Laboratory Studies on Static and ELF Fields

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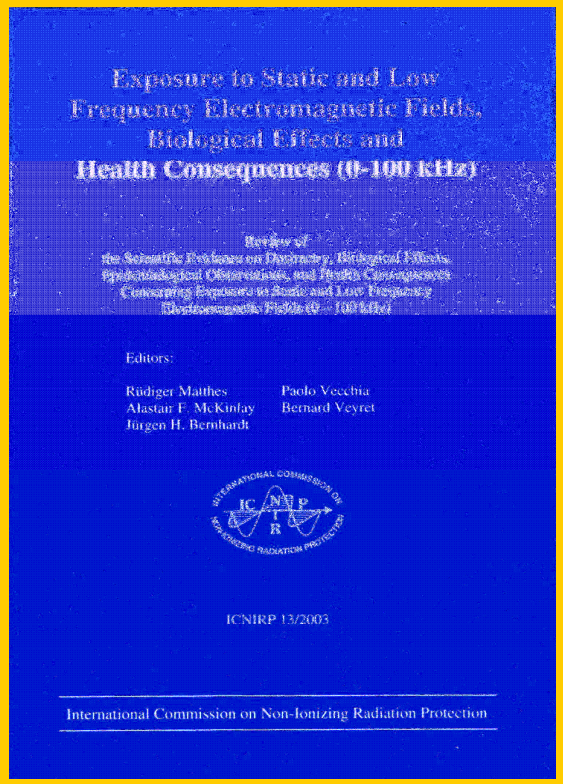
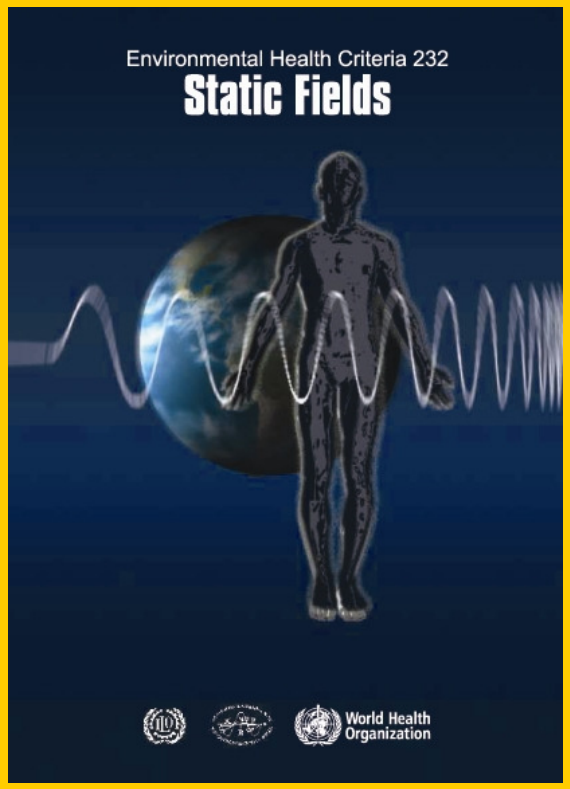
Static and ELF Fields

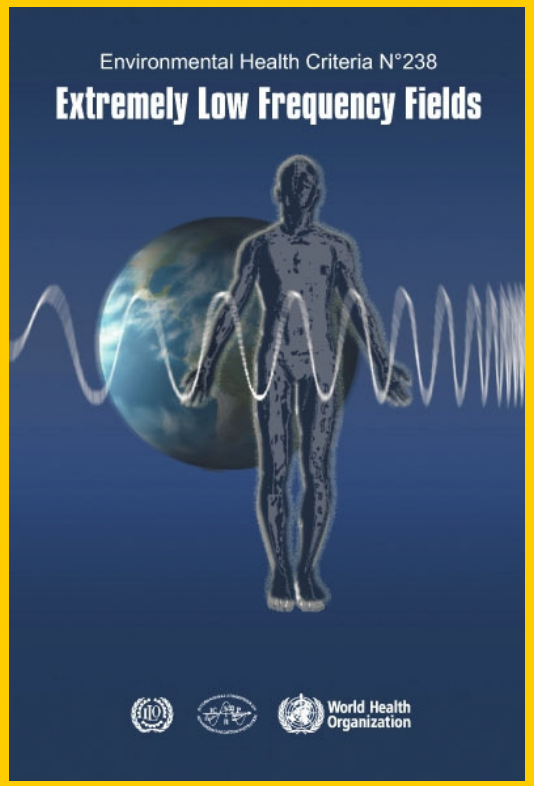
Major Literature Reviews:



ICNIRP, 2003



WHO, 2006



WHO, 2007

http://www.icnirp.de/PubEMF.htm

http://www.who.int/peh-emf/publications/en/

Static and ELF Fields

Human, Animal and Cellular Laboratory studies:

- Volunteer studies can investigate transient physiological responses in people
- Animal studies can investigate reproductive outcomes and cancer
- Cellular studies can give insight into mechanisms of interaction *in vitro*

Static and ELF Fields

Presentation:

- Surface Electric Charge Effects
- Static Magnetic Fields
- ELF (50/60 Hz) Magnetic (± Electric) Fields

Surface Electric Charge Effects

Human studies:

- Static and ELF E-fields induce an electric charge on the body surface
- 50/60 Hz E-fields perceptible by 10% at ~ 2 – 5 kV m^{-1}
- 50/60 Hz E-fields annoying to 5% at ~ 15 – 20 kV m^{-1}
- Spark discharges to ground painful in 7% at ~ 5 kV m^{-1}

Static Magnetic Fields

Interaction mechanisms:

- Electrodynamic interactions with moving charges such as ions, leading to induced electric fields and currents
- Magnetomechanical interactions with magnetically anisotropic structures, leading to orientation effects.
- Interactions with electron spin states of some chemical intermediates, which may be involved in animal navigation

Static Magnetic Fields

Human studies: neurobehavioral effects

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

Static Magnetic Fields

Human Studies: cardiovascular responses:

- Electrical ‘flow’ potentials generated across blood vessels by the flow of blood in a static magnetic field (eg 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, 2003b)

Static Magnetic Fields

Animal studies: reproductive outcome and cancer

- 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 tumour incidence following exposure at up to 800 mT (Bellossi, 1984, 1986a; Mevissen et al, 1993)
- No effect on transplanted tumour growth following exposure at up to 1 T (Bellossi, 1986b)

Static Magnetic Fields

Conclusions:

- Cardiovascular responses such as changes in blood pressure can be seen but lie within the normal range in static fields of up to 8 T
- Vertigo and other sensations can occur during movement in/around MRI systems > 2 – 4 T and eye-hand co-ordination may be affected following head movement
- It is not possible to draw firm conclusions regarding long-term effects

Static Magnetic Fields

Research Agenda (WHO, 2006):

- 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.

http://www.who.int/peh-emf/research/smf_research_agenda_2006.pdf

ELF Magnetic Fields

Interaction mechanisms:

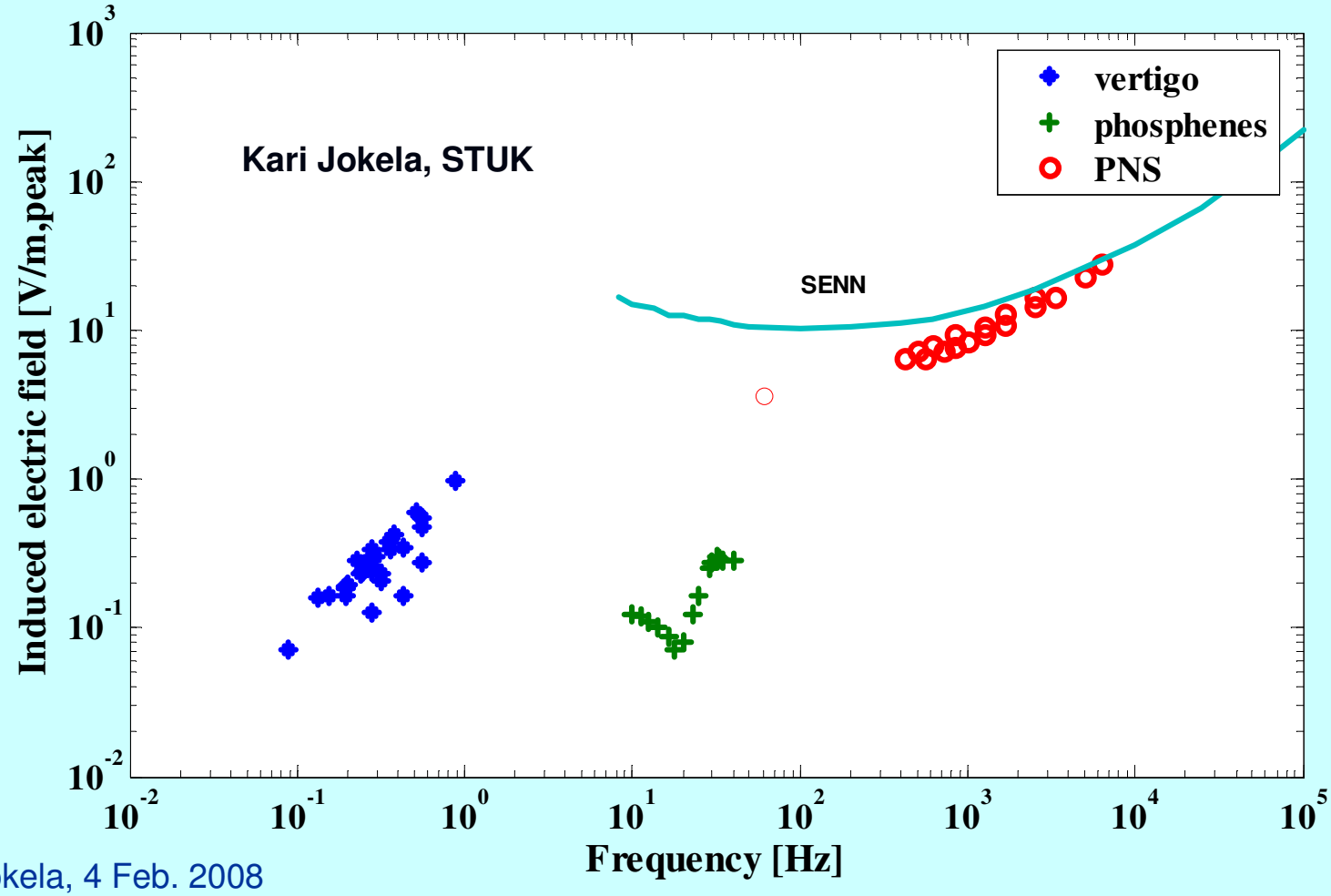
- Faraday induction of electric fields and currents, leading to effects on electrically excitable cells
- Interactions with electron spin states of some chemical intermediates, leading to possible free radical release
- Other proposed mechanisms eg ‘cyclotron resonance’ considered implausible (Swanson & Kheifets, 2006)

ELF Magnetic Fields – High Levels

Human studies: nervous system effects

- Large, rapidly pulsed magnetic fields used in MRI or TMS can stimulate myelinated nerves in volunteers.
- Induced electric field thresholds are as low as a few V m^{-1} between a few hertz and a few kilohertz.
- Phosphene and vertigo thresholds are much lower at 20 Hz (phosphenes) and below about 1 Hz (vertigo).

Volunteer Nervous System Responses to ELF Magnetic Fields



Kari Jokela, 4 Feb. 2008

ELF Fields – Low Levels

Human Studies: neurobehavioral effects

- Generally, effects of 50/60 Hz ELF fields of up to 100 μT, occasionally up to ~ 1 mT, on brain electrical activity (EEG), cognition and mood are unclear
- Possible field-dependent effects on reaction time and accuracy (eg Keetley et al, 2001; Podd et al, 2002)
- Inconsistent results from sleep studies (eg Akerstedt et al, 1999; Graham and Cook, 1999)
- Symptoms felt by hypersensitive people are unrelated to exposure (eg Lonne-Rahm et al, 2000; Lyskov et al, 2001)

ELF Fields – Low Levels

Human Studies: neuroendocrine effects

- Most volunteer studies find no evidence of effects of ELF exposure (50/60 Hz fields of up to 300 μT) on night-time melatonin levels (eg Graham et al, 1996, 1997; Warman et al, 2003)
- Possible increase in intra-individual variability and/or delayed night-time melatonin rise (eg Wood et al 1998; Graham et al, 2000)
- No effects on pituitary hormone levels (eg Selmaoui et al, 1997)

ELF Fields – Low Levels

Animal Studies: melatonin levels

- Non-human primates: No effect seen on melatonin levels in one large study using baboons (Rogers et al, 1995)
- Seasonally breeding animals: No effects on melatonin-dependent reproductive status (eg Lee et al, 1993; 1995)
- Laboratory rodents: Data equivocal; several studies report ELF-induced melatonin depression (eg Kato & Shigemitsu, 1997), others report no effect (eg Bakos et al, 1995, 1996, 1997)

ELF Fields – Low Levels

Animal Studies: developmental effects

- No adverse developmental effects of exposure to 50/60 Hz electric fields of up to 150 kV m^{-1} (eg Rommereim et al, 1987, 1990, 1996)
- No gross external, visceral or skeletal malformations after exposure to 50/60 Hz magnetic fields up to 20 mT (eg Juutilainen, 2005)
- Some studies report slight increases in minor skeletal variants (eg Kowalczuk et al, 1994)

ELF Fields – Low Levels

Animal studies: cancer (i)

Large scale life-time studies (50/60 Hz fields):

Mandeville et al, 1997	2, 20,200 or 2000 μT	250 rats	No effect on tumour incidence
Yasui et al, 1997	500 or 5000 μT	144 rats	No effect on tumour incidence
McCormick et al, 1999	2, 200, or 1000 μT	1000 mice	No overall effects, slight overall reduction in females
Boorman et al, 1999	2, 200, or 1000 μT	1000 rats	No overall effects, increase in thyroid C-cell tumours
Otaka et al, 2002	500 or 5000 μT	300 mice	No effect on tumour incidence

ELF Fields – Low Levels

Animal studies: cancer (ii)

Leukaemia/lymphoma prone mice (50/60 Hz fields):

Harris et al, 1998	1, 100, 1000 μT	500 Eμ-*Pim1* mice	No effects
McCormick et al, 1998	1000 μT	60 heterozygous TSG-*p53* knockout mice	No effects
Sommer and Lerchl, 2004	1 or 100 μT	480 AKJ/R mice (carrying the AK virus)	No effects

ELF Fields – Low Levels

Animal studies: cancer (iii)

Induced leukaemia/lymphoma (50/60 Hz fields):

McCormick et al, 1998	2, 200 or 1000 μT	ENU-induced Lymphoma in 150 Eμ-*Pim1* mice	No effects
Babbitt et al, 2000	1420 μT	γ-ray-induced lymphoma in 2660 mice	No effects
Heikkinen et al, 2001	1.3 – 130 μT	x-ray-induced lymphoma in 150 mice	No effects

ELF Fields – Low Levels

Cell studies: cancer-related studies

- Genotoxicity: In general, exposure to fields of up to 50 mT not genotoxic. Positive effects reported by Ivancsits et al (2003a,b) not replicated by Scarfi et al (2005)
- Gene-expression: No good evidence for effects on expression of cancer-related genes such oncogenes (eg Lacy-Hulbert et al, 1995).
- Proliferation, differentiation, apoptosis, malignant transformation: results inconsistent or inconclusive

ELF Fields

Conclusions:

- Large, rapidly pulsed magnetic fields can stimulate myelinated nerve fibres. Vertigo and phosphene thresholds are lower at low frequencies.
- No good evidence of effects on brain or endocrine function at lower field strengths
- No good evidence of adverse developmental effects
- In contrast to the epidemiological data, the animal and cell cancer data are almost universally negative

ELF Fields

Research Agenda (WHO, 2007):

- EEG, cognition and sleep studies in volunteers, including children
- Development of transgenic mouse models of childhood leukaemia for EMF studies
- Evaluation of possible co-carcinogenic effects using animal and cell models
- *In vitro* studies of multi-cell/neural network thresholds

http://www.who.int/peh-emf/research/elf_research_agenda_2007.pdf