

## **WHO Framework for Developing EMF Standards**

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### **INTRODUCTION**

The following provides the elements of a draft WHO Framework for developing EMF standards that will be completed by the end of 2003. This paper gives a summary of the various components of the Framework, but the details of the finally approved Framework may change slightly. For the final version, readers are referred to the EMF Project web site when completed: <http://www.who.int/peh-emf/standards/en/>.

Globalisation of trade and the rapid expansion of devices using electromagnetic fields (EMF) has focused attention on differences existing in exposure guidelines or standards limiting exposure to EMF. In some cases, the differences in the exposure limits are large. Since protecting populations is part of the political process, it is expected that different countries may choose to provide different levels of protection against environmental hazards, responding to their citizens' wishes.

However, some of the disparities in EMF standards around the world appear not to arise from this fact alone. In some cases they seem to have arisen from different interpretations of the scientific data and from different philosophies for public health standards development. Such differences in EMF exposure guidelines might reflect, in part, deficiencies in communications among scientists between different regions. Large disparities between national limits and international guidelines can increase public anxiety. This anxiety is further exacerbated by the introduction of new technologies, often associated with increased EMF exposure.

In November 1998, WHO's International EMF Project commenced an activity aimed at the harmonization of EMF standards worldwide. Over 45 countries and 8 international organizations are involved in WHO's International EMF Project, providing a unique opportunity to bring countries together to develop a framework for harmonizing EMF standards and to encourage the development of exposure limits and other control measures that provide the same or similar level of health protection for all people. Such an endeavour is in line with the World Trade Organization (WTO) requirement for countries who are a signatory to the General Agreement on Tariffs and Trade (GATT) to harmonize with international standards, where they exist.

A number of national organizations have formulated guidelines establishing limits for occupational and residential EMF exposure. There is currently one international guideline that has been widely adopted into national legislation: the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998, <http://www.icnirp.org>).

Public exposure to EMF is regulated by a variety of voluntary and legal limits. Present guidelines for EMF exposure are designed to avoid established hazards, from short and long term exposure,

with a margin of safety incorporated into the limit values. Currently, the international guidelines focus on prevention of acute neural and cardiac effects at lower frequencies, and heating at radio frequencies. Evidence of potential long-term effects is considered insufficient as a basis for limiting human exposure.

A summary of the national EMF standards adopted around the world is available from the WHO's International EMF Project website at <http://www.who.int/docstore/peh-emf/EMFStandards/who-0102/Worldmap5.htm>

## STANDARDS HARMONIZATION

The International Standards Organization (ISO) defines harmonized standards as standards on the same subject approved by different standardizing bodies, that establish interchangeability of products, processes, and services, or mutual understanding of test results or information provided according to these standards. The purpose of harmonized standards is to converge international methods for developing and administering standards as well as developing compatible regulations or standards.

***The purpose of the WHO EMF Standards Harmonization Project is to define a framework for developing guidelines for protection of the public and workers from exposure to EMF. In this project, EMF is defined as electromagnetic fields in the frequency range 0 to 300 GHz.***

Since much recent technology uses various parts of the electromagnetic spectrum, there is new impetus for having harmonized standards for EMF exposure. Among the many benefits of the standards harmonization of importance are:

- Increased public confidence that governments and scientists agree on health risks
- Informed debate and better understanding about EMF
- Uniform health protection

This Framework addresses the following issues:

- Criteria used to evaluate research results for standards development
- Requirements for a scientific rationale to support limit values
- Model for developing standards
- Methods for determining compliance
- How to evaluate inconsistencies and gaps in the evidence
- When research data are absent, in particular frequency ranges or exposure conditions, how and with what degree of confidence can results be extrapolated to other frequencies or intensities
- How should precautionary measures be determined and considered if needed
- Standard concepts and terminology.

This Framework is intended for national advisory and/or regulatory bodies reviewing the basis of their standards, or developing new standards. This document does not include

- guidance on the principles and practice of measurements

- electromagnetic compatibility (EMC) issues, including equipment design
- exposure of patients under medical treatment or diagnosis
- setting emission limits for specific types of devices

## RESEARCH EVALUATION

Guidelines are based on scientific data related to health effects and require consistent information from multiple studies and disciplines published in the peer reviewed scientific literature (Kheifets et. al., 2003). In principle, well designed and well conducted studies should be published regardless of the outcome, because negative results (no effect observed) are as useful as positive studies (effect observed) in the larger context of the database needed for evaluation of the scientific evidence. In practice, this is often not the case, and the possibility of such publication bias should be considered. [Note: This is not only decided by the authors, but also by the journal editors. Some journals do not publish no-effect papers. They think negative results are not worth publishing. Publication bias of this type can result in an unbalanced database.] When evaluating research results, it is important to verify that the study design and power were sufficient to detect an effect at a given exposure condition.

### A. Biological effects and adverse health effects

A **biological effect** is any physiological response related to EMF exposure. The existence of biological and health effects may be established when the research results are replicated in independent laboratories or supported by related studies. This is further strengthened when:

- there is agreement with accepted scientific principles
- the underlying mechanism is understood
- a dose-response relationship can be determined

Exposure to EMF may cause different biological effects, with a variety of consequences for a human being. Many biological effects may be without any known adverse or beneficial consequences. Some effects may result in pathological conditions, while others may have beneficial consequences for a person. Annoyance or discomforts caused by EMF exposure may not be pathological per se but, if substantiated, can affect the physical and mental well being of a person and the resultant effect may be considered as an **adverse health effect**. A health effect is thus defined as a biological effect that is detrimental to health or well-being. According to the WHO Constitution, health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

### B. Review of the scientific literature

There needs to be a **comprehensive and critical review** of peer-reviewed scientific literature. The review should be undertaken by qualified experts, recognized by the scientific community, who examine the original scientific database. These experts should be multidisciplinary and include, for example, epidemiologists, biologists, toxicologists, physicists and engineers.

Only peer-reviewed scientific studies should be included in the review. Although the rigour of peer review varies widely among scientific journals, peer reviewed work is generally of higher quality. While peer review adds confidence in the study results, additional review is necessary to evaluate study design, conduct and an analysis of each report, and to compare them with the

results of other studies. Peer-reviewed reports not published in scientific journals may be considered, but conference abstracts are of little value as they generally receive no peer review, contain sparse information, and cannot be considered as the final outcome of an experiment until all results are available, properly analysed and presented in the publication.

An important task of the expert panel is to assess the relevance of the paper for standards-setting. Many papers may contain excellent research. However, they may not be relevant for standards setting, i.e. when they study effects at field levels well above the limit values for established adverse health effects.

### C. Criteria for research evaluation

In general, studies should include a clear statement of objectives and hypotheses, a clear description of the exposure methods, experimental design and statistical analysis, and a clear description of the biological systems and the experimental procedures. To be most useful, studies should document the exposure conditions which they employ and describe, as appropriate, field characteristics, polarization, source of radiation, radiation characteristics, exposure duration, specific absorption rate (SAR), induced current and E field in tissue, and temperature (temperature in sample using non RF perturbing probes) as appropriate. A set of criteria for human, animal and laboratory studies are presented in Appendix A, and are intended as a guide only. It should be kept in mind, that useful data may be obtained from studies that do not fulfil all these criteria.

### D. Process of evaluation

A decision must first be made whether the available evidence allows the identification of an exposure hazard, i.e. an adverse health effect that is caused by an EMF exposure. In spite of the evaluation process described above, uncertainties and inconsistencies can still be encountered in comparative evaluations of the literature. Thus, it is recognized that any evaluation is at least partly based on judgements. Various schemes and criteria exist in order to make this judgement process transparent, among these the Bradford Hill criteria (Hill, 1965) and the IARC scheme for assessment of carcinogenicity (IARC 1987) can be mentioned.

For further risk assessment (i.e., an actual estimate of risk in the general population or in a specific group) the selected studies should provide additional, mostly quantitative data. Such data would include:

- the definition of the biologically effective quantity, which may vary with tissue or organ,
- exposure-effect relationship, and identification of a threshold, if any,
- exposure distribution and identification of sub populations with high exposure, and
- differences in susceptibilities within a population.

This information in whole or in part is necessary for the development of exposure guidelines.

## MODEL FOR DEVELOPING STANDARDS OR GUIDELINES

Exposure limits are intended to protect against adverse health effects of EMF exposure. When developing guidelines, the effects to be prevented need to be specified. Because short- and long-term adverse consequences of EMF exposure could vary across the entire range from trivial to life threatening, a balanced judgement is required before deciding on exposure guidance.

### A. Basis For Standards Or Guidelines

For standards or guidelines aimed at protecting people, ideally the data should be derived from human studies. The relationship between exposure and certain short-term biological effects can sometimes be evaluated from human laboratory studies, whereas, data on long-term effects on people are mainly derived from epidemiological studies. However, in spite of their direct relevance, the results of epidemiological studies can never provide sufficient evidence of causal relationships without biological plausibility or supportive data from experimental studies, especially when the results are inconsistent, suggested risks are small and thus susceptible to bias.

Animal experiments are valuable in the analysis of the biological effects and mechanisms, as they involve a complete organism, including all relevant in vivo reactions. Experimental in vitro studies may also be useful in clarifying whether a causal relationship exists. In vitro studies can provide detailed information on biophysical mechanisms at the level of molecular, cellular or intercellular interactions.

The results of animal and in vitro experiments need to be carefully evaluated to be extrapolated to humans. Based on the premise that the mechanism at the target level is the same in the models and in the human body, the dose-effect relationships found in the model may be adjusted for application to humans, using the biologically effective quantity. In general, supportive human data are important for a full evaluation of the relevance to human health of the results from animal studies.

### B. Safety factors

Some uncertainties in the data can be addressed by **safety factors**, and the exposure limits accordingly are set below the thresholds of observed adverse effects. Examples of sources of uncertainty about the dose-response or evidence for threshold levels include the extrapolation of animal data to effects on people, differences in the physiological reserves of different groups of individuals with corresponding differences in susceptibility, statistical uncertainties in the dose-response function, and possibility of combined effects of exposures at different frequencies and other environmental stresses.

### C. Basic Restrictions And Reference Levels

Limits on EMF exposure are termed **basic restrictions** and are expressed in terms of selected quantities that closely match all known biophysical interaction mechanisms that may lead to adverse effects. Protection against adverse health effects is assured if these basic restrictions are not exceeded. Identification and quantification of various adverse effects of EMF exposure on health and well being are difficult at best, and such judgements require extensive experience and expertise. Some of the acute effects can be quantified with reasonable precision and so

derivation of guidelines will not require a substantial reduction below the observed threshold levels. When the precision and certainty of the relationship between exposure and adverse outcome is lower, a larger reduction may be warranted. There is no rigorous basis for determining precise safety factors. The magnitude of the reduction is a matter of judgement.

Because basic restrictions are often specified as quantities that may be impractical to measure, **reference levels** utilizing quantities that are practical to measure, are provided as an alternative means of showing compliance with the basic restrictions. It should be noted that the use of reference levels as in the ICNIRP guidelines would, in many cases, introduce additional safety ,” as they correspond to basic restrictions under worst case exposure conditions. Exceeding the reference levels does not necessarily imply that the basic restrictions are exceeded. In this case, demonstration of compliance with the basic restrictions is evidence of compliance with the standard or guideline.

#### D. Is There A Need For Multiple Tiers?

Different groups in a population may have differences in their ability to tolerate a particular EMF exposure. Children, the elderly, and some chronically ill people may have a lower tolerance for one or more forms of EMF exposure than the rest of the population. Thus it may be useful or necessary to develop separate guideline levels for different population groups. This can be accomplished by the use of larger safety factors for special population groups in the determination of the guideline limits.

A complementary approach is to distinguish between members of the general public and adult working population. Such distinction acknowledges the ability to better control occupational exposures and inform workers. In its exposure guidelines, ICNIRP defines occupational and public exposures in general terms. When applying the guidelines to specific situations, the appropriate authority in each country should decide whether occupational or general public guideline levels are to be applied, according to existing (national) rules or policies.

Many forms of EMF find application in medical practice, often at exposure levels that are much greater than normal population exposure levels. EMF exposures that are part of medical treatment or diagnosis are usually considered to lie outside the scope of exposure guidelines as they involve different risk-benefit considerations.

#### E. Methods For Determining Compliance

Exposure guidelines should provide general practical information on measurable levels that correspond to basic restrictions on EMF exposure. Once national exposure standards are developed, they may be placed within a legal framework and based upon international guidelines and recommendations.

Further technical advice on special exposure situations requires physics and engineering expertise to develop practical measures to assess and/or to enable assessment of compliance with exposure guidelines. This includes guidance on the principles and practice of measurements, design of equipment and/or shielding to reduce exposure, and where appropriate, setting emission limits for specific types of devices. Organizations carrying out such tasks are the international, regional and national technical standards bodies, including the International Electrotechnical Commission (IEC), the International Telecommunication Union (ITU), the

International Organization for Standardization (ISO), the Institute of Electrical and Electronics Engineers (IEEE) and the European Committee for Electrotechnical Standardization (CENELEC).

Uncertainty in measurements used to evaluate compliance is a practical problem best handled by organizations responsible for the development of compliance methods. However, it is worth noting that better technical measurement techniques and computational dosimetry are now available, and when properly incorporated in guidelines, these will reduce uncertainty and thus the magnitude of safety factors.

#### F. Costs Of Compliance And Direct Health Benefits

Public debate often focuses on the potential detriments of electromagnetic fields, but often ignores its benefits. Without electricity, society would have a greatly reduced quality of life with a negative impact on health. Similarly, broadcasting and telecommunications have become a part of modern life. It is important to weigh the benefits of the technology against the hazard, should one exist.

**The distribution of exposure levels and the fraction of the population that may be exposed at each level are important factors in relation to implementing exposure guidelines for EMF. Often there are limited data available on such distributions, but where they exist, they can provide an important insight on the social and economic impact of implementation of recommended guidelines for EMF exposure. Safety of workers and the public is of utmost importance when setting basic restrictions. In some countries, economic considerations can enter into play when setting reference levels to avoid unnecessary economic burden. To that end, governments should consider undertaking cost/benefit analyses before adoption of guidelines to gather a national perspective on the matter.**

### **PRECAUTIONARY ASPECTS**

The establishment of adverse health effects form the rationale for current EMF exposure guidelines. However, while scientific research is continuing, in some situations the data are insufficient to allow definite evaluation of potential adverse human health effects related to EMF.

Various approaches to protection have been suggested to deal with uncertainty. In recent years, increased reference has been made to cautionary policies, and in particular the Precautionary Principle. A cautionary policy for EMF should be adopted only with great care and deliberation. A principal requirement is that such policies be adopted in such a way not to undermine scientific assessments of risk and science-based exposure limits. The WHO International EMF Project is currently finalizing a practical framework for developing health protection measures in areas of scientific uncertainty. The goal is to consider precautionary measures to address concerns in areas where there is uncertainty about risks to health, i.e. where the science is not yet adequate for rigorous risk assessments.

## STANDARD CONCEPTS AND TERMINOLOGY

Consistent international guidance requires that all countries have a common understanding the meaning of terms and concepts used. Many countries having EMF standards use different terminology which can lead to confusion and misunderstanding. Concepts and terms used in this document are given below. It is recommended that the same definitions be used for all national standards. Definition of concepts and terminology to be included in the final Framework will be taken from internationally accepted sources.

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## APPENDIX A

### CRITERIA FOR RESEARCH STUDIES

#### *Human studies*

Investigations in human beings of associations between exposure levels and adverse health effects can utilize either *human laboratory* or *epidemiological* studies. Such studies require the fulfilment of a number of criteria that effectively take into account and reduce possible impacts of bias, confounding, and chance variation in the interpretation of results. Bias is the operation of factors in the study design or execution that lead erroneously to a consistently weaker or stronger association than actually exists between exposure and the adverse-health end-point under study. Confounding occurs in situations in which a relationship is made to appear stronger or weaker than it actually is as a result of an association between the exposure under study and another factor that is causally associated with the adverse health effect. Lack of appropriate action to reduce the impact of these sources of error can decrease the credibility and the final weight given to the results of the study.

Guidelines on the conduct of high-quality *epidemiology* are given in Beaglehole *et al.* (1993) or Ahlbom (1996) and, for human trials, in Pocock (1983). A summary of these criteria is given below.

1. The study design must lead to maximum efficiency, both in reaching study objectives and in utilizing resources. Depending on the nature of suspected relationships between exposure and adverse health effects, as well as the specific study aim, various designs, such as case-control or cohort, may be appropriate.
2. Ascertainment of an adequate population sample size and statistical power should be based on prior statistical evaluations. These are important considerations when small elevations in relative risk are expected.
3. Study populations should be well defined at the outset. Hypotheses to be investigated must be explicitly and clearly stated. The manner by which cases of adverse health are ascertained must also be clearly stated, and case identification must be independent of exposure.
4. In case-control studies, controls should be appropriately chosen, taking into account the specific study aim and design. This enables the study to minimize the impact of factors other than those under study.
5. Regardless of study design, the minimization of non-response or non-participation is important, both to achieve the required study sample size, and to minimize the possibility of bias due to selective non-response (e.g., related to both disease and exposure status). A high participation rate may be encouraged by the careful dissemination of information on the study and the involvement of representatives of study groups in the planning process.
6. Both in study design and analysis, researchers should take into account the possibility of confounding factors. Data on potential confounders should be collected and appropriate statistical analysis used to minimize the effect of confounding on results and conclusions. It is recognized that identification of possible confounders may be difficult given the often-limited knowledge about causal factors that may affect the adverse-health end-point(s).
7. Investigators should characterize the exposure as precisely as possible. Data on different levels of exposure, its duration and temporal location should be collected, and the dosimetric

measure utilized should be identified. Such data, and successful ascertainment and utilization of them should be taken into account at both the design and analysis stage of the study. It is important that the exposure is assessed in a way that is not related to the case status. Preferably, exposure assessment should be on an individual basis. It is recognized that, in practice, there may be a need to utilize surrogate measures of exposure. Categorizing exposure into groups can lead to misclassification. Such non-differential exposure misclassification often produces a bias towards the null, i.e. it tends to underestimate real effects.

8. In light of the complexity of the topic, studies should be designed and implemented using expertise from all appropriate scientific disciplines.
9. The method(s) used for statistical analysis should be appropriate for the purpose of the study, and they should be clearly described.
10. When sophisticated or non-standard analytical procedures are used, researchers should also report a descriptive analysis of the data. At a minimum, the number of exposed and unexposed cases and controls in case-control studies, and the number of observed and expected cases in cohort studies, should be provided. The effects of factors investigated (potential confounders) other than the exposure of interest, should also be reported.
11. Well-designed and -conducted studies should be published regardless of the outcome, since negative results are as useful as positive studies in the context of the database.
12. To allow combined analysis of several studies in the future, appropriate means to enable this, such as the use of standardized questionnaires, methods and reporting data, should be considered.

In *human experimental* studies, such as clinical trials or provocation studies, in addition to the points raised above, good practice should include:

1. A double-blind design, as appropriate to the study aim.
2. Appropriate and well described criteria for inclusion and exclusion of volunteers.
3. Adherence to relevant ethical rules and restraints.

### ***Animal studies (in vivo)***

All known human carcinogens studied adequately in experimental animals have produced positive results in one or more animal species (IARC, 1995). In general, if adequate data are absent from human studies, it is biologically plausible and prudent to regard studies that provide sufficient evidence of disease in animals, as evidence of disease risk in humans (IARC, 1995). However, animal models need to be relevant to diseases reported in humans. The possibility that exposure may cause a certain disease through a species-specific mechanism which does not operate in humans should also be considered. Consistency of positive results using a variety of animal models is important.

1. An assessment of disease from exposure involves several considerations of qualitative importance. These include the experimental conditions under which the study was performed (exposure regimen, animal species, strain, sex, age, and duration of follow-up), the consistency of the results across species and target organs, spectrum of disease outcomes (e.g., for cancer, the spectrum of neoplastic response from preneoplastic lesions and benign tumours to malignant neoplasms), and the possible role of modifying factors.

2. Complete characterization of exposure and related environmental factors is essential for animal studies.
3. The probability that a disease will occur may depend on the species, sex, strain, age of the animal, and the duration of exposure. Evidence of an increase in disease with level of exposure strengthens the inference of a causal association. The form of the dose-response relationship is important and may vary widely. For carcinogenesis, both DNA damage and increased cell division are important aspects.
4. If human studies suggest, for example, a 25% increase in a rare cancer, the animal studies should be sensitive enough to detect this small effect. The animal model should be sufficiently well characterised so that the basic level of cancer incidence is known, and that it is low enough to allow the detection of increases resulting from exposure, if they occur. If studies are negative, they should be able to demonstrate this with some assurance and should indicate the magnitude of risk they had power to detect. Many negative studies do not have enough power to detect effects of interest.
5. When considering statistical analyses of long-term animal experiments, adequate information should be given for each treatment group. These include the numbers of animals studied and the number examined histologically, the distribution of disease types, and survival time. Types of analyses and statistical methods used should be those generally appropriate and refined for this purpose (Gart, 1986).

#### ***Laboratory studies (in vitro)***

Detailed guidelines on the conduct of high quality laboratory research can be found in the good laboratory practice guidance of the US Food and Drug Administration (FDA, 1993) and in the specifications of the US National Toxicology Program (NTP, 1992). A summary of the essential points is given below.

Experimental techniques, methods and conditions should be as completely objective as possible and based on biological systems appropriate to the endpoints studied. Safeguards from bias, such as double-blind techniques, blind scoring or codes, should be employed where appropriate. Where separate controls are used, an effort should be made to employ both positive and negative controls. The sensitivity of the experiment should be adequate to ensure a reasonable probability that an effect would be detected, if indeed one exists.

1. All data analyses should be fully and completely objective, with no relevant data deleted from consideration, and with uniform use of analytical methods. Data from experiments within the same protocol should be internally consistent. When results are reported as ratios, the underlying data should also be reported, or be available for in-depth analysis.
2. Published descriptions of methods should be given in sufficient detail that a critical reader would be convinced that all reasonable precautions were taken to meet requirements 1 and 2, and that other researchers can reproduce them.
3. Results should be statistically significant using appropriate tests.
4. Results should be quantifiable and susceptible to confirmation by independent researchers. Preferably, the experiments should be repeated and the data confirmed independently, or the claimed effects should be consistent with results of similar experiments, for which the biological systems involved are comparable. Theories (e.g., for mechanisms of interaction) should make sufficiently concrete predictions that they can be tested experimentally and be capable of being verified, if correct.

5. Results should be viewed with respect to previously accepted scientific principles before ascribing them new ones. Research findings pointing to previously unidentified relationships should be carefully evaluated and appropriate additional studies should be conducted before the findings are accepted.