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EPRI Comments on the WHO *Environmental Health Criteria* for Extremely Low Frequency EMF

The World Health Organization (WHO) released its *Environmental Health Criteria* (*EHC*) monograph on extremely low frequency (ELF) electric and magnetic fields (EMF) on June 18, 2007.[1] According to Dr. Emilie van Deventer, Acting Coordinator of WHO's Radiation and Environmental Health Program, the monograph summarizes "the most thorough health risk assessment currently available" on ELF EMF. The monograph includes recommendations for further research, a discussion of public health policy, and recommendations to national authorities on precautionary measures.

Background

The widely recognized *Environmental Health Criteria* monographs are intended to inform national and international authorities conducting risk assessments and making risk management decisions. WHO emphasizes that the documents do not include recommendations for standard setting or regulation. However, EMF *EHC* monographs provide the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and other international guideline-setting organizations with scientific information for reevaluating exposure guidelines. A reevaluation of the ICNIRP guidelines based on information in the new ELF EMF monograph is currently under way.

The monograph on ELF EMF (>0 Hz–100 kHz) is part of a series of three documents that together cover the frequency range 0–300 GHz. The first monograph in this series, on static fields (0 Hz), was published in 2006,[2] and work on a monograph covering radio-frequency fields (>100 kHz–300 GHz) is tentatively scheduled for 2008. *EHC* monographs are initiated when new data would substantially change an evaluation, increasing exposure has caused public concern about health or environmental effects, or a considerable amount of time has passed since an evaluation was made. Previous monographs covering ELF EMF were published in 1984 and 1987.[3,4]

The health risk assessment described in the new ELF EMF monograph is based on both the scientific literature and previous reviews by other national and international organizations. Particular importance was given to a 2003 ICNIRP review of the EMF literature on biologic and health effects that was commissioned by WHO,[5] reviews published from 2001–2006 by the Advisory Group on Non-Ionising Radiation for the UK Health Protection Agency,[6–9] and a 2002 evaluation of the evidence on the carcinogenicity of EMF by the International Agency for Research on Cancer (IARC), a branch of WHO.[10] In its evaluation, IARC classified ELF magnetic fields as a 2B, or possible, carcinogen. This classification was based on limited evidence for carcinogenicity from epidemiologic studies of magnetic fields and childhood leukemia indicating an approximate doubling of risk associated with exposures above 0.3–0.4 μT, along with inadequate evidence for carcinogenicity from laboratory animal studies, which are mostly negative.

WHO's International EMF Project conducts the health risk assessments published in the EMF *Environmental Health Criteria*. The process begins with development of a first *EHC* draft by expert scientific consultants, with working groups producing chapters on selected topics. The completed draft is sent out for expert comment, and a second draft incorporating comments is distributed to a multinational, multidisciplinary task group of individual scientists. The task group evaluates the information in the document and assesses health risks. The task group's conclusions and recommendations—decided by consensus—are final. The entire process for the *EHC* on ELF EMF took about 4 years.

In addition to the *EHC* monograph, the International EMF Project has produced a new fact sheet on exposure to extremely low frequency fields[11] that has been posted on the International EMF Project website (http://www.who.int/peh-emf/en/). A report on a workshop to discuss development and implementation of precautionary measures, to be held on June 20–21, 2007 in Geneva, will also be posted on the website.

WHO's Conclusions and Recommendations

Health Risk Assessment

The WHO health risk assessment included epidemiologic and human volunteer studies as well as studies in laboratory animals and cells. For ELF magnetic fields and cancer, the review focused mainly on studies that were published after 2001 and thus were not included in the IARC evaluation. Studies were evaluated both individually and, according to a weight-of-evidence approach, all together. The evidence for each health outcome considered was termed *limited* if it was based on a single study or if the design, conduct, or interpretation of a number of studies was questionable. The evidence was *inadequate* if studies had major limitations that precluded interpretation or if no data were available (this classification includes studies with inconsistent results).

The main conclusions of the assessment of the evidence on health risks from exposure to low-level ELF EMF are as follows:

- The evidence for an association between ELF magnetic fields and childhood leukemia remains limited and does not change the IARC classification of ELF magnetic fields as a possible human carcinogen.
- The evidence for childhood brain cancer and other cancers remains inadequate.
- The evidence for adult female breast cancer does not support an association.
- The evidence for adult brain cancer, leukemia, and other cancers remains inadequate.
- The evidence for the neurodegenerative diseases amyotrophic lateral sclerosis (ALS) and Alzheimer disease is inadequate.
- The evidence does not support an association between ELF EMF exposure and cardiovascular disease.
- There is some evidence suggesting that exposure might be linked to neurobehavioral effects such as changes in cognitive function and brain electrical activity. However, studies of effects on sleep have been inconsistent, and the evidence for depressive symptoms and suicide is inadequate. Symptoms attributed to electrical hypersensitivity appear to be unrelated to EMF exposure.
- The evidence for effects on the neuroendocrine system, including production of melatonin (a pineal gland hormone that may be involved in breast cancer development independently of EMF exposure), is inadequate.
- The evidence for effects on the immune and hematologic systems is inadequate.
- The evidence for developmental and reproductive effects is inadequate.

Research Recommendations

As part of the health risk assessment, gaps in knowledge were identified and recommendations for research to address these gaps were made and prioritized. The highest priority cancer research area identified in the *EHC* is work to reconcile the epidemiologic evidence showing an association between ELF magnetic fields and childhood leukemia with the lack of supporting evidence from experimental and mechanistic studies. Specific high-priority research recommendations include an updated pooled analysis of childhood leukemia studies. Also assigned high priority are development of a transgenic rodent model of childhood leukemia for use in experimental studies and evaluation of ELF magnetic fields as a cocarcinogen in cell and animal studies. A pooled analysis of childhood brain cancer studies, which could shed light on both selection bias and possible effects of magnetic field exposure, is another high-priority area.

Investigation of ALS in electrical occupations was identified as a high-priority research topic. The *EHC* notes, however, that the reported epidemiologic link between EMF and ALS could be due to confounding by another exposure, such as electric shock, that may be present in electrical occupational environments. Further investigation of ELF magnetic fields and Alzheimer disease was also given high priority.

Other high-priority research topics are identification of gaps in knowledge about occupational exposures and mechanistic research to determine threshold responses to electric fields induced in multicellular systems in the body. A number of additional research recommendations were assigned medium or low priority. It is of note that further research on breast cancer was given very low priority, and cardiovascular disease was not considered a research priority. There were no recommendations for further research on electromagnetic hypersensitivity.

Policy Recommendations

The *Environmental Health Criteria* monograph includes a number of recommendations for development of public health policy and implementation of measures to protect people from possible health risks from exposure to ELF EMF. In discussing these recommendations, the *EHC* document notes that compliance with international guidelines limiting exposure to

ELF EMF (for example, the ICNIRP guidelines) provides adequate protection for scientifically established acute effects such as nerve stimulation. Such acute effects may occur at magnetic field levels that are virtually never encountered by the general public (except for partial-body exposures from use of appliances such as hair dryers and power tools), and are found only very rarely in occupational settings. Electric fields may approach or exceed guideline exposure limits within rights-of-way of high-voltage transmission lines—usually those energized to 345 kV or more.

The *EHC* document emphasizes that the scientific evidence on possible health effects from low-level chronic exposure is too weak to provide a basis for setting exposure limits. However, it states: ". . . Because of the limited evidence for a link between exposure to ELF magnetic fields and childhood leukaemia. . . . the use of precautionary approaches is warranted." Since the scientific evidence for an association is weak and the public health impact would be limited even if the association were causal (accounting for an estimated 0.2–4.9% of the annual number of leukemia cases), WHO states that the costs of precautionary measures should be very low. Moreover, precautionary measures should not compromise "the health, social, and economic benefits of electricity."

WHO's recommended precautionary approach would include no- or low-cost measures to reduce exposures. Recommended measures include the following:

- adoption of guidelines based on ICNIRP or other international guidelines to protect against known acute effects of high-level ELF EMF exposure (as opposed to arbitrary guidelines limiting low-level exposure that are not science based)
- establishment of a protection program that includes ELF EMF measurements to ensure public and worker compliance with exposure limits
- implementation of very-low-cost measures in the design and engineering of new facilities, devices, and equipment, including appliances
- inclusion of safety, reliability, and economic aspects when considering reduction of ELF fields from existing sources
- enforcement of existing wiring regulations to reduce unintentional ground currents
- evaluation of wiring practices in residences, schools, and other buildings
- better planning for facilities that are possible sources of ELF EMF exposure, including stakeholder involvement to discuss siting of major facilities
- effective communication to inform stakeholders (including information on inexpensive steps people can take to reduce their exposure)
- additional research to reduce scientific uncertainty

EPRI Comments

The conclusions of WHO's ELF EMF health risk assessment regarding both possible health effects and implementation of no- or low-cost precautionary measures are consistent with the conclusions of previous EMF health risk evaluations.[6–10, 12, 13]

Health-related research in several areas recommended for further investigation in the *EHC* document is already under way in EPRI's EMF Health Assessment and RF Safety program. The program's research agenda, which focuses largely on childhood leukemia, is in accord with WHO's assignment of high priority to this research area. As mentioned in IARC's 2002 report and in the *EHC*, selection bias and confounding are possible explanations for the epidemiologic association between magnetic fields and childhood leukemia. EPRI is conducting research to investigate both selection bias and confounding. EPRI has investigated residential exposure to contact current as a candidate confounder in the United States and, as WHO recommends, has already assessed potential contact current exposure in relation to residential wiring in other countries.

EPRI is also developing a mouse model of childhood leukemia to test potential effects of environmental exposures, including contact current and magnetic fields. In addition, a pooled analysis of childhood brain cancer studies, which could shed light on selection bias, is in progress. These projects were given high priority in the *EHC*. Updated meta-analyses of adult brain cancer and adult leukemia are also under way. Other EPRI research projects that coincide with WHO's research recommendations are investigation of occupational EMF exposures and characterization of homes with high magnetic field exposure in different countries.

Dr. Robert Kavet, manager of the EMF Health Assessment and RF Safety program, attended the WHO task group meeting as an observer in October 2005, when the essence of the *EHC* monograph was finalized. He contributed technical comments to the final revisions of the chapters concerned with biophysical mechanisms, dosimetry, and exposure assessment. In addition, EMF Health Assessment and RF Safety program epidemiologist Gabor Mezei contributed to the WHO risk assessment as a member of an expert working group on childhood leukemia.

Regarding WHO's recommendations for precautionary measures, it should be mentioned that no- or low-cost measures to reduce people's exposure to power-frequency EMF have already been implemented in several countries and U.S. states, as the *EHC* document points out. One such measure is prudent avoidance, a precautionary approach introduced by Nair et al. in 1989.[14] Prudent avoidance has been adopted in Australia, Sweden, and other countries, as well as in California and several other states. It involves taking low-cost steps to reduce exposure, including rerouting facilities and redesigning electrical systems and appliances. In California and elsewhere, prudent avoidance has worked well to address concerns about health risks. However, as noted in the *EHC*, "given both the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, and the limited impact on public health if there is a link, the benefits of exposure reduction on health are unclear."

Perhaps the most essential outcome of the WHO ELF EMF health risk assessment is that IARC's classification of ELF magnetic fields as a possible human carcinogen remains unchanged. Reevaluation of this classification can be envisioned only with the emergence of new information from continued research.

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