ISSUES OF ESTABLISHING STANDARDS FOR RADIATION SAFETY OF WILDLIFE INCLUDING THE RADIOACTIVE WASTE MANAGEMENT

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Article received on April 02, 2021

Although some regulatory requirements are available in Russia to ensure and demonstrate the radiation safety of the environment including those covering the atomic energy sector, still no criteria establishing the safe levels of radionuclide concentrations in the environment have been approved by the Ministry of Natural Resources and Ecology of the Russian Federation. Threshold concentrations in the environment established to protect human health have been largely used as such criteria. The experience gained shows that in some cases due to the radioactive contamination of the environment, certain biological species received higher radiation doses compared to humans. In 2014, a methodology was developed to assess the radiation damage caused to the environment at RW storage facilities taking into account relevant international recommendations. Safe level of non-human biota exposure of 1 mGy/d was established for mammals, vertebrates and pine trees as a criterion providing favorable environment and radioecological safety, whereas relevant value for the rest of flora organisms and invertebrates was taken equal to 10 mGy/d. In 2016, Roshydromet approved the recommendations on a procedure developed to calculate the reference levels of radionuclide concentrations in the environmental components taking into account relevant testing methods. The experience gained from the testing of the environmentally safe levels proposed in these papers can be used to develop and adopt the environmental quality standards. In the near future, environmental quality standards should be developed and approved to implement the provisions of the Federal Law No. 7 and relevant decrees of the Government of the Russian Federation which will be aimed at preserving the wildlife and the gene pool of plants, animals and other living organisms.

Keywords: *wildlife, environmental quality standards, radioactive waste, radiation safety, deep geological repository.*

Since the middle of the 20th century, studies have been carried out in Russia and other countries to assess the impact of man-made sources of ionizing radiation on wildlife. For decades, under a generally accepted concept it was assumed that the radiation protection level set for humans would be sufficient to protect other types of organisms as well [1]. As more knowledge got acquired, it became clear that sometimes other organisms can receive higher radiation doses as compared with humans [2], for example, during radiation accidents, in areas contaminated due to past activities, at the sites of radioactive waste (RW) storage facilities [3].

Based on the research performed in the 21st century, the International Atomic Energy Agency (IAEA), the International Commission on Radiological Protection (ICRP) and other authoritative international organizations started to pay considerable attention to the radiation safety of environmental medium, namely, to its regulation and scientifically-based demonstration considering various exposure situations, including RW disposal. In 2014, IAEA basic safety standards were issued [4] emphasizing that the protection of the environment from the radiation exposure should be considered of great importance within the concept of sustainable development.

At present time, the main goals of environmental protection can be summarized as follows: preventing or reducing the frequency of effects that may result in premature mortality or a decreased reproductive potential of certain animal and plant species, protecting species, maintaining the biodiversity or protecting the communities of living organisms, as well as providing proper quality of the living environment [5].

Today, considerable attention is paid in Russia also to the scientific and methodological aspects related to the assessment of radioecological impacts on the biota. Collective monographs and scientific articles on this topic were published in recent years [6—10]. Their findings have been reflected in a number of recommendations provided by the Roshydromet of the Russian Ministry of Natural Resources (for example, [11]) and in relevant provisions of Rosenergoatom's methodology [12].

The article presents the methods developed to assess the impact produced on the biota by nuclear facilities, including RW storage and disposal facilities. In particular, it summarizes the results of their practical testing. The results obtained clearly demonstrate that safe levels of biota exposure (hereinafter referred to as SLBE) and the discussed methods can be reasonably applied in the development of environmental quality standards specifying the levels of radioactivity for various objects, as well as for the radiation safety demonstration purposes.

Studied objects and research methods. Requirement for the environmental safety assessment in Russia

State Policy Fundamentals for Nuclear and Radiation Safety of the Russian Federation until 2025 and for Further Perspective consider the safety of nuclear facilities, including the protection of the environment, as a top priority.

Recent amendments to the Federal Law 7-FZ On the Environmental Protection of January 10, 2002, as well as relevant supporting regulations, for example [13], provide for the development of environmental quality standards, including those concerning the radioactivity levels. These standards are to be complied with both during the nuclear decommissioning and to provide the long-term safety of RW disposal facilities (RWDF). Environmental quality standards should be established, in particular, to protect the natural ecological systems, the genetic fund of plants, animals and other organisms.

The above topic is still considered as an open issue in Russia and in the world community in general. The topic associated with maximum concentrations of radionuclides in individual components of the natural environment and the establishment of relevant standards in Russia has become especially relevant due to the intensification of efforts on RWDF development and nuclear legacy cleanup being implemented under federal target programs.

Radiation exposure to wildlife and its assessment methodology

In 2014, a methodology for the economic assessment of damage caused by the radiation exposure of biota in RW storage facilities was first developed and tested [6, 8]. The assessment was based on the radiation dose rates calculated for representative (reference) wildlife objects in the area affected by a RW storage facility and their comparison with the accepted criteria for favorable environment and radioecological safety, the so-called safe levels for biota exposure (SLBE). Therefore, a $SLBE_a$ of 1 mGy/day was established for mammals, vertebrates and pine trees, whereas for other plant organisms and invertebrates specified was a $SLBE_p$ of 10 mGy/day [10, 14]. According to the considered methodology, if the above SLBE are exceeded, the wildlife objects are conservatively assumed as dead, i. e., relevant potential damage is assessed as an already inflicted one.

Results and discussion

SLBE application to assess the current safety level at near-surface storage facilities for accumulated RW

The developed methodology was applied to evaluate the state of 72 storage facilities for the accumulated RW inventory located on the territory of ROSATOM enterprises (Table 1 shows examples of the results obtained [8]).

Collected data have shown that for the majority of facilities and for all SRW storage facilities, the radiation dose rates for the biota organisms found in their vicinity do not exceed the established SLBE. Therefore, the damage estimated in accordance with the methodology described in [8] can be considered as being equal to zero.

Assessing the long-term safety of near-surface RW storage facilities via the SLBE

Modern software systems can predict the distribution of radionuclides in the environment and

Table 1. Radiation dose rates for reference biota species and evaluated damage

RW storage facility	Radiation dose rates, mGy/day			Most important radionuclides	Environmental damage, mln RUB
	Plants	Animals			
		invertebrates	vertebrates		
FSUE PA Mayak					
Reservoir V-9	0.02–52	0.01–76	0.01–340	^{90}Sr, ^{137}Cs, Pu isotopes	39–65
Reservoir V-17	4–6	3–5	10–110	^{90}Sr, ^{137}Cs, Pu isotopes	55
TCR	0.02	0.010–0.015	0.03–0.37	^{90}Sr, ^{137}Cs, Pu isotopes	0
JSC CMP					
Tailings	0.3–0.9	0.8–2.2	0.7–0.9	^{226}Ra, ^{231}Pa, ^{238}U	0
PPGKhO					
Tailings	0.001–0.009	0.003–0.02	0.0006–0.007	^{226}Ra, ^{230}Th, ^{238}U	0

the levels of dose loads on the biota both caused by atmospheric emissions and the migration of radionuclides in the lithosphere with groundwater flows.

A case in point is the migration of radionuclides evaluated for a reference purpose-designed reinforced concrete near-surface storage facility for accumulated RW holding over 8,000 m^3 of solid radioactive waste also containing some radionuclides (^{9}0Sr, ^{137}Cs, ^{239}Pu). Considering a normal evolution scenario, the evaluated concentrations of the main radionuclides at the groundwater discharge into the river adjacent to the facility have shown that the exposure level (EL) would not be exceeded along the entire period while the RW potentially remains hazardous (Figure 1a, b). Calculation module Ecorad-express being developed at IBRAE RAS based on the ICRP model algorithms to assess the doses to reference species of biota [9] has allowed to calculate the dose loads for various types of biota during the entire period while the RW potentially remains hazardous. Figure 1c shows the calculated dose load for the inhabitants of water bodies.

The study has shown that the contribution of ^{239}Pu to the doses found in the reference species of aquatic biota is essential. However, SLBE was not found to be exceeded for any of the considered species. At the same time, radionuclide concentrations in water during the entire period while the RW potentially remains hazardous were found to be much lower than the EL.

SLBE application in the long-term safety assessment of a deep RW disposal facility

The potential impact produced on terrestrial biota by deep RW disposal facilities intended for irradiated graphite and high-level RW disposal was evaluated for the period of their operation. The results presented in [7] showed that considering air emissions, ^{14}C seems to be the predominant source

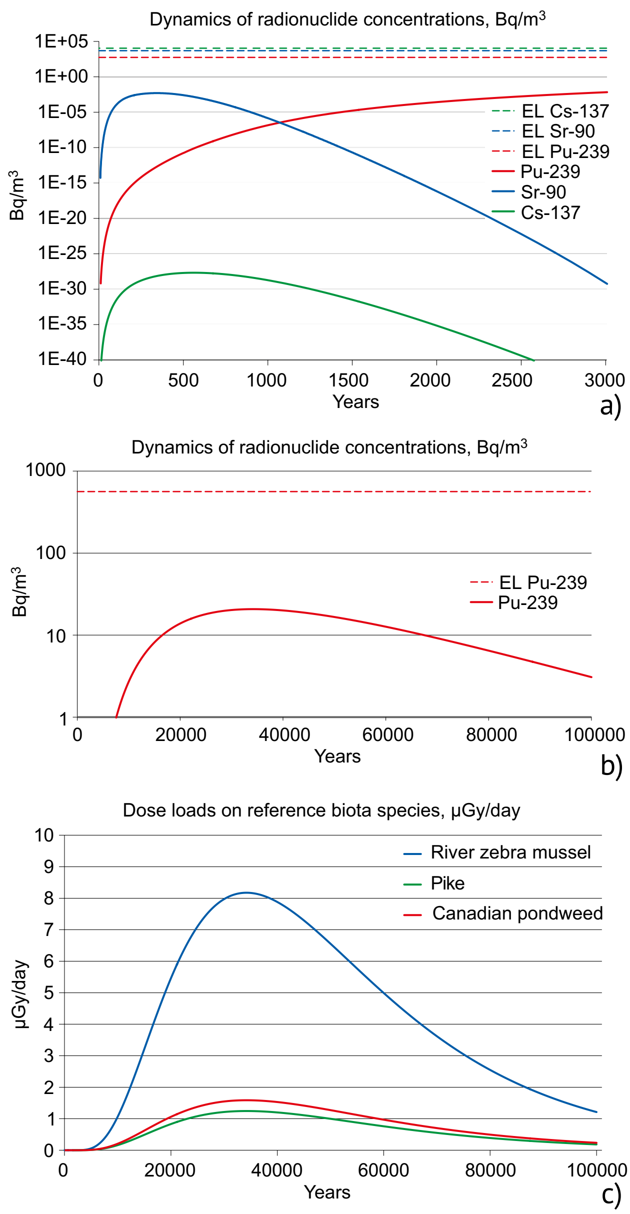

Figure. 1. Assessment results: dynamics of radionuclide concentration in the water for the first 3,000 years (a) and for 10,000 years (b), as well as the dynamics of the absorbed dose for the reference biota species (c)

of radioactive impact. The maximum estimated ^{14}C emission amounted to 6 TBq/year or 0.075 % of its total inventory found in the DDFRW [15]. Table 2 summarizes the estimated irradiation dose rates for representative objects of the biota calculated according to the above levels.

Table 2. Expected dose loads on terrestrial biota during DDFRW operation

Organism	Dose rate, μGy/day	SLBE, μGy/day
Wood (pine)	0.03	1,000
Grass	0.01	10,000
Mammals (mouse)	0.02	1,000
Bird	0.02	1,000
Frog	0.02	1,000

Additional exposure doses to biota caused by radioactive releases during DDFRW operation turned out to be similar considering various representatives of biota species being, on average, about 2 times lower compared to the natural background radiation from ^{14}C. These can be viewed as negligible compared to the general radiation background and even more so as compared to SLBE.

Conclusion

The methodology developed in 2014 to assess the radiation damage to the environment associated with storage facilities holding the accumulated RW inventory can be considered as the first and successful step in the efforts implemented by Russia under the project on the development of such a toolkit. We believe that its further refinement based on modern software systems will provide adequate quantitative estimates regarding the radionuclide migration from the RWDF (DDF RW) into the biosphere and the levels of radiation impact produced on various types of biota.

To date, the Roshydromet of the Russian Ministry of Natural Resources has approved certain recommendations on the flowchart that can be used to calculate the reference levels of radionuclides in the components of the natural environment, which are based on the SLBE. A positive experience has been gained in the application of these recommendations during the development of the Rosenergoatom methodology [12].

Based on international experience in assessing the impact of nuclear facilities on biota, the developed methods and recommendations have been tested and generalized. The results obtained demonstrate the potential SLBE applicability in the development of environmental quality standards according to the radioactivity levels, as well as in the radiation safety demonstration, including the one associated with the long-term safety.

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Bibliographic description

Kryshev I. I., Sazykina T. G., Arakelyan A. A., Vedernikova M. V., Panchenko S. V. Issues of Establishing Standards for Radiation Safety of Wildlife Including the Radioactive Waste Management. *Radioactive Waste*, 2021, no. 2 (15), pp. 99—105. DOI: 10 .25283/2587-9707-2021-2-99-105. (In Russian).