



# Static magnetic field Guidelines

Occupational Exposure to Electromagnetic Fields: paving the way for a future EU initiative, Umeå, Sweden, October 6-8, 2009

## **The ICNIRP guidelines: rationale and state of play for static magnetic fields**

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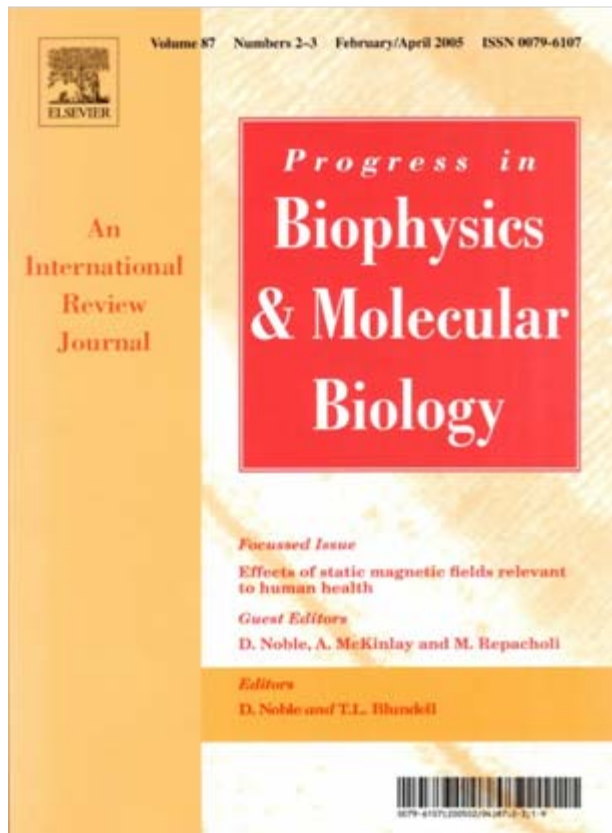
*International Commission on Non-Ionizing Radiation Protection*



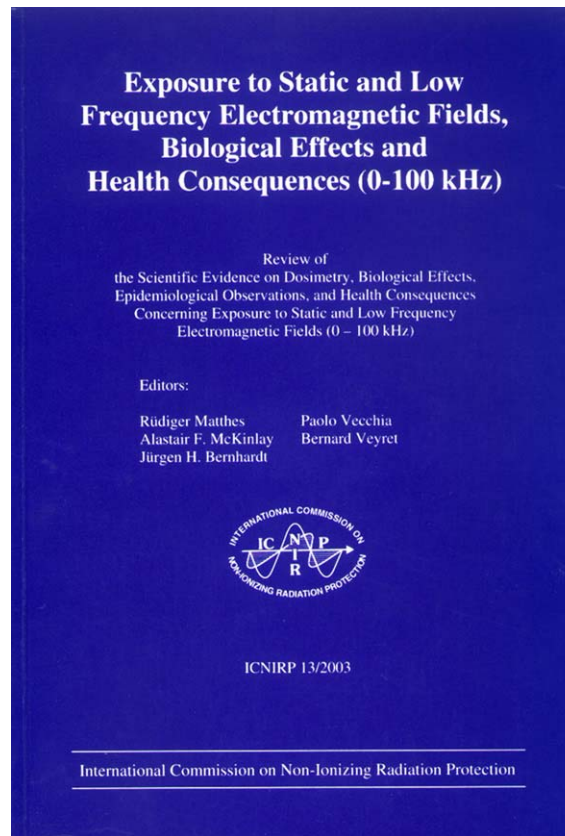
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## Major Reviews



**NRPB, WHO, ICNIRP 2004**



**ICNIRP 2003**



**WHO 2006**

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## ICNIRP publications

- **General approach to protection against non-ionizing radiation. Health physics 82:540-548 (2002)**
- **Guidelines on Limits of Exposure to Static Magnetic Fields. Health Physics 96(4):504-514 (2009)**
- **Statement on Medical Magnetic Resonance (MR) Procedures: Protection of Patients. Health Physics 87(2): 197-216 (2004)**
- **Amendment to the ICNIRP “statement on medical magnetic resonance (MR) procedures: protection of patients” Health Physics 97(3): 259-361 (2009)**



**RATIONALE**

A review of the biological effects from exposure to magnetic fields is contained in UNEP/WHO/IEA (1987) and ICNIRP (1997a) and b, 1999. Additional data and references can be found in Nagai et al. (1992), IEC (2001) and Sherlock (2001a). Recommendations for radiofrequency exposure levels are based on the data contained in reports by the NCRP (1966), UNEP/WHO/IEA (1987), ICNIRP (2001), WHO (2003) and on the rationale appended to ICNIRP (1996).

The following is a brief summary of conclusions drawn from the review of scientific literature.

**Static magnetic fields.**

The possible health effects that might result from acute exposure to intense static magnetic fields have been recently reviewed by Sherlock (2001, 2003). The basic actions of static magnetic fields are physical effects (translation and orientation), electrodynamic forces on moving electrolytes, and effects on electronic spin states of chemical reaction intermediates. At a higher level of organization, biological effects in cells, tissues and living organisms have been studied.

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## Interaction mechanisms

- **Electrodynamic interactions**

Flow potentials

Magnetohydrodynamic effects

Induced electric fields and currents

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

- **Magneto-mechanical interactions**

Orientation effects

Translation effects

- **Electronic spin interactions**

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## Electrodynamic interactions

$$\psi = |E_i|d = |v||B|d \sin \theta$$

- **Flow potentials**

- Induction of electrical potentials as a result of blood flow
- Largest in blood vessels around and in the heart
- Predicted current density at the sino-atrial node about 220 mA m<sup>-2</sup> at 10 T
  - Changing rate of excitation (> 8 T)
  - Inducing ectopic activity (> 8T)
  - Triggering arrhythmias (threshold lower but ??)

Increased risk in people with high susceptibility to reentrant arrhythmias - enlarged or damaged hearts or rare disorders in repolarisation (5-10 per 10 000, WHO)

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## Electrodynamic Interactions

$$\mathbf{f}_m = \mathbf{j} \times \mathbf{B}$$

- **Magnetohydrodynamic effects**

- Magnetohydrodynamic forces may reduce blood flow (5% at 10 T)
- Magnetohydrodynamic forces on the endolymphatic fluid in the vestibular organ is one possible mechanism for sensation of vertigo (2 – 4 T).
- Magnetohydrodynamic forces on nerve impulse conduction (extremely weak)

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## Electrodynamic interactions

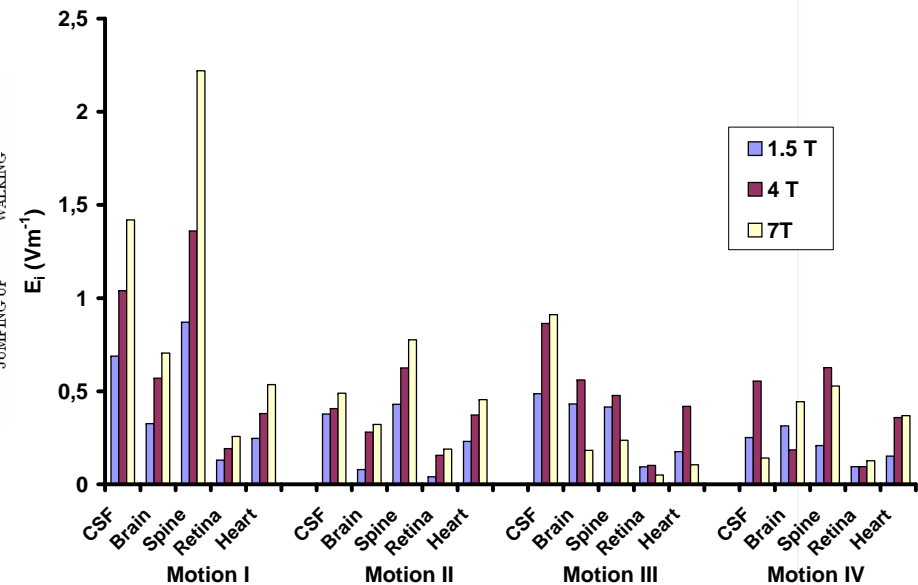
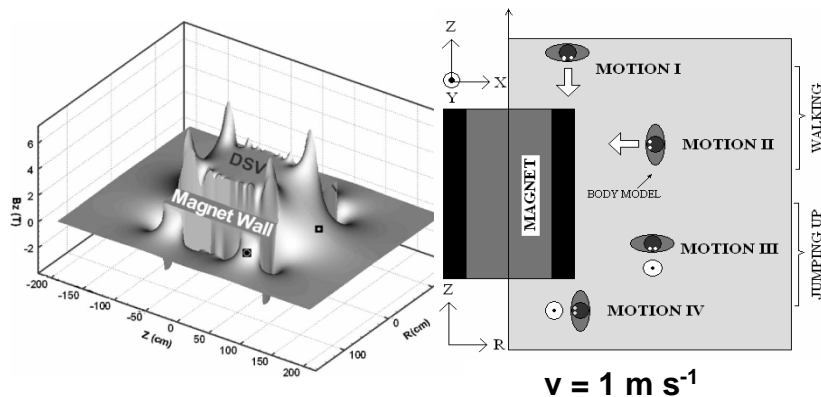
- Induced electric fields in tissue**

Exposure to time varying magnetic fields

Movement in spatially varying magnetic fields

→ Excitation of nervous tissue (CNS, peripheral nerves, heart)

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$



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## Magnetomechanical interactions

- **Torque on paramagnetic / anisotropic compartments**
  - Orientation of magnetically anisotropic macromolecules  
1% of DNA in solution at 13 T
  - Orientation of molecular assemblies  
Retinal rod outer segments, muscle fibers, etc. at 1 T in solution
  - Orientation of cells  
Deoxygenated stickled erythrocyte, at 0,35 T; normal erythrocytes at 8 T

Magneto orientation of biologically important structures can be shown in vitro, biological implications in vivo are unclear.

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## Magnetomechanical interactions

- **Translation**

- Attraction of paramagnetic objects
  - High risk in MRI for ferromagnetic object
- Repulsion of diamagnetic objects
  - Diamagnetic levitation, “Moses” effect
- Forces within tissue
  - Extremely small for single molecules
  - For large aggregates ??
  - For red blood cells 4% of gravity in 4 T
  - Iron containing proteins and magnetite in tissue need consideration in ultra high fields

$$F(z) = \frac{\chi V}{\mu_0} B \frac{dB}{dz}$$



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## Electronic spin interactions

- **Effects on electronic spin states of reaction intermediates.**
  - several classes of organic chemical reactions
  - static magnetic fields in the range of 10 to 100mT
  - established for only few enzyme reactions in vitro (non-physiological)
  - neither physiological effects on cellular functions, nor long-term mutagenic effects established

## Animal studies

- **No effects on embryo/fetal development following exposure at up to 6.3 T**
  - Sikov et al, 1979; Konerman and Monig, 1986; Murakami et al, 1992; Okazaki et al, 2001
- **No effects on spontaneous or chemically induced tumor incidence following exposure at up to 800 mT**
  - Bellossi, 1984, 1986; Mevissen et al, 1993
- **No effect on transplanted tumor growth following exposure at up to 1 T**
  - Bellossi, 1986

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## Human studies

- **No effect on cognitive function in fields up to 8 T**  
→ Chakeres et al 2003
- **Transient loss of eye-hand co-ordination following head movements may occur in fields up to 7 T**  
→ de Vocht et al, 2006, 2007
- **Vertigo and other sensations can occur during movement in/around MRI systems > 2 – 4 T**  
→ Schenck et al, 1992; Glover et al, 2007

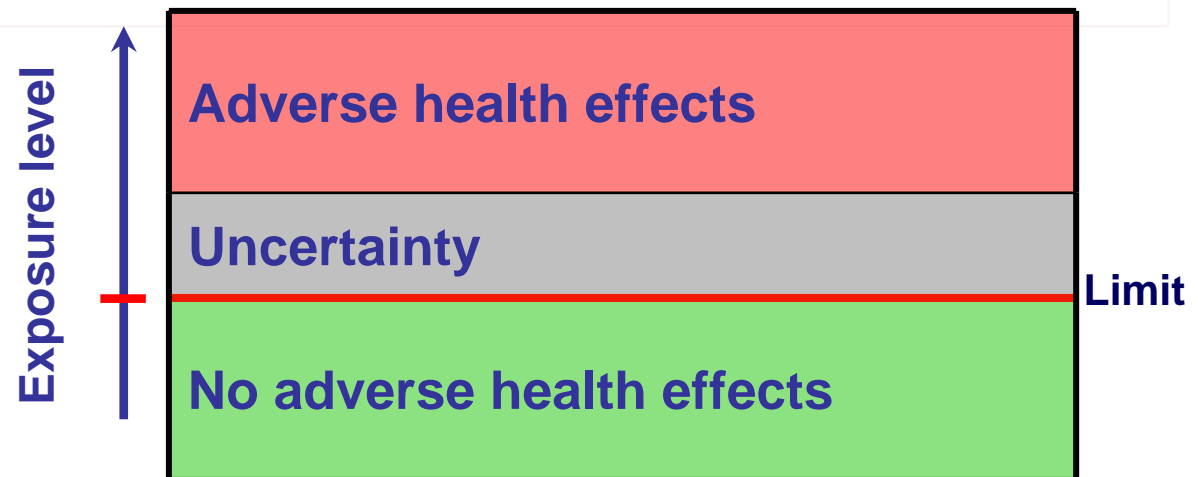
## Human studies

- **Electrical ‘flow’ potentials generated across blood vessels by the flow of blood in a static magnetic field**  
→ Tenforde, 2005
- **Blood flow predicted to slow and blood pressure rise by 5% in 10 T**  
→ Kinouchi et al, 1996
- **Small increase (< 4%) in systolic blood pressure in volunteers exposed to 8 T but no other effects**  
→ Chakeres et al, 2003

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## ICNIRP Guidelines

- **Adverse effect with lowest threshold**
- **Uncertainties considered**
  - often no rigorous basis
  - expert judgment
- **Exposure conditions considered (e.g. general public, occupational, medical)**



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## Adverse effect

- **Vertigo, nausea**
- **Eye-hand coordination**
- **Cardiovascular**
- **Lethal**



**Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.**

**Constitution of the WHO**



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## Static field limits

### Occupational\*

- Head and trunk \*\* 2 T
- Limbs 8 T

### General public\*

- Continuous 400 mT

\* spatial peak exposure limits

\*\* For specific work applications, exposure up to 8T can be justified

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## Outlook

- **Guidelines for limiting exposure to time varying fields**
  - under consultation
- **Recommendations concerning movement induced hazards**
  - under consideration
- **Research needs concerning**
  - Volunteer studies on vestibular function, eye-hand co-ordination and cognitive function
  - Long-term animal studies of carcinogenesis
  - Further animal studies of possible developmental effects
  - Studies of mutagenicity and malignant transformation in primary human cells.



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**Many thanks for your attention !**