Protection of biological objects from electromagnetic radiation

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Abstract. The article deals with issues related to the impact of electromagnetic radiation (EMR) on humans and biological objects (bio-objects). Such types of radiation as electromagnetic fields of low frequency and microwave range, infrared and ultraviolet and ionizing radiation are considered. Data on the harmful effects of EMR on biological objects are given. The basic principles of protection against EMR are considered.

1 Introduction

In today's information society, we are all surrounded by electromagnetic radiation. They arise as a result of the use of various electrical and electronic devices. Examples include mobile phones, computers, televisions, microwave ovens and radios. However, there are questions and concerns about the potential impact of these radiations on human health. Since a person belongs to biological objects, it is important to consider such an aspect as environmental safety.

The World Health Organization (WHO) and other national and international organizations have developed guidelines and standards to help minimize potential risks from electromagnetic radiation. However, there is ambiguity in scientific data and the opinions of researchers regarding the actual impact of these radiations on humans and various biological objects.

Electromagnetic radiation (EMR) is the process of formation and propagation of electromagnetic waves as a result of the interaction of charged particles moving with acceleration [1-2]. The magnitude of the impact of artificial electromagnetic radiation far exceeds the natural background. The term "radiation" comes from the Latin word "radius" and means a beam.

EMR characterized by wavelength, frequency and energy. The set of wavelengths of the entire range forms the EMR spectrum [1] (Table 1). Electromagnetic radiations are divided into different ranges depending on their frequency and energy. The spectrum is conditionally divided into two large groups: ionizing and non-ionizing radiation. Radio frequency and microwave radiation are widely used in communication and information transmission technologies. X-rays and gamma rays are of high energy and are used for medical and scientific purposes.

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Table 1. Full range of EMR.

EMR name	f, Hz	λ, m
Long (VLF)	$1-10^{4}$	$3\cdot10^{8}-3\cdot10^{4}$
Radio waves	$10^{4}-3\cdot10^{10}$	$3\cdot10^{4}-10^{-2}$
- HF	$10^{4}-3\cdot10^{7}$	$3\cdot10^{4}-10$
- UHF	$3\cdot10^{7}-3\cdot10^{8}$	$10-1$
- microwave	$3\cdot10^{8}-3\cdot10^{10}$	$1-10^{-2}$
Infrared	$3\cdot10^{10}-4\cdot10^{14}$	$10^{-2}-7{,}5\cdot10^{-7}$
Light	$4\cdot10^{14}-7{,}5\cdot10^{14}$	$7{,}5\cdot10^{-7}-4\cdot10^{-7}$
Ultraviolet	$7{,}5\cdot10^{14}-7{,}5\cdot10^{16}$	$4\cdot10^{-7}-4\cdot10^{-9}$
X-ray (Ionizing radiation)	$7{,}5\cdot10^{16}-2\cdot10^{19}$	$4\cdot10^{-9}-1{,}5\cdot10^{-11}$
Gamma (Ionizing radiation)	$2\cdot10^{19}-10^{21}$	$1{,}5\cdot10^{-11}-3\cdot10^{-13}$
Space	$> 10^{21}$	$< 3\cdot10^{-13}$

Very low frequency (VLF) refers to a frequency range of 30 Hz to 3 kHz which corresponds to wavelengths of 100,000 to 10,000 meters respectively.

Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light.

Microwaves are electromagnetic waves with wavelengths ranging from as short as one millimeter to as long as one meter, which equates to a frequency range of 300 MHz to 300 GHz. This broad definition includes both UHF and EHF (millimeter waves), but various sources use different other limits.

Infrared radiation (IR) light is electromagnetic radiation with a wavelength between 0.7 and 300 micrometers, which corresponds to a frequency range between 430 and 1 THz respectively. Thermal radiation is generated when energy from the movement of charged particles within atoms is converted to electromagnetic radiation.

Ultraviolet, of wavelengths from 10 nm to 125 nm, ionizes air molecules, causing it to be strongly absorbed by air and by ozone (O_3) in particular. Ionizing UV therefore does not penetrate Earth's atmosphere to a significant degree.

Ionizing radiation with sufficiently high energy (X-rays, Gamma radiation) can ionize atoms; that is to say it can knock electrons off atoms, creating ions. Ionization occurs when an electron is stripped from an electron shell of the atom, which leaves the atom with a net positive charge. Because living cells and, more importantly, the DNA in those cells can be damaged by this ionization, exposure to ionizing radiation increases the risk of cancer [3].

2 Materials and Methods

The objective of the study is to analyze the impact of EMR on biological objects and humans, as well as to consider ways to protect against EMR.

The biological effect of EMR on the human body is determined by such parameters as the intensity of the electromagnetic field, the frequency of oscillations, the duration of exposure, the mode of radiation generation, and the largest point of application.

For low-frequency radiation (radio waves to visible light) the best-understood effects are those due to radiation power alone, acting through heating when radiation is absorbed. For these thermal effects, frequency is important as it affects the intensity of the radiation and penetration into the organism (for example, microwaves penetrate better than infrared).

Experimental data of both domestic and foreign researchers testify to the high biological activity of electromagnetic fields in all frequency ranges. At relatively high levels of the irradiating electromagnetic field, the thermal mechanism of action is considered. At a relatively low level of the electromagnetic field (for radio frequencies above 300 MHz, this is less than 1 mW/cm^2), it is customary to speak of a non-thermal or informational nature of the impact on the body [1-2].

Numerous studies in the field of the biological action of electromagnetic fields (VLF) make it possible to determine the most sensitive systems of the human body:

- Nervous.
- Immune.
- Endocrine.
- Sexual.

These body systems are critical. The reactions of these systems must necessarily be taken into account when assessing the risk of exposure to electromagnetic fields (EMF) on the population and biological objects [4-5].

The World Health Organization (WHO) has classified radio frequency electromagnetic radiation as Group 2B – possibly carcinogenic.

Infrared radiation (IR) affects the functional state of a person, his central nervous system, cardiovascular system. The most severe lesions are heat stroke up to meningitis (headache, dizziness, increased heart rate, respiration, blackout and loss of consciousness).

Ionizing radiation can be dangerous to living organisms, causing various diseases and DNA damage. A person is exposed to natural and artificial sources of radiation. At the same time, depending on whether the source is located outside or inside the body, external and internal exposure of a person is distinguished.

When exposed to the human body, ionizing radiation can cause two types of effects: deterministic and stochastic.

Deterministic - biological effects of radiation, in relation to which the existence of a dose threshold is assumed, above which the severity of the effect depends on the dose.

Stochastic (probabilistic) effects are biological effects of radiation that do not have a dose threshold. It is assumed that the probability of these effects is proportional to the dose, and the severity of their manifestation does not depend on the dose [4].

Under normal operating conditions of sources of ionizing radiation, the following categories of exposed persons are established by the standards:

- Personnel - persons working with man-made sources of ionizing radiation (group A) or who, due to working conditions, are in the area of their influence (group B).
- The entire population, including persons from the staff, outside the scope and conditions of their production activities.

Table 2. Normalized EMR parameter (with prolonged exposure to personnel).

EMR name	Normalized parameter
Low frequency	EP intensity, 5 kV/m MP intension, 80 A/m
Radio waves	EP intensity from 3V/m to 25V/m (depending on frequency)
Microwaves (MW)	Energy flux density (PPE), 10 $\mu W/cm^2$
Infrared radiation (IR)	Thermal radiation intensity, 140 W/m
Ultraviolet	UV-A - 50.0 W/m UV-B - 0.05 W/m UV-C - 0.001 W/m
Ionizing radiation	Effective dose 0.02 Sv per year (for 5 years), but not more than 0.05 Sv per year

In the Russian Federation, the impact of EMR is regulated by several documents. There is a division by type of radiation: the main documents that regulate the impact of ionizing radiation are the "Basic Sanitary Rules for Ensuring Radiation Safety (OSPORB-99/2010)" and SanPiN 2.6.1.2523-09 "Radiation Safety Standards (NRB-99/2009)", non-ionizing radiation - SanPiN 1.2.3685-21 "Hygienic standards and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans." Table 2 shows the normalized EMR parameters depending on the frequency range.

High exposure to electromagnetic radiation can have negative health effects, so it is important to take measures to protect yourself from electromagnetic radiation.

3 Equations and mathematics

An analysis of the methods of protection against electromagnetic radiation has shown that effective methods and technologies are needed to protect biological objects from radiation. EMP protection can be carried out (Figure 1):

- Distance from the source of the field (protection by distance).
- By limiting exposure time.
- Shielding.

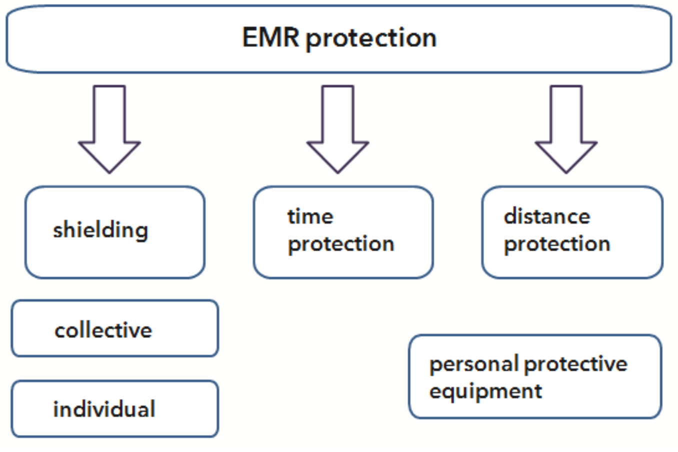

Fig. 1. EMR protection.

The definition and observance of the boundaries of the sanitary protection zone (SPZ) is the main method of protecting the population from EMF (VLF).

Time protection consists in limiting the time a person stays in the area of exposure and is used if it is not possible to reduce the intensity of the electromagnetic field in this area to standard values. There are also personal protective equipment against electromagnetic radiation. They include special clothing that can reduce the impact of electromagnetic radiation on the body [6].

In addition, Infrared radiation (IR) additional measures include measures aimed at preventing a person from overheating - maintaining the water-salt balance.

Shielding consists in creating a barrier that prevents the penetration of electromagnetic radiation into a certain area (Figure 2). Special materials with high conductivity are used (copper or aluminum) [7-8].

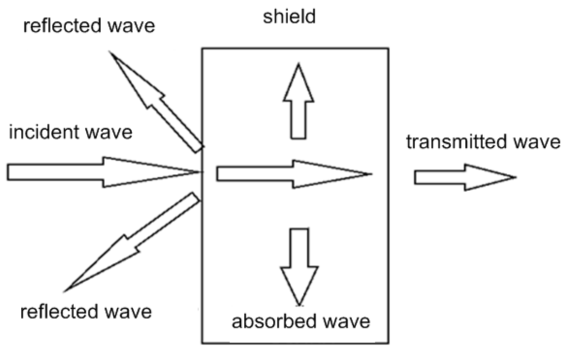

Fig. 2. EMR passing through the screen.

Shields made of lead, concrete, or other high-density materials can reduce the penetration of radiation (Ionizing radiation) into a building or room, preventing its impact on biological objects. The effectiveness of shielding depends on the type of radiation and its energy. Gamma rays require denser materials to stop completely than beta and alpha particles [9].

In addition, special substances are used to protect a person - radioprotectors. These are substances that increase the body's resistance to ionizing radiation. These compounds have an anti-radiation effect when administered a few minutes or hours before irradiation.

One of the key aspects of radiation protection is the prevention of radiation accidents and minimization of the risk of radiation pollution of the environment. This can be achieved through strict supervision and proper training of personnel working with radioactive materials, as well as through regular maintenance and inspection of radiation equipment [10].

4 Discussion

Radiation is not always dangerous, and not all types of radiation are equally dangerous. Radiation is ubiquitous on Earth, and humans are adapted to survive at the normal low-to-moderate levels of radiation found on Earth's surface. Solar radiation is the source of life on Earth.

When choosing methods of protection against electromagnetic radiation, it is necessary to take into account their effectiveness and comply with the relevant standards and regulations. The uncontrolled use of unsuitable methods or the incorrect use of shielding materials can lead to undesirable effects or a decrease in the performance of electronic systems.

There is some evidence to suggest that this is true for ionizing radiation: normal levels of ionizing radiation may serve to stimulate and regulate the activity of DNA repair mechanisms. High enough levels of any kind of radiation will eventually become lethal, however [3].

5 Conclusion

Electromagnetic shielding is an important safety and health concern in a world with high levels of EMP from a variety of sources.

A high level of exposure to electromagnetic radiation can have a negative impact on health, therefore, it is necessary to comply with the normalized values in all ranges of electromagnetic radiation when exposed to the population and personnel of various facilities.

Basic principles of EMP protection: protection by distance, protection by time and shielding. Proper application of shielding techniques, personal protective equipment, time and distance protection can help reduce exposure to electromagnetic radiation and ensure the safety of the public and the protection of biological objects in everyday life.

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