HEALTH EFFECTS AND EXPOSURE GUIDELINES

RELATED TO

EXTREMELY LOW FREQUENCY (ELF) 50/60 Hz

ELECTRIC AND MAGNETIC FIELDS

--- A N O V E R V I E W ---

Prepared by a Working Group of the

Federal-Provincial Territorial Radiation Protection Committee

Canada
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HEALTH EFFECTS AND EXPOSURE GUIDELINES

RELATED TO ELF (50/60 Hz) ELECTRIC AND MAGNETIC FIELDS

- AN OVERVIEW -

Introduction

Concerns exist over the possibility that exposure to electric and magnetic fields (EMF) of extremely low frequency (ELF) may present a health hazard to workers and the general public. This concern has arisen as a result of the controversial and contradictory findings in the scientific research, especially from epidemiological studies. This overview summarises recent scientific information on health effects and provides a status report on exposure guidelines that have been developed to date. The information is particularly relevant for government officials in Canada responsible for formulating occupational and public health policies and for providing guidance to interested or concerned persons.

Background

The wide spread use of electric power particularly in industrial societies makes this issue one of international concern. Health problems in the work place, thought to be associated with ELF exposure were first reported in a group of Russian electrical switchyard workers in the 1960's and created widespread scientific interest. In the late 1970's and early 1980's reports suggesting a link between ELF residential exposures and childhood and adult cancers heightened public anxiety. Following these early reports, extensive national and international research programs were initiated.

In Canada, concerns emerged during the mid 1980's which stimulated the formation of a national Working Group on Electric and Magnetic Fields, co-ordinated by the former Federal Department of National Health and Welfare. Representatives on this group were drawn from Canadian labour, utility companies, academia as well as federal and provincial government scientists. A report from the Working Group [1] published in 1989, reached a number of conclusions based on the status of knowledge at that time. It made recommendations regarding the need for further research as well as the necessity to inform workers and the general public about this matter (see Appendix 1).

In the United States, a large number of research papers and overview reports have been produced along with numerous conferences over the past 15 years. Unfortunately, the findings remain controversial, contradictory and seem only to exasperate rather than resolve public concern. The research findings are succinctly expressed in the conclusion

of the draft review report titled: “Evaluation of the Potential Carcinogenicity of Electromagnetic Fields”, prepared by the U.S. Environmental Protection Agency in 1990 [2]. The report was only an initial draft circulated for review and was never published. In spite of clear warnings not to cite or quote, there was significant public citing and quoting. The draft report conclusion which appears to have been adopted by the public was “While there are epidemiological studies that indicate an association between EM fields or their surrogates and certain types of cancer, other epidemiological studies do not substantiate this association. There is insufficient data to determine whether or not a cause and effect relationship exists.”

There has been a plethora of critical reviews, pubic inquiry reports, public review drafts, summaries etc. published by Universities, Government Departments, Utilities, and other expert bodies. For example, the National Council on Radiation Protection and Measurements (NCRP) in Bethesda, Maryland, set up a committee chaired by Dr. W. Ross Adey to review the possible health effects of ELF’s. The National Academy of Sciences committee, chaired by Dr. Charles Stevens, Salk Institute, California released a report in 1996 concluding: “No clear, convincing evidence exists to show that residential exposures to electric and magnetic fields (EMFs) are a threat to human health,...There is no conclusive evidence that electromagnetic fields play a role in the development of cancer, reproductive and developmental abnormalities, or learning and behavioral problems”. This report did leave the door open with regard to further research, particularly into the causes of childhood leukemia. The United Kingdom's National Radiological Protection Board (NRPB) established an Advisory Group on Non-Ionizing Radiation in 1990 to review the scientific evidence and determine the extent to which this evidence suggests possible health risks. The International Non-Ionizing Radiation Committee (INIRC) of the International Radiation Protection Association (IRPA) in co-operation with the Environmental Health Division of the World Health Organization (WHO) developed recommendations for 50/60-Hz electric and magnetic field exposure limits. At the 8th Congress of the IRPA in May 1992, the IRPA established a new independent scientific organization, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) as a continuation of the former IRPA/INIRC. (ICNIRP reaffirmed the recommended interim exposure limits in 1992) In April 1998, ICNIRP published guidelines for limiting electromagnetic field exposures for frequencies up to 300 GHz, including 50/60 Hz. [3]

OVERVIEW

The following sections provide a brief overview on (I) what is known and what is unclear about the biological effects of (ELF) fields and (ii) information on the established exposure guidelines, together with the rationale for their development.

(I) Effects

Research to date has included experimental investigations into the effects on biological systems both *in vivo* and *in vitro*, and epidemiological studies on worker groups and on the general public. Very early research focused primarily on the effects of electric field exposure. During the last 15 years the primary focus of research shifted to studying the effects of exposure to magnetic fields alone. Recently, interest has been renewed in electric fields alone and in conjunction with magnetic fields. [4] The primary research effort has been directed towards determining whether a cancer risk exists. Much of the recent **experimental** research has been aimed at identifying a possible mechanism for (ELF) to act as a cancer initiator, promoter and/or copromoter.

Epidemiology

The strongest source of positive evidence for associated adverse effects has come from epidemiological studies. Such studies have suggested a weak positive association between ELF exposure and leukaemia, brain cancers, breast cancer and lung cancer. Nearly all of these studies were retrospective. Close examination of the methodologies used in early studies show major weaknesses or flaws, such as; number of cases too low to look at cancer subtypes, lack of specificity of exposure, lack of reliability of exposure data, lack of statistical power and lack of control for confounders.

The majority of positive findings have very small risk magnitudes **by epidemiological standards** and are unable to rule out other confounding factors or environmental influences such as population mobility and other social/economic factors and traffic pollution. No dose response trends have been established. Recent studies are attempting to address some of these limitations. For example the cross Canada childhood leukemia study whose results were expected to be released in the fall of 1997, has a statistical power to detect a relative risk of 2. Similarly, the large UK study currently underway (Doll, Richard et al, completion date 1998?) has 1000 childhood leukemia cases. A US study (National Cancer Institute (NCI) and the Children's Cancer Group (CCG) has released results, reference [5], from their study involving 600 acute lymphocytic leukemia (ALL) cases. These studies are able to detect low relative risks with greater certainty. It is generally agreed that the limit of epidemiological power is close to being reached and that it is unlikely that Epidemiology alone will be able to offer convincing proof to resolve this issue. There is no reliable supporting data for an association between residential exposure and cancer risk in the general public.

Occupational exposure to electromagnetic fields and its association with cancers has received significant attention due to higher ELF exposures encountered in

occupational environments compared to residential. It has been alleged that selective publication of positive findings in the literature suggests a biasing towards an overall slight excess relative risk [6], [7]. The occupational studies are more advanced than the residential studies. Some associations found in some of the occupational studies as well as some non-associations have reached statistical significance. The very large scale studies on utility workers [8]-[10] produced contradictory results and no clear, convincing proof of a detrimental health effect associated with exposure to electric and magnetic fields.

Overall, while several studies have found correlation between (ELF) and disease occurrence, including cancer, there is little consistency from the data in human studies. Although there is no conclusive evidence from the epidemiological evidence that electric or magnetic fields cause a risk of cancer, in residential or occupational environments, the research holds out a possibility of a weak risk. For residential exposures there is little evidence to support the notion of a risk associated with magnetic field exposure in children or adults. Whereas, for occupational exposures the issue of leukemia and brain cancer in adults has not been resolved. [11]

Experimental Research

Experimental investigations with cellular systems, tissues and animals has shown that electric and magnetic fields can interact with these biological systems. Of the various kinds of biological effects related to ELF exposure "... no plausible biophysical mechanisms for the systematic initiation or promotion of cancer by these power line fields have been identified."[12]

Cellular chemistry effects involving the movement of calcium ions through cellular membranes have been confirmed by several researchers. The significance of this effect as it relates to possible adverse health outcomes is not understood. Replication of early work by a few researchers who have found that ELF fields can affect gene expression have not been replicated by other researchers. The ability of magnetic fields (MF) to suppress melatonin release by the pineal gland during the dark phase of the daily "light-dark" cycle is currently being studied in animals and humans. The ability of MF to affect melatonin levels in humans has not been conclusively established. Normal melatonin levels are individual dependant varying from person to person by a factor of 2 and are affected by light, nicotine and caffeine. The significance of this hormone as a possible precursors to adverse health outcomes is not yet understood.

Direct effects on significant cellular molecules, such as DNA, have not been observed. No direct mutagenic or carcinogenic effects on animals have been observed. In contrast to ionizing radiation, this tends to support the assertion that

ELF fields are not a direct cancer initiator but does not rule out the possibility of MF as a nonmutagenic carcinogen. Current research has shifted to focusing on the role of ELF (particularly magnetic fields) as a tumour promoter or copromoter. Studies have looked at mice treated with chemical tumour initiators and a promoter and exposed to high magnetic fields (approx. 2 mT or 20 G). The study showed that MF did not increase either the number of mice with tumours or the number of tumours. No effects were observed on mice exposed without the chemical promoter. The large variation in the rate of tumour formation among individual mice, especially during the early stages, makes it difficult to determine if MF's have the potential to accelerate the growth and development of tumours.

Non-mammalian studies, generally on chickens and pigeons, have shown no significant effects on fertility, morphology, behaviour or growth. Mammalian studies concerned with prenatal exposure affecting postnatal growth and survival have been few and have shown mixed results. The lack of replication of these studies remains a major factor concerning the strength of the findings, positive or negative.

Summary on Effects

Recently the Bioelectromagnetics Society issued a statement regarding scientific research on biological effects of electric and magnetic fields. The statement reads "Some epidemiological studies have raised concern that risk of cancer may be enhanced by exposure to electric and magnetic fields associated with distribution and use of electric power. Strong criticism of these epidemiological studies has been due primarily to the variability of results as well as the incomplete nature of laboratory data to support the specific cancer findings. At present, there is no scientific consensus as to which physical factors, the electric field and/or the magnetic field, may be biologically important. Similarly, there is no clear indication whether higher field levels present greater risk than lower fields. Whether adverse effects are (1) real and significant, (2) real but of minor importance, or (3) non-existent, must be determined by current and future research to allay public fears and to provide industry a basis for appropriate response or action." [13]

The overall view obtained from the research literature indicates that while some biological effects of exposure to ELF electric and magnetic fields occur, there are no resulting adverse health effects from these exposures. The observed biological effects have not been shown to be significant in terms of a health hazard. Therefore this lack of cause/effect evidence for disease induction for the exposure levels of concern to workers and the general public prevents the derivation of guidelines for protection against any chronic or long-term effects at typical low levels that most people are exposed to.

(ii) Exposure Guidelines

During the second half of the twentieth century, there has been concerted effort to establish and refine the radiation exposure standards and guidelines for ionizing radiation. Emphasis on the non-ionizing portion of the electromagnetic spectrum over the past twenty years has resulted in exposure limit values for the optical region of the spectrum, as well as the radiofrequency and ELF regions.

The earliest exposure guideline for the (ELF) part of the spectrum was established by the USSR in 1975 (see Table 1). This established an occupational limit for electric field exposure. The last decade has seen increased activity in the development of guidelines covering both electric and magnetic fields for exposure to workers and the general public. The International Radiation Protection Association (IRPA) published exposure limits addressing very high level exposure to 50/60 Hz electric and magnetic fields in 1990. In April 1998, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published comparable exposure limits (Table 1) [3]. Similar high exposure limits have also been established for workers by the American Conference of Governmental Industrial Hygienists (ACGIH). The exposure limits resulted from a review of the scientific literature that determined the only established mechanism for health hazard occurrence from (ELF) exposure was through the induction of significant electric currents inside the body. The basis for the limits is simply the prevention of current densities in the body, exceeding 10 mA/m^2. This limit corresponds to induced current densities that are generally at or slightly above those normally occurring in the body (up to about 10 mA/m^2). The research literature has shown the following effects for the various current densities specified:

1) between 1 and 10 mA/m^2, minor biological responses reported.

2) between 10 and 100 mA/m^2, visual and nervous system effects occur.

3) between 100 and 1000 mA/m^2, stimulation of excitable tissue is observed leading to possible adverse reactions.

4) above 1000 mA/m^2, extra systoles and ventricular fibrillation can occur (acute health hazards).

These exposure limits have <u>not</u> been based upon a consideration of cancer risk, since such a risk has not been established. The situation for chronic exposure to the very low levels (0.2 - 0.5 μT or 2.0 - 5.0 mG) of ELF magnetic and electric fields that most people are exposed to, that is, levels below those known to cause acute detrimental effects remains speculative and unresolved. Until there is a consistent significant link between cancer and ELF fields or some other parameter associated with power lines, a magnetic field exposure limit or guideline chosen well below the

above limits can not be established based upon the available data to protect against suspected health hazards associated with chronic, long term exposure.

General Conclusions

Research into the effects of (ELF) electric and magnetic fields have shown that some interactions between biological systems and the fields result in certain responses. However, significant detrimental interactions at ambient fields to which human and animals are typically exposed remains to be demonstrated. The research taken overall indicates that the evidence is insufficient to conclude that electric or magnetic fields cause a risk of cancer. Therefore the established exposure limit values can be used to provide protection against the acute hazards that can result from high intensity exposure levels. The research does hold out the possibility of a risk, but it is expected that research efforts that are currently underway will likely address this concern. These together with future research will determine whether there is need for lowering the limits to provide protection against the consequences of chronic low level exposure.

Position Statement

In light of the above information and the need for guidance in Canada by policy makers, health and safety professionals and the public, the Federal Provincial Territorial Radiation Protection Committee has issued a position statement (see page 14) to address these concerns.

References

1. "Electric and Magnetic Fields and Your Health - A Report of the Working Group on Electric and Magnetic (ELF) Fields" Health and Welfare Canada; 89-EHD-150, May 1989.

2. "Evaluation of the Potential Carcinogenicity of Electromagnetic Fields" United States Environmental Protection Agency; EPA/600/6-90-005B External Review Draft, October 1990.

3. “Guidelines For Limiting Exposure To Time-Varying Electric, Magnetic, And Electromagnetic Fields (Up To 300 GHz)”, International Commission on Non-Ionizing Radiation Protection, Health Phys. 1998 April, Vol.74, No.4, 494-522

4. “Leukemia following occupational exposure to 60 - Hz electric and magnetic fields among Ontario electric utility workers.” Miller AB, To T, Agnew DA, Wall C, Green

LM, American Journal of Epidemiology 1996 July 15; 144(2): 150-60

5. “Residential Exposures to Magnetic Fields and Acute Lymphoblastic Leukemia In Children”, Linet, M.S., Hatch, E.E., et al, The New England Journal of Medicine, 1997, Vol 337, No.1, 1-7.

6. "Editorial Peer Review in Biomedical Publications" - Dickersin, Journal of the American Medical Association 263, 1385 (1990)

7. "Publication Bias in Clinical Research " Esterbrock et al; Lancet ,1991,337, 867

8. “Cohort and Nested Case-Control Studies of Hematopoietic Cancers and Brain Cancer Among Electric Utility Workers”, Sahl, J. D., Kelsh, M. A., and Geenland, S., Epidemiology, 1993, **4**:104-114.

9. “Magnetic Field Exposure in Relation to Leukemia and Brain Cancer Mortality among Electric Utility Workers,” American Journal of Epidemiology, 1995, **141**(62): 1-12.

10. “Cancer Risks Associated with Occupational Exposure to Magnetic Fields Among Utility Workers in Ontario and Quebec, Canada and France:1970-1989”, American Journal of Epidemiology 1994, **139**:550-572.

11. “Nature and nurture: Possibilities for cancer control.” Carcinogenesis 1996: 17(2): 177-84

12. Statement by the Council of the American Physical Society, April 22, 1995, on Power Line Fields and Public Health.

13. EMF Health and Safety Digest, June 1996, p.11

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APPENDIX 1

Extract from a 1989 Report "Electric and Magnetic Fields and Your Health" (Reference 1)

Recommendations

1. The Working Group considers that additional research effort should be undertaken in Canada to resolve whether there is association between exposure to 60 Hz electric and magnetic fields and an increased risk of cancer. The Working Group recommends that:

   a. the Department of National Health and Welfare intensify its participation in its ongoing research, and

   b. an Advisory Committee be established to advise on the research. The Advisory Committee will be available to review research proposals, comment and make recommendations. It is suggested that this committee comprise representatives of all interested parties, i.e. industry, labour, academia and government. Additional technical experts will be asked to serve as consultants to the AC when required.

2. The Working Group considers that workers and the general public need to be informed on current understanding of health effects of electric and magnetic fields. The Working Group recommends that the Department of National Health and Welfare publish this report and the Working Group's document entitled "Electric and Magnetic Fields and Your Health".

Key Research Issues

The Working Group has selected the following directions of investigation as the most critical at the present time: cancer Epidemiology, exposure assessment and in vivo animal cancer studies. All three areas are considered equally important and were unanimously selected by all group members. There are now under way epidemiological studies and exposure assessment studies, both in Canada and abroad. However, there appear to be no comprehensive in vivo studies being carried out at present.

* Appendix E of that report is not included in this Appendix

Table 1 - 50/60 Hz Standards and Guidelines Limits for Continuous General Public and Occupational Exposure

	Electric Field Strength (kV/m)		Magnetic Flux Density (mT)	
Standard	**Public**	**Occupational**	**Public**	**Occupational**
ICNIRP (1998) (60Hz)	4.16	8.33	0.0833	0.4166
USA, ACGIH (1998) (60Hz)		25		1.0
CENELEC (1995) (60Hz)	8.333	25*	0.533	1.333
UK NRPB (1993) (60Hz)	10	10	1.333	1.333
Australia, NH&MRC (1989) (50Hz)	5.0	10.0	0.1	0.5
Germany (1989) (50Hz)	20.6	20.6	5.0	5.0
USSR (1975) (50Hz) USSR (1985) (50Hz)	- -	5.0 -	- -	- 1.76
Poland (1980) (50Hz)	-	15.0	-	-

* with time restrictions

ACGIH - American Conference of Governmental Industrial Hygienists

CENELEC - Comité Européen de Normalisation Electrotechnique (European Committee for Electrotechnical Standardization)

ICNIRP - International Commission on Non-Ionizing Radiation Protection

NH&MRC - National Health & Medical Research Council

NRPB - National Radiological Protection Board

POSITION STATEMENT* ON THE HEALTH EFFECTS OF EXTREMELY LOW FREQUENCY (E.L.F.) ELECTRIC AND MAGNETIC FIELDS ON THE GENERAL PUBLIC

1. The production of electric and magnetic fields are associated with the generation, transmission and use of electricity. People are exposed to these fields not only when they are near high voltage lines, but also at their places of work and in their homes. Such fields are produced by distribution lines, transformers, building and house wiring and by all devices that use electric power.

2. Studies to investigate the health effects of these fields have been taking place around the world for more than twenty-five years. Such research has included laboratory studies concerning the effects on cells, tissues and animals, as well as studies on human exposure and Epidemiology.

3. Epidemiological studies suggest a weak association between increased risk of certain types of cancer, and exposure to magnetic and/or electric fields; however the findings are inconsistent and inconclusive. Experiments with animals and cells show that these fields can interact with biological systems and with cellular chemistry. These interactions, however, have not been shown to lead to adverse health effects. Extensive world-wide research programs are ongoing in order to clarify whether or not there are indeed health risks.

4. Research to date[(1)] has not identified any biophysical mechanisms that link the initiation or promotion of cancer by power frequency field properties.

5. Recommended exposure limits to prevent acute health effects have been put forward by an international committee of experts[(2)]. It is extremely unlikely that members of the Canadian public would be exposed above these exposure limits. In the case of chronic exposure at ambient levels, currently available information on health and bioeffects does not provide a basis for establishing more restrictive exposure limits.

6. The Federa Provincial Territorial Radiation Protection Committee will continue to monitor the results of new studies and re-assess this position as new information becomes available.

*Position Statement issued by the Federal Provincial Territorial Radiation Protection Committee.

[(1)]Council of the American Physical Society - (95/04/22)

[(2)]ICNIRP Guidelines "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (Up to 300 GHz)," Health Physics, Vol.. 74, No. 4, pp. 494-522, April 1998. The Guidelines recommend a limit of 4.16 kV/m and 83.3 μT (833 milligauss) for 24-hour exposure of the general public

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