

PREAMBLE

The WHO Environmental Health Criteria Programme

In 1973 the World Health Organization (WHO) Environmental Health Criteria Programme was initiated with the following objectives:

- (i) to assess information on the relationship between exposure to environmental pollutants and human health, and to provide guidelines for setting exposure limits;
- (ii) to identify new or potential pollutants;
- (iii) to identify gaps in knowledge concerning the health effects of pollutants;
- (iv) to promote the harmonization of toxicological and epidemiological methods in order to have internationally comparable results.

It should be noted in this context that WHO defines health as the state of complete physical, mental and social well being and not merely the absence of disease or infirmity (WHO, 1946).

The first Environmental Health Criteria (EHC) monograph, on mercury, was published in 1976 and since that time an ever-increasing number of assessments of chemical and of physical agents have been produced. In addition, many EHC monographs have been devoted to evaluating toxicological methodology, e.g. for genetic, neurotoxic, teratogenic and nephrotoxic agents. Other publications have been concerned with epidemiological guidelines, evaluation of short-term tests for carcinogens, biomarkers, effects on the elderly and so forth.

The original impetus for the Programme came from World Health Assembly resolutions and the recommendations of the 1972 UN Conference on the Human Environment. Subsequently the work became an integral part of the International Programme on Chemical Safety (IPCS), a cooperative programme of the United Nations Environment Programme (UNEP), the International Labour Office (ILO) and WHO. With the strong support of the new partners, the importance of occupational health and environmental effects was fully recognized. The EHC monographs have become widely established, used and recognized throughout the world.

Electromagnetic Fields

Three monographs on electromagnetic fields (EMF) address possible health effects from exposure to extremely low frequency (ELF) fields, static and ELF magnetic fields, and radiofrequency (RF) fields WHO, 1984; WHO, 1987; WHO, 1993. They were produced in collaboration with UNEP, ILO and the International Non-Ionizing Radiation Committee (INIRC) of the International Radiation Protection Association (IRPA) and from 1992 the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

EHC monographs are usually revised if new data are available that would substantially change the evaluation, if there is public concern for health or environmental effects of the agent because of greater exposure, or if an appreciable time period has elapsed since the last evaluation. The EHCs on EMF are being revised and will be published as a set of three monographs spanning the relevant EMF frequency range (0–300 GHz); static fields (0 Hz), ELF fields (up to 100 kHz, this volume) and RF fields (100 kHz – 300 GHz).

WHO's assessment of any health risks produced by non-ionizing radiation emitting technologies (in the frequency range 0–300 GHz) falls within the responsibilities of the International EMF Project. This Project was established by WHO in 1996 in response to public concern over health effects of EMF exposure, and is managed by the Radiation and Environmental Health Unit (RAD) which is coordinating the preparation of the EHC Monographs on EMF.

The WHO health risk assessment exercise includes the development of an extensive database that comprises relevant scientific publications. Interpretation of these studies can be controversial, as there exists a spectrum of opinion within the scientific community and elsewhere. In order to achieve as wide a degree of consensus as possible, the health risk assessment also draws on, and in some cases includes sections of, reviews already completed by other national and international expert review bodies, with particular reference to:

- the International Agency for Research on Cancer (IARC) Monograph on static and extremely low frequency (ELF) fields IARC, 2002. In June 2001 IARC formally evaluated the evidence for carcinogenesis from exposure to static and ELF fields. The review concluded that ELF magnetic fields are possibly carcinogenic to humans.
- Reviews on physics/engineering, biology and epidemiology commissioned by WHO to the International Commission on Non-Ionizing Radiation Protection (ICNIRP), a non-governmental organization in formal relations with WHO (ICNIRP, 2003).
- Reviews by the Advisory Group on Non-Ionising Radiation (AGNIR) of the Health Protection Agency (HPA), United Kingdom (AGNIR, 2001a; 2001b; 2004; 2006).

Scope

The EHC monographs are intended to provide critical reviews on the effect on human health and the environment of chemicals, physical and biological agents. As such, they include and review studies that are of direct relevance for the evaluation. However, they do not describe *every* study carried out. Worldwide data are used and are quoted from original studies, not from abstracts or reviews. Both published and unpublished reports are considered but preference is always given to published data. Unpublished data

are only used when relevant published data are absent or when they are pivotal to the risk assessment. A detailed policy statement is available that describes the procedures used for unpublished proprietary data so that this information can be used in the evaluation without compromising its confidential nature WHO, 1990.

In the evaluation of human health risks, sound human data, whenever available, are generally more informative than animal data. Animal and *in vitro* studies provide support and are used mainly to supply evidence missing from human studies. It is mandatory that research on human subjects is conducted in full accord with ethical principles, including the provisions of the Helsinki Declaration (WMO, 2004).

All studies, with either positive or negative effects, need to be evaluated and judged on their own merit, and then all together in a weight of evidence approach. It is important to determine how much a set of evidence changes the probability that exposure causes an outcome. Generally, studies must be replicated or be in agreement with similar studies. The evidence for an effect is further strengthened if the results from different types of studies (epidemiology and laboratory) point to the same conclusion.

The EHC monographs are intended to assist national and international authorities in making risk assessments and subsequent risk management decisions. They represent an evaluation of risks as far as the data will allow and are not, in any sense, recommendations for regulation or standard setting. These latter are the exclusive purview of national and regional governments. However, the EMF EHCs do provide bodies such as ICNIRP with the scientific basis for reviewing their international exposure guidelines.

Procedures

The general procedures that result in the publication of this EHC monograph are discussed below.

A first draft, prepared by consultants or staff from a RAD Collaborating Centre, is based initially on data provided from reference databases such as Medline and PubMed and on IARC and ICNIRP reviews. The draft document, when received by RAD, may require an initial review by a small panel of experts to determine its scientific quality and objectivity. Once the document is acceptable as a first draft, it is distributed, in its unedited form, to well over 150 EHC contact points throughout the world who are asked to comment on its completeness and accuracy and, where necessary, provide additional material. The contact points, usually designated by governments, may be Collaborating Centres, or individual scientists known for their particular expertise. Generally some months are allowed before the comments are considered by the author(s). A second draft incorporating comments received and approved by the Coordinator (RAD), is then distributed to Task Group members, who carry out the peer review, at least six weeks before their meeting.

The Task Group members serve as individual scientists, not as representatives of their organization. Their function is to evaluate the accuracy, significance and relevance of the information in the document and to assess the health and environmental risks from exposure to the part of the electromagnetic spectrum being addressed. A summary and recommendations for further research and improved safety aspects are also required. The composition of the Task Group is dictated by the range of expertise required for the subject of the meeting (epidemiology, biological and physical sciences, medicine and public health) and by the need for a balance in the range of opinions on the science, gender and geographical distribution.

The membership of the WHO Task Groups is approved by the Assistant Director General of the Cluster on Sustainable Development and Health Environments. These Task Groups are the highest level committees within WHO for conducting health risk assessments.

Task Groups conduct a critical and thorough review of an advanced draft of the ELF EHC monograph and assess any risks to health from exposure to both electric and magnetic fields, reach agreements by consensus, and make final conclusions and recommendations that cannot be altered after the Task Group meeting.

The World Health Organization recognizes the important role played by non-governmental organizations (NGOs). Representatives from relevant national and international associations may be invited to join the Task Group as observers. While observers may provide a valuable contribution to the process, they can only speak at the invitation of the Chairperson. Observers do not participate in the final evaluation; this is the sole responsibility of the Task Group members. When the Task Group considers it to be appropriate, it may meet *in camera*.

All individuals who as authors, consultants or advisers participate in the preparation of the EHC monograph must, in addition to serving in their personal capacity as scientists, inform WHO if at any time a conflict of interest, whether actual or potential, could be perceived in their work. They are required to sign a conflict of interest statement. Such a procedure ensures the transparency and probity of the process.

When the Task Group has completed its review and the Coordinator (RAD) is satisfied as to the scientific consistency and completeness of the document, it then goes for language editing, reference checking, and preparation of camera-ready copy. After approval by the Director, Department of Protection of the Human Environment (PHE), the monograph is submitted to the WHO Office of Publications for printing. At this time a copy of the final draft is sent to the Chairperson and Rapporteur of the Task Group to check the proofs.

Extremely Low Frequency Environmental Health Criteria

This EHC addresses the possible health effects of exposure to extremely low frequency (>0 Hz – 100 kHz) electric and magnetic fields. By

far the majority of studies concern the health effects resulting from exposure to power frequency (50–60 Hz) magnetic fields; a few studies address the effects of exposure to power frequency electric fields. In addition, a number of studies have addressed the effects of exposure to the very low frequency (VLF, 3–30 kHz) switched gradient magnetic fields used in Magnetic Resonance Imaging, and, more commonly, the weaker VLF fields emitted by visual display units (VDU's) and televisions.

The ELF EHC is organized by disease category; separate expert working groups met in order to develop drafts addressing neurodegenerative disorders (chapter 7), cardiovascular disorders (chapter 8), childhood leukaemia (Section 11.2.1) and protective measures (chapter 13). The membership of these expert working groups is given below. Drafts of the other chapters were prepared by consultants, staff from WHO collaborating centres and by RAD Unit staff. These included Prof. Paul Elliot, Imperial College of Science, Technology and Medicine, UK, Prof. Maria Stuchly, University of Victoria, Canada, and Dr Bernard Veyret, ENSCPB, France, in addition to individuals who were also members of one of the expert working groups and/or the Task Group (see below). The draft chapters were individually reviewed by external referees prior to their collation as a draft document.

The draft EHC was subsequently distributed for external review. Editorial changes and minor scientific points were addressed by a WHO Editorial Group and the final draft was distributed to Task Group members prior to the Task Group meeting.

The Task Group met from October 3–7, 2005 at WHO headquarters in Geneva. The text of the EHC was subsequently edited for clarity and consistency by an Editorial Group consisting of Prof. Emilie van Deventer and Prof. Chiyoji Ohkubo, both from WHO, Geneva, Switzerland, Dr Rick Saunders, Health Protection Agency, Chilton, UK, Dr Eric van Rongen, Health Council of the Netherlands, Prof. Leeka Kheifets, UCLA School of Public Health, Los Angeles, CA, USA and Dr Chris Portier, NIEHS, Research Triangle Park, NC, USA. Following a final review by the Task Group and scientific and text editing, the EHC was published on the International EMF Projects website on 18 June 2007.

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ABBREVIATIONS

AC	alternating current
ACTH	adrenocorticotrophic hormone
AD	Alzheimer's disease
AF	attributable fraction
AGNIR	Advisory Group on Non-Ionising Radiation
ALL	acute lymphocytic leukaemia
ALS	amyotrophic lateral sclerosis
AMI	acute myocardial infarction
AML	acute myeloid leukaemia
aMT6s	6-sulphatoxymelatonin
AN	attributable number
BP	benzo(a)pyrene
CA	chromosomal aberrations
CAM	cell adhesion molecule
CBPI	cytokinesis-blocked proliferation index
CI	confidence interval
CNS	central nervous system
Con-A	concanavalin-A
Cx	connexin
DC	direct current
DENA	diethylnitrosamine
DMBA	7,12-dimethylbenz(a)anthracene
DNA	desoxyribonucleic acid
EAS	electronic access and security system
EBCLIS	electric blanket cancer Long Island study
ECG	electrocardiogram
EEG	electroencephalograms
EHC	Environmental Health Criteria
ELF	extremely low frequency
EM	electromagnetic
EMF	electromagnetic fields
ENU	N-ethyl-N-nitrosourea
ER	estrogen receptor
ERP	evoked or event-related potentials
ES	embryonic stem cells
FDTD	finite-difference time-domain
FFT	fast Fourier transformation
FSH	follicle stimulating hormone
GABA	gamma-aminobutyric acid
GCS	ceramide glucosyltransferase
GH	growth hormone
GJIC	gap junction intercellular communication
H2O2	hydrogenperoxyde
HIOMT	hydroxyindole-O-methyltransferase
HRV	heart rate variability

HSF	heat shock factor
hsp	heat shock protein
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronic Engineers
IEI	idiopathic environmental intolerance
IFN	interferon
Ig	immunoglobulin
IL	interleukin
JEM	job-exposure matrix
LAK	lymphokine activated killer
LH	lutening hormone
LIBCSP	Long Island breast cancer study project
LPS	lipopolysaccharide
LTP	long-term potentiation
MBM	mouse bone marrow
MN	micronucleus
MRI	magnetic resonance imaging
mRNA	messenger ribonucleic acid
MS	multiple sclerosis
NA	noradrenaline
NADH	nicotinamide adenine dinucleotide
NADPH	nicotinamide adenine dinucleotide phosphate
NAT	N-acetyl-transferase enzyme
NDI	nuclear division index
NGF	nerve growth factor
NHL	non-Hodgkin lymphoma
NIEHS	National Institute for Environmental Health Sciences
NIOHS	National Institute for Occupational Safety and Health
NK	natural killer
NMDA	N-methyl-D-aspartate
NMU	N-methylnitrosurea
NO	nitric oxide
NRPB	National Radiological Protection Board
ODC	ornithine decarboxylase
OHCC	ordinary high current configuration
8-OhdG	8-hydroxydeoxyguanine
OLCC	ordinary low current configuration
OR	odds ratio
PAGE	poly-acrylamide gel electrophoresis
PARP	poly-ADP ribose polymerase
PBMC	peripheral blood mononuclear cells
PHA	phytohemagglutinin
PKC	protein kinase C
RAD	Radiation and Environmental Health Unit
RF	radiofrequency
RFID	radiofrequency identification
RNS	reactive nitrogen species

ROS	reactive oxygen species
RR	relative risk
SCE	sister chromatid exchange
SD	standard deviation
SES	socioeconomic status
SMR	standardized mortality ratio
SIR	standardized incidence ratio
SPFD	scalar potential finite difference
SRR	standardized relative mortality risk ratio
TGFR	transforming growth factor- receptor
TMS	transcranial magnetic stimulation
TNF	tumour necrosis factor
TNFR	tumour necrosis factor receptor
TPA	12-0-tetradecanoylphorbol-13-acetate
TSH	thyroid-stimulating hormone
TWA	time-weighted average
UG	underground
UKCCSI	United Kingdom childhood cancer study investigators
ULF	ultra low frequency
UV	ultraviolet
VDU	visual display unit
VHCC	very high current configuration
VLCC	very low current configuration
VLF	very low frequency
WBC	white blood cell
WHO	World Health Organization

Units

A	ampere
kA	kiloampere, 10^3 ampere
eV	electronvolt
F	farad
μ F	microfarad, 10^{-6} farad
Hz	hertz
kHz	kilohertz, 10^3 hertz
MHz	megahertz, 10^9 hertz
J	joule
kJ	kilojoule, 10^3 joule
M	molar
nM	nanomolar, 10^{-9} molar
N	newton
pN	piconewton, 10^{-12} newton
V	volt
kV	kilovolt, 10^3 volt
mV	millivolt, 10^{-3} volt
μ V	microvolt, 10^{-6} volt

T	tesla
kT	kilotesla, 10^3 tesla
mT	millitesla, 10^{-3} tesla
μ T	microtesla, 10^{-6} tesla
nT	nanotesla, 10^{-9} tesla
W	watt
kW	kilowatt, 10^3 watt
Ω	ohm
k Ω	kiloohm, 10^3 ohm