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Environmental factors - electromagnetic field and visible light affecting cells and tissues. An interdisciplinary research field

Abstract: *The electromagnetic field and visible light are factors affecting living organisms. They belong to the physical factors affecting plant and animal organisms. The paper presents the issues of interdisciplinary research on the effects of electromagnetic fields and visible light on animals and humans. Existing research results indicate that it is necessary to cooperate with researchers from many disciplines - biologists, electrical engineers, biotechnologists, veterinarians and medical doctors. The obtained results will be extremely helpful in developing new applications of physical factors in physiotherapy and rehabilitation. The presented studies show that this interdisciplinary field is extremely interesting and should be developed and the research continued.*

Streszczenie: *Pole elektromagnetyczne i światło widzialne są czynnikami oddziałującymi na organizmy żywe. Należą do czynników fizykalnych oddziałujących na organizmy roślinne i zwierzęce. W artykule przedstawiono zagadnienia interdyscyplinarności badań nad wpływem pola elektromagnetycznego i światła widzialnego na organizmy zwierząt i ludzi. Dotychczasowe wyniki wskazują, iż konieczna jest współpraca badaczy z wielu dyscyplin – elektrotechników, biologów, biotechnologów, lekarzy weterynarii i lekarzy medycyny. Uzyskane wyniki będą niezwykle pomocne w opracowywaniu nowych zastosowań czynników fizykalnych w fizjoterapii i rehabilitacji. Zaprezentowane badania wykazują, że ta interdyscyplinarna dziedzina jest niezwykle ciekawa i należy ją rozwijać, a badania kontynuować. (**Czynniki środowiskowe - pole elektromagnetyczne i światło widzialne oddziałujące na komórki i tkanki. Interdyscyplinarna dziedzina badań**)*

Keywords: bioelectromagnetism, electromagnetic field, visible light, biological effects.
Słowa kluczowe: bioelektromagnetyzm, pole elektromagnetyczne, światło widzialne, efekty biologiczne.

Introduction

The electromagnetic field (EMF) is a state of the energy of space that occurs throughout the universe. Starting from the natural frequency of the hydrogen atom with a frequency of 4.5 Hz and ending with an unimaginably strong source of gamma radiation, which are stars whose life cycle is coming to the end The value of the Earth's natural magnetic field depending on the latitude is from 0 μT at the magnetic pole to 67 μT at the magnetic equator [16].

Artificial electromagnetic fields have been introduced into the natural environment by human. Building new high voltage lines, switchgears or mobile telephony stations increase the amount of electromagnetic field impacts on the environment. Our flats, work and rest places are full of wires supplying electricity to a huge number of devices, which are also sources of overlapping electromagnetic fields affecting the surroundings. Every individual in a greater or lesser extent, is affected by this field, and is not always aware of the effects of its impact. In the human body, ions and electrons, which are components of atoms and molecules and have an electric charge, are most exposed to the impact of the field. [15].

For centuries, people have been adapted to being in the Earth's natural magnetic environment, and depriving them of this radiation leads to significant changes in physiological regulations. Isolating plants from the natural field also causes adverse effects. Seeds do not germinate, plants stop growing and their tropisms are disturbed [8].

There are no receptors in the human body, that is, specialized structures of the nervous system, which would be excited by an electromagnetic field (especially a low-frequency field), informing the central nervous system about its interaction. The effects of the electromagnetic field on organisms depend on the frequency of the interacting field (spectral characteristics) [3]. The biological structures undergo depolarization under the influence of the electromagnetic field, which results in differentiation of cell membrane potentials. It affects the change in ionic transport in cell membranes. The extremely low frequency electromagnetic field causes an increase in the amount of free radicals in the cells, which causes a disturbance of the signal transmission in the cell membrane and can lead to oxidative stress [18].

Table 1 shows the types of radiation depending on the frequencies.

Table 1. Types of electromagnetic radiation [9]

Types of radiation	Frequency [Hz]	Name
Ionizing	10^{25}	Cosmic radiation
	10^{21}	Radiation γ
	10^{20}	Radiation X
Non-ionizing	10^{18}	Ultraviolet
	10^{14}	Visible light
	10^{12}	Infrared
	100 GHz	Extremely High Frequency (EHF)
	10 GHz	Super High Frequency (SHF)
	1 GHz	Ultra High Frequency (UHF)
	100 MHz	Very High Frequency (VHF)
	>100 kHz	High Frequency (HF)
	3 kHz	Very Low Frequency (VLF)
	1-300 Hz	Extremely Low Frequency (ELF)

The range has no limit values, because there is no natural limit on the electromagnetic wavelength either from high or low frequencies.

There is a relationship between the wavelength γ and the frequency *f*:

$$\gamma = \frac{c}{f} \tag{1}$$

where *c* is the speed of light. It shows that as the frequency increases, the wavelength decreases.

The research studies on the impact of physical factors on living organisms are the interdisciplinary research and require the cooperation of scientists from various fields, who using research methods typical for their fields lead to the solution of a given research problem. The cooperation of biologists, medical and veterinary doctors, scientific workers

from technical disciplines - electrical engineers, electronics engineers and statisticians, physicists and analysts lead to obtain the results that significantly approximate the effects of electromagnetic field and light on living organisms with knowledge of the intermediate stages. Figure 1 presents a diagram of the individual stages of research in the field of bioelectromagnetism, detailing the profession of participants of the experiments. Conducting such interdisciplinary research requires, apart from the laboratory associated with the generation of the electromagnetic field, having a well-organized and equipped molecular biology laboratory in which research using in vitro techniques as well as molecular analyzes will be possible.

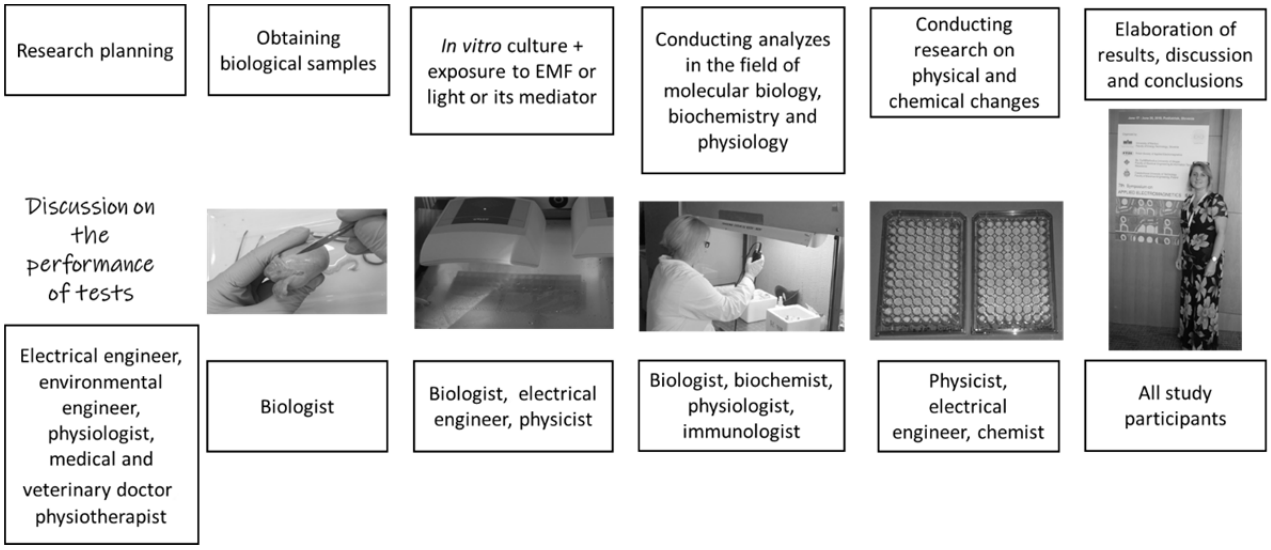

Fig. 1. The diagram of interdisciplinary research in the field of bioelectromagnetism - from research assumptions to the presentation of the results

Interdisciplinary studies of the effects of electromagnetic fields on the cells and tissues of living organisms

In vivo research studies showed the effect of electromagnetic field and light on the physiology of living organisms, however, when determining the impact of the electromagnetic field on the human body, only effects measurable by non-invasive methods were observed - variability of hematological and biochemical parameters [1], variation in hormone levels [2], behavioral change - electromagnetic hypersensitivity (EHS) [14]. Only the use of in vitro techniques for research allows you to track individual stages not only at the cellular but also at the molecular level.

In the research area of the electromagnetic field interactions, it is required to use a generator that allows the generation of fields with different frequency values, magnetic induction, shape or character. The *in vitro* techniques laboratory requires a laminar chamber that allows sterile preparation of the obtained tissues and cells for *in vitro* culture or commercial lines dispensing. The next stage of research requires incubation of the collected samples, in a controlled and procedure required temperature and atmosphere of mixture of carbon monoxide and oxygen (atmosphere of 95% humidity and 5% CO_2) and in a medium imitating natural environment. After the incubation, during which cells or tissues are exposed to electromagnetic fields, the samples are transferred to a laboratory, where further analysis are performed. In own research, cell viability analysis were performed using the MTT test method [4, 5] in order to obtain the effects of the field at different frequencies, magnetic induction values, exposure times and the nature of the field. Exemplary results are presented in Fig. 2, where for an electromagnetic field with a frequency of 50 Hz and a square shape, normal cells show reduced viability with an increasing value of magnetic induction from 2 to 6 mT. This indicates that the electromagnetic field can be a factor used to enhance regenerative processes in post-traumatic conditions.

The electromagnetic field affects the environment and the animals residing in it. Own research on the impact of the field on the tissues of the European roe deer (*Capreolus capreolus*), which showed changes in the biochemical profile of tissues, was conducted. The modern infrared spectroscopy method was used and it was confirmed that FTIR and FT-Raman assess molecular-level changes in testicular tissues (results prepared for printing).

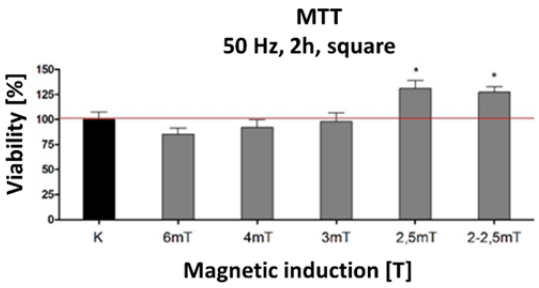

Fig. 2. Viability of cells influenced by electromagnetic field

The extremely low-frequency electromagnetic field affects migrating animals, especially birds, disrupting their magneto-orientation. Field impact studies with a magnetic induction of 25 μT have been conducted and have been shown to cause complete disruption and abolition of the magnetoorientization of bees that try to avoid sites with elevated field values. Birds sit on the lines of power lines and build nests on poles (e.g. storks). Transmission lines are a threat to the health and life of birds with which they collide, especially at night [16].

In modern medicine, an electromagnetic field is used as a therapeutic agent. Fields with magnetic induction from

several to several dozen microtesles and frequencies up to 3 kHz are used in magnetostimulation. Fields with magnetic induction in the range of 0.1 to 20 mT and frequencies from 10 to 100 Hz are used in magnetotherapy [11]. The electromagnetic field used in magnetotherapy is used in the treatment of bone fractures, osteoporosis, injuries such as ligament and tendon damage, rheumatoid arthritis [7]. It can be used as a stand-alone therapy or as an adjunct to pharmacological treatment. The magnetic field used for magnetostimulation induces in the human body suitable processes, such as pain reduction [7], dilating blood vessels, improving thermoregulation, improving microcirculation, regulating blood sugar levels. A particularly pulsating field has a positive effect on the cardiovascular system by inducing increased leaching of calcium ions, which leads to a decrease in the tone of the walls of the blood vessels and thus to their expansion.

Interdisciplinary studies of the effects of visible radiation on organisms

The visible light is a fragment of the electromagnetic spectrum that is recorded by the eye and is located between infrared and ultraviolet. It is an electromagnetic wave with a wavelength range from 0.39 μm to 0.74 μm. The scheme of the electromagnetic radiation spectrum is presented in Fig. 1.

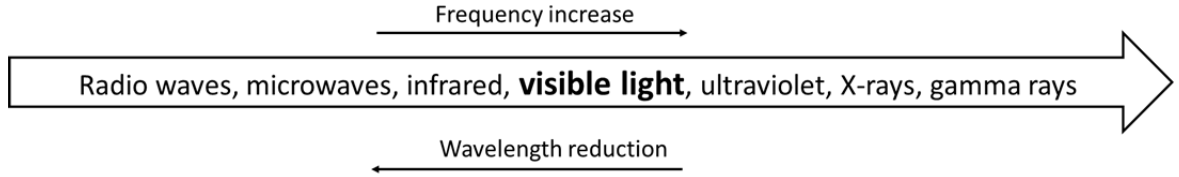

Fig. 3. Scheme of the electromagnetic radiation spectrum

Light is not only an important factor in the process of photosynthesis, where the synthesis of organic energy occurs, but also affects animal organisms. Sunlight is the most important regulator of biological cycles, both daily and seasonal. The effects of light are observed not only on the macro scale (long light day and short light day affect changes in the entire population), but also when assessing the functioning of single individuals. The length of the light day is a deciding factor, inter alia, about the seasons of the year, so it is the decision maker for the vegetation of plants in our climate, and thus the food base for animals. The sun, acting individually on animal organisms, especially mammals, determines the level of many hormones, including melatonin, which is a sleep hormone [17]. It decides about the start and end of reproductive activity, regulates metabolic processes, including fat storage for the winter.

In human, sunlight and its intensity is an extremely important factor affecting brain functions. The mechanism of this action is manifested through the activation of heme oxygenase and degradation of heme to, inter alia, carbon monoxide. The most intensive process occurs in the eye area, and then through the venous outflow, carbon monoxide goes the cavernous sinus in the region of the carotid rete, where via counter-current transfer it flows directly into arterial blood to the brain [13]. The increased amount of carbon monoxide in the area of arterial cerebral circulation results in the vasodilatation in the area of the brain, and thus its better functioning [6] During a short light day, a decrease in the level of carbon monoxide in the brain is the cause of, inter alia, SAD (Seasonal Affective Dissorder), commonly known as autumn-winter depression. In human in the spring and summer time, due to increased light activity, there is an increased level of carbon monoxide, and thus better blood flow through the brain, increased brain activity and better mood. Subjecting patients with SAD to phototherapy gives good results without pharmacotherapy [12].

Light is used as a therapeutic agent. The therapies used in medicine include therapies that combine the use of electromagnetic field and light. These are magnetolaserotherapy and magnetoledotherapy. They are included in new physiotherapeutic methods using the physical interaction of the electromagnetic field and laser or LED light. The impact of laser radiation on tissues depends on the type of tissue and light parameters. The laser rays affect tissues and are reflected, scattered and absorbed. Medical indications for magnetolaserotherapy include osteoarticular and soft tissue disorders. It is also used for impaired blood flow in the limbs and in dentistry for the treatment of dental and periodontal disease. LEDs use the phenomenon of emitting electromagnetic radiation under the influence of stimulating electric current - electroluminescence. LED diodes used in magnetoledotherapy emit electromagnetic radiation not coherent in the range of red (Red) and infrared (IR (infrared) and RIR light, and their panels have coils generating pulsed heterogeneous magnetic field. LED light therapy gives anti-inflammatory, antibacterial and analgesic effect, positively affecting for healing post-operative wounds and is used, for example, in gynecology [10, 19, 20].

Conclusions

The increasing number of sources of the electromagnetic field and increasing the intensity of solar radiation forces science workers to learn about the mechanisms of impact on living organisms and may in the future allow the use of innovative therapeutic methods. The effects of visible radiation are increasingly used in medicine both in phototherapy - inter alia in supporting the treatment of seasonal depression, and also in diagnostics. The use of magnetotherapy and magnetostimulation supports existing pharmacological and physical therapies.

The biological effect of the electromagnetic field on living organisms is due to the biophysical effects:

- cyclotron ion resonance of cations and body fluid anions;
- electrodynamic interaction of the field on ionic currents in the body;
- magnetomechanical interaction of the magnetic field with particles with uncompensated magnetic spins.

The research studies conducted in the Laboratory of Bioelectromagnetism of the University of Rzeszów has shown the possibility of significantly expanding the use of the electromagnetic field for therapy in many areas of medicine, veterinary medicine, physiotherapy and rehabilitation. Changes occurring in cellular structures - lengthening or shortening the viability depending on the

type of biological material and physical parameters of the field clearly indicate that the interaction of the electromagnetic field can have the desired effect and also have negative effects. The main barrier in conducting research studies in the interdyscyplinary field of bioelectromagnetism at the moment is the lack of close cooperation in the field of research planning, for example using biological material of representatives of technical sciences - electrical engineers, as well as biologists, biotechnologists, veterinarians and medical doctors. However, it seems that the thriving Polish Society for the Application of Electromagnetism already today, bringing together representatives of technical and natural disciplines, may be the scientific society that will pave the way in developing new research topics that, in addition to cognitive values, will have great application values. These studies should use the present-day, new research methods which will allow the publication of results in the best JCR journals.

The conducted research studies, which fragments have been presented, show that this interdisciplinary field is extremely interesting and the research should be continued and developed in the future.

Conflicts of Interest: *The authors declare no conflict of interest.*

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