

**Comments on “Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz)” issued by the International Commission on Non-ionizing Radiation Protection (ICNIRP) for public consultation.**

Exposure to power-frequency fields is ubiquitous, as it is associated with power transmission and distribution networks, domestic and industrial wiring and all kinds of electrical equipment. Since the advent of high voltage technologies in the '60, CIGRE has always recognized the importance of potential health effects of exposure to high electric and magnetic fields. In 1987, well before ICNIRP and IEEE recommendations were published, the administrative council of CIGRE set up a working group comprising doctors, biologists, epidemiologists and engineers with the remit of keeping the President, members and others informed of the various aspects of this important issue. CIGRE welcomes the opportunity to comment on the new guidelines. The following comments, focussed on power-frequencies were assembled by the CIGRE working group on EMF and health.

**1. Varying recommendations**

So far, two international organizations have issued exposure limits to power frequency electric and magnetic fields. The current ICNIRP guidelines were published in 1998 and the IEEE published its standard in 2002. In general, exposure limits recommended by the ICNIRP were more restrictive than the limits recommended by the IEEE at 50 and 60 Hz. For example, the current ICNIRP reference level for the general public at 60 Hz is 83  $\mu\text{T}$  for magnetic fields whereas IEEE reference level is 904  $\mu\text{T}$ , more that an order of magnitude higher. Many experts, including the World Health Organization have expressed the need to harmonize these two standards. The differences at 50 and 60 Hz are illustrated in the following table.

<b>Comparison of ICNIRP and IEEE reference levels at 50/60 Hz</b>		
	<b>ICNIRP 1998</b>	<b>IEEE 2002</b>
<b>Electric field</b>	General public : 5 kV/m (50 Hz) 4.2 kV/m (60Hz) Occupational: 10 kV/m (50Hz) 8,3 kV/m (60Hz)	General public : 5 kV/m (50 & 60 Hz) 10 kV/m (HVTL ROW) Controlled environment : 20 kV/m (50 & 60 Hz)
<b>Magnetic Field</b>	General public : 100 $\mu\text{T}$ (50Hz) 83 $\mu\text{T}$ (60Hz) Occupational: 500 $\mu\text{T}$ (50Hz) 420 $\mu\text{T}$ (60Hz)	General public : 904 $\mu\text{T}$ (50 & 60 Hz) Controlled environment : 2710 $\mu\text{T}$ (50 & 60 Hz)

The differences between the two recommendations created some confusion on both aspects of adverse health effect protection and compliance assessment methodology which still persists today regarding safe levels of exposure for the workers and the general public. The revision of ICNIRP guidelines would have been a unique opportunity to better understand and perhaps alleviate the differences between the two standards. However, adequate rationale of chosen restrictions still has not been presented and the reference levels recommended in the draft ICNIRP guidelines remain unchanged.

Unfortunately, it appears that the existing confusion will not dissipate and may be even exacerbated if the revised ICNIRP guidelines are not more explicit about the various choices and judgments made in the process of developing the basic restrictions and their corresponding reference levels. We will address more specifically some of these aspects in the following comments.

## **2- The role of ICNIRP**

In order to develop its guidelines, ICNIRP takes into consideration the appropriate scientific data and will need to take into consideration other essential elements which are necessary for setting up exposure limits. Identifying potential health risks of electric and magnetic fields and assessing the intensity of the effects at various levels of exposure is crucial to the establishment of an exposure limit but it is not sufficient. Adequate data on rationale and traceable derivation of numeric limits must be given for correct compliance leading to the intended adverse health effect protection. Characteristics of the complex electric and magnetic field environments (e.g. spatial, temporal and spectral) and human exposure factors (nature of activity, part of body) need also to be taken into account.

We believe that it is important to take into consideration the practical consequences of applying a specific exposure limit for all stakeholders including the public and the electrical utilities. In particular, it is important to avoid under/over compliance or misinterpretation because of inadequate transparency of protective guidelines.

Unfortunately, the present draft does not fully address these aspects. If they are not within the scope of the ICNIRP, on the basis that these aspects are not purely scientific, it should make it clear for policy makers when they regulate or enforce exposure limits. In particular, the section “*Managing risk in occupational exposure*” and “*general public exposure*” (line 693 – 722) written without any reference to real exposure situations is not appropriate. This section should be removed.

## **3- Specific comments**

On many important points, the guidelines proceeds by claims and assertions for which no direct references are given. This lack of transparency makes it difficult and sometimes impossible the follow the rationale of the guidelines. From a technical and a scientific point of view, the guidelines are ambiguous. We would like to draw the attention on the following aspects which would benefit from some clarifications.

### 3.1 Basic restrictions

ICNIRP has changed the measure of the basic restriction from induced current density to induced electric field. Although this change is scientifically sound and also facilitates the comparison with the IEEE standards, the change is not limited to a simple change of unit but it also suggests a real change in the level of the restriction which is not discussed in the guidelines. Indeed, the previous guidelines identified a threshold for acute changes in the function of the central nervous system (CNS) of  $100 \text{ mA/m}^2$ . Then, a safety factor of 10 was applied for the workers and 50 for the general public. This led to the basic restriction of  $10 \text{ mA/m}^2$  for the workers and  $2 \text{ mA/m}^2$  for the public. The 1998, the guidelines estimated the conductivity of the CNS at  $0,2 \text{ S/m}$  which means that the  $10 \text{ mA/m}^2$  basic restriction corresponded to a induced electric field of  $50 \text{ mV/m}$ . On this very specific aspect, ICNIRP basic restriction was very similar to IEEE basic restriction ( $53 \text{ mV/}$  at  $60 \text{ Hz}$ ;  $44 \text{ mV/m}$  at  $50 \text{ Hz}$ ).

The new guidelines promotes a new basic restriction of  $100 \text{ mV/m}$ , stating that this value represents the “*lower estimate of possible effects on CNS function*” (line 484). This statement raises some important points which need to be clarified:

1- Is it the intention of ICNIRP to allow a less restrictive basic restriction ( $50$  to  $100 \text{ mV/m}$ )? If so, what is the scientific basis for such a change?

2- The guidelines do not mention what is the precise nature of the effect on the CNS which is to be prevented. It is not clear whether it is the induction of *phosphenes*, mentioned at several places of the document (lines 31- 33; lines 399-391; line 485) or the “*cognitive processing*” (line 282) or the “*in vitro neurophysiological evidence*” (line 372). If the induction of phosphenes is the effect ICNIRP wants to prevent for, it has to be mentioned clearly. Also, it would also be appropriate to remind that phosphenes do not constitute *per se* an adverse health effect (it occurs occasionally during the magnetic resonance imaging diagnostic procedures, without consequences for the visual system).

3- Does the basic restriction ( $100 \text{ mV/m}$ ) represent the threshold for an effect at  $50/60 \text{ Hz}$  or is there a safety factor applied to higher threshold ? As mentioned before, the previous guidelines explicitly applied a safety factor of 10 to define the basic restrictions. In the new guidelines, line 52 states that “*these restrictions provide a high level of protection to workers and members of the public...*”. This suggests that a safety factor has been applied but it is not discussed.

4- A reduction factor of 5 is mentioned (line 488), reducing the induced electrical field to  $20 \text{ mV/m}$  for general public exposure although this choice appears to be arbitrary. No data from literature is provided to support this.

We are particularly concerned with the following statement used for the rationale of the guidelines: “*There is also strong indirect scientific evidence that CNS functions such as cognitive processing can be affected by induced electric fields below the threshold for*

*direct stimulation*” (line 281). We are not aware of such evidence and no specific references are given.

We would like to point out some deficiencies in the scientific references. The guidelines assert that “*the experimental evidence for effects of ELF induced electric field on brain function in volunteers is less clear. Generally, such studies have been carried out at exposure levels below those required to induce the effects described above: further studies are required to clarify the uncertainties regarding this possibility*”. We note that an important experimental human study carried out at high magnetic field levels (1000 uT) is not mentioned (Legros, A., Beuter, A., *Bioelectromagnetics* 26, 657-669, 2005). The fact that this study has failed to identify any perception or adverse effects at field levels well above ICNIRP reference levels should have been integrated in this document.

### **3.2 Dosimetry and reference levels**

The dosimetry allows to translate the basic restriction in practical values of external magnetic and electric fields (reference levels). In 1998, ICNIRP applied a simple circular conductive loop model to represent the central nervous system and assumed that the body had a homogeneous and isotropic conductivity. These approximations led to reference levels very likely to be unduly restrictive. In fact, the model used by ICNIRP was one of the main reason for the differences with the exposure levels recommended by IEEE.

The new guidelines acknowledges that “*in recent years, more realistic calculations based on anatomically and electrically refined heterogeneous models resulted in a much better knowledge of in situ electric fields in the body from exposure to electric and magnetic fields*”. ICNIRP welcomes the use of these new models and claims that “*the most useful dosimetric results for the purpose of these guidelines have been obtained from high resolution calculations of induced electric field ..*”. ICNIRP recommends (line 533) “*to determine the induced electric field as an average of the magnitude of the electric field in a an average of the magnitude of the electric field in a cubical volume of  $5 \times 5 \times 5 \text{ mm}^3$  (Bahr) et al 2007*”, again, a reference to an anatomically and electrically refined heterogeneous model.

Further, the guidelines states that: “*the reference levels are obtained from the basic restrictions by mathematical modeling.*” (line 545). Four references are given: ICNIRP 2003; Bahr et al 2006, Dimbylow 2005 and 2006.

This is where some important inconsistencies arise in the guidelines: none of these references can lead to the reference levels described in Table 3. They would all lead to higher reference levels.

For example, according to one of the models considered by ICNIRP as one of the most appropriate (Dimbylow 2005), the basic restriction of 100 mV/m corresponds to an external 50 Hz magnetic field of 1250 to 2000  $\mu\text{T}$  (derived from line 428), much higher values than the 500  $\mu\text{T}$  reference level for the workers.

The reader is misled. Surprisingly, ICNIRP has apparently decided to use the same model used in 1998 in contradiction with its own recommendations. Although it is not explicitly mentioned in the text, the note 4 under table 2 states, referring to ICNIRP 1998, “*adopted for the relation between the basic restriction and reference level*” . If it is the case, then the statement that specifies that new models have been used to derive the reference levels is false. Moreover, if the old model has actually been used, it should have led to a reference level of 1000  $\mu\text{T}$  since the new basic restriction (100 mV/m) is twice the previous one ( $10 \text{ mA/m}^2 = 50 \text{ mV/m}$ ). There is no logical way to reconcile the reference levels in Table 3 with the basic restriction of the new guidelines.

It is interesting to notice that, had ICNIRP followed its rationale by using the new dosimetric models, the reference levels would have been much closer to IEEE reference levels and consequently reinforced the confidence in both recommendations.

For electric fields, according to the new dosimetric models, the basic restriction (100 mV/m) corresponds to an external field of 25 to 33 kV/m (derived from line 428), again, a value much higher than the reference level for the workers (8,3 kV/m at 60 Hz; 10 kV/m at 50 Hz). Of course, other considerations have to be taken into account in order to establish an electric field exposure limit: the contact currents and the micro shocks. These considerations are addressed in the guidelines but the rationale that leads to the electric field reference level remains ambiguous.

We are deeply concerned by these internal inconsistencies in the dosimetry section of the document. Since the dosimetric model is at the heart of the rationale and is the main reason to explain the divergence with IEEE standards, we strongly recommend that ICNIRP be more transparent and clarify this important issue.

### **3.3 Reference levels for contact currents**

The guidelines states that : “*the reference levels (for contact currents) are not intended to prevent perception but to avoid painful shocks. Perception of contact current is not per se hazardous but could be considered an annoyance*” (line 591-594).

The reference levels given in table 5 (1 mA for the workers and 0,5 mA for the public) are somewhat contradictory with this statement since they are closer to perception levels than to thresholds for let-go contact current. The discrepancy is misleading and if ICNIRP has chosen to apply a safety factor, it should be stated clearly.

For more than 50 years, the safe maximum contact current has been considered to be about around 5 mA and electrical installations have been designed so that the electric fields at ground level would not cause contact currents higher than 5 mA under worst conditions (a person in contact with a large object).

Since contact currents are very dependent on circumstances (size of objects, grounding etc...) it is not relevant to recommend a particular limit to the electric field without

describing the particular scenario that would lead to the maximum contact current. We recommend that if an electric field limit is recommended to prevent contact currents, all other relevant parameters of the exposure scenario be explicitly described.

### **3.4 Combined exposure to electric and magnetic fields**

ICNIRP 1998 guidelines stated that : *“For the purpose of demonstrating compliance with the basic restrictions, the reference levels for the electric and magnetic fields should be considered separately and not additively.”* The new guidelines states precisely the opposite: *“For the purpose of demonstrating compliance with the basic restrictions, the reference levels for electric and magnetic fields should be considered additively.”* (lines 568-569). No explanation is given.

This change in the new guidelines lacks any theoretical and practical considerations and is not justified. In the vast majority of exposure situations, both fields are present and contribute to the internal induced electric fields. However, these are vectors and in order to be additive, the vectors would need to have the same spatial orientation within the central nervous system, they would also have to be in phase with each other and in a situation of maximum coupling for both fields at the same time. In practice this very specific configuration is extremely unlikely. But more importantly, there is simply no way to implement such a principle since the magnitude and orientation of both fields are extremely variable in time and space at the workplace. This recommendation by ICNIRP is not realistic.

## **4- Conclusions**

CIGRE considers important that reputable and independent scientific bodies such as ICNIRP and IEEE reviews the science and provide a sound scientific background in support of eventual regulations on exposure limits. However, it is CIGRE’s opinion that the draft document presented by ICNIRP needs significant improvement in order to fulfil its role. This includes revision of the draft to provide clear data on established adverse health effects, rationale of protection and method of deriving the corresponding basic restrictions

The draft document does not provide any new scientific observations suggesting that a particular health effect could be attributed to current exposure levels for both the workers and the general public. The document correctly reviews and promotes the use of more realistic dosimetric models that were not available in 1998. However, contrary to all expectations, it seems that ICNIRP decided to use its old model despite its inherent limitations. Had it followed its own rationale, the new reference levels would have been much closer to the existing recommendations issued by IEEE and the confusion created by the large differences between those recommendations would have been alleviated.

