Information No. 16/2009
NRL for non-ionizing electromagnetic fields and radiation

Electromagnetic field (0 Hz – 300 GHz) – status as of 1 January 2009

In 1996 the World Health Organization (WHO) initiated a research project to obtain sufficient knowledge and assess whether, in addition to the two identified short-term effects of exposure to the electromagnetic field in the 0 Hz – 300 GHz frequency range (heating of body tissue and effects on the nervous system), there are other issues such as long-term health effects that may cause serious diseases such as cancer, Alzheimer's disease and Parkinson's disease. Due to the considerable funds allocated for this research, the number of research workers focused on this issue increased several times, leading to a rapid increase in the number of publications and reports focused on the "electromagnetic field and health". Scientific knowledge on the influence of electromagnetic fields on humans has improved to the extent that the uncertain issues which, among other things, caused huge differences among the standards prescribed or used in various countries worldwide, were eliminated to a large extent. The principal issues covered by the WHO research project, which were resolved over the past ten years, can be summarized in the following four points:

a) Does the health risk associated with exposure to electromagnetic waves depend on their modulation (phase modulation, amplitude modulation, frequency modulation)?
b) Does prolonged human exposure to electromagnetic fields with intensity below the 1998 ICNIRP exposure limits cause cancer or other serious diseases such as Alzheimer's disease and Parkinson's disease?
c) Are some individuals hypersensitive to electromagnetic fields? Is their health adversely affected by exposure to an electromagnetic field with intensity far below the 1998 ICNIRP limits [1] ? (This hypothesized predisposition similar to allergy to chemical or biological substances, have been termed "electromagnetic hypersensitivity".)
d) Has any causal link been proved between acute leukemia in children and exposure to magnetic fields in proximity to overhead high-voltage power lines?

Pertaining to a): There is no dispute that the thermal effects of high-frequency electromagnetic fields depend only on the effective values of their components. Modulation of this field could result in any effects only if, during absorption of high-frequency energy within body tissue, there were some non-linear processes which would be able to demodulate the absorbed wave in full or in part. In such a case, in addition to high-frequency current, there would also be currents (electric fields) with modulation frequency in the tissue. Like the contact currents, these low-frequency currents would stimulate the nervous system, which would have to be evaluated in parallel with the heating of the tissue. In 1999, the WHO organized a special workshop on this topic [2] in the Sicilian city of Erice, which was attended by approximately 200 experts from around the world. The conclusion arising from this workshop was that no effects other than thermal effects can be expected in a high-frequency field with intensity below the 1998 ICNIRP limits [1], irrespective of the manner of field modulation. The most drastic case of modulation of an electromagnetic wave is undoubtedly a sequence of very short intense pulses, which are commonly used in surveillance radars. Such pulses, which have sufficient field intensity, elicit an auditory sensation ("microwave hearing"). The initial interpretations that the perceived sound is evidence of non-thermal effects of an electromagnetic field turned out to be false: the perceived sound originates as a result of very slight heating of the brain (a few tens of millionths of a degree at most), which generates a sound wave. This wave is detected by sound receptors from the inside.

A thorough evaluation of possible effects of modulation of the absorbed electromagnetic radiation was published by P. Valberg, E. van Deventer and M. Repacholi in an article issued in the renowned international journal *Environmental Health Perspectives* in 2007 [3]. The content and focus of the article is much broader than could be guessed from its title. Among other things, the article includes a

theoretical microphysical analysis of the impact of the electromagnetic field on biological tissue at the cellular, molecular and atomic levels, which takes into account the content of frequency components of the modulation. The analysis has shown that modulation does not add any specific effects to the thermal effects of the field. The transformation of energy of high-frequency electromagnetic radiation into heat energy remains the only identified, potentially harmful effect of high-frequency energy absorption in body tissue. The practical outcome of this conclusion also concerns the issue of looking for problems that has remained open: there is no point in repeatedly studying potentially different health risks whenever a new information-transmission technology is launched. Technologies such as GSM, UMTS, WiFi, digital transmission of information, etc. use electromagnetic waves, the characteristics of which are described by Maxwell's equations, and their quantum interactions with substances, including biological tissue, are by Schroedinger's equation. The frequently used argument that nothing or only very little is known about the risks of exposure to electromagnetic fields emitted by new technologies demonstrates a lack of knowledge of the basics of physics. In their article, Valberg et al. also point out the fact that long-term health risks associated with high-frequency fields emitted by base-station antennas also must be evaluated taking into account the fact that radio and TV broadcasting have been widely used for more than 50 years without any adverse effects of emitted electromagnetic waves having been identified. This is explicitly stated in the article. Therefore, we can safely claim that there are no long-term adverse effects of low-intensity, high-frequency electromagnetic fields.

Pertaining to b): The quanta of the electromagnetic field with frequency up to 300 GHz carry energy which is approximately one hundred times lower than the energy of thermal motion of molecules in living tissue. For this simple reason, it cannot be expected that there are any effects other than thermal effects during absorption of high-frequency energy in body tissue: by absorbing a photon, a molecule increases its inner energy (mostly the molecule's rotational energy; in the case of larger molecules, also vibrational energy); but quickly loses this energy upon colliding with another molecule. On collision with another molecule, the rotational energy of this other molecule or its translational energy (speed of its motion) increases. The changes in the rotational, vibrational or translational energy caused by absorption of the electromagnetic field quantum are very small in comparison with the energy transferred in collisions of molecules during thermal molecular motion, and they cannot in any case lead to a change in molecular structure. Indeed, the molecules that are essential for vital functions must be sufficiently robust so that their structure is not damaged in thermal collisions between molecules, let alone on absorption of at least one hundred times less energy quanta of electromagnetic radiation. In spite of this simple summary based on the fundamental laws of quantum physics, many researches have been focusing on searching for changes that, upon exposure to high-frequency radiation, would disrupt the function of molecules, for example, by breaking bonds in DNA molecules. There is a number of publications that have reported such unexpected findings. The articles published by the Reflex research team led by Professor Franz Adlkofer of the Medical University of Vienna represent a lesson and a sad example of this. In 2005 [4], the members of the Reflex team claimed to have succeeded – for the first time in history – in proving that low-intensity electromagnetic fields with frequencies and intensities at the levels used by mobile operators damage DNA molecules. They insisted on this finding even after independent studies could not successfully repeat it. They published a number of other articles with the same findings, the last of them in 2008 [5]. However, Dr. Lerchl of Bremen University managed to show [6], by analyzing statistical spread of individual observations that the published findings could not have originated from the experiments. The lab technician who had evaluated the effects of electromagnetic fields on molecules subsequently admitted that she had fabricated the results. Therefore, even after 2008, it still holds true that no verified scientific finding exists that would prove the occurrence of molecular damage in the cells of biological tissue caused by radio- and microwave frequency electromagnetic radiation. Thermal effects remain the only identified, potentially harmful factor after more than fifty years of using equipment emitting high-frequency fields.

Pertaining to c): The idea that some people are hypersensitive to electromagnetic fields originated about thirty years ago. Swedish professor U. Bergqvist [7] used hypersensitivity as an explanation for symptoms such as skin itching and rashes reported by some workers who operated computer monitors, while the absolute majority of others did not have any such symptoms. The concept of hypersensitivity of some people to the electromagnetic field has gradually extended to fields generated by other electrical equipment, including transmitters of all types and low-frequency household appliances. The list of symptoms has also extended and includes practically all known disorders (insomnia, headaches, dizziness, fatigue, skin irritation, loss of appetite, tinnitus, deficient memory and poor concentration, Alzheimer's and Parkinson's diseases, heart problems, digestive disorders, changes in brain activity and the nervous system, inflammatory and allergic reactions, stress, genotoxic effects, immune-system disorders, and many types of cancer including childhood leukemia, etc.). Although a causal link between exposure to (usually extremely low) electromagnetic fields and health problems that were attributed by ill people and researchers to electromagnetic-field effects have never been proved despite great effort and considerable research funding, the concept of an "allergy" to electromagnetic field is still topical. In some European countries, up to three percent of the population claim to be hypersensitive to electromagnetic fields. Their demand requirement that such a condition must be taken into account when determining standards is even recognized by official authorities in a number of countries. The problem is that the belief that some people are hypersensitive to electromagnetic fields is false. This false belief has, for more than thirty years, been the reason for wasting public money and, what is worse, created conditions for psychogenic illnesses among people who are sensitive not to electromagnetic fields, but to reports about adverse health effects of such fields. For the whole period of duration of experimental research on people claiming to be hypersensitive to electromagnetic fields, no study could successfully prove a causal relationship between the persons' health problems and the presence and intensity of an electromagnetic field to which they were exposed. The WHO International Workshop on EMF Hypersensitivity held in Prague in October 2004 [8], which was attended by 152 participants, reached the clear conclusion that there is no evidence of a causal link between the reported symptoms and exposure to electromagnetic fields. The term "electromagnetic hypersensitivity" (EHS) was therefore replaced with the neutral term "idiopatic environmental intolerance" (IEI). One of the reasons for which this finding is still being ignored is the fact that an explanation of the reported symptoms has not been officially provided, although such explanation was published by three Swedish professors [9] in their article as early as in 1995, showing, that the health troubles are due to a psychosomatic syndrome. This explanation was ignored and various studies have been ongoing, without any positive findings, even after the Prague workshop, with financial support totaling tens of millions of euros. Perhaps a change can be expected following the direct experiment focused on stimulation of brain centers via the functional magnetic resonance imaging method. Using this method, M. Landgrebe et al. [10] convincingly showed that during sham exposure to a fictive (i.e., reported but non-existent) electromagnetic field, subjectively electrosensitive persons suffer real stimulation in the part of the brain that perceives pain or unpleasant sensations. This definitely puts paid to professor Bergqvist's idea. This is of great importance also for the purpose of treatment of subjectively hypersensitive patients because their health problems are real and often so serious that the patients are incapable of working or move to a caravan in a forest, believing that they can thus avoid exposure to electromagnetic radiation. It can be expected that a correct diagnose can lead to effective treatment. In any case, it is possible to say that whether electromagnetic hypersensitivity is a valid phenomenon has been clearly answered in the negative.

Pertaining to d): The question of whether the (slightly) increased incidence of leukemia in children living in the vicinity of high-voltage power-transmission lines has a causal association with exposure to low-frequency (50 Hz or 60 Hz) magnetic field, is thirty years old as well. The statistical correlation between these two parameters was published by N. Wertheimer and E. Leeper [11] and, since that time, several dozen expensive epidemiologic studies have been conducted on this topic. Figure 1 below taken from the overview compiled by J.E. Moulder [12] shows the results of individual epidemiological studies for two five-year periods. The points on the right of the vertical line pertain to the studies that showed statistical correlation between the increased incidence of leukemia and living

near power lines. The points on the left of the vertical line represent a correlation in the opposite direction, i.e. lower incidence of leukemia. In the language of epidemiological studies it could be stated that the points on the right of the division (neutral) line show a harmful effect and, to the contrary, the points on the left show a protective effect of this field with respect to childhood leukemia. The number of points on the right is approximately the same as the number of points on the left; but, of course, they reflect a varying number of cases and, therefore, they have various weights. The point obtained through a meta-analysis is very close to the neutral line; but it is on the right and thus represents a tendency towards increased incidence of the disease. Detailed findings were obtained from later made meta-analyses. Therefore, in 2002 the International Agency for Research on Cancer classified low-frequency magnetic fields under Group 2B, i.e. a possible carcinogen.

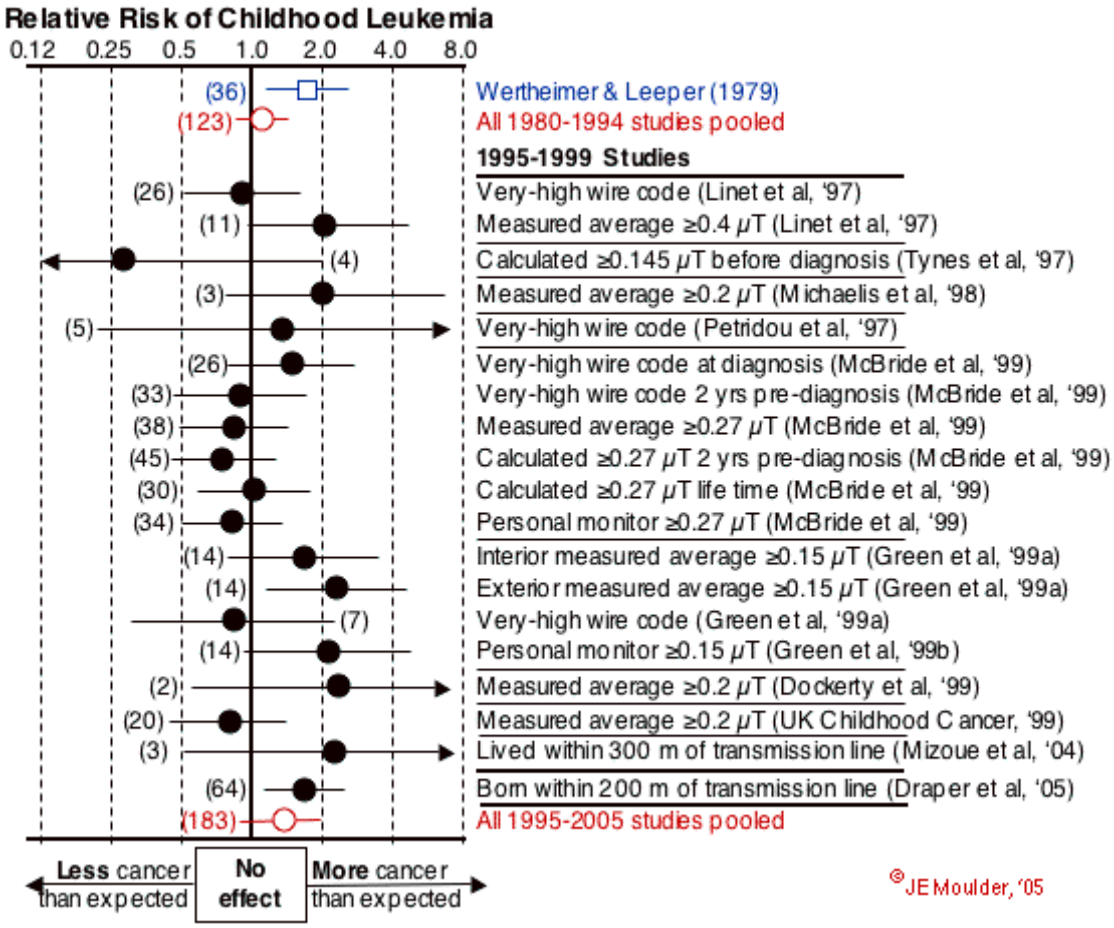

Figure 1: Results of epidemiological studies for two five-year periods (after Moulder 2005)

Epidemiological studies cannot prove a causal link. Experiments on animals did not identify any carcinogenic effect of low-frequency magnetic fields, not even of fields with orders of magnitude higher than those found near power lines. Despite intense efforts, no plausible mechanism could be found showing that a low-frequency magnetic field could cause or support the origin of the said disease. Epidemiological studies focused on other types of cancer have not identified any similar correlation. At present, the scientific community is predominantly of the opinion that the identified very small, though significant correlation between exposure to a magnetic field in the vicinity of high-voltage power lines and the incidence of childhood leukemia is due to a factor which is termed “bias”, or confounder. In any case, there is no convincing proof of a causal link between low-frequency magnetic fields and the increased incidence of childhood leukemia.

The opinion, repeated over thirty years, on the effects of a magnetic field with magnetic flow density of 0.4 microtesla, which is 250 times lower than the current reference value recommended by the ICNIRP for general public (the value of 0.4 microtesla has been based on evaluation of epidemiological studies) suffered a forceful, unexpected blow by the research conducted by G. Draper

[13]. He used a database of more than 9,000 cases of childhood leukemia reported in Great Britain, collected the addresses of the affected children and mapped how far each afflicted child lived from an overhead high-voltage power line to search for increased incidence of this disease at smaller distances from the lines. He indeed found increased incidence, but he also found within the distance between 200 and 600 meters from power lines. Dr. Draper himself commented on this unexpected result, saying that this increase cannot be a direct effect of magnetic field generated by electric currents in the high-voltage power line. New theories immediately appeared, such as that focusing on the effect of corona ions, which are electrically-charged particles created by power lines corona discharges and blown several hundred meters away by the wind. It is difficult to imagine how these ions could cause childhood leukemia, but one fact is certain: the intensity of the magnetic field generated by high-voltage power lines is lower within the indicated distance than the intensity of the field emitted by the low voltage wiring in houses. And this does not depend on the distance from high-voltage power lines. It is useless to point out that thirty-year-old false belief had and still has significant economic and political impacts.

Conclusion:
Heat and induced currents remain the only factors by which electromagnetic fields can have any effects on health. It is hard to predict when this finding will be reflected in a world-wide harmonization of standards. Continuation of research studies and the frequent alarming rumors about brain cancer caused by mobile phones and about leukemia caused by high-voltage power lines can significantly delay the application of scientific findings, as is apparent from other industries. What should not be delayed, is finding an answer to the question of how the absolutely obvious and very expensive mistakes could remain undetected for decades despite intensive and well-funded research.

Reference:

[1] International Commission on Non-Ionising Radiation Protection (ICNIRP). Guidelines on limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Physics Vol. 74, April 1998, No. 4, pp. 494 – 522

[2] WHO International workshop on biological effects of pulsed radiofrequency fields. Erice, Italy, 21.-25. November 1999

[3] Peter A. Valberg, T. Emilie van Deventer, and Michael H. Repacholi. Base Stations and Wireless Networks – Radiofrequency (RF) Exposures and Health Consequences. Environmental Health Perspectives Vol. 115 No 3, March 2007, pp. 416-423

[4] Diem E, Schwarz C, Adlkofer F, Jahn O, Rudiger H. Non-thermal DNA breakage by mobile-phone radiation (1800MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. *Mutat Res.* 583:178-183, 2005.

[5] Schwarz C, Kratochvil E, Pilger A, Kuster N, Adlkofer F, Rüdiger HW (2008) Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes. Int Arch Occup Environ Health. DOI 10.1007/s00420-008-0305-5

[6] Alexander Lerchl: Comments on "Radiofrequency electromagnetic Fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes" by Schwarz et al. (Int Arch Occup Environ Health 2008: doi: 10.1007/s00420-008-0305-5). Int Arch Occup Environ Health DOI 10.1007/s00420-008-0323-3

[7] Bergqvist U.; Vogel E. Possible health implications of subjective symptoms and electromagnetic fields. A report prepared by a European group of experts for the European Commission, DGV Arbete och Hälsa 19; 1997:19. Swedish National Institute for Working Life, Stockholm. ISBN 91-7045-438-8

[8] Electromagnetic Hypersensitivity. Proceedings International Workshop on EMF Hypersensitivity, Prague, Czech Republic. October 25 -27, 2004.World Health Organization, Ed.: Kjell Hanson Mild, Mike Repacholi, Emilie van Deventer, Paolo Ravazzani

[9] Göthe C. L., Odont, C. M., Nilsson, C.G: The environmental somatisation syndrome. Psychosomatics 36: 1-11; 1995

[10] Landgrebe, M., Barta, W., Rosengarth, K., et al. Neuronal correlates of symptom formation in functional somatic syndromes. A fMRI study. NeuroImage, 2008, 41, p. 1336–1344.(Short note „Sham radiation can cause real pain in *The Economist,* printed version, 25. September 2008, p. 10-14.)

[11] Wertheimer N, Leeper ED: Electrical wiring configurations and childhood cancer. Am. J. Epidem., 109. No. 3: 273-284, 1979

[12] John E. Moulder, Professor of Oncology, Medical College of Wisconsin. http://www.mcw.edu/display/docid5175.htm

[13] Draper, G. *British Medical Journal*, June 4, 2005; vol 330: p 1290-1295.

Authors:
Ing. Lukáš Jelínek, Ph.D., doc. RNDr. Luděk Pekárek, DSc.
National Reference Laboratory on Non-Ionizing Electromagnetic Fields and Radiation
National Institute of Public Health
Šrobárova 48, Prague 10, Czech Republic