

## Cores Symposium on non-ionizing radiation (NIR) research and safety

### Summary of presentations

Non-ionising radiation surveillance in Finland was introduced by **Lauri Puranen** (STUK). Established adverse health effects by the different types of NIR form the basis for protection and exposure limits. Ultraviolet (UV) radiation induces acute effects (erythema and ceratitis, ie. snow-blindness) and long-term effects (skin cancers, cataract and aging of skin). Lasers can cause injuries in the eye and skin. Electromagnetic fields cause stimulation at low frequencies and thermal effects at high frequencies. Ultrasound has been shown to cause inflammation and follicles in tissues, injuries in nerves and blood vessels (necrosis) and injuries due to the excess heat in tissues.

Reliable EMF dosimetry is essential for any study on biological effects as pointed out by **Sami Kännälä** (STUK). Assessment of the EMF exposure level inside the body is based on SAR (specific absorption rate), electric field and current density. However, measurement of internal exposure is practically impossible and numerical simulations are needed in most cases even though analytical methods can give a rough estimate in simple situations (uniform field, homogeneous model).

**Riikka Pastila** (STUK) reviewed the biological and health effects of UV radiations and concluded that there is no safe tan from natural or artificial UV-sources. Sunbed use has been linked with skin cancer formation, especially with melanoma. Ultraviolet tanning can be addictive through  $\beta$ -Endorphin secretion from skin cells after UV exposure, leading to relaxation, pain relief and positive mood effects. Solarium use restrictions aim to protect adolescents from UV derived health problems and also to minimize health care expenses for the long run.

Health effects of intermediate frequency magnetic fields such as those encountered in several household appliances and e.g. anti-theft electronic article surveillance systems in stores have been recently studied at the University of Eastern Finland as part of the EU funded GERONiMo project. **Mikko Herrala** studied effects of exposure to 7.5 kHz MFs up to 300  $\mu$ T and concluded that there was no adverse effects on male fertility indicators, prenatal and early postnatal development of the brain, or genotoxicity in vitro or in vivo. Mild impairment of learning and memory may result from exposure of adult animals. Overall, the findings indicated rather favorable than adverse biological effects, such as increased sperm motility, increased relative cell number and suggestive decrease in the level of genetic damage.

**Anssi Auvinen** reviewed epidemiological studies addressing the health risk of mobile phones. He concluded that case-control studies have not shown strong evidence for brain tumor risk in relation to mobile phone use. Real world data (cancer registries) do not show increases in brain tumor incidence rates during almost 20 years of large scale adoption of mobile phone use. Furthermore, cohort studies show little indication of increased risks. Overall, there are still uncertainties but the balance of evidence weighs towards no major health impact.

**Päivi Roivainen** discussed epidemiological studies on health effects of extremely low field magnetic fields (ELF MFs) and approaches for exposure assessment. Main sources of exposure to general public comes from powerlines, in-house electrical installations and household appliances. ELF MFs are classified as a possible human carcinogen (Class 2B) by IARC in 2001, mainly based on two pooled analyses on childhood leukemia showing 2-fold risk with ELF MFs above 0.3 – 0.4  $\mu$ T. Pooled analyses of more recent studies of ELF MF and childhood leukemia are in line with this assessment. Research data on adult cancers are more limited and contradictory. Common problems in previous studies include the low number of highly exposed subjects, poor exposure assessment, confounding by e.g. socioeconomic status and other environmental exposures and selection bias (differential participation of cases and controls). As a way forward, Roivainen proposed that indoor transformers in residential buildings provide an approach providing better dosimetry

for epidemiological studies as indoor transformers generate stronger MFs than commonly encountered in the environment.

**Carlos Martino** gave a lecture on quantum optimal control of reactive oxygen species production. The radical pair mechanism and altered ROS production may provide an explanation for the EMF effects. ROS are known to exert a wide range of biological effects from deleterious oxidative stress in pathogenesis to beneficial regulatory functions. Examples of spin-correlated radical pair mechanism include magnetoreception in bird navigation, photosynthesis, and olfactory sensing.

**Maria Rosaria Scarfi** discussed protective effects of radiofrequency fields in mammalian cells damaged by mutagens (adaptive response). Overall, protective or beneficial effects have been reported for many frequency ranges (SMFs, ELF-MFs, RFs) and also applied in therapies. She concluded that most of the studies on biological effects of RF alone have been negative whereas studies of combined effects of RF have been positive. She exposed cultured human lymphocytes to RF and challenged them by mitomycin-C (MMC). RF delivered during the S/G2 phase (dividing cells) induced a significant reduction in MMC-induced DNA damage, whereas RF delivered during G0/G1 phase did not protect from subsequent treatment with MMC.

**Jonne Naarala** discussed genomic instability and non-ionizing radiation. Induced genomic instability means appearance of *de novo* genetic damage in the progeny of exposed cells. Such delayed effects manifest e.g. as mutations, apoptosis, chromosomal aberrations or micronuclei, and the cells (or organisms) inherit not only mutations but an increased mutation frequency. After exposing cells to different types of non-ionizing radiations, he concluded that induced genomic instability was only induced by ELF-MF and not by intermediate frequency or radiofrequency magnetic fields. The radical pair mechanism is considered one of the more plausible mechanisms for explaining biological effects of weak magnetic fields. Altered DNA damage responses or altered redox signaling mediated via MF effects on radical reactions in cryptochromes could potentially explain the induced genomic instability, and finally cancer.

In his honorary lecture “Investigations by a doc”, professor **Jukka Juutilainen** summarized his experience on more than 35 years of research, focusing on ELF and IF from the perspective of environmental health: hazard identification, dose-response assessment, exposure assessment and risk characterization.

In the early days in 1980's there were no commercial measurement tools for ELF measurements and such devices had to be constructed yourself until the early 2000's when commercial ELF-MF meters became available. Measurements were subsequently carried out around power lines and a range of household appliances and indoor transformer stations. The conclusions for the exposure assessment were that only a small fraction of the population is exposed to MF levels ( $>0.3\text{-}0.4\ \mu\text{T}$ ) that are suspected to be associated with adverse health effects. Individuals with “high” exposure levels can be identified with reasonably low exposure misclassification, and high quality epidemiological studies are possible by studying groups exposed to MF from indoor transformer stations.

The studies by Juutilainen on health effects of low frequency (ELF and IF) magnetic fields addressed reproduction and development, effects on the nervous system and cancer, again focusing on low environmental fields and possible adverse effects below the current exposure limits. The early work on chick embryos showed a non-linear (plateau above a threshold) dose response for the observed frequencies of abnormal embryos as a function of the magnetic field strength. Lessons learned about effects on reproduction and development were that subtle effects on development are possible at low exposure levels. However, more research would be needed (for example, to understand dependency on exposure level and frequency). The studies on nervous system concluded that effects may occur below known thresholds for nerve cell stimulation.

The studies on carcinogenesis by Juutilainen have covered epidemiology, animal experiments, co-carcinogenicity, and a large variety of potential mechanisms, most recently the radical pair mechanism: static and low frequency magnetic fields affect recombination of radical pairs. As for the carcinogenic

effects of ELF, Juutilainen concluded that they are possible. However, if they exist, they are really hard to show and the mechanism may be different from that of any known carcinogen.