The method of radiation control of water areas deep parts and bottom sediments

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Abstract. The article substantiates the need to control the underwater water area and bottom sediments in marine water areas, lakes and rivers. Especially in cases where hazardous facilities are located next to them (nuclear power plants, production using radioactive components, storage facilities, etc.). For various reasons, small radioactive releases occur from these facilities. The radioactive substances fall into the water and are deposited in bottom sediments. Gradually, the expositional irradiation dose in the bottom sediment increases. Sea, lake or river inhabitants begin to get sick. It is extremely difficult to establish a high level of radiation in the bottom sediment by measuring the exposure dose over the water surface. The bottom sediments may be washed ashore during water movement or various cyclones. Further, then are dispersed by wind. This can lead to radioactive damage to people, animals and territory. The methodology for the radioactive state research of the water areas deep parts and bottom sediments using an autonomous deep-sea apparatus is presented. The apparatus is equipped with sensors for measuring the expositional irradiation dose, a video camera for monitoring the bottom, a depth sensor and an echo probe to determine its coordinates under water. The using an autonomous apparatus allows to determine the presence of radioactive contamination in bottom sediments and determine the configuration of their location. This allows to plan and effectively carry out work on the cleaning of rivers, lakes and coastal zones of the seas from radioactive bottom sediments.

1 Introduction

Currently, the development of nuclear energy, industrial production using radioactive materials and other factors has led to an increase in emissions of radioactive elements into the...
the atmosphere [1-9]. A particularly large number of radioactive elements are observed in water bodies that are close to potential sources of pollution [7-13]. In addition, most of the emissions into the atmosphere come in the form of precipitation in rivers, lakes and seas. This is due to the washout of the soil after rains into the rivers, through which soil particles can enter the lakes during fast flow.

Modern monitoring tools that use various instruments [14-28] during environmental monitoring on the water surface do not allow to obtain information about radioactive contamination of the bottom of a lake or river. Sampling from great depths and their further control using express methods [29-34] is not very effective for large research areas. It is impossible to establish the presence of garbage and other hazardous substances [35-42] that have not yet started a chemical reaction with water at the depths of the sea or river water using classical instruments for environmental monitoring [14-22, 43-45]. Radar methods that use electromagnetic radiation [46-49] also cannot investigate the state of bottom sediments at depth.

To solve this problem, many different methods are being developed. In our work, we propose the use of an autonomous apparatus (small amphibian) to study the state of parts of the water area located at great depths and bottom sediments. A special attention in the control is paid to detecting the presence of radioactive contamination and debris in the bottom sediments.

2 The design of the autonomous underwater vehicle and the control method

To control the bottom surface of the sea in Japan, multifunctional amphibians are actively used, especially after the accident at the Fukushima-1 nuclear power plant (NPP). The crew of this amphibian is two people. In the study of lakes, rivers and cooling reservoirs of nuclear power plants, the use of such amphibians is economically impractical. And the depth of immersion compared with the sea and ocean is small (up to 100 m). Therefore, it is proposed to use a small-sized underwater apparatus controlled by a special cable. Fig. 1 shows its design and operation scheme.

Due to the presence of algae on the bottom surface, the apparatus must be at a certain height above it. Algae can complicate the work of screw mechanisms. Movement will be difficult. The estimated optimal scanning height of radioactive contamination of the bottom surface is 0.4 m. The apparatus may hover above the bottom surface at a height of \( h_D = 1 \) m. The effective scanning area is determined by the area of the circle, the radius of which is determined by the ratio \( R_{\text{eff}} \approx 0.75 h_D \). The container with dosimetric equipment extends 1 m. This is enough to take measurements, for example, in a sludge containing radioactive contamination. It should be noted that the range of light propagation from the underwater searchlight is not more than 1.5 m at great depths. Without light, the operation of camcorder 3 is inefficient. The use of an echo sounder allows to detect foreign materials in the sludge that the camcorder does not see. In some cases, their classification is possible.

Information about all measurements and a video image is received via a specialized cable to the boat. From this boat, the movement of the underwater vehicle is controlled. The use of an antenna to control the device is not effective. There may be a large number of interference. The radio frequency signal is strongly attenuated in water, especially salty. This may result in loss of control over the operation of the machine.
The research area of the bottom surface and the design of the apparatus: 1 — the apparatus body; 2 — a special underwater searchlight; 3 — video camera; 4 — echo sounder; 5 — capacity for placement of dosimetric equipment with a device for its extension by 1 m; 6 — ballast water tanks; 7 — power and rotary screws; 8 — horizontal rudders; 9 — hatch; 10 — valve; 11 — a specialized connector for connecting a multi-function cable.

In some devices, it is possible to use laser emission [50-56] to solve environmental problems. For radioactive control and determination of debris in the bottom sediment, the use of laser radiation is not advisable.

The research methodology consists of the rapid passage of the underwater water area and the determination of foci of pollution with the mapping. The pollution coordinates are tied to the territory relative to the position of the base boat. After identifying the foci, a detailed study of them during the slow movement of the apparatus and the preparation of a detailed map of pollution from different scan heights. The map is drawn in the direction of the line of movement. The distance between the lines of movement is 1 m.

3 The results of experimental studies and their discussion

While radiation monitoring is conducted, the degree of danger to living organisms is determined by the measured value of the exposure dose of $P_{ex}$. In fig. 2 as an example, the results of the study of bottom sediments and the lower layers of the water area of Lake Lubenskoye (Leningrad Region) using the autonomous apparatus Nyrok-3M are presented.

Fig. 1. The research area of the bottom surface and the design of the apparatus: 1 — the apparatus body; 2 — a special underwater searchlight; 3 — video camera; 4 — echo sounder; 5 — capacity for placement of dosimetric equipment with a device for its extension by 1 m; 6 — ballast water tanks; 7 — power and rotary screws; 8 — horizontal rudders; 9 — hatch; 10 — valve; 11 — a specialized connector for connecting a multi-function cable.

Fig. 2. The dependence of the change of the exposure dose $P_{ex}$ on the distance $L$ along the bottom of the lake. Graph 1, 2, 3 corresponds to the results of $P_{ex}$ measurements in bottom sediments, on algae
grass, and at a height of 0.8 m from the silt surface. Graphs 4, 5, 6 correspond to the calculation of the safe value of $P_{ex}$ for these measurement cases.

The lake is located near the Leningrad NPP. Tourists often relax on the lake, and locals fish. Using an underwater vehicle, bottom sediments in the central part of the lake were investigated. The coastal zone was investigated by manual sampling without the use of an apparatus.

In fig. 3 as an example, studies of the coastal zone of the lake are presented. For comparison, the part of the water area in which algae grows was selected.

![Fig. 3. The dependence of the change of the exposure dose $P_{ex}$ on the distance $L$ along the bottom of the lake. Graph 1, 2, 3 corresponds to the results of $P_{ex}$ measurements in bottom sediments, on algae grass, and at a height of 0.8 m from the silt surface. Graphs 4, 5, 6 correspond to the calculation of the safe value of $P_{ex}$ for these measurement cases.](image)

The research results show that the greatest radioactive contamination is observed in bottom sediments located at a depth. In this part, they accumulate. In some places, the standard threshold level of radiation level is exceeded twice. In this place, living organisms with prolonged exposure can be affected. A more detailed study of this sector is needed. In the coastal zone, excess radiation levels are negligible. This level may vary due to the movement of bottom sediments.

4 Conclusions

The results show the effectiveness of using an autonomous apparatus for conducting research of bottom sediments. It is impossible to determine the detected pollution using standard control devices on the surface of the water.

The data from the studies will help specialists of the relevant services make an informed decision on the purification of part of the bottom territory from radioactive sludge.

References

1. V. Yushkova, G. Kostin, V. Dudkin, and L. Valiullin, IOP Conference Series: Earth and Environmental Science 578 (2020) 012050 doi:10.1088/1755-1315/578/1/012050
2. G. Shafeev, E. Barmina, L. Valiullin, A. Korshunov, and R. Denisov, IOP Conference Series: Earth and Environmental Science 390(1), 012016 (2019)
3. N.N. Kabal’nova, S.A. Grabovskiy, N.M. Andriayshina, L.R. Valiullin, I.S. Raginov, and Y.U. Murinov, Letters in Drug Design and Discovery 14(12), 1409-1414 (2017)
4. T. Bugaeva, A. Khabarov, O. Novikova, and U. Plotkina, IOP Conference Series: Materials Science and Engineering 497(1), 012056 (2019)
5. M. Petrichenko, N. Vatin, D. Nemova, N. Kharkov, and A. Staritcyna, Applied Mechanics and Materials 627, 297-303 (2014)
6. V. Mushchanov, V. Sievka, A. Veshnevsk, and D. Nemova, Procedia Engineering 117(1), 1018-1026 (2015)
7. R. Davydov, V. Antonov, S. Makeev, V. Dudkin, and N. Myazin, E3S Web of Conferences 140, 02001 (2019)
8. N. Rumyansev, O. Bondareva, S. Makeev, and V. Krasnoshekov, IOP Conference Series: Earth and Environmental Science 390(1), 012037 (2019)
9. M. Kozar, L. Sabliy, M. Korenchuk, S. Makeev, A. Korshunov, and V. Kosolapov, IOP Conference Series: Earth and Environmental Science 390(1), 012002 (2019)
10. V.V. Elistratov, M.V. Diuldin, and R.S. Denisov, IOP Conference Series: Earth and Environmental Science 180(1), 10 (2018)
11. T. Akimov, O. Beloshapkina, M. Diuldin, and J. Molnár, IOP Conference Series: Earth and Environmental Science 390(1), 012015 (2019)
12. E. Stepanov, S. Kotelnikov, G. Ratushnyk, E. Nikulina, and M. Diuldin, IOP Conference Series: Earth and Environmental Science 390(1), 012033 (2019)
13. K. Artem'ev, L. Kolik, I. Podkoryvov, V. Meshalkin, and M. Diuldin, IOP Conference Series: Earth and Environmental Science, 390(1), 012039 (2019)
14. K.J. Smirnov, Journal of Physics: Conference Series 1368(2), 022073 (2019)
15. V. Antonov, D. Molodtsov, A. Cheremisin, and V. Korablev, MATEC Web of Conference 245, 15002 (2018)
16. A.Yu. Karseev, and V.A. Vologdin, Journal of Physics: Conference Series 643(1), 012108 (2015)
17. N.S. Myazin, V.V. Yushkova, and T.I. Davydoava, Journal of Physics: Conference Series 917(4), 042017 (2017)
18. A.V. Cheremiskina, E.N. Velichko, and A.Yu. Karseev, Journal of Physics: Conference Series 541(1), 012006 (2014)
19. N. S. Myazin, V. V. Davydov, and T. I. Davydoava, Russian Journal of Nondestructive Testing 53(7), 520-529 (2017)
20. A. S. Grevtseva, and K. J. Smirnov, Journal of Physics: Conference Series 1035(1), 012056 (2018)
21. V. V. Davydov, V. I. Dudkin, N. S. Myazin, and V.Yu. Rud, Instruments and Experimental Techniques 61(1), 140–147 (2018)
22. V.V. Davydov, E. N. Velichko, N. S. Myazin, and V.Yu. Rud, Instruments and Experimental Techniques 61(1), 116–122 (2018)
23. N.S. Myazin, S.E. Logunov, N.M. Grebenikova, and V.V. Yushkova, Journal of Physics: Conference Series 929(1), 012064 (2017)
24. N. Myazin, Y. Neronov, V. Dudkin, and V. Yushkova, MATEC Web of Conference 245, 11013 (2018)
25. N.S. Myazin, V.V. Davydov, V.V. Yushkova, and V.Yu. Rud, Environmental, Research, Engineering and Management 75(2), 28-35 (2019)
26. N. M. Grebenikova, N. S. Myazin, and R. V. Davydov, Proceedings of the 2018 IEEE International Conference on Electrical Engineering and Photonics, EExPolytech 2018, 8564409 295-297 (2018)
27. V. Fadeenko, I. Fadeenko, V. Dudkin, and D. Nikolaev, IOP Conference Series: Earth and Environmental Science 390(1), 012022 (2019)
28. E. Gryznova, N. Grebenikova, D. Ivanov, and V. Bykov, IOP Conference Series: Earth and Environmental Science 390(1), 012044 (2019)
29. M. Nikitina, N. Grebenikova, V. Dudkin, and Y. Batov, IOP Conference Series: Earth and Environmental Science 390(1), 012024 (2019)
30. N.S. Myazin, V.V. Yushkova, and V.I. Dudkin, Journal of Physics: Conference Series 1400(6), 066008 (2019)
31. E. Gryznova, Y. Batov, and N. Myazin, E3S Web of Conferences 140, 09001 (2019)
32. N.S. Myazin, V.V. Yushkova, and N.I. Taranda, Journal of Physics: Conference Series 1410(1), 012130 (2019)
33. S.E. Logunov, I.Yu. Podkorytov, and V.Yu. Rud, Journal of Physics: Conference Series 1410(1), 012113 (2019)
34. V.I. Dudkin, and A. Yu. Karseev, Russian Physics Journal 58(2), 146-152 (2015)
35. E.V. Rukin, N.S. Myazin, V.V. Davydov, and V.I. Dudkin, Journal of Physics: Conference Series 1368(4), 042011 (2019)
36. L. Molodkina, D. Tryastsina, and A. Cheremisin, IOP Conference Series: Earth and Environmental Science 390(1), 012005 (2019)
37. M. Andrianova, E. Bondarenko, S.-P. Reinikainen, and A. Cheremisin, IOP Conference Series: Earth and Environmental Science 390(1), 012006 (2019)
38. A. Korshunov, N. Gaitova, M. Gaitov, A. Cheremisin, and A. Gerner, IOP Conference Series: Earth and Environmental Science, 390(1) 012009 (2019)
39. S. Van, A. Cheremisin, and V. Yushkova, E3S Web of Conferences 140, 09008 (2019)
40. S. Van, A. Cheremisin, A., Chusov, F. Switala, and R. Davydov, IOP Conference Series: Earth and Environmental Science 390(1), 012011 (2019)
41. V.I. Antonov, V.L. Badenko, V.I. Maslikov, and D.V. Molodtsov, Journal of Physics: Conference Series 1236(1), 012049 (2018)
42. V.I. Antonov, and D.V. Molodtsov, Journal of Physics: Conference Series 1135(1), 012088 (2018)
43. V.I. Dudkin, and A.Yu. Karseev, Measurement Techniques 57(8), 912-918 (2014)
44. V.I. Dudkin, and A.Yu. Karseev, Technical Physics Letters 41(4), 355-358 (2015)
45. R.V. Davydov, I.K. Saveliev, V.A. Lenets, M.Yu. Tarasenko, T.R. Yalunina, and V.V. Davydov, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 10531 LNCS, 177-183 (2017)
46. V.A. Lenets, M.Yu. Tarasenko, N.S. Rodygina, A.V. Moroz, Journal of Physics: Conference Series 1038(1), 012037 (2018)
47. V.I. Antonov, Journal of Physics: Conference Series 929(1), 012040 (2017)
48. R. Davydov, V. Antonov, and N. Kalinin, Journal of Physics: Conference Series 643(1), 012107 (2015)
49. R.V. Davydov, and V.I. Antonov, Journal of Physics: Conference Series 769(1), 012060 (2016)
50. K.J. Smirnov, S.F. Glagolev, and G.V. Tushavin, Journal Physics: Conference Series, 1124(1) 022014 (2018)