BASIC CRITERIA FOR ELF-STANDARDS

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ABSTRACT

Since possible late effects resulting from ELF-field exposure have not definitely been proven standards are based on acute effects. The established basic limits (i.e. induced current densities) and derived limits (i.e. electric and magnetic field strengths) are summarized. Additionally, contact currents, interferences with medical implants and field perception must be considered for establishing intervention levels, especially, with regard to the aspects of preventive public health care.

INTRODUCTION

Though several epidemiological studies suggest, that a weak association exists between the exposure to ELF-fields and an increase of various kinds of cancer, a final risk assessment of long-term continuous exposure to ELF-fields is so far not possible. It has not definitely been proven, that the electric and magnetic ELF-fields occuring at working places or in every-day life are mutagenic or cancerogenic. The main critical points are concerning statistical evaluation, the insufficient determination of the field strength during the exposure and dose-effect relationships, furthermore, the inadequacy in the demarcation of concomitant factors and the absence of known interaction mechanisms. The final clarification of the question of possible late effects requires further elucidation. Therefore, for deriving standards, the non-stochastic ELF-field effects are well in the foreground [1,2].

ACUTE FIELD EFFECTS

Electric and magnetic ELF-fields can generate - due to different interaction mechanisms - electric field strengths (in V/m) and electric current densities (in mA/m^2) within the body. These tissue field strengths and current densities can produce - dependent on their intensity - biological effects. Although the electric tissue field strength is the basic quantity responsible for the biological effects, in most cases dose-effects-relationships are given in terms of the current density. Both of these quantities are connected via the electric conductivity.

No biological effects are scientifically confirmed so far below about 1 mA/m^2. Current densities between 1 and 10 mA/m^2 are corresponding to the endogenous background level of current densities in most organs and tissues of the body [2,3]. On the surface of electrically active nerve or muscle cells current densities of up to 1000 mA/m^2 can occur for short times.

From in-vitro laboratory studies using current densities between about 1 and 10 mA/m^2 some minor biological effects have

been reported. Some of these effects were observed only at distinct frequencies and field strengths ("windows"). Examples include changes in the calcium-efflux from preparations of brain-tissue following exposure of 16 Hz-electric or magnetic fields, modified calcium - uptake of lymphocytes following magnetic field exposure, and inhibition of melatonin synthesis by the pineal gland following exposure to weak static magnetic fields. The significance of these findings with human beings is not clear.

ELF-fields of relatively high intensity, producing internal body current densities exceeding about 10 mA/m^2, can cause some biological effects which cannot be ignored. Examples are enhancement of DNA synthesis, alteration of the molecular weight distribution during protein synthesis, delay of the mitotic cell cycle, blocking of the action of parathyroid hormone at the site of its plasma membrane receptor, and inhibition of the cytotoxicity of T-lymphocytes.

A systematic evaluation of the actually induced currents and field strengths at the tissue and cellular level of these findings is complicated by the following facts:
- large variations of the exposure conditions and,
- lack of details on the geometry of the biological samples.

Furthermore, the lack of reproducible results between different laboratories limit the interpretaton. Since dose-response relationships have not yet been identified, systematic determinations of threshold values for tissue field strengths are urgently needed.

Controlled laboratory studies on volunteers exposed for short periods to electric field strengths up to 20 kV/m or magnetic flux densities up to 5 mT revealed no adverse clinical or significant physiological changes. These data do not exclude that health effects may occur by long term exposure. The thresholds for stimulation of excitable cells are above 100 mA/m^2; for frequencies above about 300 Hz these thresholds increase proportionally with the frequency [1].

In addition to effects caused by induced tissue field strengths, there exist surface effects due to electric field exposure resulting in sensory perception and, furthermore, perception of transient or steady electric currents occurring from touching charged objects in electric fields. At 50/60 Hz a field strength of 20 kV/m is the perception threshold of 50% of people for sensations from their head hair or of tingling between body and clothes. A small percentage of people can perceive a field strength of 2 to 3 kV/m. The efffects of steady or transient ("spark discharges") contact currents are depending on many factors, e.g., the size and geometry of the object, the electric field strength, the body impedance, the size of the contact area and the strength and duration of the contact current [1]. Typical electric field strength levels leading to spark discharges which are felt as an annoyance in our daily environment are between 2 and 7 kV/m. A small percentage of people can perceive a field strength of .5 kV/m via spark discharges.

A further group of indirect effects result from possible effects of ELF-fields on electric or electronic implanted medical devices. Typical example is the implanted pacemaker.

BASIC AND DERIVED EXPOSURE LIMITS

For establishing exposure limits and safety factors, duration of exposure, presence of controlled or uncontrolled environments, existence of risk groups (e.g. with medical implants) should be considered. The evaluation of the acute effects have lead to recommendations of exposure limits which are different for occupationally exposed persons and the general public.

The International Non-Ionizing Radiation Committee (INIRC) of IRPA recommends that the ELF field induced current density should not exceed 10 mA/m^2 in the body [2]. Since most evidence is based on short term observations and, since there is a limited knowledge of the possible effects of long term exposure, the INIR Committee recommends to limit of induced current density to 4 mA/m^2 for the continuous occupational exposure and 2 mA/m^2 for the general public (a factor of 5 below 10 mA/m^2). The current densities should be averaged over a period of 1 s and a cross-section of 1 cm^2 perpendicular to the current direction. This averaging seems to be sufficient for picking up spatial and temporal peak values, in view of the fact that the effects of current densities are occurring at the cellular levels, that a plurality of cellular effects are resulting in an action on the whole organisation and, furtermore, the safety zone from stimulating effects are sufficiently large.

From these basic restrictions for the current density the dosimetric quantities, which are necessary for practical purposes, must be derived. The derived secondary exposure limits, i.e., the external electric and magnetic field strengths must be deducted in such a way, that the protective aim is guaranteed also under worst case conditions. For the derivation of field strength exposure limits from the basic restriction there exist numerical and measuring methods. For both methods considerable simplifications were used up to now not taking into account, i.e., the inhomogeneous distribution and anisotropy of the electric conductivity. Due to such simplifications possible spatial increased values of the basic restriction remain disregarded.

CONCLUSIONS

The table summarizes the results of measurements and calculations. The table reflects partially the heterogeneous distribution of the current density within the human body produced by external electric or magnetic fields. For example, an electric field strength of 5 kV/m (the IRPA/IRNIC recommendation for the limit of continuous exposure of the general public to 50/60 Hz electric fields) produces in trunk, head, neck and ankles current density of up to 1.7, 0.5, 2.5 and 10 mA/m^2, respectively. A magnetic flux density of 0.1 mT induces in trunk, head and wrists/ankles current densities of up to 1.7, 0.4 and 0.15 mA/m^2, respectively. A refinement of such model estimations, however, is urgently needed.

Table: Derived values for the electric field strength and magnetic flux density approximately producing a current density of 1 mA/m² in different body parts at 50 or 60 Hz.
Left: Values of the electric field strength;
Right: Values of the magnetic flux density (peripheral regions; R: Radius of current loop; a homogeneous conductivity of 0.2 S/m is assumed).

Electric field strength in kV/m				Magnetic flux density in mT		
Trunk (average)	Head	Neck	Ankles (both feet grounded)	Trunk (R= 0.3m)	Head (R= 0.075m)	Wrist/ Ankles (R= 0.03m)
3	10	2	0.5	0.06	0.25	0.6

Generally, for the establishment of standards, the simultaneous occurrence of other physical agents, noxious chemicals or biologicals factors is not being considered. The exposure limit of 5 kV/m provides substantial protection for the public from annoyance caused by contact currents or transient discharges, which is considered acceptable for occupational exposed persons. For occupationally exposure, hazardous body currents and contact voltages must be avoided by special measures. An electric field strength of 5 kV/m, however, cannot completely eliminate perception of electric field effects. Additionally, there is a small probability that a malfuction of some sensitive unipolar cardiac pacemakers will occur under worst-case conditions at electric field strength values between 2.5 and 5 kV/m and magnetic flux densities between 0.02 and 0.1 mT. Furthermore, in view of this and some other unknowns and uncertainties concerning the complete understanding of the interacting mechanisms and the final clarification of possible long term effects it may be prudent not to exhaust the exposure limits. Such aspects of preventive public health care should be taken into consideration especially on developing new technologies by using electric energy or building transmission lines near public dwellings.

REFERENCES

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