Survey identification of impact the 50 Hz magnetic field on selected biochemical parameters of human blood

D Sztafrowski\textsuperscript{1} and J Jakubaszko\textsuperscript{2}
\textsuperscript{1} Wroclaw University of Science and Technology Electrical Power Engineering, Faculty of Electrical Engineering, Poland
\textsuperscript{2} Wroclaw Medical University, Poland

E-mail: dariusz.sztafrowski@pwr.edu.pl, juliusz.jakubaszko@umed.wroc.pl

Abstract. The paper presents the influence of 50 Hz magnetic field on selected biochemical parameters of human blood. The analysis was carried out in test environment created in the department of Electrical Power Engineering at Wroclaw University of Science and Technology, using magnetic field of 50 Hz, with values and homogeneity equivalent to these of electrical power objects. The study was conducted in collaboration with the Wroclaw Medical University.

1. Introduction
The use of alternating current at the frequency of (50/60Hz) is connected to emission of many physical factors into the environment. These factors include most importantly: noise, ozone, and electric and magnetic fields MF. The last two of these factors have been present in the environment for less than 150 years. This is a new element of the environment inhabited by live organisms. Due to insufficient knowledge of the effects of extremely low frequency electromagnetic fields on living matter, the construction of new power facilities, including overhead high-voltage lines, is often a cause of concern and protests of residents of the area. At the same time it should be noted that the analysis of the literature available today does not provide a clear answer regarding all potential health risk connected to the exposure of the human body to magnetic field.

In recent years, there have been numerous works that discuss the observed influence of ELF-MF fields on living organisms. Not all effects of such influence, however, have been fully explained, and there are contradictory views concerning some of these effects. The mechanisms of interaction of EMF fields with living organisms and the potential health risk associated with it, is yet to be studied. Analysis of the results of experimental studies conducted so far on the determination of the effect of electric and magnetic components of the electromagnetic field on living organisms reveals that these factors can in many cases yield different measurable effects on these organisms [1-7]. Since the late seventies of the previous century, these fields have been suspected for some cancers in people (especially children) living in the vicinity of power facilities [8-13]. In 2002 a monograph was published by the International Agency for Research on Cancer (IARC) (in which the magnetic 50/60 Hz component falls into category 2B). This category, apart from extremely low frequency magnetic fields, contains 232 other factors that are potentially carcinogenic. These factors include, among others, gasoline and gasoline engine exhaust gases [14]. For this reason, legislators in most countries have introduced bills aimed at reducing the exposure of humans to these physical factors. In Poland, the maximum intensity
of the magnetic field with mains frequency 50 Hz in areas accessible to humans and with continuous exposure is 60A/m [15, 16]. Little is known about these issues, thus making research in this area is a very desired. A reliable analysis of such issues should be the subject of scientific analyses of specialists from different fields of science, and obtaining objective results is only possible with interdisciplinary study of the problem.

Guided by these premises, the Department of Industrial Electrical Power Engineering at Wroclaw University of Science and Technology began to conduct research with Department of Emergency and Disaster Medicine at Wroclaw Medical University, and the results presented below are the product of jointly conducted research.

Figure 1. Chamber used during the research for exposing humans to magnetic field.

2. Materials and methods used in the study
In the study of human exposure to 50 Hz magnetic field a specially designed workstation was used, built in the Department of Industrial Electrical Power Engineering. The construction of the station is based on Helmholtz coils system, which is characterized by relatively simple construction, ease of determining the field distribution in the exposure space and at the same time they ensure high uniformity of thus generated magnetic field. Therefore this makes one of the best solutions for the exposure of living organisms of considerable size (animals, people Figure 1), as well as in applications for testing cell systems in in-vitro tasks. A block diagram of the test station is illustrated in Figure 2. The following measuring

Figure 2. Block diagram of the test station for human exposure to magnetic field [4].
3. Investigation of the effect of 50 Hz magnetic field on selected biochemical parameters of blood of subjects

The study involved a group of 38 healthy volunteers aged 20 to 68. The analysis focused on the influence of magnetic fields at power grid frequency on selected biochemical parameters in the blood of subjects.

The laboratory room was located at the Wroclaw Medical University, where the study was conducted. The background of the room was analysed with the goal to locate the magnetic component of 50 Hz electromagnetic field. This measurement was intended to locate potential sources of such type of parasitic fields that would affect the results of the research. After performing all the necessary measurements a spot was located where the background was zero (at the sensitivity limit of the measuring instruments used). This spot was chosen for the location of test chamber with alternating magnetic field of 50 Hz for subject exposure. Next, the test station used in the study was installed [4].

The test consisted in placing the subject in the exposure chamber generating an alternating magnetic field with a frequency of 50 Hz with the possibility of changing its intensity in the range from 0 to 60 A/m. The 55-minute cycle of exposure to the magnetic field was used. The cycle consisted of three time periods. In the first fifteen minutes of the experiment, the subjects were not affected by the magnetic field. In the second twenty-minute exposure cycle, the subjects were exposed to a magnetic field of 50 Hz with an intensity of 20 A/m. Respectively, in the third exposure cycle lasting 20 minutes, the subjects were exposed to a magnetic field of the intensity equal to 60 A/m.

It is the highest value of the magnetic component H intensity allowed for exposure to the 50 Hz magnetic field according to the Regulation of the Minister of Health of December 17, 2019 on the permissible levels of electromagnetic fields in the environment and methods of their enforcement [17].

The test cycle consisted of a series of stages. In the first stage the people participating in the research underwent a preliminary health check. This evaluation consisted of interviewing the subject. Then, blood was collected and a series of biochemical tests was performed. Biochemical examination of arterialized blood was performed using ABL 700 Radiometer Copenhagen (Fig. 3.). The following

Figure 3. Biochemical analyser of critical parameters, ABL 700 by Radiometer Copenhagen.
parameters were determined: lactates and electrolytes, including sodium, potassium, chloride and calcium, and glucose level.

The results thus obtained were statistically analysed using computerized statistical software suite EPIINFO Ver. 3.5.2. Homogeneity of the variance of all the parameters before and after exposure was checked using Bartlett's test. In order to determine whether the compared distributions of individual parameters before and after exposure differ substantially from each other, the verification was carried out on the hypothesis of equality of X means of these parameters. For dependent groups with determined homogeneity of variance, the verification was performed using a parametric Student's t-test. In this analysis a critical significance level of p=0.05 was assumed, determining the probability of making the error consisting in rejecting the hypothesis of equality of means. 4)

The data analyzed by the authors (biochemical parameters measured before and after exposure of people in the study group to the magnetic field) belong to the dependent variables, which was determined using the Student's t-test for dependent changes.

4. Study results commentary

The results of the analysed biochemical parameters of blood (electrolytes) and the results of their statistical analysis are presented in Tables 1 and 2. In the tables below, the following symbols (parameters) and their statistical distribution parameters were used:

Symbols of surveyed quantities:

- K - potassium ion concentration in [mmol / l],
- Na - sodium ion concentration in [mmol / l],
- Ca - calcium ion concentration in [mmol / l],
- CL - chlorine ion concentration in [mmol / l],
- Glu - glucose concentration in [mg / dl],
- Lac - lactate concentration in [mmol / l].

Symbols of parameters of statistical distribution of surveyed quantities:

- m - mean values,
- SD - standard deviation,
- MIN - minimum value,
- MAX - maximum value,
- 25Q - lower quartile,
- M - median,
- 75Q - upper quartile,
- p -value - extreme level of significance.

Conducted analysis of the obtained results of humans allow to conclude that the magnetic field of 50 Hz with corresponding to fields produced by power lines operating at AC of 50 Hz showed no effect at the level of significance α = 5% in relation to any of the examined parameters.
Table 1. The results of blood biochemical parameters (electrolytes) in subjects before exposure to 50 Hz magnetic field.

| The test parameter | Before exposure |   |   |   |   |   |   |   |
|-------------------|----------------|---|---|---|---|---|---|---|
| K [Mmol / l]      | 4.47 38 0.64 3.70 6.80 4.10 4.35 4.60 0.879 |
| NA [Mmol / l]     | 141.4 38 3.8 121 145 140 142 143 0.662 |
| CA [mmol/l]       | 1.26 38 0.05 1.14 1.38 1.23 1.25 1.28 0.515 |
| CL [mmol/l]       | 108.2 38 2.2 105 112 107 108 110 0.088 |
| GLU [Mg/dl]       | 98.9 38 12.0 50 127 92.0 98.5 105.0 0.111 |
| LAC [mmol/l]      | 0.57 38 0.12 0.10 0.90 0.50 0.60 0.60 0.924 |

Table 2. The results of blood biochemical parameters (electrolytes) in subjects after exposure to 50 Hz magnetic field.

| The test parameter | After exposure |   |   |   |   |   |   |
|-------------------|----------------|---|---|---|---|---|---|
| K [mmol/l]        | 4.49 38 0.55 3.70 7.20 4.20 4.40 4.70 0.879 |
| NA [mmol/l]       | 141.7 38 4.0 120 147 140 142 144 0.662 |
| CA [mmol/l]       | 1.27 38 0.06 1.12 1.56 1.23 1.27 1.30 0.515 |
| CL [mmol/l]       | 109.4 38 4.9 104 137 107 109 110 0.088 |
| GLU [mg/dl]       | 96.5 38 10.5 57.0 127 91.0 95.0 103 0.111 |
| LAC [mmol/l]      | 0.56 38 0.11 0.20 0.90 0.50 0.50 0.60 0.924 |

Analysis of the results of earlier studies on the assessment of the impact of magnetic field 50 Hz on changes in hemodynamic parameters of human body and the results presented in this paper indicate the need to continue the research and expand its scope [4]. These studies may enable the clarification of mechanisms of interaction of ELF-MF fields on living organisms, including the human body. Detailed knowledge of this type of interaction between the magnetic fields with this frequency range and organic matter can contribute to the objective determination of the minimum value of magnetic field strength which significantly affects individual physiological processes in living organisms.
5. References

[1] Halgamuge Malka N 2013 Critical time delay of the pineal melatonin rhythm in humans due a weak electromagnetic exposure (Indian j. Biochem. Biophys), VOL 50

[2] Sztafrowski D and Jakubaszko J 2005 Wpływ zmiennego pola magnetycznego na funkcje narządu wzroku. Przegląd Elektrotechniczny R. 81 25-29

[3] Sztafrowski D Wróblewski Z Łukaszewicz M 2013, Survey identification of 50 Hz magnetic field impact on selected biological processes in the model organism Saccharomyces cerevisiae. Przegląd Elektrotechniczny R 89

[4] Jakubaszko J Sztafrowski D Wróblewski Z 2014 Wpływ składowej magnetycznej pola elektromagnetycznego 50 Hz na zmiany hemodynamiki organizmu człowieka Przegląd Elektrotechniczny, R. 90 pp 238-241

[5] Korzeniewska E Gąłda-Ćzarnecka I Czarnecki A Piekarska A Krawczyk A 2018 Influence of PEF on antocyjans in wine Przegląd Elektrotechniczny vol. 1

[6] Gocławski J Sekulska-Nalewajko J Korzeniewska E Piekarska A 2017 The use of optical coherence tomography for the evaluation of textural changes of grapes exposed to pulsed electric field Computers and Electronics in Agriculture vol. 142 Part A,

[7] Krawczyk A., Korzeniewska E., Łada-Tondyra E., 2018 Magnetophosphenes – History and contemporary implications Przegląd Elektrotechniczny vol 1

[8] McBride M. et al. 1999 Power-frequency electric and magnetic fields and risk of childhood leukemia in Canada Am. J. Epidemiol Vol. 149, pp.831-842

[9] Wertheimer N Leeper E 1982 Adult cancer related to electrical wires near home American Journal of Epidemiology, vol. 11 pp.345-355

[10] Linet MS et al. 1997 Residential exposure is the magnetic fields and acute lymphoblastic leukemia in children N Eng. Journ Med. vol. 337 pp.1-7

[11] Kleinerman R.A. et al. 2000 Are children living near high-voltage power lines at risk of triple play and beyond acute lymphoblastic leukemia? American Journal of Epidemiology vol. 151 pp.512-515

[12] Myers A. et al. 1990 Childhood cancer and overhead power lines. A case-control study Bro. J. Cancer., vol62 pp 1008-1011

[13] Ahlbom A 2000 A pooled analysis of magnetic field and childhood leukaemia British Journal of Cancer vol. 83 no. 5 pp 692-698

[14] IARC Non-ionizing Radiation 2002 Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields IARC Monographs on the Evaluation of Carcinogenic Risks are Humans

[15] Regulation of the Minister of Health, dated 17 December 2019 on the permissible levels of electromagnetic fields in the environment and ways to enforce these levels