

◆ **Characterization of Exposure**

Researchers should consider conducting exposure assessments or surveys of selected occupational groups/jobs in order to characterize their potential for exposure to EMF prior to the selection of these worker populations for epidemiologic studies. New epidemiologic studies should include a characterization of exposure.

◆ **Health Effects/Responses of Interest**

The priorities were defined as cancer, reproductive effects, health effects resulting from hormonal changes (e.g. sleep disorders, behavioral changes, motor neuron diseases, immunologic changes), and non-disease end points and biomarkers (e.g. melatonin).

◆ **Methodological Issues**

Common protocols should be developed for both exposure assessments/characterization as well as the epidemiologic analyses; multi-center studies should be considered; the use of existing databases should be explored; hypotheses need to be well formulated based on previous epidemiologic studies or on laboratory findings; potential confounders need to be

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identified and analytical techniques need to be improved to evaluate these confounders; and hypothesis generating studies, such as PMR studies based on union or company death benefit records should continue to be pursued.

◆ Potential Worker Populations to Study

Populations to be considered included “high” exposure groups, with significant variation in EMF exposure and no other confounding exposures; women workers (for reproductive and breast cancer studies); groups exposed to extremely low frequencies other than the “power” frequencies of 50 and 60 Hz; health care workers; welders; aluminum reduction potroom workers; electric railroad workers; and electric machinery/motor workers.

Exposure Assessment Studies

◆ Measurement Guidelines

Standardized measurement protocols are required and training programs are needed for health and safety professionals in assessing exposure to EMF.

◆ Exposure Metrics

Accurate and uniform exposure metrics need to be developed for epidemiologic studies.

◆ Measurement Instrumentation

Independent assessments are needed to evaluate instrument performance, and standardized quality assurance programs should be established. Personal dosimeters are needed that will measure transient magnetic fields and their time rate of change. Also, contact current meters need to be developed and evaluated.

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◆ **EMF Dosimetry**

Dosimetric modeling techniques are needed that will estimate the distribution of induced currents throughout the body and provide a basis for specifying a dose measure.

◆ **Non-Utility Sources of Exposure**

Recommendations in this area are essentially identical to those developed by the Panel on Epidemiologic Studies.

◆ **Worker Communication**

Ways of effectively communicating the concepts of EMF exposure assessment to workers must be developed and validated.

Methods for Reducing Exposures

◆ **Identify EMF Sources**

The identification and characterization of EMF sources are important to any control strategy. Attention should be paid to the magnitude of EMF as a function of frequency and phase.

◆ **Review and Recommend Electrical Code Changes**

Important items to consider for potential code changes include use of safe installation practices and computer modeling of EMF.

◆ **Continue Research on Field Cancellation Techniques**

Important items to consider in improving cancellation techniques include computer modeling of EMF, and examining the wiring and circuit design of industrial equipment, power tools and office appliances.

◆ **Materials Research**

Research is needed to develop better materials for shielding from magnetic fields.

◆ **Work Practices**

Work task redesign and workstation design methods should be developed.

◆ **Substitution**

Substitutes should be designed to eliminate appliances that generate high EMF.

◆ **Transient Suppression**

A study of generic approaches to reducing transient fields should be conducted.

◆ **Personal Protective Equipment**

Material research is needed to develop light weight, practical materials which can be fashioned into functional garments for the worker

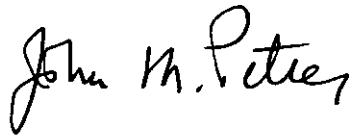
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◆ Training and Education

Education of professionals and workers in the concerns associated with exposure to EMF will help as a control mechanism for reducing future EMF exposures.



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