

Non-Thermal Effects of Electromagnetic Radiation on a Living Organism

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Abstract—The paper reviews the current studies on the recorded effects of non-thermal factors of electromagnetic radiation (EMR) on humans and experimental animals. The non-thermal effects of EMR impact various systems of a biological organism, which leads to changes in biological processes. They disrupt the normal functioning of the body and its systems: sexual, nervous, endocrine, immune. The study presents the registered changes in a biological object caused by the influence of EMR, starting from the intracellular level and ending with the effect on the body as a whole. The results of EMR exposure are shown and include stimulating negative and positive processes in biological objects. In particular, the relationship between the EMR impact on the initiation and development of cancer processes is traced. There is also a negative effect on spermatogenesis and the activity of male germ cells, which ultimately leads to a decrease in sexual function. The positive effect of EMR is observed in a decrease in neurodegenerative changes in the brain of experimental animals.

Keywords—*non-thermal factors of electromagnetic radiation, living organism, intracellular level, functioning of the body, metabolism, oncology, nervous system, reproductive system, reactive oxygen species.*

I. INTRODUCTION

Currently, there is a steady increase in cancer diseases according to the World Health Organization report for 2019. Some scientists associate the growth of cancer with the influence of various carcinogenic factors. An example is an increase in the number of electronic devices (mobile phones, Wi-Fi routers, various gadgets, and others) since 2000, which boosts the danger of cellular EMR near a person. Since the impact of EMR on people has been equated with carcinogenic effects, in the modern world there is no clear answer to the question of how big is the physical impact of communication devices on a person. This question causes some concern to people who are in constant contact with such electronic devices. There is evidence that the EMR from a mobile phone physically impacts the overall functioning of biological tissues [1, 2]. The influence of EMR on biological tissues is subdivided into thermal and non-thermal effects [1, 3–4].

The paper presents the analysis of non-thermal factors of EMR exposure on a living organism in the ranges from 800 MHz to 3.5 GHz. The analysis focuses on the changes in the nervous and reproductive systems, metabolism, and carcinogenic effects in a body under the EMR exposure in

this range to low-energy radiation.

The EMR impact on a living object can have both positive and negative effects. The first is used in treating various human diseases in medical practice such as various physiotherapy procedures [5]. The second is a complex exposure to the area where an electronic device is located, which leads to the accumulation of negative effects over a certain time. This can result in a dysfunction of normal physiological processes [6, 7].

The therapeutic effect of EMR is based on the use of the positive role of thermal factors in treatment practice. For this purpose, electromagnetic impact on tissues and organs is used. Different medical devices have various effects on living organisms depending on the frequency, modulation, and intensity of EMR, thereby producing a particular impact on the organs stimulating and increasing their tone. Getting on the human body, part of the EMR energy is absorbed by the tissues while heating up and producing a thermal effect. As a result, the activity of various biochemical processes increases, which affects the expansion of blood vessels and increases blood flow. Consequently, this reduces spasm of smooth muscles, normalizes the processes of inhibition and excitation of the nervous system, accelerates the passage of pulses through the nerve fiber, and accelerates biochemical processes. Thus, such tissue and organ stimulations are used in various medical procedures: treating musculoskeletal system, neurological and oncological diseases, and certain inflammatory processes; restoring stagnant tissues; reducing pain. The exposure of certain areas of the body to radiation increases the rate of biochemical processes in the local area, thus improving metabolism and blood circulation and ultimately leading to the improvement in regeneration processes in tissues. However, there are different conditions to be met in applying this approach in treatment; the duration and the course of medical procedures are determined by the time of exposure and the characteristics of EMR [5].

Studying the processes that occur in the body under the EMR influence will allow us to better understand the effects that occur in the biological system. To determine the non-thermal impact of EMR on biophysical processes, it is necessary to minimize the heat effect. The influence of thermal factors on a living body is significant in comparison with the electromagnetic effects. Thus, it is advisable to analyze the effects of these factors on a living organism, which will allow assessing the changes in the biological processes occurring with this object under the influence of radiation [8].

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The study aims to analyze the current research on the consequences of non-thermal EMR exposure on a living organism.

II. CHANGES IN METABOLISM WHEN EXPOSED TO EMR FROM MOBILE DEVICES

The EMR impact on a living organism can lead to certain changes in metabolic processes. In response to EMR, the endocrine system stimulates or inhibits the secretion of certain substances. For example, the effect of electromagnetic energy on the brain tissue causes the stimulation of increased glucose consumption and signals its increased sensitivity to the EMR from a mobile phone. It has been found that the areas of increased glucose metabolism are located closest to the location of the mobile phone antenna, which suggests that exposure to cell phone radiation increases the excitability of brain tissue. When the brain is stimulated with short magnetic pulses of 1ms and the duration of exposure is 40 minutes, the total excitability of the brain substance increases. This causes the increased consumption of glucose by the brain resulting in a decrease in its level in the blood [9–11].

An example is the studies in which experimental rats have been exposed to EMR. They were located at a distance of 0.5 m from a device that turns off the GSM for a prolonged period of 24, 48 and 72 hours. They showed a significant decrease in the level of sugar in the test animals compared with the control group. As all tests were made on an empty stomach, this fact confirms the increased glucose intake by the brain. In addition, exposure to low-energy radiation can also stimulate the oxidative processes in the body, which is characterized by a change in the redox balance and leads to an increase in the number of free radicals. As a consequence, this results in a disorder in biochemical processes in the body and the formation of reactive oxygen species, which negatively affects the state of metabolic processes in tissues. To normalize vital functions, the body increases the level of antioxidants, which increases the number of free radicals in the blood and signals the changes in metabolic reactions in response to external radiation [12]. Thus, metabolic processes in the body are disrupted under the stimulating influence of EMR.

III. EFFECTS OF EMR ON THE NERVOUS SYSTEM

EMR has a tangible effect on nerve tissues due to the specificity of functions they perform. The cells of the brain that consists of a huge number of different nerve cells forming nerve tissues suffer from the greatest EMR impact. As a result of brain activity, various electrical potentials are formed in the brain and affect the work of organs and tissues of the human body. Therefore, the emission from EMR sources represented by communication devices located near the brain can change electrical activity in the brain, thus affecting the overall state of the body. Therefore, the EMR impact on the brain differs depending on its power, duration, frequency, and modulation. The effects of EMR exposure are manifested in various consequences for the entire nervous system. Negative effects are manifested in memory impairment, disorders in cognitive and sensorimotor functions of the body [1, 13–14]. For example, when receiving a dose of 953 mJ/kg per day, people who took part in the study showed deterioration in the ability to learn new

material. When the dose was reduced to 341 mJ/kg, only half of the participants showed such results. The control of this ability to assimilate new information was carried out using a memory test [13]. Another study demonstrated that when talking on a mobile phone for more than 90 minutes a day, young people aged 18 to 25 years had problems with concentration and attention [15]. In addition, prolonged exposure to EMR on the cerebral cortex leads to distress of the electrical potential of the cell membrane, which affects the enzymatic activity of the cell. This results in a decrease in the production of the hormone melatonin, the lack of which leads to insomnia [13–15].

It is worth noting that people have age-related physiological characteristics. These properties are manifested in general differences of the body such as height, weight, the structure of internal organs, bone thickness, and other features of the human body. For example, when a person is exposed to EMR in the brain area, the energy of the radio-electronic device near the brain penetrates the brain tissue in different depths. The depth of EMR penetration directly depends on the thickness of the skull bones. In adults, the thickness of the oblique shell of the skull is greater than in children, so children's bones absorb more radiation energy from a functioning mobile phone. This indicates that EMR damages a larger part of children's brains compared to adults. Therefore, exposure to EMR from an early age has negative consequences in the future, as the body grows. The negative effects of EMR exposure can accumulate and cause irreversible consequences in an organism that is not yet fully formed affecting the nervous system and other systems. The results might remain for the rest of a person's life [1, 14].

EMR can also cause damage to nerve tissues. Studying the damage to the nervous system of a person under the influence of EMR requires a biological model, for example, live mice. Since these subjects have a sufficiently developed nervous system, the consequences may be similar to humans'. For these purposes, the experimental animals were exposed to EMR with a frequency of 835 MHz to detect changes in their overall activity. At the end of the experiment, there was a general disorder on the part of the nervous system, namely, myelin damage to the neurons of the cerebral cortex. This disorder in the test group led to an increase in their motor activity during the experiment. This may indicate the damage to the protective layer of neurons and lead to forced stimulation of neural activity under the influence of external EMR. The above facts increase the physical activity of the animals. An increase in the excitability of the nervous tissue hurts the overall functioning of the nervous biological system [16].

To treat intracerebral diseases, a study has been conducted in which neural activity was stimulated in experimental rats. In the course of the studies, there was an improvement in cognitive functions. For this purpose, the whole body of the animal was exposed to EMR twice a day for an hour at a frequency of 918 MHz with a specific absorption coefficient of electromagnetic energy of 1.05 W/kg. It was found that in young rats, improvement occurred after 4-5 months, and adults needed 6-7 months. In addition, the groups exposed to EMR showed a decrease in beta-amyloid deposits that cause neurodegenerative diseases of the nervous system [17]. Thus, it is necessary to take into

account both possible negative and positive effects of EMR on the nervous system.

IV. EFFECTS OF EMR FROM MOBILE PHONES ON THE REPRODUCTIVE SYSTEM

When EMR impacts the reproductive system, there is a disruption of the normal physiological processes in the cells because of the formation of electric potential in them. This leads to a disorder in redox balance, which affects the work of mitochondria that provide the synthesis of substances necessary for the movement of spermatozoa, and also negatively affects the functioning of spermatozoa [18-21].

Damage to the reproductive cells and DNA of animals, as well as humans, after the exposure to EMR of the microwave range, was confirmed in [22]. In addition, there is a decrease in the production of the sex hormone testosterone in men, the lack of which negatively affects the entire reproductive system including their sexual function. The combination of the above factors leads to a decrease in the reproductive functions of the body observed in studies [22-23]. Moreover, there is apoptosis of spermatogenic cells and a decrease in intracellular calcium ions, which affects the decrease in the overall mobility of spermatozoa [24].

The female reproductive system is also vulnerable to EMR. Changes occurring in the body of a woman are primarily associated with damage to the egg, violation of the integrity of DNA molecules, increased production of reactive oxygen species, as well as the loss of functionality and viability of the oocyte; all of these lead to the fertilization failure [25].

First, with increased oxidative processes, the cell envelope hardens. This is one of the classic signs of post-ovulatory aging of female gametes and leads to difficulty in fertilization.

Secondly, the processes caused by oxidative stress are involved in the inseparable connection of chromosomes, which is further characterized by an increase in problems in the development of embryos in women and directly affects the future generation.

Third, the aging of oocytes, as well as the aging of spermatozoa, is accompanied by the leakage of electrons from the cell mitochondria along with the process of lipid peroxidation, which leads to the formation of toxic lipid aldehydes. This, in turn, results in significant cellular damage characterized by the death of gametes, increased generation of reactive oxygen species, damage to DNA molecules, and activation of apoptosis.

From all this it follows that to minimize harmful oxidative processes in the germ cells, it is possible to use antioxidants that can have a therapeutic role in reproductive processes, thereby having a beneficial effect on fertility. All this is confirmed by the improvement in the overall function of the gametes [25].

Thus, it is advisable to limit the impact of EMR near the genitals to minimize the negative effects on the cells of the reproductive system.

V. RELATIONSHIP OF EMR AND ONCOLOGY

Changes in the body under the influence of EMR do not occur immediately, they take a long time and recurrence. Negative effects accumulate over the years, like radiation. As a result, various disorders of the immune system occur.

Experiments have shown that in animals under the influence of EMR, infectious processes are burdened, immunogenesis is disrupted in the direction of inhibition of general immunity. The effect of high EMR intensities on the body's immune system is manifested in a depressing effect on the cellular immunity system [26].

It is known that with a certain effect of EMR on biological tissues, they change the electrical potential of the cell membrane affecting the functioning of cells. In addition, the influence of EMR can stimulate the formation of free radicals whose increase leads to the violation of the redox balance and uncontrolled oxidative processes. Oxidative stress characterizes the processes in which free radicals and their derivatives disrupt the normal functioning of metabolic processes, as well as damage DNA molecules. All this is associated with one of the causes of cancer [27].

The study [28] described the relationship between the risk of breast cancer and the use of a mobile phone before going to bed, provided that the device was located close to the breast. This confirms the existence of a relationship between the increased risk of breast cancer and how long the phone is used.

An increase in the widespread use of mobile phones, which leads to an increase in the dose of EMR absorbed by the brain, can be an indirect confirmation [7] of the increase in the number of brain cancers. At the same time, the link between the use of a mobile phone and the detection of similar tumors was confirmed in animals that were exposed to EMR at a frequency of 1.8 GHz [1]. In addition, it was found that the exposure to EMR with a frequency of 50 Hz, together with the acute exposure to gamma radiation or the introduction of formaldehyde into drinking water, causes a significant increase in malignant tumors in rats. It follows that EMR exposure together with other negative factors provokes the growth of tumors [1].

The general negative impact of EMR on cancer processes is in stimulating them, which means that it is necessary to minimize the impact of EMR to prevent the development of risk factors for cancer.

VI. CONCLUSION

The non-thermal effects of EMR on a biological object consist in disrupting the potential of the cell membrane, thus provoking violations of the redox balance. Exposure to EMR leads to the formation of free radicals and the consequent oxidative stress results in changes in the metabolic reactions of a living organism. The study of the EMR impact on humans will allow us to further better understand the emerging complex of biochemical, physiological, immunological and other processes. All this helps to determine the mechanism of the occurrence and course of diseases, as well as to identify other negative or positive processes that occur, including those to be used for treating or preventing diseases in humans. Even now, the destructive influence of EMR on the reproductive and nervous systems has become clear. This allows us to talk about the unconditional limitation of the impact of electromagnetic waves on these most important systems of the human body.

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