Study of the influence of the electron and gamma radiations on the bottom sediments of Sorbulak lake

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Abstract. The influence of electron and gamma radiation on the bottom sediments of Sorbulak Lake was investigated. It is shown that irradiation with both electrons and gamma quanta changes significantly the dependence of intensity (I) on time (t). From the curves of intensity versus time, regularities were obtained which have the same character both for the unirradiated and for the irradiated biomaterial. Curve dependencies I (t) are satisfactorily described within the framework of the exponential model.

1. Introduction
The protection of the environment and the preservation of sustainable development of industry is an important environmental problem. Much attention is paid to the study of bottom sediments accumulation conditions in lakes, as a factor that depends objectively on the state of the reservoir [1]. Expanding the use of natural resources, introducing new and modernizing existing technologies and increasing production lead to the ecological problem of water purity, bottom sediments (BS) and the use of coastal materials in the national economy [2, 3]. The process of accumulation of heavy metals in bottom sediments of inland water bodies, rivers and canals is characterized by a rather high content of phosphate ions, which bind heavy metals in hardly soluble compounds, leading to their transition to BS [4, 5]. Various methods are used on local sewage treatment plants for the extraction of heavy metals from wastewater: precipitation with alkaline reagents, adsorption, ion exchange, and sometimes biological purification. In treated wastewater, the heavy metal content does not reach zero using common methods of treatment. Uncleaned water is supplied to the sewers, to municipal wastewater treatment plants. Some of them transfers to the natural reservoirs, where also contaminated rain water flows, which leads to contamination of natural reservoirs with BS [6, 7]. The degree of purification of bottom sediments and biomaterials is largely determined by the rate of their sedimentation and is described by the silt index, as microorganisms participate in the natural purification of reservoirs. Well-deposited materials have an index of about 60 mL/g, a less dense 80-90 mL/g, and an index above 300 mL/g indicates a disruption of the treatment plant [8]. If you use the method of biological post-treatment for reservoirs, in addition to the above, the indicators adopted in sewage treatment practice (biochemical oxygen consumption, nitrate and ammonium nitrogen, nitrite content), as well as the characteristic of activated sludge, are determined additionally. Determination of their quantity by dry weight, ash content, and observation of the vital
activity of protozoa and rotifers by means of a microscope are conducted to obtain the state of microorganisms after irradiation with particle flows [9, 10]. The present work is devoted to the study of the influence of electron and gamma radiation on the bottom sediments of Sorbulak Lake.

2. Experimental

To study non-irradiated and irradiated BS we developed a special installation. The circuit is shown in Figure 1. It consists of a laser source of red color with a length of a monochromatic wave of 780 nm; radiation detector which is a photodiode sensor with a measurement range of 0 – 5000 lux; electronic unit of “Science cube” is a new digital measuring laboratory; racks and various holders.

Bottom sediments were placed in a flask with 25 mL of water, thoroughly shaken and installed between the laser and the detector. Study of the properties of bottom sediments depends on the concentration, so its determination is carried out at a constant dose of BS equal to 30 g/l. If the mixture to be analyzed has a smaller dose, then its thickening is necessary, and if the dose is greater than this, dilution occurs. In studies conducted, the dependence of light intensity on time was taken. The time of the experiment is approximately two minutes.

Irradiation of samples with electrons and photons was carried out on a linear accelerator ELU-6 with an energy of 2 MeV in the air. Samples for irradiation were placed at a distance of 40, 60 cm from the exit window of the accelerator. The magnitude of the beam current was 0.1 – 0.2 μA/cm², the dose of irradiation by electrons was 500 kGy, and the photons by 3P. The irradiation time was 77 minutes and 48 seconds, respectively. Also, studies were carried out on unirradiated and irradiated samples obtained two years ago in similar doses.

![Figure 1](image)

**Figure 1.** Scheme of the experiment on the passage of radiation through a biomaterial

3. Results and discussion

Experimental studies have been carried out on the effect of electron and gamma radiation on bottom sediments by the optical method. It was obtained that the complete subsidence occurs within two minutes. Figures 2 and 3 show the time dependences of the intensity for different types of radiation. As follows from these figures, the intensity increases with time, first in the time interval 0 – 20 seconds increases sharply, and then gradually goes to saturation. Experiments carried out on bottom sediments irradiated with electrons and photons (gamma rays and X-rays) indicate that particle beams significantly
influence the specific dependences. In this case, the nature of the dependence of \(I\) on \(t\) after irradiation does not change. When the biomaterial is irradiated by electrons with 500 kGy dose, the sedimentation rate increases in comparison with the unirradiated samples. The quality of treatment systems and natural purification can be judged from the sedimentation rate of bottom sediments, which affect the value of the silt index. In Figure 3, for curve 2, biomaterial irradiated with photons 3P, the sedimentation rate decreases. It follows from this that the activity of microorganisms in the bottom sediments is activated by irradiation. After conducting a series of experiments and calculations, it was found that the experimental error is \(\sim 5\%\).

\[ I = I_0 \left(1 - \exp\left(-\frac{t}{t_0}\right)\right), \]

where \(I_0\) is the intensity at complete sedimentation of bottom sediments, and \(t_0\) is the time during which the \(I/I_0 - 1\) material decreases by \(e\) times. For this study \(t_0 = 12\) seconds. As follows from the figure, the calculated dependences satisfactorily describe the experimental curves obtained.

Table 1. Dependence of parameters \(I_0\), \(t_0\) on dose and type of irradiation

| D      | \(I_{\text{max}}\), (Lux) | \(I_0\), (Lux) | \(t_0\), (s) | Year |
|--------|--------------------------|----------------|-------------|------|
| 0      | 1330                     | 1330           | 14          | 2018 |
| 500 (kGy) | 1072                 | 1070           | 12          | 2016 |
| 500 (kGy) | 1072                 | 1070           | 12          | 2018 |
| 3 (R)  | 1420                     | 1420           | 15          | 2016 |
4. Conclusions

1. The influence of electron and gamma radiation on the bottom sediments of Lake Sorbulak was studied. From the intensity versus time curves, regularities have been obtained that are of the same nature for both unirradiated and irradiated biomaterials. In the time interval 0 – 20 seconds, the intensity increases sharply, and at t > 20 s gradually goes to saturation.

2. Both electron and gamma irradiation of biomaterial samples leads to a significant change in the optical properties of bottom sediments. The reason for this is a reduction in the activity of microorganisms.

3. The curves of the dependence of I on t are described satisfactorily by the exponential model.

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