Management of special radioactive wastes: practical advances and current challenges

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The article covers methodological approaches for substantiating the assignment of radioactive wastes (RAO) to special radioactive wastes, as well as the results of its practical application within initial registration of RAO.

Key words: *radioactive wastes classification, special radioactive wastes, potential hazard period, disposal scenario, criteria of assignment, collective effective dose, combined risk of potential radiation exposure*

Introduction

Federal law dd. 11.07.2011 № 190-FZ «On management of radioactive wastes and on amendments to certain legislative acts of the Russian» (hereinafter – №190-FZ) introduced the subdivision of radioactive wastes (RAO) into disposable and special RAO, based on the comparison of radiation and other risks and costs for the alternative RAO management options, including its disposal [1]. Legislation implementation of special RAO category allows to put into practice a brand new strategy of accumulated RAO management, taking into account the specific character of nuclear legacy formation. The first step of it is the initial registration of accumulated RAO, that results into assignment of the part of RAO to special RAO [2].

Decree of the Government of the Russian Federation dd. 19.10.2012 № 1069 «On criteria of assignment for solid, liquid and gas wastes to radioactive wastes, criteria of assignment of radioactive wastes to special radioactive wastes and to disposable radioactive wastes and criteria of disposable radioactive wastes classification» (hereinafter – PP № 1069) [3] defines complex radiological, radioecological and economical criteria of RAO assignment to the special RAO. It also formed the basis for amendments of sanitary rules [4-6], as regards wastes assignment to RAO, and of other documents.

Consolidated statement of criteria in PP № 1069 reveals the gaps in long-term safety regulation and produces the number of ambiguities in its interpretation from the perspective of modern radiological protection system, that results in development of special methodological approach [7,8]. Lead specialists from IBRAE RAN, State corporation «Rosatom»; FGUP «PO «Mayak»; NPO «Tayfun» of Roshydromet; safety regulation agencies for nuclear energy application and its scientific organizations, including: Ministry of Natural Resources of the Russian Federation, FBU«NTC YARB» of Rostechnadzor, FBUN Research institute of Radiation Hygien after professor P.V.Ramzaev, FGBU GNC A.I. Burnazyan FMBC of FMBA of Russia took part in the development of the approach.

The purpose of this article is to describe the developed principles, approaches, allowances and procedures, that were recommended for comparison analysis of radiological risks and costs for different RAO management options, for assessment of its conformity to the modern radiological protection system and conformity assessment of practical results for RAO assignment to the special RAO, according to the basic principles of radiological protection.

1. Development of RAO management legal and normative framework

The legal aspects of RAO management were regularly given an appreciable attention within the contemporary history of Russia. The starting point should be considered the decree of the first Congress of People's Deputies of the RSFSR, that interlinked the problems of radiological safety generally with radioactive wastes. In the pursuance of this decree the President of Russia had issued the Directive dd. 21.11.1991 № 70-rp with specific instructions to the Council of Ministers of the RSFSR, including the following:

«- to develop the draft of State program of the RSFSR for radioactive wastes and used nuclear materials management, for its utilization and radioactive wastes disposal;

- to form the Russian scientific commission for radiological protection, and authorize it for development of corresponding concepts and regulatory documents».

The second step took place in 1995, when the Federal law dd. 21.11.1995 № 170-FZ «On use of nuclear energy» was enacted. At the same time the bill «On radioactive wastes management» was drafted, and later passed by the Federal Assembly, but declined by the President of Russia. At that period 18 federal, president and industry programs, concerning the certain problems of nuclear and radiological safety, were developed and approved. However, the major part of the tasks, that face these programs, were not accomplished, as the provided funding was only of a few percents of the planned investments.

The start of the third step can be assigned to 2007, when the Federal target program «Nuclear and radiological safety for 2008 and up to 2015» (the order of the Government of the Russian Federation dd. 19.04.2007, №484-r), was enacted, that became one of the main mechanism for implementation of activities for accumulated RAO safe handling.

The Federal law dd. 11.07.2011 №190-FZ «On management of radioactive wastes and on amendments to certain legislative acts of the Russian» (hereinafter – №190-FZ) came into force in 2011. For today, the system of legal, normative and organizational documents is formed, that designed to regulate the RAO management, including its disposal. These documents include the Decrees of the Government of the Russian Federation от 25.07.2012 №767 «On initial registration of RAO» and PP №1069, sanitary rules OSPORB-99/2010 and SPORO-2002 with amendments dd. 16.09.2013 [1-6], federal regulations [9,10], orders of the State corporation «Rosatom» and the Ministry of Natural Resources of

the Russian Federation. This vigorous legislation synchronizes with evolutionary revision of International Commission on Radiological protection (ICRP) recommendations and International Atomic Energy Agency (IAEA) documents, but it was not entirely harmonized with international system content-wise [11-15]. Among 5 key factors, that determine the state policy within the «State policy framework in the context of nuclear and radiological safety of the Russian Federation for the period up to 2025», approved on the 1st of March, 2012, by the President of Russia, two factors can be emphasized, which are related to the subject of the article:

«- high sensitivity of the policy of leading nuclear-weapon states to the radiological accidents, to the problems of handing of used nuclear fuel and radioactive wastes, as well as to the clean-up of accumulated environmental damages and to the rehabilitation of contaminated areas at the territory of the Russian Federation;

- severization of international requirements for the safety of nuclear facilities and, subsequently, the harmonization of nuclear and radiological safety regulations at the global level ».

However, it should be noticed, that the specific character of accumulated RAO problem in Russia, and its scale, still do not find its way into international requirements and regulations. Criteria of RAO assignment to the special RAO, prescribed by PP № 1069, at the current phase in some ways fill this gap.

2. Criteria of RAO assignment to the special RAO

The structure of criteria of RAO assignment to the special RAO, approved by PP №1069, shows the different nature of limitations, that aimed at radiological safety of current and future generations, as well as at the environmental protection (Fig. 1).

Figure 1 illustrates the following:

- firstly, the nomenclature of PP № 1069's criteria doesn't take into account the «other risks» of non-radiological nature, while categorizes the RAO into special and disposable RAO, mentioned in №190-FZ;

- secondly, in the capacity of quantitative indicators of the «risks, related to the radiation exposure», collective effective dose of radiation exposure, risk of potential radiation exposure (hereinafter – ORPO) and overall possible environmental damage (hereinafter – SRVV OS) during the whole potential hazard period of the RAO, are established;

- thirdly, the qualitative criterion is a mandatory requirement for location of RAO storage facility (PKhRO) and its sanitary protection zone (SZZ) outside of the boundaries of population centers, specially protected natural reservations, coastal buffer zones and water protection zones of water bodies, and other reservation and protection zones, indicated in accordance with the legislation of the Russian Federation.

Therefore, criteria, introduced by PP № 1069, are regulatory requirements additional to the existing federal and sanitary regulations and rules, concerning radiological safety. The specific character of these supplementary requirements lies in the fact, that they refer not to the reference person – individuals from the critical population group and the crew of nuclear and radiation hazardous objects, but to the population of the current and future generations.

Uncertainty of long-term evaluations of criterion parameters for radiation dose, risks and costs is quite significant. It also aggravated by the absence of design solutions and operating experience for special and disposable RAO management at the preservation and disposal phases for a lot of RAO storage facilities. ICRP believes, that predictive assessment of radiation doses and risks for hundreds of years should be considered more as the safety indicators for the disposal chart used, and not as an accurate measure of personal and environmental radiological and radioecological hazard. National practice for radiological safety supervision consists in onevalued interpretation of radiological event: the evaluation of compliance or non-compliance of existing requirements and norms. That's why, proceeding to development of methodological approach, designed for the implementation

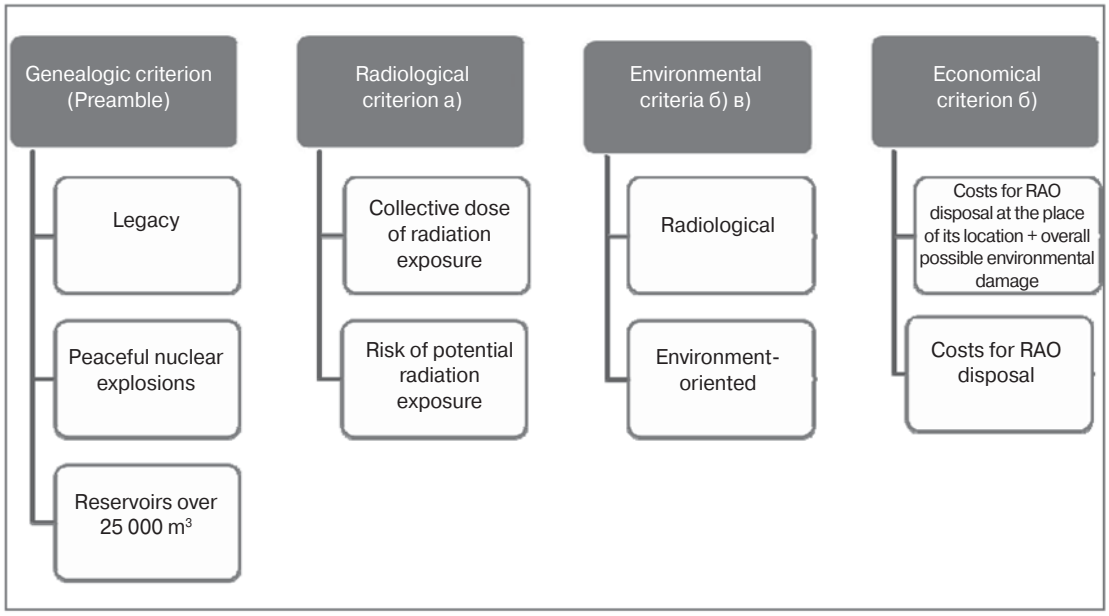

Fig.1. Logic diagram of criteria of RAO to the special RAO [3]

of provisions of №190-FZ and PP №1069, existing national regulatory requirements and norms, prospects for its development towards the harmonization with modern international recommendation and standards have been analyzed. Risk- and cost-minimizing rule for evaluation of alternative options for RAO disposal is a combination of objectives and principles of radiological safety:

– principle of substantiation of practical activity, defined in NRB-99/2009, cl. 2.2 [16];

- principle of protection of the current and future generations, that in the context of RAO is defined in Fundamental safety principles, cl. 3.29 [12]: «RAO management should be organized in such a manner as to not cause an unjustified problems for the future generations, i.e. the generations, producing the wastes, should find and apply rational and ecologically acceptable methods for long-term wastes management …»

New recommendations of ICRP and regulations of IAEA [11,13] may consider the RAO management within the case of planned radiation exposure, when the steps of wastes handling, including disposal, are the integral parts of technology of atomic energy use, or within the case of existing radiation exposure, if this event «has already emerged to the moment, when the decision of taking the situation under control had been made, including the natural background effect, residual radiation exposure, because of the activities in the past, or due to the radiological emergencies …». Actually, the subdivision of RAO into special and disposable RAO within №190-FZ is in line with this primary approximation of the modern international radiological protection system and, consequently, with the concept of dose constraints, boundary risks and reference levels, that shall be used for indicated radiation exposure events. For the control of radiation exposure of the population due to RAO disposal, including the planned disposal of long lived RAO, ICRP within Publications 76 and 81, issued in 1997 and 1998 respectively, recommended the dose constraint value less than 0,3 mSv year-1 for the individual from the population. This value was verified in Recommendations of 2007 [11]. At the same time OSPORB-99, SPORO-2002 and OSPORB-99/2010 established stricter dose limits:

- in the initial edition of OSPORB-99/2010 [4]: «Effective dose of radiation exposure of the population due to RAO management, …including its storage and disposal, should be less than 10 μSv/year»;

- in 2013 edition [6]: «Annual effective dose of radiation exposure of critical population group under all types of RAO management up to its disposal should be less than 0,1 mSv. Annual effective dose of radiation exposure of critical population group by RAO after its disposal should be less than 0,01 mSv».

Thus, sanitary rules establish the annual dose quota after RAO disposal complying with the level of negligible individual lifetime risk 10-6 year-1.

PP № 1069 has no radiological criteria, referring to the individual and annualized radiation exposure, and speaks in terms of collective effective dose during the whole potential hazard period of RAO. International recommendations [11] assume to use collective effective dose for optimization of radiological protection, primarily, of the personnel, and for comparison of radiation technologies. Whilst in Publication 101b ICRP [17] the term «dose matrix» was introduces, that defines disintegrated collective dose, considering 3 factors: the range of annual individual dose, time period (from the current time to far future) and proliferation of radiation exposure over a distance (local, regional and global scale). Actually, the dose criterion of PP № 1069 is a degenerate matrix, consisting of one element, that is substantiated because individual dose under special RAO management are negligible during the whole potential hazard period RAO and the radiation exposure scale has a local character.

It should be noticed the disagreement of PP № 1069 and NRB-99/2009 in the context of safety evaluation of the final condition of repository (PZRO): after transfer the RAO storage or preservation facilities into PZRO, on one hand, it stops being a radiation hazard (dose should be less than 0,01 mSv year-1), but on the other hand, PP № 1069 prohibits the location of radiation safe PZRO within certain areas (criterion в). This requirement of PP № 1069 should be clarified and specified.

3. Methodological substantiation for RAO assignment to the special RAO

Aiming for uncontroversial combination of PP № 1069 and existing regulations and rules became the main objective for methodological approach development [7,8].

One of suggested methodological solutions consists in application the monetary approach for joint quantitative assessment of radiation risks and costs. This was supposed to be used to exclude the dispute, while comparing the disposal options that would occur, if one of PP № 1069 criteria wouldn't be accomplished. This approach was declined by experts, because the primacy of economic efficiency in comparison with radiological safety and using of simplified optimization method of «cost-benefit analysis» for strategic planning are not acceptable from the perspective of social attitude.

Another option for combining the radiological criteria into one indicator was suggested within the informative appendix of FMBA of Russia [18]. The decision about RAO assignment to the special RAO is considered to be justified, if the following condition is fulfilled: the sum of collective doses of personnel and of population under normal conditions of RAO management and in case of emergencies for the option of RAO disposal exceeds the similar sum for the option of preservation and disposal of RAO at the place of its location. If the limitation of individual dose of personnel and of population for alternative options of RAO management under consideration are observed, than such resultant of collective doses of personnel and of population is not prohibited by existing radiological safety regulations [16], but seems questionable on the basis of international recommendations – par. (40) and Publication 103, cl. 4.4.7 [11]. Up to the present, radiation exposures for personnel and for population were considered disconnectedly.

The third suggested approach was focused on minimization of calculations for substantiation of RAO assignment to the special RAO. To that effect, it was provided to exclude from the analysis the one-type steps of special and disposable RAO management, such as performing the integrated engineering and radiological survey (KIRO), infrastructure development at the site of RAO location, and to consider only those steps of RAO management, that make the biggest contribution into the risks and costs. Even noting the rationality of this approach, the specialists of regulatory agencies mentioned incomplete correspondence of criterion parameters, calculated using this method, to the criteria of PP № 1069.

After all, the basic approach, approved for implementation, provides the full analysis of criterion characteristics for disposal scenario at the site of RAO location.

Collective effective dose

Assumptions, that were made for calculation of collective effective dose, included the following:

(1) Doses for personnel and for population are calculated separately.

(2) To substantiate the assignment of RAO to the special RAO it is sufficient, that collective dose of personnel, estimated for the most dose-consuming operations, prescribed in RAO disposal scenario, accurately exceeds the collective dose of personnel for RAO disposal in the place of its location, taking into account all operations, prescribed in scenario, during which the dose is formed.

(3) When substantiate the assignment of RAO to the special RAO, it is recommended to provide the conservative estimation of radiation exposure dose for RAO disposal scenario in the place of its location by using the upper bound estimates of labor costs under performing of certain operations, and the radiation situation at the workplaces. For RAO disposal scenario more realistic models of dose evaluation should be used. In this way, the confidence of RAO assignment to the special RAO is achieved without uncertainty analysis.

(4) It is assumed, that at any step of RAO management the compliance with specified dose limitations for personnel is achieved based on operational requirements, and not by personnel shifting. This term corresponds to the IAEA provision: «The number of required personnel should be selected based on the operational requirements only, and it should not be increased for providing the compliance with specified radiation exposure limits ».

(5) The evaluation and comparison of collective doses radiation exposure of population, relating to RAO disposal in the place of its location and RAO removal, are not performed, if during the whole potential hazard period under the normal RAO management the mean annual individual effective dose radiation exposure of the population is less than 10 μSv. In this case the individual lifetime risk will be less than the negligible low risk level 10-6 [16].

Risk of potential radiation exposure.

NRB-99/2009 specifies the limits of annual combined risk of potential radiation exposure (ORPO) for personnel as 2×10 -4 $year^{-1}$ and for population as 1×10^{-5} $year^{-1}$. PP № 1069 specifies integral indicators of ORPO over potential hazard period. Thus, mean dose values for individual, who can be involved in possible emergency situations, should be estimated, as well as the number of these individuals. This means that, in addition to individual annual risk, the collective risk for personnel and population should be calculated. The following approach is used for calculating the collective ORPO:

(1) Radiological accidents may be caused by external effects to the object, as the result of natural and man-made emergency situations, and by technological emergencies at any step of RAO management.

(2) For input data it is recommended to use the project for storage facility isolation (if this project is available); the report for substantiation of object's radiological safety; data, used for definition of potential hazard category of radiation object.

(3) For long-term periods of operation of RAO repositories and PZRO (hundreds of years) in accordance with international regulations it is suggested to include the events, that occur with the frequency 1 time per 100 years and less (up to 10^{-2} $year^{-1}$), into the situations of potential radiation exposure. More frequently occurred emergencies and radiation exposures as the result of it should be considered within the planned radiation exposure. Accidents with probabilities:

– 10^{-4}year-1 to $10^{-2}$$year^{-1}$ refer to design accidents,

- 10^{-6}year -1 to $10^{-4}$$year^{-1}$ refer to anticipated accidents,

- up to $10^{-6}$$год^{-1}$ can be disregarded for ORPO evaluation.

Overall possible environmental damage.

Biota protection became the integral part of radiological protection system in recent ICRP recommendations [11]. Radiological principles, concepts and models are dynamically developed by ICRP, UNSCEAR and International Union of Radioecologists. In Russia the implementation of these approaches is made under the aegis of the Ministry of Natural Resources of Russia. The member of the Academy of Sciences R.M. Aleksakhin and professor I.I. Kryshev play the great role in this process as distinguished scientists. Considering the estimating procedures for the damage, inflicted to the wildlife, and specified statutory prices, the overall possible environmental damage in case of RAO disposal in the place of its location is understood as an estimated monetary equivalent of the wildlife demise due to radiation exposure. The estimation is made based on the calculation of dose rate on reference wildlife objects at the territory of RAO storage facility, and the comparison of obtained values with criteria of favorable environment conservation and radiological safety. For this conservative criteria of environmentally safe radiation exposure level for the wildlife objects the value 1 $vGy \cdot day^{-1}$ is used for fauna and 10 $vGy \cdot day^{-1}$ for flora. Non-exceedance of these levels allows to affirm the absence of possible environmental damage. If these levels are exceeded, the demise of wildlife is conservatively assumed, and the calculation of environmental damage is performed. The estimation of the monetary equivalent of overall possible environmental damage is made in accordance with regulatory and procedural documents for environmental protection: Decrees of the Government of the Russian Federation, orders of the Ministry of Natural Resources of Russia, the Ministry of Agriculture of Russia and Russian Federal Fisheries Agency, published in 2010-2012.

Cost estimation for two options of RAO management

According to PP №1069, to assign RAO to the special RAO the cost estimation for 2 options of RAO management should be made. Estimation of costs, related to RAO disposal (including the expenses for its removal from the storage facility, reprocessing, conditioning, shipping to disposal facility (PZRO) and disposal), should be made in accordance with the procedure of cost analysis, approved by State corporation «Rosatom» dd. 28.11.2013.

№ 1/16-NPA. Estimation of costs, related to RAO disposal in the place of its location, should include the expenses for transformation of this storage facility into RAO disposal facility, its operation and closure and provision of its safety during the whole RAO potential hazard period, at that, there is no the list of documents, according to which those estimations should be performed, in PP №1069. The following approach for carrying out these estimations is suggested within the substantiation process:

(1) the cost of works is taken in prices of the reference year unadjusted for inflation;

(2) for substantiating of RAO assignment to the special RAO, it is enough to estimation the costs, related with

RAO disposal, accurately exceeds the obtained estimation of costs, related with RAO disposal in the place of its location, as well as the estimation of overall possible environmental damage in case of RAO disposal in the place of its location;

(3) Cost estimations for the option of RAO disposal, as well as for the option of RAO disposal in the place of its location, is performed considering the data of design, construction and operational documents, including the project for storage facility isolation.

Concerning the estimation of costs, related to RAO disposal in the place of its location, it is suggested to use the data of project for isolation of specific RAO storage facility, if this project was already developed, the data of prototype, the specific costs for standard handling operations or for expert reviews, based on the analysis of already performed works at the following enterprises: FGUP «RosRAO», FGUP Federal nuclear organization «Mining and chemical combine (GKhK)», FGUP «Production association (PO) «Mayak», JSC «Siberian Chemical Combine (SKhK)», NIC «Kurchatov Institute». The approach provides the step-by-step performing of operations for RAO disposal, and the cost estimation is stopped when it exceeds the costs for RAO disposal and the obtained value of overall possible environmental damage.

Methodological approach application for initial registration

In 2013-2014 State corporation «Rosatom» is carrying out the initial registration of accumulated RAO, placed in more than 1000 storage facilities. Organizations within the industry prepared 70* substantiations for assignment of RAO to the special RAO, placed at the facilities of FGUP «PO «Mayak», JSC «SKhK», JSC «ODC UGR», FGUP FYaO «GKhK», JSC «NZKhK», JSC «ChMZ», JSC «PPGKHO», JSC «PO EKhZ». If commissions approve these substantiations, more than 472,8 mln. m3 of accumulated RAO will be assigned to the special RAO. Even without considering the facilities, from which the RAO removal never supposed, for instance, V-9 reservoir (lake Karachay), Techenskiy reservoir cascade, and tailings storage facilities of JSC «PPGKHO», avoided costs forward for the listed facilities are more than 260 bln. rubles and decrease the dose consuming forward minimum for 50 man • Sv, that corresponds to more than 50 reactor-year of nuclear power unit operation. The effect of RAO assignment to the special RAO for a number of facilities is shown in Table 1.

As the result, the assignment to the special RAO allows to provide the possibility of implementation the same safe but essentially cheaper method for the final isolation of previously accumulated RAO – the RAO storage facility isolation, and then the justified, in the context of long-term safety, the transformation into RAO disposal facility.

4. Relevant radiological health-related aspects of special RAO management

Dose quotas. According to NRB-99/2009 the dose quotas are specified only for technology-related radiation exposure. Extension of the dose quotas philosophy to the RAO, containing natural radionuclides, based on the fact, that they are formed within the nuclear industry, is not a result of national sanitary normalization. Such approach for treating all steps of nuclear fuel cycle, including uranium ore mining and handling of its wastes, is typical for IAEA standards. ICRP suggests more effective opinion, when the limitation of radiation exposure from the natural sources assigned to the existing radiation exposure situation. Concerning the special RAO, containing natural radionuclides, it is suggested to use the elevated levels of specific radioactivity, typical for uranium deposits, for example, as the criterion for assignment to RAO.

Truncation concept for radiological quantitative parameters.

The scope limitation of radiological protection system is based on the axiom of Roman law «de minimis non curat lex – the law does not concern itself with trifles». In IAEA standards two concepts are distinguished: withdrawal of a priori radiation source or practical activity out of regulatory control, and decontrol of radioactive materials, that are used within authorized practical activity out of further regulatory control. Based on the dose criteria, NRB-99/2009, cl. 1.4, shows the list of sources, withdrawn out of regulatory system, and in OSPORB-99/2010, cl. 1.7, the term «regulatory control » is changed for «radiological control and accountability », and, formally, the withdrawal and decontrol are characterized by the levels of MZUA, MZA (Appendix 4, NRB) and levels of specific radioactivity, permitting unrestricted use of materials (Appendix 3, OSPORB).

Table 1

Results of estimation of alternative options for RAO management, for substantiation of assignment of RAO to the special RAO.

№	Name of RAO storage facility / Organization	RAO volume, m^3	Criterion characteristics derating		
			Collective doses of radiation exposure, man. Sv	Ratio of ORPO derating	Costs forward, bln. rubles
1.	Waste disposal site/ JSC «PO EKhZ».	6,65E+03	over 0,04	100	over 0,8
2.	Storage facility of solid radioactive wastes (TRO) / JSC «UEKhK»	4,99E+04	over 0,3	4	over 8,2
3.	Tailings storage facilities of NZKhK / JSC « NZKhK »	9,56E+05	over 1,8	2400	over 27
4.	F. 650/1 (repository of TRO) / FGUP «GKhK»	8,37E+03	over 1,1	200	over 14,5
5.	F. 651/2 (repository of TRO) / FGUP «GKhK»	4,28E+03	over 0,4	500	over 7
6.	F. 354 (repository of TRO) / FGUP «GKhK»	1,10E+04	over 0,4	3500	over 45
7.	Repository №8 / FGUP «PO «Mayak»	1,25E+04	over 0,13	7	over 4,5

* Initial registration was not performed for the number of facilities at the time of publication of this article, so there was no commission decision about RAO assignment to the special RAO.

In the context of RAO management there is provided to broaden the range of radiological parameters, that characterize the lower limit of the radiological safety system scope, including combined risk of potential radiation exposure, overall possible environmental damage and the end date of RAO potential hazard period.

Table 2 demonstrates the report for proposed «bottom» boundary conditions for criterion characteristics calculation.

Potential hazard period.

According to №190-FZ and NP-055-04 [1,9] the RAO potential hazard period is defined as a period of time, during which the RAO levels of radioactivity decrease to the values, where the radiation control is not required.

The most conservative estimation of TRO potential hazard period is based on threshold values of radionuclide specific activity (PZUA), specified by PP №1069, lower than which the RAO conceptually is no longer radioactive. For the mixture of radionuclides the potential hazard period, T, is the period of time on the expiry of which the sum of maximum specific activities of radionuclides in the wastes (УАi(T)) to their threshold values (ПЗУАi) ratio is less than 1, i.e.:

$$\sum_i \frac{\text{УА}_i(T)}{\text{ПЗУА}_i} \leq 1 \qquad (1)$$

The practical use of this conservative approach in operation organizations, where TRO accumulated in tailings storage facilities or repositories contains natural radionuclides, leads to the absurd conclusion: ONRAO, assigned to the disposable RAO, class 6, keeps its potential hazard during millions of years, and within this period it should be under radiation control. The reasons of this antinome are to be sought in highly overrated (for about an order) requirements of Russian regulations and rules, concerning the dose quotas, as against international standards, that was mentioned above. It also should be taken into account, that radiation exposure scenarios, accepted for the substantiation of withdrawal level in IAEA documents (MZUA in NRB-99/2009, respectively), were based on worst-on-worst conditions of external and internal radiation exposure from the sources of limited weight (approximately one or few tons). Using the combination of radionuclide specific activity estimations, that result to the annual dose of 10 μSv, the lowest values of specific activity were selected and recorded as the levels of withdrawal. And, now MZUA values are carried over RAO as PZUA values in PP №1069, without taking into account the natural and engineering safety barriers of PKhRO. To some extent the PZUA values adequately represents the potential hazard from disposable RAO handling during the removal, assorting, reprocessing and conditioning of RAO, but these values are overly conservative for operations with special RAO, including the RAO, that contains natural radionuclides.

In the context of these international recommendations, suggesting to use the elevated levels of specific radioactivity, typical for uranium deposits, for example, as a criterion for assignment to RAO, are based on the following:

- the wastes, containing uranium, are not supposed to be used, and after PKhRO isolation, they virtually do not migrate beyond the barriers;
- at the territories with elevated radiation background, because of rocks, containing elevated concentrations of natural radionuclides, the natural radiation exposure is excluded from the radiological protection system, since eventually it is impossible to influence on;
- if on the results of long-term monitoring after the PKhRO isolation it is proved that specified health standards, concerning the radionuclides, that are included into natural series ^{238}U, ^{232}Th and ^{235}U, are respected, so that will be the evidence of the end of potential hazard period;
- it is possible to reliably predict for the period of 300 years the erosion of upper layers at the preservation facility.

Sanitary protection zone (SZZ) dimension specification

In general, the boundaries of SZZ around PKhRO or PZRO are determined on the basis of the requirement for limitation of radiation exposure of the population by the annual dose limit or by the quota of annual dose limit, specified for this facility, that is formed due to gas-aerosol atmospheric emissions, liquid effluents, etc. [19]. It is the special feature of PKhRO, preservation facilities and PZRO, that for them permissible release (DV) and permissible effluent (DS) technically are not specified. That's why the external boundary of SZZ designed in this case is based on the result of radionuclide migration estimations, as well as by reference to the absence of possible effect to the population due to inhalation intake of radionuclides. During the phase of RAO assignment to the special RAO it is not useful to consider the possible changes of SZZ boundaries during the process of PKhRO isolation. Usually, the identified SZZ boundary of the enterprise, that has RAO storage facilities, is calculated with health-related margin for

Table 2

Truncation of the range of quantitative parameters values

Parameter	Truncation concepts	Boundary value
Potential hazard period	Scientific forecast horizon, containment of RAO with the course of time	1000 years – technology-related radionuclides 300 years – natural radionuclides
Collective dose of personnel	Negligible ambient equivalent dose rate (MAED) at the work place	0,3 μSv/h
Collective dose of population	Decontrol	10 μSv/year
ORPO of personnel	Boundary ORPO before the disposal	$2 \cdot 10\text{-}4$ year^{-1}
	The range of events probability, that result to potential radiation exposure after the disposal	P=10^{-2} year^{-1} – 10^{-6} year^{-1}
ORPO of population	Boundary ORPO before the disposal	R=1,0 10^{-5} year^{-1}
Overall possible environmental damage	Threshold exposure value Threshold value of biota radiation exposure dose rate	Fauna – 1 mGy day-1 Flora – 10 mGy day-1

the main facilities in operation, and its changing would be defined, first of all, by the technological development, modernization of existing process unit and decommissioning of storage facilities.

Restriction for location and origin of special RAO

Additional restrictions for location of special RAO storage facility: «RAO storage facility and its sanitary protection zone are located outside of the boundaries of population centers, specially protected natural reservations, coastal buffer zones and water protection zones of water bodies, and other reservation and protection zones, indicated in accordance with the legislation of the Russian Federation», and for the origin of RAO: «RAO, formed as the result of arms program or state defense order, are assigned to the special RAO», approved by PP №1069, give no opportunity to transfer several storage facilities into safer condition in compliance with federal regulations and sanitary rules. Following facilities, for instance, cannot qualify as the special RAO storage facilities:

– Unit of using the nuclear charge for peaceful uses «Tavda», in Velizhansky water-intake, Tyumen region;

– Storage facilities of JSC «MSZ», with over 126 ths. m3 of RAO, containing of uranium-238, thorium-230, radium-226, are located within the boundaries of Electrostal;

– Storage facilities of Kirovo-Chepetsk branch of FGUP «RosRAO», with about 300 ths. m3 of RAO, are located within the boundaries of Kirovo-Chepetsk;

– Repositories №1 and №2 in Rezhevsk district of Sverdlovsk region, with over 40 ths. m3 of wastes, formed during the thorium -232 mining, are located in Ozerny settlement, and the bank of the river Ozernaya;

– Storage facility of JSC «GMZ» (over 12 mln. m3 of RAO) is located at the territory of specially protected ecological resort of Caucasian Mineral Waters region;

– Repositories of FGUP «RADON» (over 120 ths. m3 of RAO), with RAO formed as the result of national economy.

Therefore, additional requirements for existing federal regulations and sanitary rules, induced by PP № 1069, do not allow to provide more cost-effective and safer method of accumulated RAO handling, even if it would be proved, that collective effective doses, risks and costs for RAO disposal would significantly exceed the doses, risks and costs for RAO disposal in the place of its location.

Summary

1. The article sums up principles, general and specific approaches for RAO assignment to the special RAO, applied during the initial registration of RAO, and describes methodological difficulties, related to the uncertainty of criterion parameters calculation over the potential hazard period and not full agreement of national and international regulatory documents.

2. Within the framework of substantiation of RAO assignment to the special RAO the series of new radiological and health-related provisions, concerning the potential hazard period estimation for the special RAO, PKHRO and PZRO definitions in the context of SZZ, including the approach that provide the usefulness of design period limitation by 1000 year period, and 300 year period for RAO, containing nuclear radionuclides, were used.

3. The article shows, that the assignment of RAO to the special RAO is made for less than 10% of the time. For these cases the full compliance with the fundamental requirements for radiological protection of the decisions of RAO assignment to the special RAO was demonstrated.

4. In some cases, RAO assignment to the special RAO turns out to be impossible because of non-compliance with PP №1069 criteria for origin and location.

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