

Investigation of the optical properties of unirradiated and irradiated sediments

A I Kupchishin^{1,2}, M N Niyazov¹, V M Lisitsyn³, B G Taipova¹, N A Voronova¹, A T Abdukhairova¹ and N N Khodarina¹

¹Abay Kazakh National Pedagogical University, 13 Dostyk Ave., Almaty, 050000, Kazakhstan

²Al-Farabi Kazakh National University, 71 al-Farabi Ave., Almaty, 050040 Kazakhstan

³National Research Tomsk Polytechnical University, 30 Lenin Ave., Tomsk, 634050, Russia

E-mail: ankupchishin@mail.ru

Abstract. Complex experimental studies of the properties of unirradiated and irradiated sediments using an optical method have been carried out. On the curves of intensity (I) versus time (t), regularities that are of different nature for unirradiated and irradiated by electrons and photons (gamma quanta and X-ray radiation) of biomaterial samples are found. The curves obtained are satisfactorily described within the framework of the exponential model.

1. Introduction

One of the most important problems of the world community is the protection of the environment and the preservation of the sustainable development of human civilization. The unprecedented catastrophic increase in the population of the Earth, the expansion of the use of natural resources, the introduction of new technologies, the production increase in the energy, industry, agriculture, construction, transport led to the global ecological problem of water purity [1, 2]. The development and introduction of new, continuously improved cleaning technologies, types and designs of treatment plants and the utilization of materials has become a very important area in the fight against harmful emissions. Proper treatment of wastewater makes it possible to reuse it before entering water bodies or into the soil, and other purposes are also pursued, for example, keeping water reservoirs clean that are resting places, preserving fish resources [3-7]. As is known, biological decomposition and self-purification from harmful substances is the very slow process. Therefore, the natural purification of sewage is replaced by artificially created industrial facilities. To increase the activity of microorganisms in bottom sediments and sludge, they are irradiated with electrons and photons of various doses [8]. Treatment plants are whole water purification plants, including various types of purification: mechanical, chemical, and biological purification as an obligatory final stage before the discharge of sewage into reservoirs [9, 10]. Its effectiveness depends on the sludge performance (a complex of microorganisms), which, in particular, is part of the bottom sediments. The sad experience shows that the majority of sewage treatment plants are unsatisfactory [11]. It is important to study the various properties of sediments, including by optical methods.



This paper is devoted to the study of the properties of unirradiated and irradiated sludge of the Sorbulak Lake by the optical method [12].

2. Experimental

To determine the parameters of sediments, an experimental setup was created, the scheme of which is shown in figure 1. It consists of a rack, holders, a quantum optical generator (laser source), a light flux detector, a camera and a time latch. The dried sediments and sludge placed in a flask (chamber) with water were carefully shaken and installed between the laser and the light intensity recording detector. The dependence of the illumination (intensity) of light on time was recorded. The time of each experiment was 2 minutes. Irradiation of the samples with electrons and photons was carried out on ELA-6 linear accelerator with an energy of 2 MeV in the air. Samples for irradiation were placed at the distances of 20, 40, 60 cm from the exit window of the accelerator. The magnitude of the beam current was $0.1-0.2 \mu\text{A}/\text{cm}^2$, the dose of irradiation with electrons was 500 kGy, and with photons – 3R. The irradiation time was 77 minutes and 48 seconds, respectively. Studies of unirradiated and irradiated samples, obtained two years ago in similar doses, were also carried out.

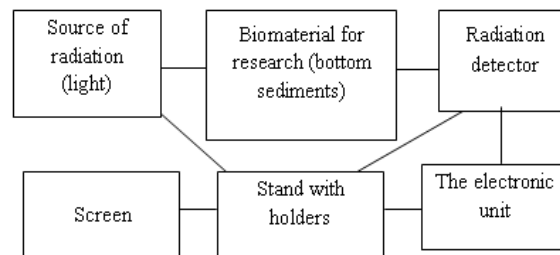


Figure 1. Design of the experiment on the passage of radiation through a biomaterial.

3. Results and discussion

Complex experimental studies of the properties of sediments by the optical method have been carried out. The results of the study are shown in figure 2. It was obtained that the complete subsidence occurs within 120 seconds.

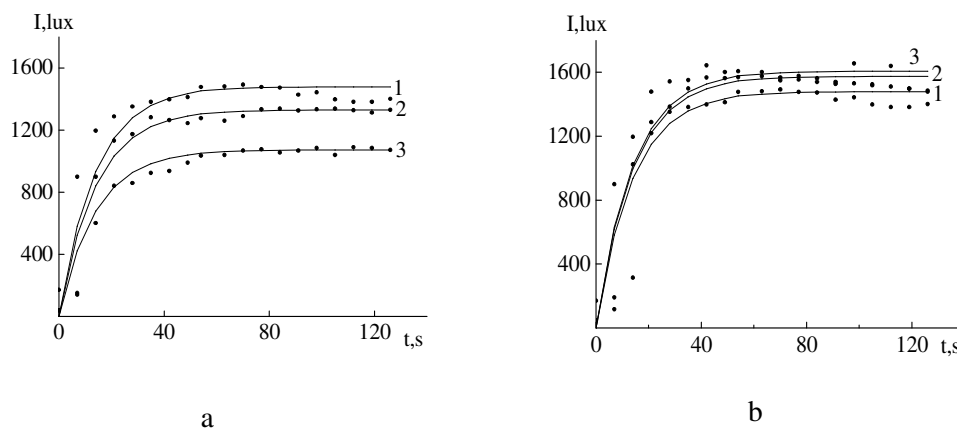


Figure 2. Time dependences of laser radiation intensity during its passage through materials unirradiated and irradiated with electrons in the dose of 500 kGy (a) and photons in the dose of 3 R (b). 1 – unirradiated; 2 – irradiated in 2018; 3 – irradiated in 2016.

As follows from figure 2, the intensity (I) increases with time (t): firstly it rises sharply in the region of 0-20 s, and then gradually comes to saturation in the region of 20–120 s, both for the unirradiated and irradiated biomaterial. Regularities having different nature were obtained from the curves of the intensity dependence on time. Similar experiments were carried out using sediments irradiated with electrons and photons (gamma quanta and X-ray radiation) (figure 2, curves 2 and 3). In this case, irradiation affects significantly the specific dependencies. As can be seen from the figures, the dependence of I on t does not change after irradiation. When the biomaterial is irradiated with electrons with the dose of 500 kGy (figure 2a, curves 2 and 3), the settling rate increases compared to the unirradiated samples, which indicates an improvement in the parameters of natural purification. The quality of purification systems and natural purification can be judged by the good sedimentation (sedimentation rate) of sediments that affect the value of the sludge index. In figure 2b, for the curves 2 and 3, irradiated with photons of 3R, the settling velocity increases insignificantly. From this it follows that the activity of microorganisms in the sediments decreases slightly when irradiated with photons by the dose of 3R.

The experimental curves are explained within the framework of the exponential model proposed by the authors (solid curves).

$$I = I_0(1 - \exp(-t/t_0))$$

where I_0 – intensity with complete subsidence of AS, and t_0 is the time during which the value of I/I_0 for activated sludge is reduced by e times.

Table 1 shows the values of I_0 and t_0 of unirradiated and irradiated sediments.

Table 1. Values of I_0 and t_0 of unirradiated and irradiated sediments.

Year	2016	2018	2016	2018	–
D	500 (kGy)	500 (kGy)	3 (R)	3 (R)	0
I_0 , (lux)	1073	1331	1479	1486	1400
t_0 , (s)	14	14	14	14	14

It can be seen from the table that the intensity I_0 increases with increasing irradiation dose. Moreover, t_0 does not change.

4. Conclusion

1. From the curves of the dependence of the density (I) on time (t), certain regularities have been obtained that are of a character both for unirradiated and irradiated biomaterials. In the time interval of 0-20 seconds, the intensity increases sharply, and at $t > 20$ s it gradually reaches saturation.

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

3. The curves of the dependence of the density (I) on time (t) are described satisfactorily in the framework of the exponential model.

Acknowledgments

The study was supported by the Grant of the Ministry of Education and Science of the Republic of Kazakhstan.

References

- [1] Aulanbergenov A A, Zubairov O Z, Koldeyev Ye I, Aydarova S B, Tleukulov A T, Zhandauletova F R and Ospanov K T 2012 *Improving the quality of natural water and wastewater treatment* (Textbook for high schools Almaty)
- [2] Zakhtaeva N V and Shelomkov A S 2013 *Active sludge as a managed ecological system* (M.: Expo Media Press)

- [3] Henze M, Armoes P, La-Cour-Jansen J and Arvan E 2004 *Wastewater treatment. Biological and chemical processes* (M.: Mir)
- [4] Nemeth-Katona J 2008 *Acta Polytechnica Hungarica* **5** 117
- [5] Zhmur N S 2003 *Technological and biochemical processes of wastewater treatment at facilities with aerotanks* (M.: AKVAROS)
- [6] Yesyrev O V, Kupchishin A I, Abdukhairova A T, Nauryzbayev M K, Khodarina N N and Cherednichenko V C 2017 *IOP Conf. Series: Materials Science and Engineering* **168** 012017
- [7] Benina N N 1990 *Ecology of infusoria of active sludge Ecology of marine and freshwater free-living protozoa; Collection of scientific works* (L.: Nauka) 143 p
- [8] Kupchishin A I, Niyazov M N, Voronova N A, Kirdiashkin V I and Abdukhairova A T 2017 *IOP Conf. Series: Materials Science and Engineering* **168** 012016
- [9] Pogrebnyak A D, Pshyk, Coyb E, Zaleskib K, Peplinskab B, Nowaczykb G, Kupchishin A I, Kassenova A I and Kravchenko L G 2016 *The Physics of Metals and Metallography* **117** 990
- [10] Orosov N S 1987 *Biocenosis in nature and industrial conditions. Pushchino* 20
- [11] Alimov A F 1986 *Materials of the Fifth Congress of the All-Union Hydrobiological Society* (Kuibyshev: Publishing House of the USSR Academy of Sciences) 132
- [12] Yesyrev O V, Kupchishin A I, Abdukhairova A T, Nauryzbayev M K, Khodarina N N and Cherednichenko V C 2017 *IOP Conf. Series: Materials Science and Engineering* **168** 012017