MICRO WAVE NEWS
A Report on Non-Ionizing Radiation

NCRP Draft Recommendations on EMF Exposure Guidelines

Reprinted below is Section 8 of the June 13, 1995, draft of the report of NCRP Scientific Committee 89-3 on Extremely Low Frequency Electric and Magnetic Fields, which contains its conclusions and recommendations.

8.1.0 Conclusions and Recommendations for Interim Exposure Guidelines

In 1989, the International Radiation Protection Association (IRPA) approved interim EMF exposure guidelines prepared by its International Non-Ionizing Radiation Committee. The guidelines recommended the following limits for occupational exposure and for exposure of the general public:

Exposure	Electric Field Strength	Edge of ROW
Occupational: Whole Working Day	10 kV/m	0.5 mT (=5,000 mG)
Short Term	30 kV/m	5.0 mT (=50,000 mG)
Restricted to Limbs	-	25.0 mT (=250,000mG)
General Public: Up to 24 hours/day	5 kV/m	0.1 mT (=1,000 mG)
Few hours/day	10 kV/m	1.0 mT (=10,000mG)

Table 1

The IRPA committee based its recommendations on the premise that the existing literature does not provide evidence that EMF exposures at present-day levels have a public health impact that would require corrective action. Its summary position was that "although some epidemiological studies suggest an association between exposure to 50/60 Hz fields and cancer, others do not. Not only is this association not proven, but present data do not provide any basis for health assessment useful for the development of exposure limits."

Further, the IRPA guidelines were developed "primarily on established or predicted health effects produced by currents induced in the body by external [EMFs]," and those limits correspond to induced current densities that are generally at, or slightly above, those attributable to normal excitation currents occurring physiologically in the body. Thus, the IRPA-recommended exposure limits are orders of magnitude greater than field levels that may create a risk, in the light of extensive evidence reviewed in this report. Concerns about inadequacies of IRPA guidelines have been summarized in a review of international standards (Gibbs, 1991)1:

Since the guidelines proceed on the basis that adverse human health effects from exposure to ELF electric fields at strengths normally encountered in the environment or in the workplace have not been established, it is apparent that they are not intended to provide protection against any adverse health effects that may be caused by such exposure, and they would not do so. The levels of exposure recommended are many times greater than the levels at which it has been suggested that the fields may create a risk.

In the U.K., the National Radiological Protection Board (1989) also set exposure guidelines for 50/60 Hz fields on the same basis as the IRPA committee in fixing its interim guidelines. For occupational exposures and for the general public, the recommended 50 Hz field levels were the same: for electric fields: 12 kV/m; for magnetic fields: 2 mT (20,000 mG).

In the USA, some states have established limits for electric field strengths on or at the edge of the rights-of-way for high voltage transmission lines. Only Montana has established magnetic

field limits (Table 2).

Exposure criteria at these levels do not reflect epidemiological findings that suggest significantly enhanced cancer risks, particularly for childhood leukemia, in ambient power frequency fields exceeding 2 mG. This level is proposed for a Swedish general population guideline, based on correlates of incidence of childhood leukemia with annualized magnetic field levels in dwellings adjacent to high voltage transmission lines.

8.2.0 Rationale for Interim Exposure Guides

In reviewing available evidence, neither laboratory studies nor epidemiological findings, whether considered separately or jointly, can yet establish well-defined thresholds for safety guidelines that would encompass the temporal spectrum from short-term to lifelong ELF exposures. Although it might thus be justified to offer no specific guidelines, nevertheless it would appear prudent to offer interim guidance.

Population exposure to EMFs at power line frequencies involves not only the basic sine wave fields at 50 or 60 Hz, but also harmonics at higher frequencies. Secondary fields generated in the use of electric power are substantially more complex due to their harmonic content. Although this report focuses on the ELF spectrum from near-DC to 300 Hz, information has been included on studies as high as the kilohertz range, because of their widespread environmental occurrence and because they have not been reviewed elsewhere.

In key areas of bioelectromagnetic research, findings are sufficiently consistent and form a sufficiently coherent picture to suggest plausible connections between ELF EMF exposures and disruption of normal biological processes, in ways meriting detailed examination of potential implications in human health. These specific areas of research are briefly reviewed.

8.2.1 Carcinogenesis

Epidemiological studies in the USA and Europe cited elsewhere indicate a positive association between childhood cancers and exposure to magnetic fields, on the order of 0.2 µT, generated by electric power transmission and distribution systems. Evidence has accumulated in other epidemiological studies implicating exposure to ELF EMFs as a factor common to an increased incidence of leukemia and brain cancer in occupationally exposed adults.

In laboratory research, further studies will be necessary to determine existence of an unequivocal link between exposure to ELF EMFs and cancer. Nevertheless, reported EMF effects in animal and tissue models at critical steps in cell growth regulation are consistent with an initiation-promotion (epigenetic) model of tumor formation, and are consistent with results of epidemiological studies.

State	on ROW	Edge of ROW
Florida[1]	8 kV/m	2 kV/m
Florida[2]	10 kV/m	2 kV/m
Minnesota	8 kV/m	-
Montana	7 kV/m	1 kV/m
Montana[1]	-	150 mG
Montana[2]	-	200 mG
Montana[3]	-	250 mG
New Jersey	-	3 kV/m
New York	11.8 kV/m	1.6 kV/m
North Dakota	9 kV/m	-
Oregon	9 kV/m	-

[1]Lines less than or equal to 230 kV [2]500 kV lines [3]500 kV double circuit lines
Table 2

8.2.1.1 Gene induction: There is no evidence of gross chromosomal damage or sister-chromatid exchanges following exposure to ELF EMFs, interpreted as an indication that field exposure does not cause initiation as the first step in the initiation-promotion cancer model. However, ELF magnetic fields have been shown to alter gene transcriptional processes, with repression and derepression of portions of the genetic code, thus leading to changes in expression of proteins in cells. This process may represent an abnormal cell function, leading to reduced control of cell growth, and ultimately to unregulated growth. Such a loss of growth regulation would be consistent with a promotional role (or copromotional with other promoting agents) in the cancer process.

8.2.1.2 Biochemical changes: Intracellular biochemical changes following ELF magnetic field exposures. They include responses of messenger and cell growth-related enzymes, and alterations in gene expression, including modulation of activity of proto-oncogenes. These changes are consistent with actions of chemical cancer promoters, suggesting the possibility of combined actions of chemicals and ELF EMFs as cancer promoters.

8.2.1.3 Enhanced cell tumorigenicity: Increased tumor incidence and decreased tumor latencies have been reported in animal tumor models when 50/60 Hz magnetic fields at intensities of 0.1 mT or less were presented as promoters or copromoters. Increased concentrations of transferrin receptors have been reported on the surface of human colon cancer cells when exposed to 60 Hz magnetic fields, or to combined electric and magnetic ELF fields. A relationship to increased tumorigenicity may be suggested, since raised serum iron levels and an associated decrease in levels of transferrin iron binding have been described in human cancer. These findings are consistent with the possibility that prolonged exposures to ELF fields may progressively lead to recloning of already transformed cells to a more cancerous state.

8.2.1.4 Immune deficiencies: Accumulating epidemiological evidence from population studies and from the workplace now correlates environmental ELF EMF exposures with increased risks for leukemia in children and adults. Certain of these studies have suggested a dose-dependence in long-term exposures. In laboratory studies, the natural defense response of T-lymphocytes taken from the immune system of mice is reduced by exposure to ELF electric fields, and after exposure to combinations of electric and magnetic fields. It may be argued that if these exposures mitigate normal immune defense responses in the intact subject, there may ensue less efficient detection and elimination of aberrant cells, including cells undergoing recloning to more malignant states.

8.2.2 Reproduction/Teratology

Unlike the growing and increasingly consistent evidence linking ELF EMF exposure to increased risks of certain cancers, epidemiological evidence on human reproduction has remained limited. A single preliminary study has described a modest increased risk of pregnancy termination associated with use of electric blankets.

A series of studies in Scandinavia and the USA have reported increased risks of miscarriage associated with VDT use, including evidence of dose-dependency. Studies in mice, rats and swine have all reported teratological effects, but many lack consistency in site and type of teratology. Several independent studies have noted growth abnormalities in chick embryos exposed to similar types of magnetic fields. A single study in rats of neuroendocrine and psychosexual responses following intrauterine ELF magnetic field exposure in late pregnancy has described defective territorial marking in adult male offspring and increased gonadal organ weights.

Available evidence from these epidemiological and laboratory studies indicates needs for further research on possible reproductive anomalies, including studies of subtle neurobehavioral effects that may be revealed only after puberty and in later development.

8.2.3 Neurobiology

Limited human studies have addressed a spectrum of altered physiological responses that appear correlated with ELF electric and magnetic field exposures. This spectrum of bioeffects shades progressively into certain neuroendocrine and autonomic responses which, separately or collectively, may have pathophysiological implications. These human observations are supported and extended by a much larger body of laboratory animal research, with responses to ELF fields in species from fish to man. These fields may influence development of the nervous system. In the adult organism, they elicit neurochemical, physiological, behavioral and chronobiological

responses.

There has been a strong focus on ELF field actions in the pineal gland, relating to effects on synthesis and secretion of the pineal hormone melatonin, and on a broad series of regulatory functions mediated by this hormone. Melatonin plays a key role in controlling the 24-hour daily biological rhythm. Disturbance of the normal diurnal melatonin rhythm is associated with altered estrogen receptor formation in the breast, a line of experimental evidence now under study for possible links between ELF field exposure and human breast cancer. Further, melatonin has general properties as a free radical scavenger, with the possibility of a preventative role in oxidative stress, recognized as a basic factor in a broad spectrum of human degenerative disorders, including coronary artery disease, Parkinson's and Alzheimer's diseases, and aging.

8.3.0 Conclusion

Although incomplete, available epidemiological and laboratory data share certain consistencies that would link ELF environmental EMFs with increased health risks. These findings appear to warrant a substantive national commitment to further research, and the serious attention of cognate regulatory agencies and of the general public. Some epidemiological studies relate health effects to broad measures of exposure levels. From these measures, there is an implication that a significant proportion of the world's population may be subjected to a low level of risk, but a risk factor with significant societal consequences, by reason of its pervasive nature and the serious consequences for affected individuals. Much additional research will be necessary to determine the complex nature of dose-response relationships, and the specific contributions of field frequency, intensity and waveforms. A deeper knowledge of mechanisms is needed to elucidate observed differences between intermittent and chronic ELF field exposures. In establishing safety guidelines, there may also be a need to identify populations with specific sensitivities, as is customary with certain chemical toxins. As yet, no research has examined possible synergisms between EMFs and other environmental agents. Further, many electrically operated appliances, such as television receivers, computer display terminals and certain types of electric motors, may generate substantial magnetic fields in their immediate vicinity at frequencies above the ELF spectrum. Although beyond the scope of this report, these fields may also be biologically active. A broader base of experimental data will be required before there can be regulatory implementation of comprehensive safety guidelines; but this considered approach in no way diminishes the desirability of interim standards.

8.4.0 Interim Exposure Guides

Based on available evidence, the committee concludes that it is desirable to reduce human exposure to electric and particularly to magnetic fields over the frequency range from near-zero to 3 kHz. This may be accomplished, particularly in areas with frequent and prolonged human occupancy, by recommending an exposure standard, or a set of safety guidelines; or by recommendations that fall short of establishing either a standard or guideline, but offer guidance to limit exposure.

The past century has seen exponential growth in the universal use of electric power in every facet of civilized society. With this universal acceptance, engineering considerations have driven the developing technologies of power generation and distribution in ways offering few options for possible changes dictated in the hindsight of either environmental or medical concerns. The burden of fiscal investment alone may make unfeasible drastic modifications of existing systems in the short term.

The committee has therefore addressed these questions of safety in an historical perspective. What safety issues may arise from continuing exposure to existing environmental fields? And for the future, should these exposures be mitigated, and if so, to what levels? Beyond an evaluation of existing exposures, a more pressing issue involves planning for the future of a society wherein use of electric power will continue to grow at every turn.

On the one hand, mitigation of existing exposures may be appropriate in certain instances where exposures may be deemed excessive, based on available epidemiological and laboratory data. In planning for the future, societal impact of this mitigation is likely to prove complex and costly. Prior to implementing major mitigation programs, they will require rigorous evaluation of their risk/benefit ratios. An approach developed by cognizant federal agencies in handling some environmental toxic agents has involved incremental safety guidelines that reflect growth of medical knowledge and availability of improved or more cost-effective mitigation techniques over

a period of years.

By contrast with deep-rooted problems inherent in mitigation of many existing exposures, plans for the future should address exposure guidelines in new construction of housing, schooling and industrial plants, with specification of acceptable interior electromagnetic environments, as well as proximity to existing electric power transmission and distribution systems. A second concern addresses construction of new power transmission and distribution systems, and their permissible proximity to existing houses, schools and industrial developments

Although precise numerical levels in safety guidelines covering current environmental exposures may require further research, there is a different perspective on needed guidelines for the future of an increasingly electrified society. From available epidemiological and laboratory data, it appears both prudent and responsible to set limits on permissible future exposures, exercising these options now at a time when their implementation will carry minimal societal impact or fiscal burden.

8.4.1 The Existing ELF Electromagnetic Environment

With respect to the existing electromagnetic environment, four options were considered:

8.4.1.1 Option 1: No recommendation for use of specific field levels to define an exposure safety guideline: EMFs from distribution and use of electric power have created new exposures in the human environment. Virtually no one in Western society escapes some form of exposure. For that reason, there should be a continuing aggressive pursuit of possible adverse health effects from these exposures. However, the existing evidence bearing on health effects is inadequate to offer exposure guidelines at this time. There is not sufficient consistency among epidemiological studies, and with very few animal studies reported, it is premature to assume a causal relationship between EMF exposure and cancer risk.

Though not sufficient to conclude causality, the epidemiological studies have raised concern. In addition, animal models for skin and breast cancer are in the early stages of evaluation and preliminary results have been provocative. Despite their logical complexity, further rigorous testing of animal models may offer one of the few options for full elucidation of a possible role of EMFs in tumor formation, since it is unlikely that these data will be derived from epidemiological studies alone.

It must be emphasized that epidemiological studies completed to date do not rule out effects of EMFs on cancer risk, even large ones. This is because of limitations in exposure assessment and undoubted misclassification of exposure, as well as the absence of truly unexposed subjects.

8.4.1.2 Option 2: An exposure guideline of 0.2 µT and 10 V/m: Epidemiological evidence points to human health hazards in exposure to ambient power frequency magnetic field environments exceeding 0.2 µT. A dose-dependence for childhood leukemia is suggested for power frequency fields in the range 0.2-0.4 µT. Assessment of the ambient magnetic environment in these studies at sites near power transmission and distribution lines has generally not taken account of much higher but more focal fields in the immediate vicinity of operating devices in the home and workplace. Resulting risk estimates may thus underestimate the true exposure levels from all sources. Although largely neglected in the emphasis on magnetic field bioeffects, there is also a body of laboratory evidence relating biologically significant effects, particularly in cerebral tissue calcium binding, to ELF electric field exposures in the range 10-100 V/m. Neurobehavioral effects, including a regulatory role in biological rhythms of man and animals, have been attributed to ELF environmental electric fields at intensities in the range 10-100 V/m.

Safety guidelines established at the low levels of Option 2 could be expected to have a major impact on lifestyles and working conditions in homes and in most occupational settings. Mitigation of existing fields needed to achieve general compliance would appear impractical at this time.

8.4.1.3 Option 3: An exposure guideline of 1 µT and 100 V/m: A considerable body of observations has documented bioeffects of fields at these strengths across the gamut from isolated cells to animals, and in man. Although the majority of these reported effects do not fall directly in the category of hazards, many may be regarded as potentially hazardous. Since epidemiological studies point to increased cancer risks at even lower levels, a case can be made

for recommending 1 µT and 100 V/m as levels not to be exceeded in prolonged human exposures. Most homes and occupational environments are within these values, but it would be prudent to assume that higher levels may constitute a health risk.

In the short term, a safety guideline set at this level would have significant consequences, particularly in occupational settings and close to high voltage transmission and distribution systems, but it is unlikely to disrupt the present pattern of electricity usage. These levels may be exceeded in homes close to transmission lines, distribution lines and transformer substations, in some occupational environments, and for users of devices that operate close to the body, such as hair dryers and electric blankets. From a different perspective, adoption of such a guideline would serve a dual purpose: first, as a vehicle for public instruction on potential health hazards of existing systems that generate fields above these levels, as a basis for "prudent avoidance"; and second, as a point of departure in planning for acceptable field levels in future developments in housing, schooling, and the workplace, and in transportation systems, both public and private, that will be increasingly dependent on electric propulsion.

8.4.1.4 Option 4: The ALARA concept (as low as reasonably achievable): The ALARA concept derives from guidelines for exposure to ionizing radiation. In that context, it first requires acceptance of a specific numerical guideline, and thereafter, due diligence in seeking progressive exposure reduction to levels at or below the guideline. Although the aggregate evidence suggests a significant health risk from these fields, there is as yet inadequate information to establish thresholds that would implicate specific field levels as safe or hazardous. Therefore, in the interval required for further research, individuals, industries and government agencies would have responsibilities to make human exposures as low as reasonably achievable in meeting a postulated numerical exposure guideline developed as part of an ALARA scheme.

An ALARA approach also offers an avenue to safety guidelines to be implemented incrementally. An incremental approach to dealing with potential environmental hazards is a model successfully employed by the Environmental Protection Agency, in joint actions with other federal agencies, in dealing with toxic waste cleanup. Appropriate benchmarks are established that project realizable goals at stated future times. An incremental approach on a large scale has been applied by EPA to the control of automobile emissions in Southern California, under the federal Clean Air Act.

Based on Option 3, a set of ALARA goals may be defined with benchmarks projected over a minimum of six and a maximum of ten years, as a template for an incremental guideline. In homes, schools, nonindustrial workplaces, and in suburban environments, a first ALARA benchmark at three years should reduce ambient exposures to 1.0 µT [and] 100 V/m (Option 3). Thereafter, a second benchmark at six years would set a goal at 0.5 µT [and] 50 V/m. Beyond this point, implementation of the third benchmark in an incremental safety guideline for the general public at a further sharply reduced level (as in Option 2) at 0.2 µT [and] 10 V/m will require a careful evaluation of its socioeconomic impact, as well as its cost-effectiveness. It would not be expected to occur until about seven years after implementation of benchmark 1. Its justification would also be based on new correlated laboratory and epidemiological data expected to be available over the next decade.

For individuals, educational requirements inherent in this ALARA scheme may be difficult to achieve; but at the societal level, there should be a technological focus on such topics as grounding in electrical distribution systems, manufacturing of appliances designed to reduce stray field levels, and elevation of consumer awareness of possible hazards associated with particular appliances.

8.4.2 Conclusion on an Interim Exposure Guideline for the Existing Electromagnetic Environment

Though not unanimous, the predominant view of the committee is to recommend the ALARA approach. It is proposed that this ALARA guideline be progressively implemented over a ten-year period. It is recommended that specific field levels cited here be regularly reviewed as more information becomes available that might suggest either more or less stringent figures as the basis for a continuing ALARA policy. Specifically, the pathophysiology of cumulative dose has yet to be defined, and with it, the relevant parameters in long-term EMF exposure.

The proposed initial benchmark for a safety guideline would be developed under Option 3. After three years, maximum acceptable field levels would not exceed 1.0 µT and 100 V/m over the

spectrum from near-zero to 3.0 kHz in homes, schools, and other non-industrial environments. In a review after six years, there would be an option to establish a guideline at 0.5 µT and 50 V/m. Thereafter, at ten years, and only after full review of socioeconomic as well as its technical implications, there would be an option to establish a guideline at 0.2 µT [and] 10 V/m. There would be options to truncate both lead times and acceptable field parameters if favored by availability of appropriate laboratory or epidemiological evidence.

With respect to occupational exposures, the committee reviewed the composite nature of exposures in the workplace, where EMFs, often at high levels, coexist with a variety of chemical factors known to be hazardous, including neurotoxins, pesticides, herbicides and organic solvents. Although there is evidence that EMFs may promote actions of these chemical factors in pathogenesis of human disease, particularly in relation to joint exposures over many years, these data are insufficient for evaluation of their joint or separate roles. Moreover, in most instances, economic considerations would render unfeasible a major reduction in existing industrial field levels through engineering approaches. These exposures may also involve high levels of static magnetic fields, for which there is very little relevant laboratory or epidemiological data.

In typical office environments, ambient field levels may differ very little from domestic ambients. The committee therefore recommends use of the incremental ALARA guideline described above. However, the industrial workplace may involve intermittent or continuous exposure to fields orders of magnitude higher. In these situations, the committee also recommends an ALARA approach for 60 Hz fields, but with an awareness that neither major reductions in existing field levels, nor options to significantly reduce operating personnel exposures are immediately feasible on technical or economic grounds. As a long-term (ten-year) goal, an ALARA approach to mitigation in existing industrial environments would envisage a time-limited personnel exposure not exceeding one hour in any eight-hour workshift, and with time-averaged fields not to exceed 10 µT and/or 1 kV/m for any one hour in an eight-hour workshift. This guideline does not address magnetic transients associated with starting or stopping large inductive devices. Its development towards time-limited exposures is suggested by laboratory reports of ELF and RF exposures that modulate immune cell functions in a time-dependent manner.

The committee recommends further research into field mitigation, including the possibility of developing protective clothing capable of magnetic shielding, as a possible option in personnel protection in high-level industrial magnetic fields.

8.5.0 Exposure Guidelines Relating to Future Developments Affecting the ELF Electromagnetic Environment

There may be important societal options in considered planning for the future of electric power transmission, distribution and use. Planned development may avoid hazards and pitfalls of existing systems, and by offering guidance in new construction, may avoid much of the heavy economic impact inevitable in retrofitting and mitigating suspected health hazards associated with past and present technologies.

As safety guidelines for future planning, the committee recommends that: 1) New day care centers, schools and playgrounds should not be built where ambient 60 Hz magnetic fields exceed 0.2 µT; 2) New housing should not be built under existing high voltage transmission lines, or in such close proximity to these lines that measured ambient field levels would exceed 0.2 µT for periods longer than two hours daily; 3) New transmission and distribution lines should not be built in locations where they would produce fields exceeding 0.2 µT in existing housing; 4) In new office and industrial environments, design considerations should encompass problems of personnel exposure to high magnetic field levels, with the aim of reducing intermittent and ambient exposures to a 0.2 µT level, over the spectrum from near-zero to 3.0 kHz.

8.5.1 Conclusion

In arriving at the proposed guidelines, the committee has considered available laboratory studies on bioeffects and epidemiological reports of health hazards from electric and magnetic field exposure. Lacking a basis for calculation of cumulative dose, these guidelines have been determined without drawing distinctions between acute and chronic exposure. They have not determined exposure levels from safety factors frequently used with other agents, nor has there been special consideration for sex, age or potentially sensitive populations, such as pregnant women, because current knowledge of mechanisms of field interactions does not allow

identification of those likely to be affected. In medical diagnostic and therapeutic applications, these guidelines would exclude patients, but would apply to physicians, nurses and to all other health providers.

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