World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:6, No:2, 2012

Identification of Impact of Electromagnetic Fields at Low and High Frequency on Human Body

P. Sowa

***Abstract*—**The article reviews the current state of large-scale studies about the impact of electromagnetic field on natural environment. The scenario of investigations – simulation of natural conditions at the workplace, taking into consideration the influence both low and high frequency electromagnetic fields is shown.The biological effects of low and high frequency electromagnetic fields are below presented. Results of investigation with animals are shown. The norms and regulations concerning the levels of electromagnetic field intensity are reviewed.

***Keywords*—**Electromagnetic field and environment, biological effects of electric field on human body, simulation of natural condition at workplace

I. Introduction

ELECTROMAGNETIC fields of different frequencies interact with the body in different ways. At low frequency the harmful influence to the human body coming into existence in surrounding the line and devices of electrical power engineering stations.Heating is the main biological effect of the electromagnetic fields of radiofrequency fields.
The areas of current scientific investigation about interactions between living organisms and electromagnetic fields are at extremely low frequency (50 - 60 Hz) and at frequencies generated by cell (satellite) phones (in the kilo-, mega- and giga-Hz range).

Research works carried on intensively during the past two decades concern of determining development potentialities of cancers (child's leukemia, brain tumors and lymphatic illness) under the influence of the electromagnetic field and of coming into existence of illness of the electromagnetic nervous system.

Despite many studies, the evidence for any effect remains highly controversial. However, it is clear that if electromagnetic fields do have an effect on natural environment, but the results to date contain many inconsistencies.

The mistakes of examinations are as consequence of statistically wrong selection of the investigated group, of incorrect information about the daytime exhibition and impossibility of the selection of the optimal control group.

This work was supported by the Ministry of Science and Higher Education (Warsaw, Poland)as investigative project2010-2012 (under Grant N N511 351737).

P. Sowa, is the Director of Institute of Power Systems & Control and Vice-Dean for science and organization of the Faculty of Electrical Engineering at Silesian University of Technology, Poland (email: Pawel.Sowa@polsl.pl) phone: +4832371481

In addition the aim of the examination is conditioning results (producer-issuers).

Countries set their own national standards for exposure to electromagnetic fields. However, the majority of these national standards draw on the guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). This non-governmental organization, formally recognized by WHO, evaluates scientific results from all over the world. Based on an in-depth review of the literature, ICNIRP produces guidelines recommending limits on exposure. These guidelines are reviewed periodically and updated if necessary.

The basic for the ICNIRP guidelines are the results of analysis and experiments making around the world. The rules in many countries (national standards) are drawing as consequence of these international guidelines [1,2].

From prescriptive regulations concerning the environmental protection it results that assumed and applied in Poland acceptable values of intensities of electromagnetic fields 50 Hz in the natural environment are a more rigorous from recommended in the European Union and by the World Health Organization.

The comparison of permissible public exposure levels – for electric field for ICNIRP (recommendations from 1998) and Polish ordinance (2003) are shown – as example, in figure 1.

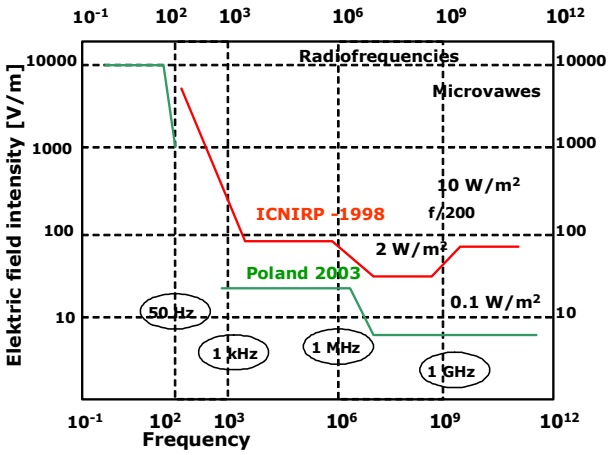

Fig. 1 Permissible public exposure levels in electric field

II. Electromagnetic Fields Of Low Frequency

At low (50 – 60 Hz) frequency the harmful influence to the human body coming into existence in surrounding the line and devices of electrical power engineering stations.

To the maximum value and the disintegration of the electric field in surrounding the overhead power grid its parameters influence of (among others) firebrands: line voltage,distance between phase conductors and earth, between conductors of different phases, geometric system of phase conductors, and in lines two- and multi-lane – mutual situating wires (or of bundles) of the same phase in different paths,diameter of wires and in the case of bundles wires also space of wires in the bundle.Different structural elements of the line, e.g. earth wires field strengths have the smaller influence on the schedule under the line.

One of the first observations about negative effects on electromagnetic field on human health is appearance of different symptoms. By review of investigation of impact of electromagnetic field at low frequency it is clear that only sparse data on the effect at extremely low frequency electric fields generated nearby high voltage transmission lines on the function of central nervous system resulting in behavioral alterations in occupationally exposed humans are at disposal. The results of experimental studies shown that low frequency high voltage electric fields can change transitory the behavior of mice, rats, and nonhuman primates and did not suggest acute adverse effects. The study made by Silesian Medical University in cooperation with Silesian University of Technology [3,4,5] shown the influence of long-term, whole-body exposure to electric field occurring nearby HVDC transmission lines on such behavioral reactions as locomotors activity, exploratory activity, space memory and irritability in rats. Another aim of this experiments were to find the answer on question how is the effect of long-term exposure to electric field with intensities allowed by actual legislative regulations on activity of some antioxidant enzymes and concentration of malonedialdehyde in animal model of male rats.

III. Electromagnetic Fields Of Radio And Microwave Frequencies

Within the range between a few MHz to some GHz the numerous broadcasting sources in addition to mobile telephony exist. As examples of high-power sources in this range could be radio transmitters at some 100 MHz and television (UHF) broadcasts at around 800 MHz.

Mobile telephony specific emissions are limited to 450 MHz (analog system), 850, 900, 1800 MHz (GSM), as well as 1900-2200 MHz (UMTS). The mobile phone system works as a network containing base stations, which can link with a number of handsets.

Heating is the main biological effect of the electromagnetic fields of radiofrequency fields. The electric and magnetic fields are closely interrelated and typically measured as power densities in watts per square meter (W/m^2).

Mobile phones are operated very close to the head. Therefore, the distribution of absorbed energy in the head of the user must be determined rather than the heating effect across the whole body.

As shown in figure 2 around heads of the man are concentrating in the result isoline of electromagnetic field of what electromagnetic energy inside the head can achieve quite considerable value.

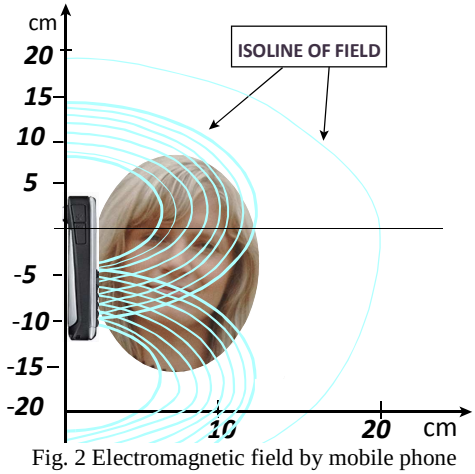

Fig. 2 Electromagnetic field by mobile phone

Real radiating characteristics of radiating movable terminals while sending are difficult to determine, depend from the way of putting the phone call for the head, of situating the hand of the user of the aerial counterbalancing, of individual conductance of liquids in internal organs of the man but also of being elements of different kind in direct surrounding the radiant of the aerial of the phone.

The increased radiation around aerials of mobile phones is very important phenomenon because the problem is connected with head - the most sensitive organ of human body.

IV. Biological Effects Of Low Frequency Electromagnetic Fields

Experimental material was consisted of 24 (by investigation of behavioral reactions) or 96 (by investigation of activity of some antioxidant enzymes) male Wistar albino rats (age: 8 weeks, weight: 180-200g). All animals were randomly divided into 3 groups (8 or 32 animals each respectively). The rats from two experimental groups were exposed for 56 consecutive days (8 hours daily) to electric fields with intensity values of 16 kV/m and 35 kV/m respectively, in a specially designed experimental system. The control animals were subjected to a sham-exposure in the same experimental system, during which no electric field was generated between electrodes. At 14, 28 and 56 day of exposure cycle and then in 28 day after the end of exposure cycle a part of animals from all groups (8 rats at a same time) was exsanguinated in Morbital narcosis.

A locomotors activity was determined in the open field test by recording a number of episodes of crossings, peeping, rearing, washing and defecation per 3 minutes of observation. An exploratory activity was examined in the “hole test” by recording a number of head dips into a board hole per 3 minutes. Space memory was determined by means of water maze test on the basis of measurement of time required for crossing of a specially constructed water maze(see. Fig. 3). Irritability was investigated by means of Nakamura and Thoenen’s score test.

The results of investigation shown that in both groups of electric field – exposed rats no significant changes in the water maze crossing time, in the number of episodes of rearing and head dips in hole test as well as in irritability score were observed comparing with control animals.

Fig. 3 Water maze test

As presented in example results in figure 4, the long-term whole-body exposure of rats, to strong electric field with generated nearby HVDC transmission lines, causes only a transient significant reduction of locomotors activity in the initial phase of exposure cycle.

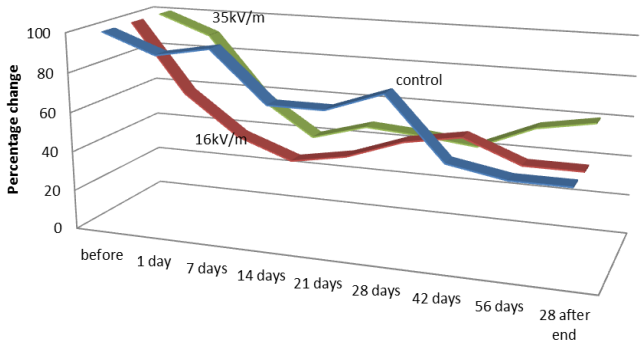

Fig. 4 Test of peeping in „open field"

The second part of experiment is connected with Influence of long-term exposure to high voltage electric field on antioxidant activity of erythrocytes in rats. In obtained hemolysates of erythrocytes samples activity of antioxidant enzymes as: catalase, glutathione reductase, glutathione peroxidase and superoxide dismutase as well as malondialdehyde concentration was determined with use of kinetic and spectrophotometric methods.

Very important in the example results were the changes of catalase activity in erythrocytes of rats exposed to static electric field of different intensities and control rats are presented.

In some paper are suggested that strong electromagnetic fields occurring in the neighborhood of electric field transmission lines can produce an increased amount of reactive oxygen species in tissues, resulting in stimulation of peroxidation of membrane lipids leading to apoptosis and death of cells

The results of above mentioned experiments shown that the proper construction of high voltage constant current transmission lines enables to avoid serious health hazards for human population related to disturbances of antioxidant processes in living organisms.

V. Biological Effects Of High Frequency Electromagnetic Fields

The radiofrequency fields penetrate bodily tissue and heat it due to the absorbed energy. The depth of penetration decreases at higher frequencies. Unfortunately the heating occurs from the inside, therefore it is not perceived (or perceived too late) since we perceive heat primarily through receptors situated near the skin surface. Despite the large number of studies undertaken to detect biological effects of electric and magnetic fields, few systematic studies have defined the threshold field characteristics that produce significant perturbations of biological functions. It is well established that induced electric current can stimulate nerve and muscle tissue directly once the induced current density exceeds threshold values

Very high field strengths are needed to produce problems such as cataracts or skin burns. They will not occur through normal everyday exposure to radiation, but they can occur in the immediate vicinity of powerful radar systems, for example.

Nowadays there are now many reporting side effects from use of mobile phone. At least one of the symptoms noted, which include dizziness, concentration difficulties, memory loss, and a burning sensation, showed up in 47 percent of people who reported using these wireless devices an hour or more daily.

In [6] the effects of the electromagnetic fields emitted by cellular phones on the human EEG in adults and children were studied. The EEG was found to show normal activity during exposure, except a slight increase in the global median frequency. It was concluded that the electromagnetic fields emitted by cell phones may be harmful for the human brain, since the delta waves are pathological if seen in awake subjects.

Concerning the human brain, the above mentioned studies suggest that electromagnetic fields emitted by cellular phones may affect the human EEG. The current scientific literature is, however, full of inconsistencies.

There are numerous reports on the behavioral and physiological reactions of laboratory animals to thermal interactions of electromagnetic fields.

Several studies with rodents and monkeys have also shown a behavioral component of thermoregulatory reactions [7].

VI. Simulation Of Biological Effects Of Electromagnetic Fields At Workspace

Electrical engineer or technician working near electrical equipment (power lines, transformer stations, etc.) is exposed to the double action field - both low and high frequencies.Very often working 8 hours close to HV devices simultaneously talk on the mobile phone by setting the appropriate activities and tasks to be performed.

Simulations of such situations are performed in the laboratory of Silesian Medical University in cooperation with Silesian University of Technology with the use of experiments on animals (rats).

The laboratory consists of a generator of alternating electric field of industrial frequency of 50 Hz and variable values of the intensity E (near field interaction zone) and the

electromagnetic field generator, realized in the form of a mobile terminal multiple ranges Nokia, (far field interaction zone). The principle idea of laboratoryis shown in Figure 5.

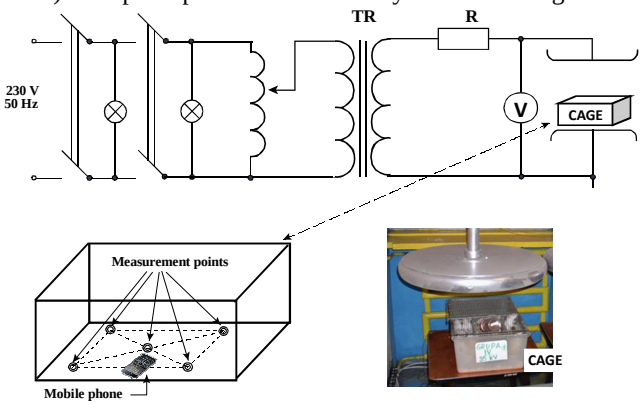

Fig. 5 Idea of system of simulation

In the experiment on an animal model research material were rats, male Wistar, 8-week, which were divided randomly into four equal groups: a control group subjected to sham exposure (during which the system was not generated showroom electromagnetic field), a group subjected to the action field electromagnetic current of 10 kV/m is generated in a typical transmission line surrounded by an alternating current with a frequency of 50 Hz, a group subjected to an electromagnetic field generated by a standard mobile phone with a frequency of 900-1800 Mz and a group subjected to the simultaneous interaction of the electromagnetic field intensity 10 kV/m generated in the environment of the AC transmission lines with frequency of 50 Hz electromagnetic fields generated by mobile phone with a frequency in the range 900-1800 Mz (simulation of daily activity of engineers working close to electric devices and talking by mobile phone during work). Each group consisted of 10 animals. Cycle times daily 8-hour exposure of animals from different groups on appropriate forms of interaction of the electromagnetic field was 28 days. After the exposure to electromagnetic field or sham exposure the animals were necropsied under anesthesia to obtain blood for biochemical research, as well as tissues and organs for histopathological evaluation and implementation of the homogenates for biochemical determinations. The resulting serum and tissue homogenates prepared in the near future will be carried signs include the following biochemical parameters: the activity of selected antioxidant enzymes: superoxide dismutase, glutathione peroxidase and catalase, and selected markers of oxidative stress (dialdehyd malonic). The results of simulation will be published in the next future.

VII. Final Remarks

In presented paper the current state of studies about the influence of electromagnetic field on natural environment as well as the scenario of simulation of natural conditions at the workplace are presented.The effects of external exposure to electromagnetic field on the human body and its cells depend mainly on the electromagnetic field frequency and magnitude or strength. Low and high frequency electromagnetic waves affect the human body in different ways. At low frequencies, external electric and magnetic fields induce small circulating currents within the body. The main effect of radiofrequency electromagnetic fields is heating of body tissues.

To find the protection at workplace close to h.v. devices and by using mobile phones the simulation of natural conditions must be take into account.

Animal studies are essential for assignation effects in human organisms whose physiology resembles that of humans to a degree. Results of diverse studies (cellular, animal, and epidemiology) must be taken into consideration together before any conclusions about possible health risks of a suspected environmental hazard.

References

[1] P.Sowa, Influences of electromagnetic fields on the natural environment, Electrical Review (Przegląd Elektrotechniczny), 9, 2008, ISSN 0033-2097, pp.55- 60,

[2] Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz). Official Journal L199, 30/07/1999, pp.59-70. 1999/519/EC..

[3] G.Cieślar, J.Mrowiec, P.Sowa, A.Sieroń, Effect of Static Electric Field Generated Nearby High Voltage Direct Current Transmission Lines on Behavior In Rats, ISEF 2011 - XV International Symposium on Electromagnetic Fields in Mechatronics, Electrical and Electronic Engineering Funchal, Madeira, September 1-3, 2011,

[4] G.Cieślar, J.Małyszek-Tumidajemicz, P.Sowa, A.Sieroń, Effect of Static Electric Field Generated Nearby High Voltage Direct Current Transmission Lines on Prooxidant –Antioxidant Balance in Rats, EHE 2011, 4th International Conference on Electromagnetic Field Health and Environment, Coimbra, Portugal, May, 2011, s.1-7,

[5] G.Cieślar, P.Sowa, B.Kos-Kudla, A.Sieroń, Influence of Static Electric Field Generated Nearby High Voltage Direct Current Transmission Lines on Hormonal Activity of Experimental Animals, Electromagnetic Field Health and Environment, Studies in Applied Electromagnetics and Mechanics, Volume 29, IOS Press, ISBN 978-1-58603-860-1, Amsterdam 2008, str. 72 – 78,

[6] Alexander v. Kramarenko, Uner Tan, Effects of high- frequency electromagnetic fields on human EEG: a brain mapping study, Intern. J. Neuroscience, 113:1007–1019, 2003.

[7] Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 Ghz), Health Physics April 1998, Volume 74, Number 4, pp. 494 – 521

Paweł Sowa (M'1998) received his Dipl.-Ing. degree in electrical engineering from the SilesianUniversity of Technology (SUT)/Poland in 1971. After his studies, he joined the Institute of Power Systems & Control in SUT, Poland, where he received his PhD degree in 1980, and D.SC. degree in 1997. He is Professor (1999), Director of Institute of Power Systems & Control (2008) and Vice-Dean for science and organization of the Faculty of Electrical Engineering (2005) at Silesian University of Technology. His major scientific interest is focused on influences of electromagnetic fields on the natural environment,modeling and digital simulation of faults and emergency conditions in electric power systems, development and optimization of power systems protection and local control schemes.