THE EFFECT OF IONIZING RADIATION ON THE HUMAN BODY IN MEDICAL AND BIOLOGICAL PHYSICS

https://doi.org/10.5281/zenodo.19720695

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Abstract

This article examines the importance of lesson plans in improving the quality of education in medical and biological physics at higher medical institutions, demonstrated through the topic "The Effect of Ionizing Radiation on the Human Body." The study explores the impact of ionizing radiation on the human organism and ways to reduce it. Types of ionizing radiation, radiosensitivity of organs, and preventive measures are analyzed. The findings contribute to developing scientific and practical safety recommendations in the fields of radiology and roentgenology.

Keywords

Quality of education, ionizing radiation, alpha rays, beta rays, gamma rays, X-rays, equivalent dose, protection from ionizing radiation.

It is well known that improving the quality of education is a matter of national importance and an urgent issue that must be resolved in order to train competitive national professionals. For this reason, numerous documents have been developed and implemented at the initiative of our President regarding the improvement of educational quality. For example, at the expanded Cabinet of Ministers meeting on January 14, 2017, the head of state emphasized the need to fundamentally revise educational curricula, noting the critical role of regulatory documents and instructional-methodological support alongside qualified teachers in organizing effective instruction. These efforts are reflected in the Law on Education adopted in 2020, the Presidential Resolution No. PQ-6108 dated November 6, 2020 on measures to develop education, upbringing, and science in Uzbekistan's new era of development, and the Development Strategy of New Uzbekistan for 2022–2026.

It was no coincidence that 2023 was declared the "Year of Human Attention and Quality Education." It should be particularly emphasized that specific documents have also been developed and implemented regarding the improvement of medical education quality, as training skilled healthcare workers is a demand of the time.

In this article, we examine the importance of lesson plans in improving the quality of medical and biological physics education, using the topic "The Effect of Ionizing Radiation on the Human Body" as an example.

For this type of radiation, the greater the radiation dose, the greater the biological effect. However, different types of radiation produce different effects even at the same absorbed dose. In dosimetry, it is accepted practice to compare the biological effects of various types of radiation with those produced by X-rays and gamma rays. The coefficient K, which indicates how many times greater the biological effect of a given type of radiation is compared to X-ray or gamma radiation when the absorbed dose in tissue equals one, is called the **quality factor**. In radiobiology, it is also referred to as **Relative Biological Effectiveness (RBE)**. The absorbed dose together with the quality factor provides information about the biological effect of ionizing radiation; therefore, their product is used as the overall measure of this effect and is called the **equivalent dose of radiation (N)**:

$$N = D \cdot K$$

Since K is a dimensionless coefficient, the equivalent dose has the same unit as the absorbed dose D, but is called the **sievert (Sv)**. Outside the SI system, the unit of equivalent dose is the **rem** (from "biologicheskiy ekvivalent rentgena" — biological equivalent of roentgen): 1 rem = 10^{-2} Sv. The equivalent dose expressed in rems equals the product of the absorbed dose in rads and the quality factor. Natural radioactive sources — cosmic rays, radioactivity of the Earth's crust and water, radioactivity of nuclei within the human body, and others — create a background corresponding to approximately 125 mrem of equivalent dose. For persons working with radiation, the permissible annual equivalent dose limit is 5 rem. The minimum lethal dose of gamma radiation is approximately 600 rem. These figures apply to a fully irradiated organism. The degree of contamination of an area and people is assessed by the radiation level and measured in roentgens or rads (R) per hour.

Dosimetric instruments (dosimeters) are devices used to measure the dose of ionizing radiation or quantities related to doses. Structurally, dosimeters consist of a radiation detector and a measuring device. They are typically graduated in units of dose or dose rate. In some cases, an alarm function is included to signal when the dose rate exceeds a set value. Depending on the type of detector used, dosimeters are classified as ionization, luminescent, semiconductor, photodosimeters, and others. Dosimeters may be designed to measure doses of a specific type of radiation or to register mixed radiation. Dosimeters designed to measure the exposure dose (or dose rate) of X-rays and gamma radiation are called **roentgenometers**. They typically use an ionization chamber as the detector. The charge passing through the chamber circuit is proportional to the exposure dose, and the current is proportional to its rate. The composition of the gas in the ionization chamber, as well as the material of its walls, is selected to replicate the conditions under which energy is absorbed in biological tissue.

Each individual dosimeter consists of a small, pre-charged cylindrical ionization chamber. As a result of ionization, the chamber discharges, which is recorded by an electrometer mounted inside. Its readings correspond to the exposure dose of ionizing radiation. Dosimeters with gas-discharge counter detectors also exist. **Radiometers** are used to measure the activity or concentration of radioactive isotopes.

Radiation Standards. Protection from Ionizing Radiation

In industrial facilities where radioactive isotopes are used, it must be taken into account that not only those directly working with isotopes, but also employees in neighboring rooms and residents in the surrounding zone are exposed to some degree of radioactive radiation.

It has been established that radioactive radiation does not affect all organs simultaneously but tends to damage specific cells and organs more. Therefore, not just the total dose of radiation matters, but also which part of the body accumulates radioactive substances, since concentrated radioactive material in a specific area can endanger the entire organism.

When working with open radioactive materials, they are classified into three groups based on the harmful activity of their radiation. Substances belonging to classes III–IV of harmful radiation activity may be handled in chemistry laboratories. Working with class I and II substances is recommended only in specially equipped rooms that meet established sanitary, hygienic, and technical requirements. Class III–IV materials are typically handled on workbenches, mainly in specially ventilated cabinets. Work with class I and II radioactive materials is carried out in ventilated cabinets or dedicated boxes.

When handling radioactive materials, particles can settle on workplaces, on a person's hands and other exposed body parts, enter the air environment and create radioactive radiation sources there. Furthermore, these radioactive dust-like substances can enter the body's internal organs through the respiratory tract or skin.

It is possible to calculate the radiation dose to the skin with great accuracy. To do this, the degree of contamination of the working area is determined, taking into account the activity of the substance being used and the size of the contaminated surface.

People who work with ionizing radiation must protect themselves from its harmful effects. This is a major and specialized issue that goes beyond purely

AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-4| Issue-4| 2026 Published: |30-04-2026|

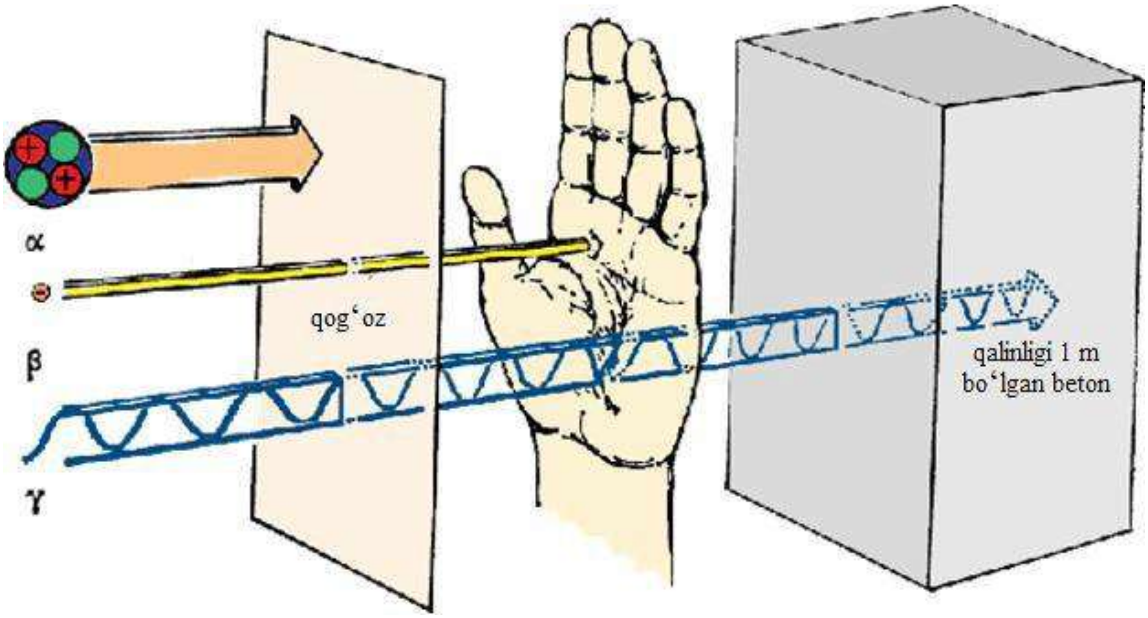
physical considerations. We will briefly review it here. Three types of protection must be distinguished: protection by time, by distance, and by material shielding. Using the model of a point source of γ-radiation, the first two types of protection are expressed as:

$X = k\gamma A r^2 t$

From this formula, it is clear that the longer the exposure time and the smaller the distance, the greater the exposure dose. Therefore, when working with ionizing radiation, one should spend as little time as possible near the source and maintain as great a distance as possible. Material shielding is based on the different ability of various materials to absorb different types of ionizing radiation (Figure 1).

Protection from α-radiation is simple — a single sheet of paper or a few centimeters of air is sufficient to absorb these rays. However, during work with radioactive materials, it is necessary to prevent α-particles from entering the body through the respiratory tract or during meals.

For protection from β-radiation, aluminum, plexiglass, or glass plates a few centimeters thick are sufficient. However, it should be noted that when β-particles interact with matter, braking (bremsstrahlung) X-rays are produced, and in the case of β^+ particles, γ-radiation is generated during their annihilation with electrons.

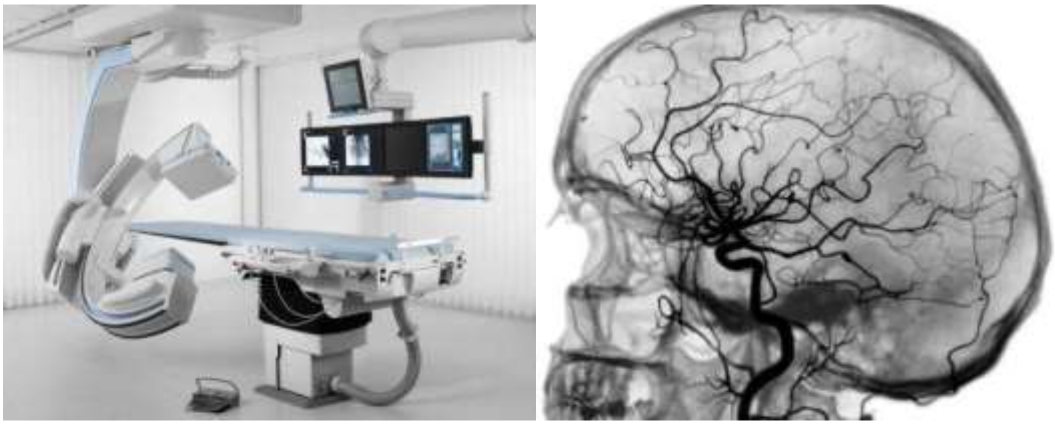


1-Image. Types of protection against ionizing radiation.

Types of protection from ionizing radiation

Protection from "neutral" radiation — X-rays, γ-radiation, and neutrons — is considerably more complex. The probability of these radiations interacting with matter particles is very low, and therefore they penetrate deeper into materials. Ignoring secondary effects, the attenuation of an X-ray or γ-ray beam follows Bouguer's law. The attenuation coefficient depends on the atomic number of the absorbing material and the wavelength. When calculating shielding, not only these relationships but also photon scattering and numerous secondary processes must be taken into account.

For diagnostic purposes, X-rays with energies of 60–12 keV are used. Based on the different absorption of X-rays in organs of varying densities, shadow projections of internal organs can be obtained.



2-Image. A modern angiograph and the appearance of cerebal blood vessels obtained through it.

Angiography is a contrast radiological method for examining blood vessels. It is used in radiography, fluoroscopy, computed tomography, and hybrid surgical procedures. Angiography studies the functional state of vessels, blood flow, and pathological conditions (Figure 2).

Figure 2. A modern angiograph and an image of cerebral blood vessels obtained with it

Conclusion

Ionizing radiation can have serious effects on the human body, and therefore its safe use in medicine and industry is one of the pressing issues of our time. It is possible to minimize the negative effects of radiation by protecting highly radiosensitive organs and implementing strict safety measures at X-ray and radiology institutions. By strictly adhering to preventive measures and safety regulations, human health can be preserved.

Thus, experiments and observations show that preparing lesson plans on topics within academic subjects allows students to master the material more easily and efficiently. Similarly, lesson plans can be used by other teachers of the same subject. This certainly creates an opportunity to save the time of both students and teachers.

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