FACT SHEET

ON THE GUIDELINES FOR LIMITING EXPOSURE TO TIME-VARYING ELECTRIC AND MAGNETIC FIELDS (1 Hz – 100 κHz) PUBLISHED IN HEALTH PHYS 99(6):818-836; 2010.

ICNIRP is the internationally recognized body that sets guidelines for protection against adverse health effects of non-ionizing radiation. It has recently published Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz); this fact sheet describes the content of these guidelines and their scientific background.

The guidelines replace previous recommendation given by ICNIRP for this frequency range. They are derived from the current scientific knowledge as described in extensive reviews especially those of the World Health Organization and ICNIRP. Some of the recommendations given in the new document deviate from former ones. Where appropriate, such differences are explained in detail.

The main interaction of low frequency time-varying electric and magnetic fields (EMF) with the human body is the induction of electric fields and associated currents in the tissues. In addition, exposure to low frequency electric fields can cause surface electric charge effects.

The responsiveness of electrically excitable nerve and muscle tissue to electric stimuli including those induced by exposure to low frequency electric and magnetic fields has been well established. A minimum electric field threshold of about 4-6 V m^{-1} has been calculated for peripheral nerve stimulation, using a heterogeneous human model and data from volunteer exposure to the switched gradient fields of magnetic resonance (MR).

The most robustly established effect of electric fields below the threshold for direct nerve or muscle excitation is the induction of magnetic phosphenes, a perception of faint flickering light in the periphery of the visual field. They are thought to result from the interaction of the induced electric field with electrically excitable cells in the retina. This is formed as an outgrowth of the forebrain and can be considered a good but conservative model of processes that occur in CNS tissue in general. The threshold for induction of phosphenes in the retina has been estimated to lie between about 50 and 100 mV m^{-1} at 20 Hz. The evidence for neurobehavioral effects on brain electrical activity, cognition, sleep and mood in volunteers exposed to low frequency electric and magnetic fields is much less clear.

The scientific data available so far do not indicate that low frequency electric and/or magnetic fields affect the neuroendocrine system in a way that these would have an adverse impact on human health. There is no substantial evidence for an association between low frequency exposure and diseases such as Parkinson's disease, multiple sclerosis, and cardiovascular diseases. The evidence for an association between low frequency exposure and Alzheimer´s disease and amyotrophic lateral sclerosis is inconclusive. The evidence for an association between low frequency exposure and developmental and reproductive effects is very weak.

A considerable number of epidemiological reports, published particularly during the 1980s and '90s, indicated that long term exposure to 50-60 Hz magnetic fields might be associated with an increased risk of childhood leukemia. Two pooled analyses indicate that an excess risk may exist for average exposures exceeding 0.3-0.4 μT. However, a combination of selection bias, some degree of confounding and chance could possibly explain the results. In addition, no biophysical mechanism has been identified and the experimental results from the animal and cellular laboratory studies do not support the notion that exposure to 50-60 Hz magnetic fields is a cause of childhood leukemia.

It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency magnetic fields is causally related with an increased risk of childhood leukemia is too weak to form the basis for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well established adverse effects and serve as the basis for guidance.

Based on the review of the scientific evidence summarized above, ICNIRP recommends the following limits on exposure:

Occupational exposures: In the frequency range 10 Hz to 25 Hz, occupational exposure should be limited to fields that induce electric field strengths in CNS tissue of the head (i.e., the brain and retina) of less than 50 mV m^{-1} in order to avoid the induction of retinal phosphenes. These restrictions should also prevent any possible transient effects on brain function. These effects are not considered to be adverse health effects; however, ICNIRP recognizes that they may be disturbing in some occupational circumstances and should be avoided, but no additional reduction factor is applied. At lower frequencies the limit value for the induced electric field strength rises in reverse proportion to frequency. At higher frequencies, up to 400 Hz the limit value rises proportional to frequency. At frequencies in the range 400 Hz to 3 kHz occupational exposure should be limited to fields that induce electric field strengths in all parts of the body of less than 800 mV m^{-1} in order to avoid peripheral and central myelinated nerve stimulation. At frequencies above 3 kHz the limit value rises proportionally with frequency.

In controlled environments, where workers are informed about the possible transient effects, exposure in the range 1 Hz to 400 Hz, should be limited to fields that induce electric fields in the head and body of less than 800 mV m^{-1} in order to avoid peripheral and central myelinated nerve stimulation. This value has been obtained by applying a reduction factor of 5 to the peripheral nerve stimulation threshold of 4 V m^{-1} in order to account for the uncertainties described above. These restrictions rise proportionally with frequency above 3 kHz.

General public exposures: In the frequency range 10 Hz to 25 Hz, general public exposure should be limited to fields that induce electric field strengths in CNS tissue of the head (i.e., the brain and retina) of less than 10 mV m^{-1}, in order to avoid the induction of retinal phosphenes. These restrictions should also prevent any possible transient effects on brain function. A reduction factor of 5 has been applied to the phosphene threshold of 50 mV m^{-1} in order to account for uncertainties. Above and below this frequency range, the basic restriction rises. At 1000 Hz it intersects with basic restrictions that protect against peripheral and central myelinated nerve stimulation. Here, a reduction factor of 10, with respect to the above mentioned stimulation threshold of 4 V m^{-1}, results in a basic restriction of 400 mV m^{-1}, which should be applied to the tissues of all parts of the body.

The rationale for these guidelines limits can be found in full in "Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz) Health Physics 99(6):818-836; 2010."

The main changes, compared with previous recommendations by ICNIRP are:

- The basic restrictions are based on induced internal electric fields, instead of induced current density, as this is the physical quantity that determines the biological effect. Previous health risk

assessments were based on induced current density as most experimental data at that time were based on this metric. Now, sufficient information based on induced internal electric fields is available to use this metric in guidelines.

- Previous guidelines were set to prevent effects on nervous system functions and a limitation of induced current density in CNS tissue only was recommended. Phosphenes were not considered to be an adverse effect. ICNIRP now considers the effects on the retina as a model of effects in the brain and the phosphene threshold provides a basis for limiting exposure as specified above. In addition, stimulation effects on peripheral and central myelinated nerves have been included as explained above. This leads to an exposure limitation in any tissue of the body. The limit values were based on current scientific evidence and not simply converted on the basis of tissue conductivity from the former guidance on induced current density.

The table summarizes the basic restrictions

Exposure characteristic	Frequency range	Internal electric field (V m^{-1})
Occupational exposure		
CNS tissue of the head	1 - 10 Hz	0.5 / f
	10 Hz - 25 Hz	0.05
	25 Hz - 400 Hz	2 x 10^{-3} f
	400 Hz - 3 kHz	0.8
	3 kHz - 10 MHz	2.7 x 10^{-4} f
All tissues of head and body	1 Hz - 3 kHz	0.8
	3 kHz - 10 MHz	2.7 x 10^{-4} f
General public exposure		
CNS tissue of the head	1 - 10 Hz	0.1 / f
	10 Hz - 25 Hz	0.01
	25 Hz - 1000 Hz	4 x 10^{-4} f
	1000 Hz - 3 kHz	0.4
	3 kHz - 10 MHz	1.35 x 10^{-4} f
All tissues of head and body	1 Hz - 3 kHz	0.4
	3 kHz - 10 MHz	1.35 x 10^{-4} f

Notes:
- f is the frequency in Hz
- All values are rms
- in the frequency range above 100 kHz, RF specific basic restrictions need to be considered additionally.

Reference levels: Reference levels have been determined by mathematical modeling for the exposure conditions where the variation of the electric or magnetic field over the space occupied by the body is relatively small, i.e., uniform exposures. They are calculated for the condition of maximum coupling of the field to the exposed individual, thereby providing maximum protection. Frequency dependence and dosimetric uncertainties were taken into account. At the power frequency (50 Hz) the reference levels for occupational exposure are 10 kV m^{-1} for the electric field, and 1 mT for the magnetic field. With

respect to general public exposure the reference levels are 5 kV m^{-1} for the electric field and 200 µT for the magnetic field.

For a very localized source with a distance of a few centimeters from the body, the only realistic option for the exposure assessment is to determine dosimetrically the induced electric field, case-by case. With greater distances the distribution of the field becomes less localized but is still non-uniform, in which case it is possible to compare the spatial average along the body or part of it with the reference levels. Contact current may result in shock and burn hazards. Therefore reference levels for contact current are given for frequencies up to 100 kHz.

The main changes compared to the previous recommendations are:

- While in 1998 dosimetric considerations were based on simple geometrical models, the new guidelines use data from computational simulations based on anatomically detailed human body models.
- The revised basic restrictions as well as the dosimetric models used result in reference levels that deviate in some areas from previous ones. There is a tendency for magnetic field reference levels to be less conservative, whereas the electric field reference levels are, with some exceptions, basically unchanged.

Additional advice is given on how to apply the guidelines in the case of simultaneous exposure to electric and magnetic fields, to multiple frequency fields and to non-sinusoidal fields. There is no fundamental change compared with previous advice.

Protective Measures: ICNIRP notes that protection of people exposed to electric and magnetic fields could be ensured by compliance with all aspects of these guidelines. Appropriate protective measures must be implemented when exposure results in the basic restrictions being exceeded. Engineering controls should be undertaken in conjunction with administrative controls. In the workplace, additionally personal protection measures can be used, but these should be regarded as a last resort. It is also essential to implement rules that will prevent interference with medical electronic devices, detonation of electro-explosive devices, and fires and explosions resulting from ignition of flammable materials by sparks. All this is in line with previous advice.

Long-Term Effects: As noted above, epidemiological studies have found that everyday chronic low-intensity power frequency magnetic field exposure is associated with an increased risk of childhood leukemia. However, laboratory studies have not supported this association and a causal relationship between magnetic fields and childhood leukemia or any other long term effect has not been established. The absence of established causality is the reason why the epidemiological results have not been addressed in the basic restrictions. ICNIRP is well aware that these epidemiological results have triggered concern within the population in many countries. It is ICNIRP´s view, that this concern is best addressed within the national risk management framework. Risk management in general is based on many different aspects, including social, economic, and political issues. ICNIRP in this context provides scientifically based advice only. Additional risk management advice, including considerations on precautionary measures, has been given for example by the World Health Organization and other entities.

Further details can be found in Health Physics 99(6):818-836; 2010.