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PROSPECTS OF DEALING WITH RW ACCUMULATED IN THE ORGANIZATIONS OF THE FUEL COMPANY JSC "TVEL"

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Decisions on designation of certain accumulated radioactive waste (RW) as non-retrievable, made during the Initial registration campaign, were based on comparative estimates of collective effective doses, risks and expenses for the two considered waste management options. The status of facilities holding non-retrievable RW allowed to start upgrading of some facilities in order to achieve their safe configuration as non-retrievable RW disposal facilities. These efforts are being performed in strict compliance with the requirements of relevant federal norms and regulations, and sanitary rules. No comparison of disposal options is required to designate RW as retrievable waste. The case study of the Fuel Company "TVEL" presented in the article demonstrates that feasibility study performed to categorize RW as non-retrievable enables to proceed with relevant efforts on isolating the waste from the environment. At the same time, retrieval operations involving retrievable RW are often performed in violation of the fundamental radiation protection principle — the justification principle. Comprehensive feasibility study enabling to choose the most safe and financially viable way of achieving the final isolation of waste can result in review of decisions regarding the designation of waste as retrievable RW.

Keywords: *non-retrievable radioactive waste, legacy, safety case, Angarsk electrolysis chemical combine.*

Large-scale RW management facilities, such as tailings, slurry and sludge storage facilities, pools, as well as near-surface storage facilities for solid radioactive waste saw heavy use across the JSC "TVEL" operating organizations. These waste management solutions correspond to waste management approaches used worldwide for particular RW types, have no viable process alternatives and, what is most important, provide for radiation protection of public and the environment to the full extent.

In the past, basic safety important factors were taken into account in the design of the abovementioned facilities. However, current legal framework in the field of RW management introduced a requirement concerning the revision of decisions on RW disposal by designating the whole accumulated RW inventory as either non-retrievable or retrievable waste under the Initial registration of accumulated RW. This work was performed in 2014—2015.

Initial inventory results were used as input data during the development of action plans under the Unified State System for RW Management regarding management of accumulated RW, as well as setting goals and implementing relevant efforts under the in-force federal targeted program "Assurance of Nuclear and Radiation safety for 2016—2020 and for the period up to 2025 "(FTP NRS-2).

The rates and cost of the final isolation of accumulated waste directly depend on the volume ratio of non-retrievable and retrievable waste. RW management practice and relevant feasibility studies on RW designation as non-retrievable waste have clearly demonstrated that in situ disposal provides a higher level of safety at significantly lower (tenfold or more) costs.

In spite of the tight schedule and a large number of innovations introduced into the criteria of RW designation as non-retrievable waste, the issues of methodological support of justification of compliance with the criteria [1] were successfully resolved already at the stage of the Initial registration. A case in point, a method enabling to evaluate the environmental damage in case of in situ RW disposal was developed and tested for the first time. The assessment of hypothetical damage to biota in the impact area of the facilities showed

that the damage was either equal to zero or was so low that it could not influence the choice of the disposal option. It should be noted that the effective recommendations of Roshydromet concerning the assessment of radiation impact on biota are based on this method.

The Initial registration commission involved representatives from all stakeholders (operators, State Corporation "Rosatom", regulatory bodies, regional and local authorities). Relevant decisions concerning the designation of RW as non-retrievable waste were made based on exposure dose, risks and costs evaluations prepared by the organizations for the two considered waste management options (retrieval with subsequent disposal and in situ disposal), justification of waste compliance to RW criteria depending on their origin (defense or accidents) and facility location (outside settlements, etc.), approved by the Decree of the Government of Russia on 19 October 2012 No. 1069. In other cases (deferred decisions and RW categorization as retrievable waste), no comparison of disposal options was required. The latter had a somewhat negative impact, as discussed below.

Non-retrievable RW

14 facilities of the Fuel Company have been formally designated as facilities for storage and disposal of non-retrievable RW, in particular: water reservoirs B-1, B-2, B-25 of JSC Siberian Chemical Combine (JSC SCC); sludge storage facilities PKh-1, PKh-2 of JSC SCC; water storage facilities VKh-3, VKh-4 of JSC SCC; SRW storage facilities at JSC SCC; tailings of PJSC Novosibirsk Chemical Concentrates Plant; tailings No. 1, 2 of JSC Chepetsky Mechanical Plant (JSC CMP), etc.

One of the most important results of the feasibility studies performed for non-retrievable RW is that the legal status of facilities holding non-retrievable waste was formally recognized, thus eliminating the risks associated with disruption of operations on facilities conversion to disposal facilities. Initial registration results influenced the inclusion of relevant activities into FTP NRS-2. It should be noted that conservation of facilities is carried out in strict compliance with the requirements of the design documents, which, in turn, are developed in accordance with the requirements of federal norms and standards, sanitary rules.

The highest potential radiation hazard among all non-retrievable RW storage facilities is posed by the reservoirs B-1, B-2, B-25 of JSC SCC — surface storage water reservoirs for liquid intermediate-level waste.

Efforts aimed at achieving long-term safe configuration of these facilities are required to ensure the isolation of RW from the environment, and, first of all, to prevent aerosol blowout of radioactive materials caused by natural events (hurricanes, tornadoes)

Already at the start of the Initial inventory (in 2012), the task of ensuring long-term safe configuration of B-2 reservoir was completed under FTP NRS resulting in the complete covering of its water surface. B-2 reservoir was a purpose designed hydro technical structure — a banked-up pit with an impervious screen on the bottom and sidewalls made of layered compacted clay up to 1 m thick (Fig. 1). The facility covered a total area of 51,400 m^2. Waste discharges to the reservoir were stopped by the end of 1982.

Efforts on achieving the safe configuration of B-2 were performed in three stages: in 1991—1992, following a number of investigations, the first trial operations were carried out to cover the narrow northern part of the reservoir by heaping of local soil on ice; in February 2001, the whole water surface area was covered; between 2007 and 2012, general construction activities were completed.

As the result of the performed activities the gamma-background at the centre of the reservoir dropped from 300,000 to 40 μR/h. The overall cost of the implemented efforts reached 643.7 mln roubles, including 513.3 mln roubles allocated from federal funds.

The completed project on achieving the safe configuration for a surface LRW storage facility is unique in world practice. The lessons learned are currently taken into account in the implementation of similar projects on conservation of reservoirs B-1 and B-25 (the work was started under FTP NRS). Relevant engineering methods can be used in the future at other LRW storage facilities of JSC SCC and other facilities of the State Corporation "Rosatom".

Grading and leveling operations at the covered B-1 water surface at JSC SCC were successfully completed in 2017 at the cost of less than 77 mln roubles. In March 2017, JSC SCC concluded a three-year State Contract at the cost of about 250 mln roubles on achieving environmentally safe configuration of JSC SCC B-1 reservoir by the end of 2019. Under the terms of the contract, JSC SCC will continue to implement the activities scheduled under the 2nd stage of the project on completing the top layer of the capping system. These activities are performed on schedule.

The preliminary stage (infrastructure development) of the project on achieving environmentally safe configuration of B-25 reservoir at JSC SCC were completed ahead of schedule at the total cost of 352 mln roubles. The State Corporation "Rosatom" plans to announce a tender for the implementation of practical efforts at B-25 reservoir by the end of 2017. The project is to be completed in 2020.

As a part of preliminary efforts on achieving safe storage configuration of facilities holding non-retrievable waste, JSC SCC has launched a characterization project for the solid RW storage facility (building 263) at the site of the radiochemical plant. This work shall be completed by the end of 2017.

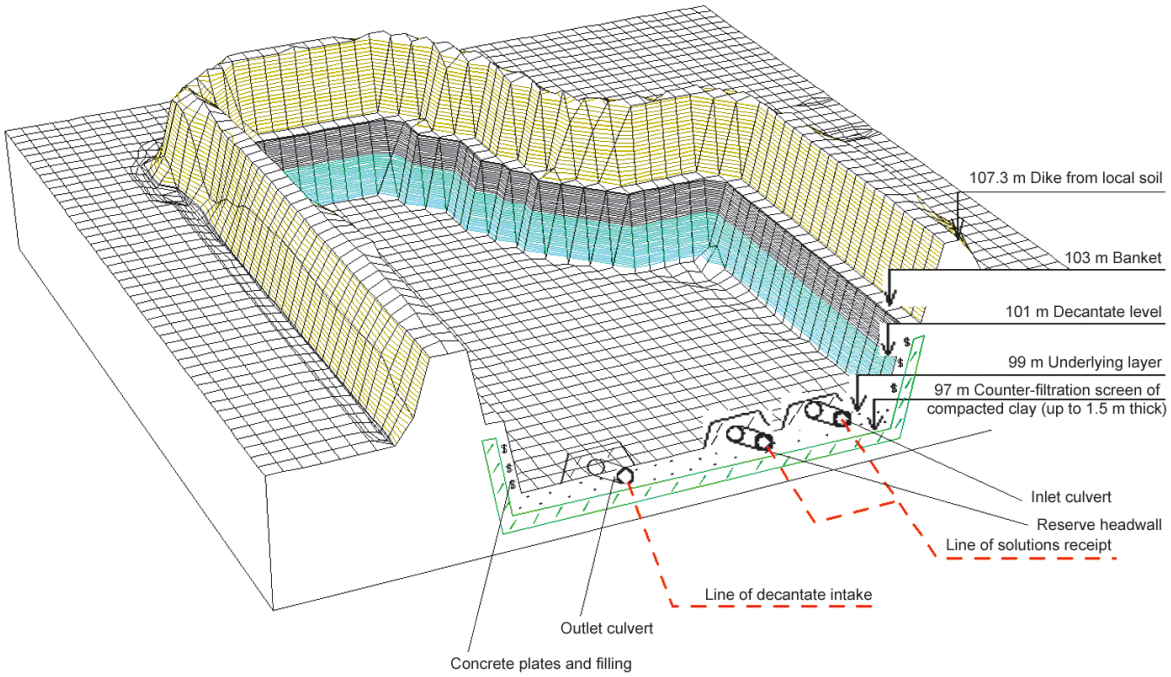

Fig. 1. Layout of B-2 reservoir

Then, the design documentation will be developed within the preliminary stage of the project on reconstruction of the facility as the disposal facility for non-retrievable RW. Federal budget will cover over 398 million roubles that will be allocated between 2021—2025 under FTP NRS-2 to perform this project.

Efforts enabling to achieve safe storage configuration of facilities holding non-retrievable RW are carried out by the Fuel Company not only within the framework of FTP NRS-2, but also using the funds from a special reserve fund No. 3 of the State Corporation "Rosatom". Thus, about 130 million roubles were allocated by the State Corporation "Rosatom" from the reserve fund for implementation of activities under the project of conservation of surface storage facilities at the site 16 of SCC chemical and metallurgic plant.

The State Corporation "Rosatom" plans to allocate additional funds amounting to 533 mln roubles at the end of 2017 covering the remaining scope of work. The work is to be completed in 2019.

Relevant efforts are being performed at the tailings of the JSC CMP site and their costs are covered through the reserve funds.

In 2017, the State Corporation "Rosatom" approved funding of 8 mln roubles allocated from the reserve fund No. 3 to perform a characterization survey as a preliminary effort under the project of achieving safe configuration of sludge storage facilities PKh-1 and PKh-2. The design project for these two facilities will be based on the results of this survey.

Thus, it can be stated that the feasibility studies performed to designate RW as non-retrievable waste even for those facilities, where relevant efforts were already underway, has allowed eliminating the risk associated with disruption of operations due to their ambiguous legal status after the enactment of the Federal law "On the Management of RW…." The decisions made on RW in situ disposal have allowed to keep the pace of activities funded both under FTP NRS-2 and from the non-budgetary funds of the State Corporation "Rosatom". The outcomes of these projects were reported during the presentation of the Fourth National Report by the Russian Federation under the Joint Convention and were welcomed by the international community [3]. It should be also noted that even though the cost of completed projects was undoubtedly very high, the choice of RW retrieval and subsequent disposal option would have resulted in at least ten-fold higher costs.

Postponed decisions

It should be emphasized that various scenarios were considered even for those JSC "TVEL" facilities that could not have been designated as facilities holding non-retrievable RW due to their location. For instance, postponed were the decisions regarding some facilities of three Fuel Company organizations (JSC Ural Electric and Chemical Combine (JSC UECC), JSC Production Association Electrochemical plant (JSC PA ECP), PJSC Machine-building plant (PJSC MBP)). The RW storage facilities were located in the areas categorized as "settlement lands". It should be noted that these areas were assigned to this type of land-use much later

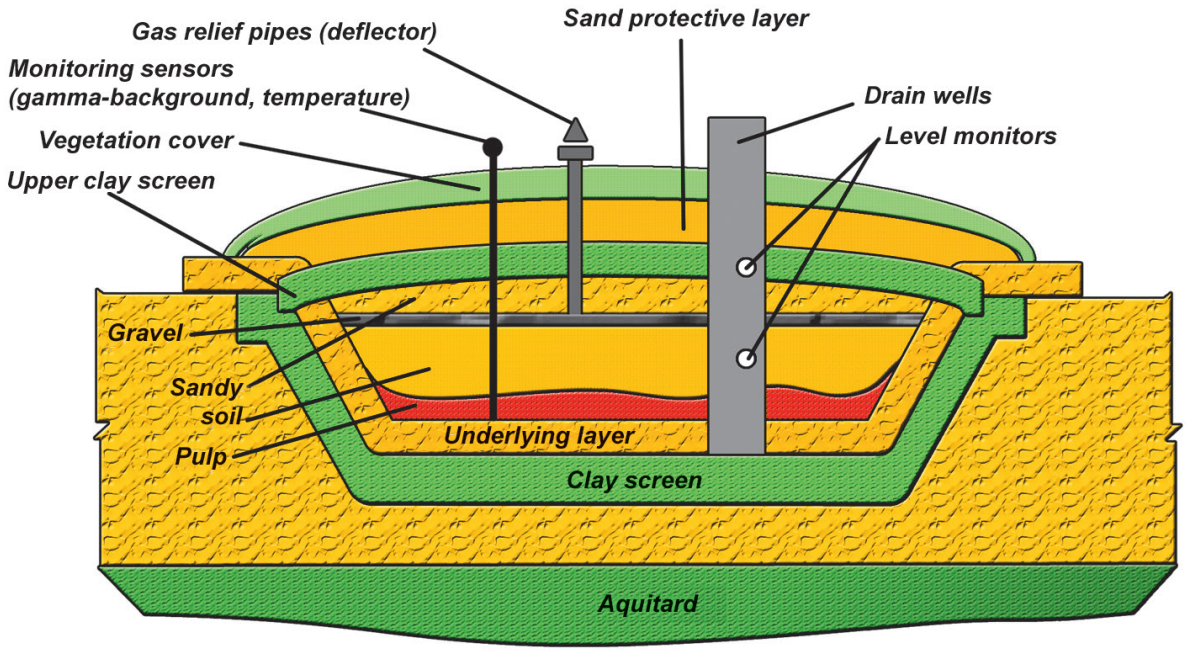

Fig. 2. Layout of B-2 reservoir after its capping

than these facilities had been established, and relevant production facilities of JSC UECC and JSC PA ECP are located within the closed administrative areas established to support their operation.

Postponed decisions regarding such facilities were taken by the Commission based on relevant dose, risk and cost estimates carried out by the organizations themselves for the two considered RW management options. The supporting papers demonstrated that all the considered values would be much lower for in-situ disposal option than for the retrieval option. The dose, risk and cost estimates provided by JSC UECC and JSC PA ECP bring us to the conclusion that making decisions based solely on the fact of non-compliance with RW location and origin criteria without taking into account the long-term radiological consequences, may lead to unjustified expenses and radiation exposure.

The status of these facilities will be reconsidered if the land use category changes.

Retrievable RW

For most part of facilities, decisions regarding the designation of RW as retrievable RW were made solely based on non-compliance with the criteria set for waste origin and the location of relevant sites. As for the retrievable RW storage facilities, no feasibility study is to be performed to confirm that waste retrieval is the safest option in terms of Article 3 of the Federal law On the Management of RW.... In other words, the decisions were made in violation of a fundamental radiation protection principle — the justification principle: "any decision that alters the radiation exposure situation should achieve sufficient benefit to offset the detriment it causes" [4].

For example, all the waste accumulated in the storage facilities of JSC Angarsk Electrolysis Chemical Combine (JSC AECC) were categorized as retrievable waste (facilities are located within the settlement area). Decommissioning efforts for the storage facility (building 310) and several other facilities of the Organization, are currently being developed or are already underway.

Remediation of legacy facilities at JSC AECC

The site of this organization is located in the southern industrial zone of Angarsk, 4 km away from the residential area, 7 km away from the Angara River and 100 km from the Lake Baykal. Assessment of the JSC AECC impact on the population of Angarsk was completed in 2016 [5]. It was found that in terms of radiation risks JSC AECC impact is equal to 1% of the total anthropogenic radiation risk, which, in turn, is much lower than the natural radiation risk (the largest contribution is that of the fossil fuel power plants burning fuel containing uranium). An approximate ratio of anthropogenic toxic and radiological risks for the population of Angarsk is equal to 23,000:1. Thus, the production or radiation legacy sites located at JSC AECC site have virtually no health effects on the population of Angarsk.

Based on the fact that the JSC AECC site is located within the city boundaries and the environmentally protected area, the commission made a decision to

designate the accumulated RW (nearly 90,000 m^3) as retrievable RW. All waste should be retrieved, treated, conditioned and transferred for disposal. The cost of the accumulated RW transfer to FSUE National Operator for Radioactive Waste Management (FSUE NO RWM) alone is estimated to be above 50 bln roubles setting aside the costs associated with conditioning, breaking up the existing safety barriers and management of waste generated due to these activities.

Buildings 802 and 804 used in the past for gas-diffusion uranium isotope separation are currently undergoing decommissioning under FTP NRS-2. Since 1996, these facilities were disconnected from utilities and converted to cold conservation state. The engineering survey of the buildings showed that the structures are currently in an emergency condition. This project alone will result in handing over of 5,000 m^3 of RW and over 18,500 tons of scrap metal to FSUE NO RWM for disposal.

According to JSC AECC estimates, over 100,000 m^3 of RW intended for disposal will additionally result from closure operations at AECC facilities. The nearest disposal facility is planned to be constructed in some 1,500 km away from these facilities. The cost of transportation alone will exceed 2 bln roubles.

In addition to these buildings, FTP NRS-2 provides for RW retrieval from the building 310 to be completed before 2030. This building holds over 1,900 m^3 of waste. Estimated unit costs of decommissioning will exceed 1.1 mln roubles/m^3.

The possibility of establishing a near-surface disposal facility at the site of JSC AECC has been discussed recently. Such a decision, if it would be made, definitely will be much safer than long-distance transportation of waste.

On the other hand, the feasibility of such project is questioned as it suggests RW retrieval from the existing facilities, their conditioning (which will most probably result in the increase of specific activity) and disposal in a new near-surface repository, which shall comply with the same safety requirements as the in-situ disposal facility. In other words, if a new RW disposal facility can be constructed at this site, then why it is prohibited to upgrade the existing storage facilities into disposal facilities?

Are such "noble" decisions regarding the closure of legacy sites justified and feasible from the safety point of view? In this context, the work implemented by the FSBU Gidrospetsgeologiya in 2016 is of great interest. This organization carried out geofiltration and geomigration simulation of the site based on subsoil facility-level monitoring data. This work provided a much clearer picture of the spatial structure, recharge and discharge and the balance conditions for ground water flows. In particular, it was demonstrated that the feeding water canal is the discharge area for the geofiltration flow formed in the site area. Chemical and radioactive contamination due to operation of storage facilities and the underground gas flue systems were estimated.

Monitoring data shows that the radioactive contamination at the JSC AECC has been found only in the vicinity of retrievable RW storage facility — building 311. The existing contamination is manifested by elevated total α-activity, with the mean values being less than 4 CPA (criteria for preliminary assessment of drinking water quality in keeping with radiation safety standards set by NRB-99/2009).

The forecasts show that, if the storage facilities holding accumulated RW are not fitted with additional safety barriers and no decom- missioning is implemented at JSC AECC site, the area of ^{238}U contamination will reach the feeding water canal within (approximately) 1,000 years. The maximum forecasted volumetric activity of ^{238}U in the canal will not exceed 0.1 Bq/kg (conservative estimate), which is 30 times lower than the intervention level (3 Bq/kg). At the same time, the contribution of building 310 to the overall volume of ^{238}U release to the feeding water canal will be less than 5%. The remaining activity (for a conservative scenario) will be due to gas flues; operations on their decommissioning have already been started.

Thus, if the current hydrological situation remains the same, and no additional safety barriers are installed to upgrade the RW storage facilities to in-situ RW disposal facilities, no impact on population is expected. On the other hand, efforts enabling to prevent the seepage of atmospheric precipitation to RW storage facilities and to remediate the territory will limit ^{238}U discharge into ground waters in the long run.

With respect to the spread of chemical contamination into ground waters in the vicinity of building 311 associated with sulphates, calculations demonstrate its present stability. If some safety barriers preventing additional release of sulphates to ground waters are constructed, its concentrations will decrease to values below the maximum permissible limits within 25 years.

In a number of cases, the decisions made during the Initial inventory of RW on defining certain RW as retrievable require a more graded approach and additional assessments to be performed to demonstrate that retrieval is the best option both from safety and economic perspective.

Conclusion

The developed methodological support tools enabled to perform necessary feasibility studies and to justify the designation of a number of nuclear legacy sites as non-retrievable RW disposal facilities. Dose, risk and cost estimates for these sites showed that in-situ disposal will ensure their final isolation in a safe and effective way. Waste designation as non-retrievable RW, in turn, enabled both

to continue operations at such facilities under FTP NRS-2, as well as to start some new projects, including those at a number of sites of the Fuel Company.

Apparently, before such stepwise process could be started at some RW storage facilities that were subject to deferred decisions in the past, additional efforts are required. The land use category should be changed for JSC UECC and JSC PA ECC, and for the facilities of PJSC MBP, either the boundaries of the settlements or the criteria for defining waste as non-retrievable RW approved by the Decree of the Government of the Russian Federation need to be revised in order to define the waste as non-retrievable. Arguments supporting the revision of the criteria are suggested not only for the Fuel Company facilities.

It should be noted that the in-force legal framework suggests that nuclear decommissioning (NPP units, nuclear installations, etc.) can be performed according to "in-situ disposal" scenario. The choice of the final state shall be based exclusively on the comparison of the possible options with due account of the forecasted radiation situation, their impact on the safety of other facilities, expected radiation impact on the personnel, population and the environment, as well as feasibility parameters. Moreover, existing RW storage facilities can be legally converted into in-situ disposal facilities. Construction of new facilities is solely prohibited if these facilities are from the very start intended to be converted to facilities holding non-retrievable RW or non-retrievable RW disposal facilities.

Operations involving retrievable RW require comprehensive feasibility studies enabling to choose the most safe and financially feasible way of their of final isolation. In some cases it can result in the review of decisions regarding the assignment of waste to the category of retrievable RW.

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