

Opinion on possible health effects from exposure to electromagnetic fields (0 Hz- 300 GHz) - Report and opinion adopted at the meeting of the Scientific Steering Committee of 25-26 June 1998,

**Remark: the present document contains opinions adopted by the Scientific Steering Committee of the European Commission, which is a neutral and independent scientific body.**

## **EXECUTIVE SUMMARY**

Note : Readers should keep in mind that the report and opinion only address the scientific aspects of the risk *assessment* of the issue (e.g., identification of hazards, levels of infectivity in the starting materials and final products, etc.). The risk *management and policing* aspects related to the implementation of an opinion, are not dealt with.

The European Commission requested the Scientific Steering Committee to provide an opinion on the possible health effects from exposure to electromagnetic fields (0 Hz - 300 GHz). The request covered more precisely:

- A. an opinion on non-thermal, long-term health effects of exposure to EMFs, in particular addressing epidemiological evidence and also biophysical and biological evidence on genetic and cancer-related effects, effects on the immune system and effects on the nervous system. The opinion should indicate whether any recommendations for exposure limits can be made, and
- B. an opinion on whether for thermal effects, the scientific advice of the International Commission on Non-Ionising Radiation Protection (ICNIRP) is the appropriate basis for a system of health protection against risks from non-ionising radiation.

The Scientific Steering Committee adopted at its plenary session of 25-26 June 1998 the following conclusions:

*As regards non-thermal exposure to EMFs, the available literature does not provide sufficient evidence to conclude that long-term effects occur as a consequence of EMF exposure. Therefore any recommendation for exposure limits regarding non-thermal long-term effects cannot be made at this stage on a scientific basis.*

*Ongoing investigations within the WHO Programme together with research envisaged within the Fifth Framework Programme of the*

*EU as elaborated in the EU Public Health Report: Non-ionising radiation - Sources, exposure and health effects may provide an appropriate scientific basis for improved assessment.*

*As regards the assessment of acute thermal effects from 0 Hz - 300 GHz electromagnetic fields the advice of the ICNIRP provides the appropriate basis to develop exposure limits against this risk.*

## **OPINION**

### **1. Request**

The European Commission requested the Scientific Steering Committee to provide an opinion on the possible health effects from exposure to electromagnetic fields (0 Hz - 300 GHz). The request covered more precisely:

A. An opinion on non-thermal, long-term health effects of exposure to EMFs, in particular addressing epidemiological evidence and also biophysical and biological evidence on genetic and cancer-related effects, effects on the immune system and effects on the nervous system. The opinion should indicate whether any recommendations for exposure limits can be made, and

B. an opinion on whether for thermal effects, the scientific advice of the International Commission on Non-Ionising Radiation Protection (ICNIRP) is the appropriate basis for a system of health protection against risks from non-ionising radiation.

### **2. Definition, Sources of Exposure**

The electromagnetic fields (EMF) of concern cover the frequency range between 0 Hz and 300 GHz. Usually, they are classified according to the major mechanisms of interaction in a group up to 100 KHz and the group 100 KHz - 300 GHz. Occasionally fields up to 300 Hz are classified as extremely low frequency fields (ELF). In addition to frequency, energy and energy density, different ranges of waveforms are also considered. As regards interaction with the organism, physical sizes and shapes, the electrical conductivity of the body, its permittivity (both varying with tissue) are further variables of interest for determining biological effects.

There are many devices emitting EMF. Some of them partly contribute to a varying electromagnetic background (smog) such as electrical power lines, radio and other communication systems (AM, FM, Radar, GSM), and household electrical appliances. Others represent distinct sources such as electric blankets, Visual Display Units, microwave ovens and mobile phones.

The potential effects of medical devices emitting EMF are not

dealt with in this report.

### 3. Background

DG V is preparing a Council Recommendation to limit exposure to EMF in order to avoid acute health effects. The draft is based on ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields. Using ICNIRP developed principles and limit values, Germany has issued an EMF Ordinance (26th BImSchV) implementing the Federal Immission Control Act in 1996. Essentially, this Ordinance takes into account the acute health effects resulting from energy absorption and electrical implications resulting in various acute health effects.

### 4. Health Effects

#### 4.1 Mechanisms and Interactions

Ionising radiation produces biochemical effects such as breaking covalent chemical bonds, and the generation of ions and other reactive chemical species. However the energy of all electric, magnetic and electromagnetic fields (term non-ionising radiation) of concern is orders of magnitudes below that associated with ionising radiation.

EMF with frequency ranges up to 100 KHz have as their primary mechanism of interaction with tissues, the induction of *currents in tissues* as well as those resulting from energy absorption. These may invoke the formation of *electric dipoles* and the reorientation of dipoles already present. The primary effect of EMF with frequency ranges above 100 KHz is absorption resulting in *thermal effects*. Changes in oxidant to antioxidant ratios may also occur. The penetration of magnetic fields into tissues decreases with increasing frequency.

From animal studies it can be concluded, that the *permeability of membranes* (as identified by  $Ca^{++}$  homeostasis) is modified by ELF and also by low frequency modulation of high frequency fields. There is no conclusive evidence that ELF fields change the structure of DNA, nor that somatic mutations occur. This lack of demonstrated *mutagenic effects* suggests, that if ELF have any effect on the process of carcinogenesis, they are more likely to act as promoters, an important consideration for risk assessment. For high frequency fields it was demonstrated in in-vitro studies with different cell systems that they have no direct genotoxic or mutagenic effects. In a limited number of experiments clastogenic effects have been reported.

*The Melatonin Hypothesis*

Pineal melatonin is involved in diurnal rhythms (levels rise at night and fall during the day). It is protective against free radicals and is involved in the steroid hormone regulation.

Low flux densities, down to 1  $\mu\text{T}$  of circularly polarised magnetic 50 Hz fields have been shown to decrease melatonin serum levels in rats.

This finding led to the hypothesis that magnetic fields may have effects on sleeping. However studies with volunteers exposed to 100  $\mu\text{T}$  of 50 Hz magnetic fields resulted, however, in relatively high melatonin levels during night time so that the expected decrease of melatonin serum levels under field exposure were not found. Exposure of volunteers to GSM and DCS fields did not result in statistically different melatonin secretion.

At present, there is a very weak evidence that melatonin interaction could be important in the explanation of the biological effects of non-ionising radiation.

The supposed influence of magnetic fields on steroid hormone regulation was the reason that a relationship was suggested between exposure and mammary cancer, a hypothesis thus far not confirmed.

#### **4.2 Acute Health Effects**

With cellular and animal systems no consistent effects of either time varying or varying field strength at frequencies below 100 KHz and current density at or below 10  $\text{mA}/\text{m}^2$  could be established. At higher levels of induced current density (10 - 100  $\text{mA}/\text{m}^2$ ) significant tissue effects including functional changes in the nervous system occur. Minor effects on nervous system function and a minor reduction in the heart rate of short duration upon exposure to extremely low frequency (ELF) fields have been observed in experimental animals. Intense ELF fields can stimulate peripheral nerves and muscle tissues directly in experimental animals.

Acute thermal health effects have been well established for the high frequency class of EMF, and there is a consensus view that local temperature increase of up to 1°C is of no concern. Such temperature changes may arise from up to 30 minutes exposure to EMF which produce a whole body specific energy absorption rate (SAR) between 1 - 4  $\text{W}/\text{kg}$ . Exposure to more intense fields can produce harmful levels of tissue heating because they exceed the thermoregulatory capacity of the body.

*Conclusion : As regards acute health effects limit values can be*

*set based on the scientific data.*

### **4.3 Genotoxicity**

A large number of genotoxicity experiments has been published. The majority of these were negative. In a few cases some equivocal effects were noted. Examples, e.g. are an enhancement of the effect of Mitomycin C (sister chromatid exchanges) in human lymphocytes exposed to the microwaves of a GSM base station (954 MHz, 15 W, SAR = 1.5 W/kg) and in an in-vitro experiment with whole blood samples exposed to GSM emission (calculated specific absorption rate 1.5 W/kg) in which there were "indications" of increased chromosome aberrations, especially dicentric chromosomes (Maes, 1997; Maes 1993).

In a pilot study with 6 workers exposed at least 1 h/day for at least 1 year to the emissions of transmission antennas (mobile phone network) some chromatid and chromosome breaks and gaps were detected, but no significant dicentrics were found.

*Conclusion : There is insufficient evidence to suggest that EMF are mutagenic or can directly interact with DNA.*

### **4.4 Chronic Effects**

A substantial number of epidemiological, in vivo and in-vitro studies regarding long-term effects of both classes of EMF (including pulsed microwave fields), especially carcinogenicity have been published.

#### *Carcinogenicity - Animal Studies*

In rodents treated with a chemical initiator, exposure to 50 Hz magnetic fields in the range of 10  $\mu$ T - 30 mT, indicated a possible promoting effect for mammary cancer. The increased tumour incidence was explained by field-induced suppression of pineal melatonin resulting in increased steroid hormone levels with increased breast cancer risk (Löscher, 1995). As already mentioned, however, confirmatory evidence to support this interpretation is lacking.

Recently two studies were performed by NTP, with 50 Hz and 60 Hz fields respectively and different intensities. In the two-years rat study the incidences of thyroid gland C-cell adenoma and carcinoma in male rats (exposed to 0.02 G) and of adenoma and adenoma or carcinoma (combined) in 0.02 and 2 G males were significantly greater than in the control group. In contrast, the incidence of mononuclear cell leukaemia in males in the 10 G intermittent group was significantly less than in the control group. In the two-years mice study the incidences of alveolar/bronchiolar

adenoma were significantly decreased in 0.02 and 2 G male mice and 2 F female mice relative to the control group. Also, the incidences of alveolar/bronchiolar adenoma or carcinoma (combined) were significantly less in males and females exposed to 2 G than in the control groups. In female mice, the incidence of malignant lymphoma in the 10 G intermittent group was significantly less than in the controls. There was no increased incidence of brain, mammary gland carcinoma and leukaemia with EMF. A second study with female rats investigated the initiation/promotion effects of 50 and 60 Hz fields on DMBA carcinogenicity. No evidence that the magnetic fields promoted the development of mammary gland neoplasms could be found.

The conflicting experimental findings in animal studies may be due to several reasons, e.g. exposure conditions.

*Conclusion : Carcinogenicity studies in laboratory animals do not yet allow a final conclusion with respect to the carcinogenicity of EMF. There is little evidence from laboratory studies to support the hypothesis that EMFs have a tumour promoting effect.*

#### *Carcinogenicity, Teratogenicity, Epidemiology*

A large number of epidemiological studies, both on exposed workers and the general population, have been carried out to investigate the issue of cancer in relation to EMF (particularly ELF) exposure.

The great majority of the epidemiological studies performed so far have major limitations, either in study design, e.g. failure to adjust appropriately for confounding factors, or in the reliability of exposure assessment. Consequently, the results are inconclusive. The findings may be summarised as follows:

A large number of studies failed to demonstrate any statistically significant risk excess. The relative risk found in most of the studies, in which positive results were noticed, was generally rather low and the types of tumours where an excess incidence was identified have varied greatly from one study to another. The lack of a dose-response trend, even when exposure was well documented (e.g. in electrical workers studies) is a further inconsistency.

A possible increase in leukaemia incidence in children living nearby power lines has been raised frequently but the findings from epidemiology studies designed to investigate this relationship are inconclusive. A Danish Expert Group on Non-Ionising Radiation, Danish Ministry of Health in its *report on the risk of cancer in children living in homes exposed to 50 Hz magnetic fields from high-voltage lines*, came to the conclusion: „*The expert*

*group believes that neither the earlier nor the latest studies offer sufficient documentation to characterise 50 Hz magnetic fields in homes adjacent to high-current electricity supply plants as a cancer-inducing factor among children. The studies described do not, however, allow this assumption to be dismissed."* A study carried out in Italy to estimate the cases of child leukemia potentially attributable to proximity to high-voltage lines, assuming a relative risk of 2.1, indicated that the maximum number of cases per year would lie between 1 and 3. (Comba *et al.*, 1985; Anversa *et al.*, 1995).

Studies in workers have also investigated whether tumours of the nervous tissue, breast and leukaemia are associated with ELF exposures. The Danish Expert Group on Non-Ionising Radiation (Danish Ministry of Health) in its *report on the risk of cancer among persons occupationally exposed to extremely low frequency magnetic fields*, evaluated existing case control, cohort and register studies (including e.g. 25.000 Danish welders) and concluded that there was no convincing evidence for increased risk of CNS cancer or leukaemia from EMF exposure. If EMF does increase cancer incidence, the incidence is likely to be very low. In a Danish cohort study, including more than 30.000 electric utility workers, no excess of incidences of leukaemia's and cancers of the brain or breast among men or women was found. In this study the hypothesis of an association of Alzheimer's disease with EMF exposure could not be confirmed (Johansen, 1998).

Epidemiological studies performed with women working with VDUs regarding adverse reproductive and teratogenic effects did not show clear evidence of increased incidence.

Presently IARC is organising an international feasibility study with the aim of establishing a comprehensive epidemiological programme (within the ongoing WHO-EMF-Programme) to obtain more definitive information.

*Conclusion : The existing epidemiological and animal studies are inconclusive with respect to a causal association between exposure and cancer. Consequently there is no scientific basis for setting limit values. If it would be assumed that an increased childhood leukaemia would be due to EMF, the relative increase would be less than  $10^{-6}$ .*

#### **4.5 Hypersensitive Individuals**

There are many individual case reports of a range of adverse health reactions (headaches, dizziness, fatigue and faintness, tingling and pricking sensations in the extremities, shortness of breath, heart palpitations, profuse sweating, depression, memory difficulties, sleep disturbances, difficulty concentrating, emotional

instability, fine tremor of the hands and unconsciousness) alleged to be due to exposure to EMF. Such episodes may be explained by individual hypersensitivity attributed to EMF exposure. The absence of clear diagnostic criteria does not allow for a conclusive judgement on the existence and nature of such a hypersensitivity. These effects are difficult to confirm and adequate investigations by traditional animal and in vitro studies will be difficult, since in the majority of cases only mild non-specific symptoms are noticed.

Last year, an European group of experts reported on this phenomenon for DG V and specified the areas of concern and proposed the research work to be done.

*Conclusion : Insufficient information is available concerning possible hypersensitivity due to EMF exposure. Further results are awaited and these may provide the basis which allows more definite conclusions. Setting limit values based on hypersensitivity is inappropriate at the present time.*

## **5. Ongoing Studies**

ICNIRP (the successor of IRPA/INIRC which has strong relations to WHO, UNEP and other international bodies) is taking the lead of investigating hazards associated with non-ionising radiation (NIR).

A five years WHO Study was started in mid 1996 in collaboration with ICNIRP, IARC and other international organisations as well as national collaborating institutions. Its objectives are co-ordination of international response to the concerns, assessment of scientific literature and status reports, identifications of gaps to achieve reliable risk assessments, encourage research programmes, develop Environmental Health Criteria Monographs with formal health risk assessments and others.

Data gaps regarding in-vitro and in vivo as well as epidemiological studies have been specified following a WHO/ICNIRP Meeting in 1996 and an European Commission Expert Group Report.

## **6. Proposed Opinion**

A. As regards non-thermal exposure to EMFs, the available literature does not provide sufficient evidence to conclude that long-term effects occur as a consequence of EMF exposure. Therefore any recommendation for exposure limits regarding non-thermal long-term effects cannot be made at this stage on a scientific basis.

Ongoing investigations within the WHO Programme together with research envisaged within the Fifth Framework Programme of the



EU as elaborated in the EU Public Health Report: *Non-ionising radiation - Sources, exposure and health effects* may provide an appropriate scientific basis for improved assessment.

B. As regards the assessment of acute thermal effects from 0 Hz - 300 GHz electromagnetic fields the advice of the ICNIRP provides the appropriate basis to develop exposure limits against this risk.

## 8. List of abbreviations, units

**ELF:** (Extremely low fields). This covers essentially the frequencies of electrical power transmission, 16 2/3 Hz, 50 Hz and 60 Hz.

### Frequencies:

*Electrical Power Supply* = 15 - 60 Hz

*Broadcasting* = 145 KHz - 854 MHz

*GSM* = 900MHz

*DCS1800* = 1800 MHz

*Radar (pulst)* = 500 MHz - 100 GHz

**TESLA:** SI Unit for Magnetical Flux Density

**GAUß:** egs Unit for Magnetical Flux Density (1 Gauß = 1 Maxwell/m<sup>2</sup>) (conversion: 10 Gauß = 1mTesla)

**Ampere/m:** magnetic field strength

**Ampere/m<sup>2</sup>:** electrical current density

**SAR:** specific Energy Absorption Rate

**Volt/m:** electric field strength

**Watt/m<sup>2</sup>:** power density

## 9. Acknowledgements

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## 10. List of Relevant, Recent Scientific and Technical Material

- Anversa, A. et al., 1995. POWER FREQUENCY FIELDS, BUILDINGS AND THE GENERAL PUBLIC: EXPOSURE LEVELS AND RISK ASSESSMENT; In: Healthy Buildings, Proceedings of the 1995 Conference.
- Bergqvist, U.; E. Vogel (eds.), Report prepared by an European group of experts for the European Commission, DG V: Possible Health implications of subjective symptoms and electromagnetic Fields. Arbetslivsinstitutet, Solna. Arbete och Hälsa vetenskaplig skriftserie: ISBN 91-7045-438-8, 1997.
- Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU): Verordnung über elektromagnetische Felder -26. BImSchV-.
- Cardis E., IARC: Communication of study design „assessment of the feasibility of a multi-centric study of adult head and neck tumours (including brain tumors) and mobile telephones", 1998.
- Comba, P.; M. Grandolfo; S. Lagorio; A. Polichetti; P. Vecchia: Risk of cancer related to 50/60 Hz magnetic fields, 23 p. Rapporti ISTISAN 95/29 (in Italian) 1995.
- Decat, G.; J. van Aarle: Kwantificering van de statisch magnetische strooivelden van een 9,5 Tesla nucleaire magnetische resonantiespectrometer gebruikt in de farmaceutische onderzoeksindustrie. Medecine Du Travail & Ergonomie, Vol. XXXIV, No. 2, 1997.
- Decat, G.; P. van Tichelen: Electric and Magnetic Fields of Domestic Microwave Ovens quantified under Different Conditions. Journal of Microwave Power and Electromagnetic Energy, Vol. 30, No. 2, 1995.
- Decat, G; R. Kerckhofs: Evaluatie van elektrische en magnetische velden afkomstig van Belgische hoogspanningslijnen bij normale exploitatie. Energie & Milieu Nr. 3, 1995.
- Decat, G; P. van Tichelen: Magnetic Field Monitoring of a Microwave Oven Operating with and without Metal Housing: A New Approach. Microwave World, Vol. 16, No.2, 1995.
- European Commission, DGV/F/1/LUX2/98: Draft Proposal for a Council Recommendation on limits for exposure of the general public to electromagnetic fields, 0 Hz-300 GHz.
- European Commission, DGV: Non-ionising radiation. Sources,

exposure and health effects. ISBN 92-827-9276-5, 1996.

- Expert Group on Non-ionising Radiation, Danish Ministry of Health: Report on the risk of cancer among persons occupationally exposed to extremely low frequency magnetic fields. SEIS Report No. 2, ISBN 87-89943-75-9.
- Expert Group on Non-ionising Radiation, Danish Ministry of Health: Report on the risk of cancer in children living in homes exposed to 50-Hz magnetic fields from high-voltage lines. SEIS Report No. 1, ISBN 87-601-4115-8.
- International Commission on Non-Ionising Radiation Protection (ICNIRP), ICNIRP Guidelines: Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz).
- Johansen, C.; J.H. Olsen: Risk of cancer among Danish Utility workers - A Nationwide cohort Study. American Journal of Epidemiology, Vol. 147 , No. 6, 1998.
- Löscher, W.; R.P. Liburdy, Review: Animal and cellular studies on carcinogenic effects of low frequency (50/60-Hz) magnetic fields. Mutation Research, 1998, in press.
- Löscher, W.; M. Mevissen: Linear Relationship between flux density and tumor co-promoting effect of prolonging magnetic exposure in a breast cancer model. Cancer Letters; 96:175-180; 1995.
- Maes, A.; M. Collier; U. van Gorp; S. Vandoninck; L. Verschaeve: Cytogenetic effects of 935.2 MHz (GSM) microwaves alone and in Combination with mitomycin C. Mutation Research 393, 151-156, 1997.
- Maes, A.; M. Collier; D. Slaets; L. Verschaeve: 954 MHz microwaves enhance the mutagenic properties of mitomycin C. Environmental and Molecular Mutagenesis 28, 26-30, 1996.
- Maes; A; M. Collier; D. Slaets; L. Verschaeve: Cytogenetic Effects of Microwaves from Mobile Communication Frequencies (954 MHz). Electro- and Magnetobiology 14 (2), 91-98, 1995.
- Maes; A; L. Verschaeve; A. Arroyo; C. De Wagter; L. Vercruyssen: IN Vitro Cytogenetic Effects of 2450 MHz Waves on Human Peripheral Blood Lymphocytes. Bioelectromagnetics, 14:495-501, 1993.
- National Radiological Protection Board: Electromagnetic fields and the risk of cancer (Report of an Advisory Group on Non-

ionising Radiation) Documents of the NRPB Volume 3 No. 1, Chilton, Didcot, Oxon OX11 ORQ, 1992.

- Reißerweber, J.H.; David R.; David, E.; Pfothner, M.; Gehlen, C.: melatonin plasma levels in healthy volunteers exposed to circularly polarized magnetic 50 Hz Flux densities of 100 Microtesla and in patients suffering from electromagnetic hypersensitivity. Second World Congress for Electricity and Magnetism in Biology and Medicine, June 8-13, Bologna, Italy, 1997.

- Repacholi, M.H.; E. Cardiz: Criteria for EMF Health Risk Assessment. Radiation Protection Dosimetry, Vol.72, No. 3-4, 305-312, 1997.

- Repacholi, M.H.: Low-Level Exposure to Radiofrequency Electromagnetic Fields: Health Effects and Research Needs. Review Article. Bioelectromagnetics 19, 1-19, 1998.

- Repacholi, M.H.; B. Greenbaum: Interaction of Static and extremely low frequency Electric and magnetic fields with living systems: Health Effects and Research needs. Submitted to Bioelectromagnetics December 1997.

- U.S. Department of Health and Human Services, Public Health Service, National Institute of Health: NTP Technical Report on the Toxicology and Carcinogenesis Studies of 60-Hz Magnetic Fields in F344/N Rats and B6C3F1 Mice. NIH-Publication No. 98-3978, 1998.

- U.S. Department of Health and Human Services, Public Health Service, National Institute of Health: NTP Technical Report on the Studies of Magnetic Field Promotion (DMBA Initiation) in Sprague-Dawley Rats (Gavage/whole-Body Exposure Studies). NIH-Publication No. 98-3979, 1998.

- Verschaeve, L.: Review: Can non ionising radiation induce cancer? The Cancer Journal, Vol. 8, No. 5, 1995.

- VITO: Evaluatie van 50 Hz Elektrische En Magnetische Velden Door Middel Van Puntmetingen, Continu metingen En Dosimetrie. G. Decat; R. Kerckhofs. ENE.RA 9505, 1995.

- VITO: Lekstraling, Energierendement En Warmteverdeling Van Huishoudelijke Microgolfovens: Meetcampagne Op 72 In Gebruik Zijnde Ovens. G. Decat. ENE.RA9316, 1993.

- VITO: Monitoring En Biologische Effecten van 50 Hz Elektrische Velden: Een Stand Van Zaken. G. Decat; A. Maes, L. Verschaeve,

J. Van Rensbergen. VITO-Seminarie,1997.

- VITO: Monitoring van Electromagnetische Velden: VITO-Publicaties & Rapporten. List of References, G.Decat.

- WHO: The International EMF Project. Health effects of static and time varying electric and magnetic fields. Progress Report 1996-1997.

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