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DEVELOPMENT OF USS RW IN THE FRAMEWORK OF FEDERAL TARGETED PROGRAM ON NUCLEAR AND RADIATION SAFETY ASSURANCE

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The article summarizes the achievements of the federal targeted program "Nuclear and radiation safety in 2016–2030" in key fields of radioactive waste management. Results are discussed for the most important projects, the encountered problems are analyzed, and the areas of further actions aimed at enhancing the organizational framework to achieve the highest level of economic and social effectiveness are identified.

Keywords: *Federal targeted program, radioactive waste, decommissioning, nuclear legacy sites, Unified state system for radioactive waste management, Unified state system for accounting and control of radioactive materials and radioactive waste.*

New edition of the State Policy "Fundamentals on Nuclear and Radiation Safety in the Russian Federation for the period up to 2025 and Further Perspective", approved by the President of Russia in October 2018, provides for a wide range of tasks, including those associated with RW management. This article overviews the state-of-art on the implementation of three main tasks in the field of RW management:

1. Decommissioning of nuclear legacy facilities, reprocessing of spent nuclear fuel, conditioning and disposal of RW and remediation of radioactively contaminated sites;

2. Integration of knowledge on the development of scientifically sound methods for the integrated nuclear and radiation safety assessment, including the development of improved techniques enabling to perform relevant calculations and experiments to justify and ensure the long-term safety of nuclear facilities, including deep and near-surface RW disposal facilities;

3. Development of improved mechanisms enabling the operation of central, departmental and regional information and analytical centers running under the system of state accounting and control of radioactive materials and radioactive waste (SSAC RM and RW) and information exchange between them.

Most of the efforts on USS RW development are being performed as part of activities carried out under the FTP Nuclear and Radiation Safety in 2016—2030 (FTP NRS-2). The following is considered of primary importance by the management body in the field of RW management: coverage of these activities in various media (a case in point — the website http://фцп-ярб2030.рф intended for specialists); regular disclosure of general results, plans and objectives relevant for USS RW development, as it was done in [1], as well as presenting the results of particular scientific and practical activities (from now on overviewed in each issue of the scientific and technical Journal Radioactive Waste). Considering this set of topics, of particular importance should be viewed a

summary of results for the activities performed by organizations on the execution of government orders, including those being carried out under the framework of FTP NRS-2. In the assessment of scientific and research performance, public discussion engaging a wide range of specialists and scientists is considered to be of a great importance. Publication of a scientific article in a peer-reviewed scientific and technical journal, after relevant activity was completed, is believed to be an important and practically flawless procedure. In seeking to reach a level suggesting that all research and practical work on the subject of RW management is covered in scientific periodicals, we will limit ourselves to a general overview and assessment of the results achieved so far. It should be noted that at present time a regular "flow" of such publications is available only on RW deep disposal topic.

Present overview is limited to the time period of 2016—2018 and basically covers the activities performed under FTP NRW-2.

Organizational framework provided by the State Corporation Rosatom is being guided by basic USS RW vectors (postulates) suggesting the following:

- Retrievable waste should be processed, brought in compliance with waste acceptance criteria and disposed of;
- Environmentally safe state (term referred to as "conservation" in Russian literature sources) should be achieved for the facilities intended for special (non-removable) RW emplacement with their further transformation into RW disposal facilities;
- RW disposal infrastructure should comply with the amounts of waste handed over for disposal accounting for those generated from nuclear decommissioning and remediation;
- RW management activities should comply with safety criteria, economic efficiency and public acceptance criteria.

Under FTP-2 in 2016—2018, activities executed under over 80 contracts (table 1) have been arranged for, including over 50 providing for RW management activities. For the rest of the contracts, these activities were considered as auxiliary by their nature. Due to the nature of such contracting, annual contracts were concluded in 2016, and in 2017 — for a period of up to three years.

Table 1. Key areas of RW management activities performed in 2016—2018

Area	Number of contracts	Contractors	Facilities in question/topic
Retrieval from storage facilities, treatment, conditioning of previously accumulated RW	26	FSUE "RADON", FSUE "RosRAO", Concern Rosenergoatom, JSC ECOMET-S, JSC PA Mayak, FSUE RFNC-VNIITF, CJSC NPO Energoatominvent	NPPs, RW storage facilities of FSUE RADON, FSUE Atomflot, FSUE RosRAO, FSUE RFNC-VNIITF, OJSC Zabaikalsky Mining and Processing Plant, Research Institute of Shipbuilding and Armament of the Naval Academy, sites with radioactive contamination in Moscow and Ulyanovsk regions
Conservation of facilities with non-retrievable RW	8	JSC SCC, FSUE Mayak, JSC RAOPROEKT, FSUE RosRAO, JSC "PDC UGR"	Construction activities at storage pools B-1, B-24 SCC, Techa Cascade of Water Reservoirs, V-9 at PA Mayak site, RW storage facilities at the Kirovo-Chepetsk site
Development of RW management infrastructure	22	SUE "NO RAO", JSC "VNIPIpromtekhnologii", JSC "FTsNIVT," SNPO "Eleron", IBRAE RAS	Design development, survey, construction and installation activities, equipment supply. Nizhnekansky massif, Novouralsk; Closed Administrative-Territorial Unit Seversk, Tomsk region; Closed Administrative-Territorial Unit Ozersk, Chelyabinsk Region; Federal State Unitary Enterprise "Radon", Sergiev Posad, Moscow region
Scientific support for efficiency and safety assurance	17	JSC "VNIPIpromtekhnologii", GEOKHI RAS, JSC "FCNRS", IBRAE RAS, Radium Institute named after V. G. Khlopin, FBI "SEC NRS", IFKhE RAS, FSUE PA"Mayak", FSUE "NO RAO", JSC "NEOLANT"	RW conditioning technologies, regulatory and legal support of activities associated with RW management, upgrading USS RW

Retrieval and processing of accumulated RW for disposal purposes

The ultimate goal of the activities planned under this project suggests that the waste is brought in compliance with relevant acceptance criteria for disposal and transferred for disposal to the National Operator for RW management. Most part of these activities was performed by Rosenergoatom Concern having most interest in removing the accumulated RW and ensures reliable funding of activities carried out at Smolensk, Balakovo, Novovoronezh, Kola, Kursk and Leningrad NPPs. Launching these efforts was believed to be of fundamental importance due to the following facts: the volume of accumulated radioactive waste was big, during

Figure 1. RW packages before and after conditioning at Balakovo NPP

storage RW passed through various processing stages, and RW classification criteria for disposal and relevant acceptance criteria have been established more recently.

In 2016–2018, relevant activities engaging a total volume of over 14,100 m^3 (gross) of waste suggesting its retrieval, treatment and conditioning to meet RW acceptance criteria for disposal was performed at five NPPs. Out of this amount, approximately 13,300 m^3 were handed over for disposal to a specialized organization, the rest of the waste was handed over to temporary storage facilities at NPP sites. Containers of the following types were used during work execution: NZK, MK, ZhZK, ZhBU and others (Fig. 1).

Most of the activities was performed by the Concern itself and two specialized organizations: FSUE Radon and FSUE RosRAO. Comparative analysis considering the effectiveness of these teams and establishment of proper conditions enabling the formation of competitive incentives was also considered under the customer's work agenda.

Under FTP-2, efforts were launched at the sites of other organizations. In 2016, conditioning of previously accumulated SRW categorized as federal property was started at FSUE Radon site. 861.4 m^3 of SRW was treated resulting in a packaged volume of conditioned radioactive waste amounting to 677.47 m^3. After certification, these were put into interim storage facility. KMZ and KRAD type containers were used during package manufacturing.

At the same time similar activities were performed in Saratov and Kazan branches of FSUE RosRAO's Volga Territorial District division.

At Saratov site, a total of 200 m^3 (net) of accumulated SRW was retrieved from SSRW "D". These included a mixture of various materials piled up in the storage facility inside wooden, plastic and paper primary packages.

To ensure future use of the SSRW "D" for temporary storage of packages with conditioned RW, SRW retrieval was followed by decontamination of its internal surfaces, bumping and protective coating was restored. The retrieved waste was segregated, partially processed and emplaced into KMZ type containers. After being certified, the packages were put into temporary storage facilities. The total volume of packages with conditioned RW amounted to 118.73 m^3 (gross) (figure 2).

Figure 2. SSRW "D" before and after work completion

Figure 3. SSRW-1 before and after work completion

Figure 4. Dismantling the floor slabs of KhTO-2 storage facility

A total of 550 m^3 (net) of SRW has been retrieved from the SSRW-1 of RosRAO's Kazan division. The waste was segregated, processed and conditioned.

The retrieved waste was brought to compliance with waste acceptance criteria and packaged into KMZ type containers. The volume of RW packages amounted to 610.4 m^3 (gross). Following waste certification, it was handed over to a temporary storage facility. After work completion, decontamination of SSRW-1's first and second sections, as well as of the immediately adjacent areas was performed (figure 3).

Retrieval of accumulated SRW was also performed in the Groznensk division of RosRAO's FSUE Southern Territorial District branch. The waste composed of metal scrap and construction waste was stored in a plie in non-standard containers inside KhTO-2 storage facility.

Preliminary stage involved construction of a frame marquee structure, storage opening with continuous radiation control (figure 4). A total of 420 m^3 of RW was retrieved with further in situ segregation. The segregated waste was conditioned, packaged into MK type containers and certified (figure 5).

Figure 5. Certification of RW packages

Figure 6. Packages with conditioned RW placed into temporary storage facility

Following certification, 131 m^3 (gross) RW packages were sealed, labeled and placed for temporary storage into container storage building for low-level waste (Figure 6).

Other operating organizations have also launched similar projects addressing the accumulated waste issue.

In 2016—2018, FSUE Atomflot completed its project suggesting retrieval, certification of some 792 m^3 of RW placed into NZK and KMZ type containers which were further handed over for disposal to a specialized organization.

For a long time, spent radioisotope thermoelectric generators (RTGs) (44 pieces) were stored at FSUE PA Mayak site. The goal of the project was to disassemble the RTGs and hand over the extracted radionuclide sources (RS) for long-term storage. By the end of 2018, the total amount of PA Mayak RTGs was disassembled. Sealed radiation sources were removed from 37 RTGs and were packaged into transport containers. For 7 sources retrieval was failed, so these were disassembled to radiation-thermal units and handed over to conditioning facilities. In addition, FSUE PA Mayak has shipped 34 RTGs from the Far Eastern Center for Radioactive Waste Management DalRAO (FSUE RosRAO branch). All the RTGs have been inspected. Relevant design and engineering documentation for new transportation units was developed. These new units were intended to replace those unfit for further use that had been used for a long time for the RTGs storage. By the end of 2018, these were shipped to FSUE PA Mayak: operations on their disassembling and further conditioning were started ahead of schedule. By present time, all potentially hazardous items of this type have been completely removed from Far East region of Russia. It should be noted that since late 2000's a total of 1,007 RTGs have been dismantled and shipped to centralized storage facilities including those previously located along the Northern Sea Route, Severomorsk, Far Eastern Center for RW management (DalRAO), the waters of the Baltic Sea and Antarctica.

In many cases, conditioning of accumulated RW requires the development of special techniques. A case in point, processing LRW composed of lubricating coolants accumulated in the storage facility of FSUE RFNC-VNIITF named after Member of the Academy of Sciences Zababkhin. By the time FTP NRS-2 was started, their total volume has amounted to 750 m^3. Their processing involved decantation of the clarified part, demulsification of the coolant concentrate, and immobilization of the concentrated sludge into magnesium phosphate matrix. This compound packaged into steel drums was placed into KRAD-1.36 containers and handed over for temporary storage. As the result of activities performed in 2016–2018, some 385 m^3 of coolant was removed and processed. This work will be continued as part of the FTP NRS-2 in 2019—2020.

RW removal has been performed also as part of remediation projects addressing the problem of radioactive contamination at different sites and facilities. In 2016—2017, remediation efforts were carried out in the Ulyanovsk region at the territory of Solovyov ravine (Ulyanovsk). These lands got contaminated in 1952 when the waste that had generated during the elimination of the consequences of a fire at the Ulyanovsk instrument plant was brought there.

The contaminated soil retrieved during these operations was processed. A small fraction of it categorized as RW following waste segregation was conditioned (figure 7) and placed into interim storage facility belonging to a specialized organization. In the future, the waste will be handed over for final disposal. The retrieved soils that had not been categorized as RW were used to level the site area. Upon work completion, radiation control, as well as water and soil sampling was performed confirming site compliance with sanitary standards.

Similar activities were performed at several small sites of a total space area of some 658 m^2 at the territory of the Moscow region. According to the formal procedure for work arrangement agreed upon with Rospotrebnadzor and local authorities, remediation of radioactively contaminated areas was performed in Domodedovo Urban District (territories adjacent to the Shcherbinka solid household and industrial waste landfill), Povarovo and Subbotino settlements, Naro-Fominsk, Podolsk Urban District. Following waste segregation, out of over 580 m^3 of radioactively contaminated soils only some 13,4 m^3 were categorized as RW and transferred to a specialized organization for storage awaiting their further hand over for final disposal. Also RW accumulated at the site of the former OJSC "Zabaikalsky Mining and Processing Plant" in the Chita region was shipped for processing and temporary storage.

Figure 7. Applying multipurpose construction equipment enabling RW retrieval, loading of primary packages with RW into containers for transportation to a specialized organization

Given below (table 2) is a list of organizations where relevant operations of RW retrieval, processing, conditioning to meet waste acceptance criteria for disposal and transfer for disposal were performed in 2016—2018 under the framework of FTP NRS-2.

Table 2. Volume of RW transferred for disposal

Organization	Volume of RW transferred for disposal (thousands of cubic meters)
Balakovo NPP	5.5
Leningrad NPP	3.2
Smolensk NPP	2.7
Kursk NPP	1.9
Atomflot	0.8
Ekomet-S	0.2
JSC AECC	0.1
Russian Ministry of Education, Ministry of Defense	0.8
TOTAL	15.3

On the whole, according to the group results, some glaring positive results can be noted: the amount of accumulated processed RW is increasing, waste processing and conditioning technologies are being developed, storage facilities are being emptied, long-term contracts are possible. At the same time, increasing amounts of newly generated radioactive waste, especially waste generated at nuclear power plants [2], are engaged in a full processing cycle with the waste being placed for storage in a form considered to be ready for further final disposal.

What is believed to be important is that all the retrieval contracts were supported by a full cycle of operations ensuring the safety — from comprehensive engineering and radiation survey and development of a work program to providing various kinds of instructions, approvals, permit certificates and quality assurance programs.

Among the negative aspects the following ones need to be mentioned. FTP indicators, being tightly bound to both the volume of waste processing and the volume of radioactive waste being handed over to the national operator. At the same time, due to large uncertainties associated with the initial data on the volumes of RW brought in compliance with waste acceptance criteria that should be passed to the national operator, contractor suffers from serious risks suggesting that the Government Contract is not fulfilled. It seems more feasible to split the competition into 2 parts: the first one would involve activities associated with waste retrieval and processing (with the volume of waste processed considered as an indicator), the second one — transfer of the radioactive waste for disposal (with the amount of radioactive waste transferred considered as an indicator based on clear data obtained following the completion of the first part of activities). This practice should be adopted in the future.

The second important circumstance that should be accounted for in the future is the low activity of radioactive waste transferred for disposal (Figure 8). This is relevant both for RW accumulated in the national economy and for certain categories of RW from NPP units.

It seems that most part of the packages should have been categorized as very low-level waste. However up to now this category is missing in the disposal tariffs. The generation background (RW accumulated in the past) and current stage of development (start of retrieval operations) to some extent explain the situation, but for the future two conclusions need to be drawn. Firstly, operating organizations should avoid such situations when dealing with newly generated waste. Secondly, VLLW should be separated into a particular class,

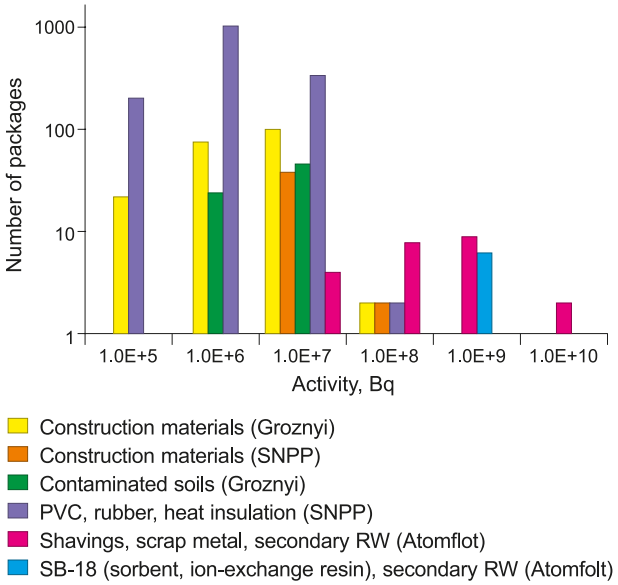

Figure 8. Activity breakdown for RW packages transferred for disposal

relevant disposal tariff should be established and plan for the construction of relevant disposal facilities intended for such waste should be developed.

Challenge associated with addressing this task seems to be both due to the lack of a clear vision of the technologies required to handle some types of RW generated by NPPs, including bituminized waste, and the lack of papers discussing even a bigger problem — handling of graphite waste from NPPs and RW from NPP decommissioning.

Conservation of facilities holding special (non-retrievable) RW

Experience accumulated to date [1] suggests that operating organizations are seen as most suitable contactors in performing activities associated with conservation of facilities holding special RW. The ability to perform significant amount of actual work, availability of a sufficient number of purpose-designed tools and infrastructure for their maintenance, as well as the cost of work, are the most important criteria in selecting the one to perform these activities and successful completion of relevant tasks on time. Contacting organizations are usually engaged in specific activities or small projects such as performing comprehensive engineering and radiation survey or testing particular technologies.

Most large-scale efforts were implemented at LRW storage pols B-1 and B-25 at JSC SCC. These pools are open surface LRW storage facilities with a clay screen lining their bottom and slopes. The pools have a capacity of 150,000 and 130,000 m^3 respectively. The first stage of the B-1 conservation project was completed under FTP NRS-1 suggesting the backfilling of its surface water area to reduce its radiation impact on personnel. As part of these activities environmentally safe configuration was achieved for the sludge accumulated at its bottom. In 2016, the second stage of the project was launched under FTP NRS-2 – final conservation of the pool and installation of an upper isolating screen.

Figure 9 presents the main stages of B-1 conservation project. In 2016, dike embankment dismantlement operations were started with the soils being transferred to the territory of the pool. Dismantlement operations are performed to enable access to the upper part of the existing clay screen. Breakage of the upper layer is required to enable further reliable "in-lock" connection of the new clay screen with the top layer of the existing one (Figure 10).

Pool conservation technology suggests complete backfilling of the its water surface, backfilling and surface leveling of the protective soil layer was followed by installation of filtration (drainage) pebble layer.

In 2018, installation of a clay screen preventing the seepage of atmosphere precipitation was performed (figure 11). In 2019—2020, work will be continued. A protective 1-meter thick layer with will be installed above the clay screen in order to protect it from external impacts. Also, a radiation monitoring system at the site is going to be equipped and a drainage system will be fitted around the pool to drain the seepage water. Furthermore, in 2016, B-25 conservation project was started. A similar technology has been applied. Preliminary stage was completed in 2017. In the next 3 years the pools will be backfilled with a clay screen installed above. In 2020, all activities associated with B-1 and B-25 pools conservation are to be completed, thus, resulting in a decrease of potential risks associated with SCC site.

Simultaneously, pre-conservation of SRW surface storage facilities with exhausted design storage capacity located at the site number 16 of the Chemical and Metallurgical Plant was performed.

Activities suggesting relatively small amount of funding but nevertheless being considered of a big importance were performed at FSUE PA Mayak facilities. These involved monitoring and corrective measures implemented at two unique facilities, namely, former LRW storage facility V-9 (illustrious in terms of the accumulated RW activity) and the Techa Cascade of water reservoirs, being considered as top one in terms of LRW amounts stored therein.

On the whole, it should be noted that monitoring was performed at all sites being at conservation

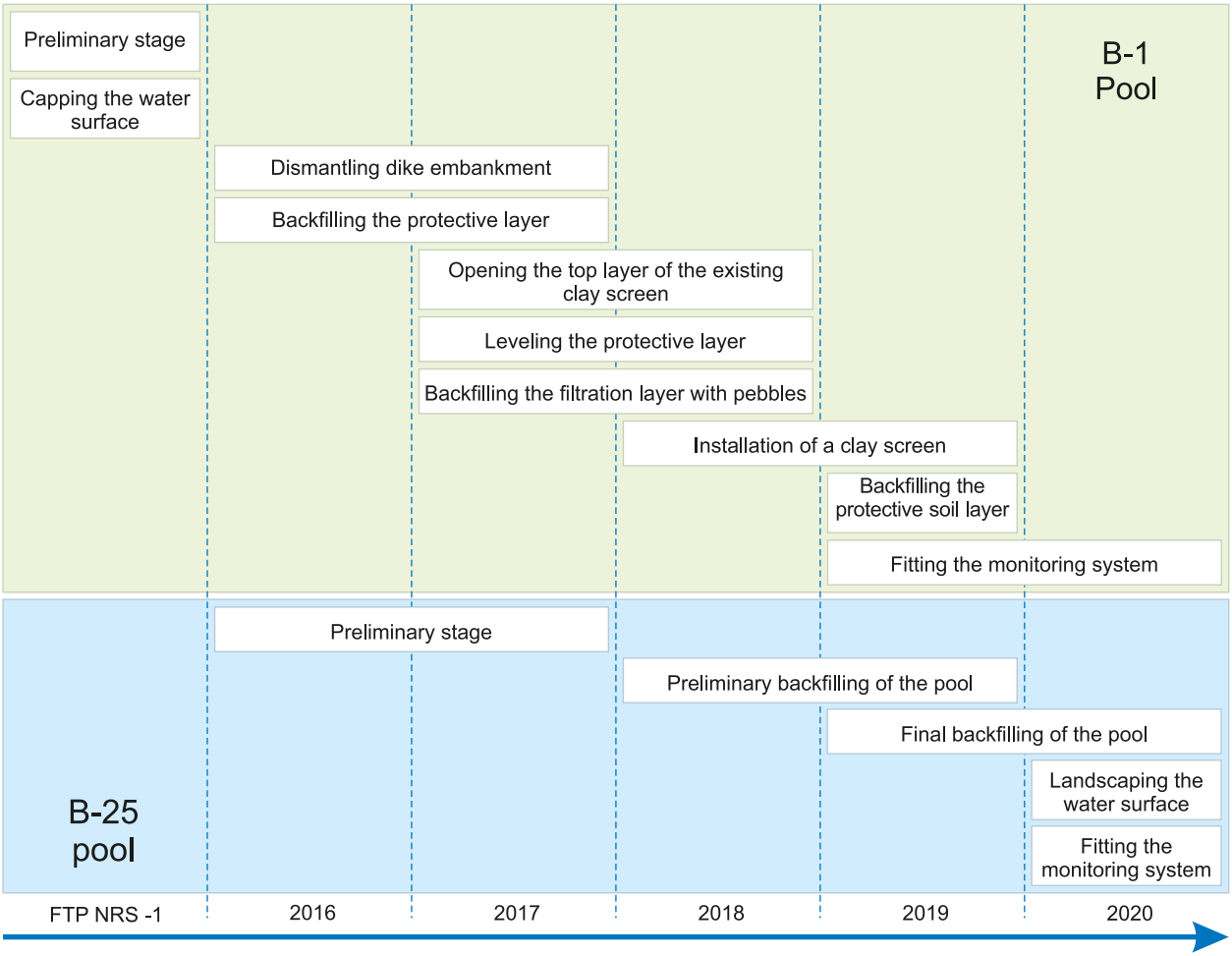

Figure 9. The main stages of B-1 and B-25 conservation project

Figure 10. Dismantling dike embankment and leveling the protective layer

Figure 11. Installation and compaction of the clay layer

stage. [3—6] discuss monitoring systems being in place, including those at MCC facilities, former V-9 facility at FSUE PA Mayak, PUGR EI-2 and some other. Operation of the monitoring systems should demonstrate the safety of the operations performed and should provide a basis for further optimization of engineering solutions proposed for future conservation projects to be implemented at facilities holding accumulated RW.

This group of activities also involves those associated with achieving the safe configuration of the facilities located at the site of Kirovo-Chepetsk division of FSUE RosRAO's Privolzhskiy territorial district branch. As the result of the past activities conducted at this site, buildings and structures, as well as the soils below, the sites where RW handling operations were taking place and the adjacent territories got contaminated with radioactive components. Considerable efforts have been implemented at the site under the FTP NRS-1. However, their completion is still to come. Two projects have been launched under FTP NRS-2. The first one provided for the development of engineering documentation on the implementation of a set of activities enabling to restore protective functions of the engineered barriers fitted inside the RW underground storage reservoirs — № 25/1-5, № 97. These efforts include construction of an impermeable curtain all along the perimeter of the site preventing the release of radionuclides into the environment combined with a multifunctional protective screen preventing the impact of external factors of natural occurrence on the RW mass.

Under the second project, comprehensive survey of RW storage facility — structure number 93 was performed. This structure has been in operation since 1991 with its emergency status being achieved to date. Based on the survey, a work plan on decontamination, dismantling and disposition of technological equipment was developed and approved.

Summarizing in brief the results achieved for this group of tasks, one can note that outspoken progress goes hand in hand with a number of issues that should be addressed in the short run. One of the challenges is associated with licensing such facilities, including the alteration of facility's category. Such issues have been also encountered in the past, for instance during the activities performed by PDC UGR on PUGR EI-2 decommissioning. Other challenging points are the timeframes for the preparation of required decommissioning documents, contracting someone to perform conservation, changing over the status of RW storage facility to a disposal facility, waste handing over to the National Operator.

Development of RW disposal infrastructure

The law stipulates that FSUE NO RAO implements the function of a customer for design development and construction of RW disposal facilities. It is also held responsible for their operation and closure. There are two sources enabling the funding of activities associated with DF RW development – cost is covered by special reserve fund established in accordance with law provisions and funds of the federal budget. Moreover, FSUE NO RAO operates LRW deep well injection facilities. It seems more reasonable to provide the overview of activities implemented under FTP NRS-2 with respect to the overall status of the disposal system and its key tasks (table 3).

Deep disposal facility for RW Class 1 and 2

In 2016—2018, construction activities were successfully implemented in a number of areas.

In compliance with all its responsibilities and powers, FSUE NO RAO completed all the activities required to obtain the construction license for Underground research laboratory in the Nizhnekansk rock mass (Zheleznogorsk, Krasnoyarsk Region) under the project on the establishment of a deep disposal facility for radioactive waste (DDF RW) Class 1 and 2. JSC Eleron, the organization being responsible for design and construction support of the project, was appointed as such. Construction of power lines for energy supply of the future activities was started.

Design development organization USS RW has arranged activities performed jointly with Nuclear Safety Institute and FSUE NO RAO on the development of a strategic master plan on long-term safety assessment and demonstration for DDF RW intended for disposal of RW class 1 and 2 in the Nizhnekansk rock mass. This Master plan was comprehensively discussed and approved [7]. Such a formal paper was required due to the multidisciplinary and unique nature of the project and the need for its testing at the international level. The Strategy was developed and approved based on the perception of the contents of research activities to be performed, relevant time frames for their implementation and the list of tasks to be addressed [8]. Moreover, foundations for the development of information-analytical support system [9] were laid providing for the establishment of a Digital URL. This served a basis for the development of detailed action plan for the next 3 years. Preliminary efforts on gaining the initial data on the characteristics of RW Class 1 accumulated in the storage facility for vitrified HLW

Table 3. State of art of disposal system development under USS RW

DDF RW type	Facilities	Facility's stutus	Key tasks
DDF RW for RW Class 1 and 2	Nizhnekansk Rock Mass	Start of URL construction	Commissioning of URL in 2025
DF RW for RW Class 3 and 4	DF RW JSC UECC, Novouralsk	1st unit is under operation, construction of the 2nd unit was started	Commissioning in 2020
	DF RW Ozersk, Chelyabinsk Region	Engineering and design	Commissioning in 2021
	DF RW Seversk, Tomsk Region	Engineering and design	Commissioning in 2021
	DF RW Sergiev Posad, Moscow Region	Design development	Commissioning in 2023
	2 DFRWs in Northwestern Federal District and Volga Federal District / Southern Federal District	Decision making on design development, siting and construction	Siting decision
LRW DF, Class 5	Zheleznogorskiy	Operating	Implementation of a program on complying with remarks and development of closure concepts
	Severskiy	Operating	
	Dimitrovgradskiy	Operating	
DF RW Class 6	Tailings of mining and enrichment enterprises	Decision making on the legal status	Elaboration and approval of the legal status
DF for VLLW	Handing over for disposal in centralized near-surface disposal facilities for RW Class 3 and 4	Decision making on the legal status	Decision making on facility development is required both under FSUE NO RAO and operating organizations

(plant 235, FSUE PA Mayak) were launched. Data stored in enterprise archives should be expanded both as it comes to data on the radionuclide composition and the actual physical and chemical characteristics of the accumulated aluminum-phosphate glass. To date, basic procedure for RW Class 1 characterization has been developed, as well as relevant approaches enabling to monitor physical and chemical characteristics of accumulated RW. It should be noted that activities addressing these issues have been rather comprehensively discussed in this Journal.

Disposal of RW Class 3 and 4

In 2016, first near-surface disposal facility for RW Class 3 and 4 developed under the USS RW started its operation in Novouralsk. Some specific aspects of its operation have been discussed in detail in [11]. In 2018, a total of 3,722.73 m^3 of RW were accepted by the facility for disposal, including 1,897.34 m^3 of RW from Kursk NPP and FSUE Atomflot.

In 2018, permit on the implementation of a project titled "Upgrading near-surface disposal facility for solid radioactive waste in Novouralsk" was given under the program on the development of RW Class 3 and 4 disposal capacities. Contract on relevant construction and installation activities was signed. In 2018, these activities were performed to the full extent in accordance with the established schedule. Construction of the repository's second unit was started as well.

Design and engineering activities are now being performed at similar sites in the Siberian and Ural Federal Districts (Restricted Access Territorial Entity Seversk, Tomsk Region and Restricted Access Territorial Entity Ozersk, Chelyabinsk Region). The main source of funding accounts for the funds of a special reserve fund on RW disposal. To date, public hearings have been held to discuss possible siting options. Positive statement of the State Environmental Expertise was obtained following the review of the materials supporting the license application for siting and construction of DF RW in RATE Ozersk, Chelyabinsk Region.

Notwithstanding general progress, some specific methodological difficulties arise during design development. These are driven by the need for demonstrating the long-term safety of the repository accounting for the entire list of radionuclides and bearing in mind that the entire capacity of the repository is filled up to the activity level corresponding to the maximum possible for RW class 3.

Disposal of LRW Class 5

Two specific points should be noted when talking about the operation of LRW disposal facilities. Firstly, safe operation is ensured. NO RAO experts have evaluated personnel exposure at the sites, including the one during maintenance activities performed in the injection wells [12]. In 2018, public hearings were held to discuss the materials supporting license application on the operational extension

for three liquid RW class 5 deep disposal facilities. Applications on State Environmental Review of the materials under operating time extension of the facilities were submitted. Secondly, special program approved by SC Rosatom and Rostechnadzor in 2015 has been implemented [13] to address the remarks posed in the course of IAEA mission. Its primary goal provides for in-detail development of the closure designs with the long-term safety of the facilities being demonstrated. This task is being addressed under R&Ds both performed by operating organization and under PA USS RW contracts. Major part of efforts planned to be implemented under FTP NRS-2 should be completed by SEC NRS in 2019. Moreover, some safety demonstration activities are scheduled for DDF LRW Severskiy. To address this issue, experts from the Physical Chemistry Institute of RAS have conducted a study on the evaluation of microbiological and colloid factors impact on the transfer of waste components. Study of reservoir fluid samples taken from the observation wells located both within the boundaries of waste component plume and beyond it, enabled to assess the contribution of these processes affecting the chemical composition of ground waters and water driven transfer of waste components. In [14] summarized are the studies of microbiological impacts on LRW disposal facilities. However, due to the complexity and lack of complete knowledge on the impacts of microbiological processes on the long-term safety of LRW disposal facilities, these studies should be definitely continued. It should be noted that the issues associated with the degree to which this factor has been studied to date have continuously manifested themselves during the review of national reports of the Russian Federation held at the meetings of Contracting Parties to the Joint convention on the Safety of Spent Nuclear Fuel Management and the Safety of Radioactive Waste Management under IAEA auspices.

Moreover, under the abovementioned activities, JSC VNIPIpromtekhnologii experts have developed a research program enabling to get a more precise vision of the parameters relevant for geological and migration modeling of DDF LRW and the associated requirements, as well as conceptual and mathematical models for reference and alternative DDF LRW Severskiy evolution scenarios.

The activities performed enabled significant extension of the evidence base on the long-term safety of LRW disposal and gaining some insights on the way further R&Ds in this area are to be arranged for.

Disposal of RW Class 6 and VLLW

It is worth reminding that based on the existing classification [15], RW Class 6 covers RW generated from mining and milling of uranium ores, as well as from activities not being associated with atomic energy use on mining and processing of mineral and organic raw materials with an elevated content of naturally occurring radionuclides. Most part of such RW is generated by PPGKhO and is disposed of in the existing tailings that according to their characteristics can be categorized as facilities holding special (non-retrievable) RW. The specific activity of the waste handed over to the tailing site is low enough to categorize it as VLLW. For this reason, the issues associated with its disposal are quite similar and allow for common examination. On the whole, a number of issues requiring further decision making on the legal status of such facilities exists.

Currently, specific provisions concerning very low-level waste provided for by law haven't been implemented to the full extent suggested. International experience [16], however, vividly testifies in favor of this waste category separate disposal. This challenge can be addressed in a several ways: by establishing a separate tariff, by arranging a more transparent procedure for the financial support of VLLW disposal activities at the sites of operating organizations and operation of relevant disposal facilities. Decision making on addressing these challenges, as well those associated with the legal status of Class 6 RW repositories is currently underway.

Specific consideration should be given to the challenge associated with industrial waste with an elevated radionuclide content. Some papers suggest to include such waste into RW management system [17]. At present time, this suggestion implying its compulsory execution cannot be considered feasible. Soon the system for managing production and consumption waste is going to survive some radical changes. Therefore, today it seems advisable that operating organizations deal with this challenge on their own addressing it under industrial waste management requirements. When VLLW disposal system becomes efficient enough with relevant disposal tariffs being lower, then those for industrial waste disposal, strict requirements on the presence of radionuclides can be withdrawn and the waste can be categorized based on its origin, the way it is done in France [18].

R&Ds to ensure effective and safe RW management

Besides already mentioned R&Ds on the safety demonstration and assurance at specific nuclear facilities (DDF RW and LRW DF), RW management authority has also implemented a set of R&Ds under four relevant study areas: conditioning

technologies, regulatory, scientific and software support of activities.

RW conditioning technology

RW conditioning technology is commonly believed to be of a key importance in RW management system. Under USS RW development, this topic was considered even of more importance, as conditioning should be ensured for all types of RW and all the range of corresponding specific activities. For this reason, FTP NRS-2 involves a program titled as follows: Development of Technologies for Radioactive Waste Treatment and Conditioning. A set of efforts has been implemented under this scope of activities aiming to develop new innovative and efficient waste conditioning technologies. Obviously, of particular importance in terms of arranging relevant R&Ds and drawing the requirements on their outcomes, was to finalize the promising undertakings up to the practical implementation of relevant insights. A number of such undertakings can be listed.

Firstly, for over 10 years, GEOKhI and IPCE RAS were engaged in the study of low-temperature phosphate matrixes for liquid ILW immobilization. By present time, the technology developed was tested at FSUE PA Mayak [19]. The tests have demonstrated its efficiency: physical and chemical properties of the compounds obtained comply with NP-019-15 regulatory requirements and enable to form an RW stream of Class 2.

Secondly, commissioning of the planned facilities enabling full SNF reprocessing cycle at PDC MCC will take place soon. In recent years, under particular FTP NRS-2 contracts and certain efforts on design support, JSC Radium Institute named after V.G. Khlopin was engaged in a number of researches on finetuning and optimizing operation modes of an induction melter with a "cold" crucible (IPCP) to ensure the application of this basic SNF reprocessing technology at PDC MCC. This complex of experimental research in this field should result in equipment designs capable of producing borosilicate glass with its characteristics being similar or even overrunning foreign analogues. It should also provide methodological support for the technological process, including the assessment of radiation resistance and etc.

Within the same technological flow chart, consideration is given to the use of non-returnable crucible containers based on reactive sintered silicon carbide (SiC). To date, experiments studying the characteristics of carbide crucible containers have revealed a number of important issues concerning the perspectives for using such crucible-based items as safety barriers in RW repositories. Firstly, these issues are associated with technological and engineering support of crucible-container lid remote welding operations, the impact of the high welding temperature on the glass parameters, the difference between the properties of the weld seam and those of the crucible-container material, high residual stresses in the crucible-container body excluding the possibility of handling them without special damping devices. Yet another disadvantage is the high cost of manufactured items and the need for rather extensive retrofitting of nuclear facilities to adapt them according to waste management purposes with HLW placed into silicon carbide crucibles.

It's worth noting that to date no evidence suggests that the tightness of silicon carbide products can be guaranteed for a timeframe of 1,000 years. However, this issue is also relevant for other materials considered as potential RW packaging options.

Regulatory support of RW management activities

Regulatory and legal support of activities in the field of RW management is considered as a key tool enabling to increase the efficiency of USS RW. For this reason, this tool is being upgraded with due account of knowledge gained on law enforcement while implementing practical activities under FTP NRS and FTP NRS-2.

In 2016, a study on the evaluation of the national legal framework and IAEA documents was carried out. Proposals on upgrading legal requirements aiming to achieve safe configuration of nuclear and radiation hazardous facilities with their further dismantlement, development of the infrastructure required for RW processing, storage and disposal were developed.

An important activity in this field was implemented in 2017. It provided for the development of a managerial and financial model covering all specific aspects of USS RW operation. The goal was to perform a comprehensive evaluation of the existing practice in RW management and to develop some proposals on the optimization of managerial and financial model in the field of RW management, including relevant corrections introduced to the existing legal framework. The main insights on this topic and the key intermediate results of project implementation were discussed in [20]. It should be noted that some differences in the way the essence of the organizational and financial model is understood depending on professional interests have manifested themselves. Thus, among work group members from FSUE NO RAO representing the financial unit of the organization, a common view was shared suggesting that the framework of this model should be exclusively restricted to

the processes associated with financial support of disposal activities and related tax and accounting issues. As a result, the challenges associated with activities on the establishment of DR RW (licensing, construction, regulatory requirements, etc.) were virtually omitted. Work in this area is still undergoing.

In 2018, text of the draft law amending provisions of the Federal law No. 190-FZ was reviewed by organizations. In 2019—2020, the draft law is planned to be submitted for interdepartmental coordination.

Currently work is also underway to develop some guideline documents prompting the implementation of the best practices in the field of RW management in Russia. It involves the development of a safety guide offering some recommendations on the use of radionuclide vector method for RW characterization purposes at nuclear fuel cycle facilities. Its application will enable significant decrease in the cost of RW certification, as well as obtaining data on the extended list of radionuclides contained in the waste including those relevant for the long-term safety of the disposal facility.

Simultaneously, a safety guide is being developed on checking the compliance with waste acceptance criteria for disposal. Establishment of a unified approach to this matter, including statistical criteria for conditioned RW inspection, risk associated with nonacceptance of RW for disposal based on the inspection of their characteristics can be avoided.

Development of scientific tools to evaluate and assess the safety of facilities beyond the established operational life

In terms of nuclear facility development, importance of computer codes (software tools) and experimental base for their verification is well known and is univocally stated in Rostechnadzor regulations, including those on certification (review) procedures. Similar activities were arranged for target facilities under FTP NRS. These also accounted for the requirements on import independence. A big amount of studies on this issue have been carried out by the Nuclear Safety Institute of RAS. The methodology for comprehensive safety demonstration of nuclear legacy facilities and DF RW developed by the Institute should integrate various purpose designed prognostic computing systems into a unified system. Some of the computer codes being under development or already applied have been presented in [21, 22]. It's worth noting that the development process goes hand in hand with testing of the developed software complexes. These are applied for solving real-world tasks associated with safety demonstration under FTP NRS-2, including the safety of DDF RW and LRW DF. This topic deserves particular consideration. In general, it can be stated that over the past three years, following relevant certification, a number of software packages has been added to the set of tools available for the safety assessment and safety cased development: GeRa (geomigration code developed by Nuclear Safety Institute of RAS), NIMFA (geomigration code developed by VNII-EF), GEOPOLIS (continuously applied for LRW repository in Zheleznogorsk).

Knowledge base supporting the decision making on RW management, including SGUK RV and RAO deserves particular attention. Capabilities of modern information technologies and computer codes demonstrated while performing relevant activities on DDF RW development, including those enabling the development of full-scale digital models of facilities and technologies (Nuclear Safety Institute and NEOLANT), clearly show that preliminary digital visualization of a facility at the design stage allows to avoid significant losses associated with subsequent correction of errors committed later during its construction.

Certainly, not all the tasks have been solved to date. In particular, practical efforts should be taken to ensure practical implementation of the proposals developed on the criteria for RW classification and the criteria enabling RW categorization either as special (non-retrievable) or retrievable. Significant potential is seen in the transformation of SGUK RV and RAO information support to a level ensuring prompt decision-making based on the information that can be comprehensibly collected and processed in a right way suggesting the use of a modern interface. Development of modern methods for digital modeling will ultimately minimize the risks of disrupting the development of infrastructure facilities or overspending the federal budget. The first practical results have already been demonstrated in the application of digital models in the development of a DDFRW in the Nizhnekansk rock mass. Ideally, RW management activities (including waste generation during production activities and nuclear decommissioning) should be fully digitized from the point of their generation till its final disposal in DF RW.

Facility monitoring

In 2008—2015, structure of industrial-wide system for facility-level monitoring of subsoil (OMSN) was developed and introduced at 55 enterprises of SC Rosatom. Such industry-wide system is required at all stages of nuclear and radiation hazardous facility lifecycle. It should continuously and regularly provide the experts engaged in the development

and verification of constantly operating geomigration models with reliable data on all environmentally significant enterprises (facilities) of the State Corporation Rosatom. Since 2016, the analytical information system OMSN was introduced at another 20 enterprises (sites), thus, enabling adequate interpretation of subsoil monitoring data to assess the current state of the sites considering the impact produced on surface and groundwater.

Papers [3—6] discuss the implemented activities and monitoring methods applied at RW repository sites demonstrating the reliability of existing safety barriers barring the way for possible radionuclide release.

Conclusion

1. The discussion provided above allows to assess the progress achieved in three areas covered by provisions of the Policy Fundamentals:

Issues associated with RW conditioning and disposal has been successfully addressed according to the rate provided for by target indicators set forth by FTP NRS-2 both under the projects for RW retrieval and attaining safe configuration of facilities holding non-retrievable RW and DF RW construction. At the same time, the quality of these activities is assessed as satisfactory with some important potential for further increase in their efficiency.

Efforts aimed at integrating the knowledge to enable the development of scientifically sound methods ensuring long-term safety of deep and near-surface disposal facilities for RW are being successfully implemented with some important elements of the methodologies and some computational tools being already applied in practice.

The task of upgrading the mechanisms ensuring the operation of SGUK RV and RAO central, institutional and regional information and analytical centers and proper exchange of information between them, is being actively addressed. At present time, an option suggesting deep transformation of SGUK RV and RAO information support with due account of Rosatom's Unified Digital Strategy is being considered.

2. The paper provides preliminary algorithm for the overview of studies performed under FTP NRS-2. In this attempt, Radioactive Waste Journal is viewed as a target that can be considered as the first peer-reviewed scientific and technical journal with its reading community most exclusively featuring specialists engaged in the field of radioactive waste management. The final form of this algorithm will provide for mandatory presentation of most important results of the work accomplished by relevant contractors on the pages of the Journal. The following formula for material presentation should be used: "what has been done — what are the results — what are the issues — the way it can be improved". Apparently, this option also provides for some summarizing articles by management authorities. The second function of the Journal, namely discussion of the development prospects by professional community, is proposed to be tested on the topic titled as follows: "Improvement of SGUK RV and RAO structure and its processes".

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