ANALYSIS OF THE RUSSIAN FEDERATION REGULATORY FRAMEWORK REQUIREMENTS FOR DISPOSAL OF VERY LOW-LEVEL RADIOACTIVE WASTE

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The article describes existing practices of very low-level radioactive waste (VLRW) disposal and presents the analysis of current Russian regulatory framework in the field of radioactive waste disposal, in particular, concerning the designs of VLRW disposal facilities. The article proposes and recommends some adjustment of the regulatory framework providing cost-effective and safe VLRW disposal.

Keywords: *radioactive waste, very low-level waste (VLRW), disposal facilities for radioactive waste, engineered safety barriers.*

Introduction

In accordance with [1—3], depending on the specific activity level, radioactive waste can be categorized as high-level (HLW), intermediate-level (ILW), low-level (LLW) and very low-level radioactive waste (VLRW). The VLRW category was introduced in the Russian Federation by the Federal Law No. 190 of July 11, 2011 [1]. Introduction of this waste category based on the ALARA optimality principle allowed to reduce waste disposal costs and corresponds to the international practice in the field of final RW disposal.

In Russia, the concept of very low-level waste (VLLW) is also in place — the waste of this category is not considered as RW (provisions of the law [1] are not applied to this waste category), but the waste itself cannot be cleared from regulatory (radiation) control and should be disposed of in VLLW disposal facilities.

In a number of countries (for example, Sweden, France [4]), the final disposal for very low-level waste are designed according to some simplified commonly recognized engineering solutions. The use of such disposal structures fitted with minimum necessary and sufficient set of engineered safety barriers may considerably reduce the waste disposal cost.

However, to date, the Russian Federation has practically no hands-on experience in the construction and operation of such facilities. Considering the forecasted VLRW generation amounts [5], development of robust and cost-effective design solutions for such disposal facilities is viewed as a quite urgent task to be addressed.

In addition to the engineering tasks associated with the development of disposal designs, cost-effective and safe disposal of VLRW also necessitates

some evaluation of the Russian regulatory framework and, if deemed necessary, its upgrading and review. For example, in accordance with [2] and the RW classification system for disposal purposes, VLRW belongs to RW Class 4 along with the LLW category of waste. Therefore, same disposal tariffs are set both for LLW and VLRW (about 52 thousand rubles/m^3 as of 2021 [6]) providing no opportunities for the reduction of costs covered by VLRW generators. At the same time, RW disposal tariffs can be differentiated (by analogy with RW Class 5), but this requires the development of a specialized repository of a lower cost and the characteristics of the engineered barrier system (EBS) should correspond to the potential hazard level associated with such waste.

This article briefly analyses the Russian regulatory requirements set for VLRW disposal facilities, provides preliminary data on the proposed disposal designs, presents a preliminary assessment of amendments to be introduced to the regulatory framework that would reduce the costs and simplify the VLRW transfer procedure for the final disposal given unconditional compliance with all safety requirements. The paper does not consider the issues associated with the disposal of Class 6 RW (RW from mining and milling of uranium ores, mineral and organic raw materials with a high content of natural radionuclides), which based on OSPORB-99/2010 provisions [3] and according to the specific activity level are attributed to VLRW category.

Regulatory framework in the field of VLRW disposal

Table 1 lists key regulatory documents (RD), the requirements of which apply to VLRW and LLW categories of waste. Since according to the classification system [2], VLRW belongs to RW Class 4, the list of regulatory documents specifying the disposal requirements is almost similar both for LLW and VLRW. Table 1, namely, the column Note presents preliminary data on the necessary changes to be introduced to the regulatory framework. The rationale behind this proposal is presented below in this article.

Table 1. List of key regulatory documents containing requirements on LLW and VLRW disposal

Document ID	Name of the document	Classification and categorization of RWDF for VLRW	Note
FZ No 190 of July 11, 2011 [1]	Federal Law of July 11, 2011 No 190-FZ On the Management of Radioactive Waste and Amendments to Certain Legislative Acts of the Russian Federation	–	Amendments are required to elaborate on the transfer of ownership for VLRW disposal facilities
GD No 1069 of October 19, 2012 [2]	Government Decree of the Russian Federation of October 19, 2012 No 1069 On Criteria Used to Categorize Solid, Liquid and Gaseous Waste as Radioactive Waste, Criteria for Radioactive Waste Categorization as Non-removable and Removable Radioactive Waste and Classification Criteria for Removable RW	VLRW handed over for disposal in a repository are categorized as removable RW Class 4	Amendments are required to distinguish VLRW into a separate Class according to the waste classification system for disposal purposes. Discussed should be the restrictions imposed on the content of long-lived radionuclides in VLRW
NP-055-14 [7]	RW Disposal. Principles, Criteria and Basic Safety Requirements	Near-surface disposal	Amendments are recommended to elaborate on VLRW disposal requirements
NP-069-14 [8]	Near-surface Disposal of Radioactive Waste, Safety Requirements	–	Amendments are recommended to elaborate on VLRW disposal requirements
NP-093-14 [9]	Waste Acceptance Criteria for Disposal	–	Amendments are recommended to elaborate on VLRW disposal requirements
RB-117-16 [10]	Long-term Safety Assessment for Near-Surface RW Disposal Facilities	–	–
GOST R 52037-2003 [11]	Near-surface Disposal Facilities for RW. General Requirements	–	Document should be abolished due to the enactment of [8]
NP-058-14 [12]	Safe Management of Radioactive Waste. General Requirements	–	-
SP 2.6.1.2612-10 (OSPORB-99/2010) [3]	Basic Sanitary Rules and Norms of Radiation Safety	RWDF for VLLW – III category according to the potential radiation hazard level	-
NP-064-17 [13]	Accounting of external natural and man-induced impacts on nuclear facilities	NP-064-17 requirements do not cover RWDF since it is referred neither to the first nor to the second category according to the potential radiation hazard level	-

Continuation of Table 1

Document ID	Name of the document	Classification and categorization of RWDF for VLRW	Note
NP-016-05 [14]	Basic safety provisions for nuclear fuel cycle facilities	Geotechnical barriers (underlying and covering screens) are considered as safety important systems. Light frame structures preventing seepage of atmospheric precipitation are not considered as safety important systems	To consider frame structures designed to prevent the seepage of atmospheric precipitation as a system not important for safety, one should demonstrate that the collapse of structures on packages with VLRW would not cause the contamination of the RWDF area
NP-031-01 [15]	Design standards for earthquake-resistant nuclear power plants	Geotechnical barriers (underlying and covering screens) – II category according to the earthquake-resistance factor. Light frame structures preventing seepage of atmospheric precipitation - III category according to the earthquake-resistance factor	–
FZ No 170 of November 21, 1995 [16]	Federal Law of 21 November, 1995 No 170-FZ On Atomic Energy Use	RWDF are considered as nuclear facilities	–
GD No 1185 of November 19, 2012 [17]	Decree of the Government of the Russian Federation of November 19, 2012 No. 1185 On the Approved Procedure and the Schedule for the Establishment of a Unified State System for Radioactive Waste Management	–	–
GD № 899 of September 10, 2012 [18]	On the approved regulation on radioactive waste transfer for disposal, including radioactive waste resulted from the development, production, testing, operation and disposal of nuclear weapons and military nuclear power facilities: Decree of the Government of the Russian Federation of September 10, 2012 No. 899	–	-
NP-100-17 [19]	Requirements on the Structure and Composition of the Safety Analysis Report on RW Disposal Facilities	-	–
GK RF [20]	Federal Law of December 29, 2004 No. 190-FZ Urban Planning Code of the Russian Federation	RWDF is considered a particularly dangerous, technically complex and unique facility in accordance with the Urban Planning Code of the Russian Federation, since it is a nuclear facility	–
FZ No 384 of December, 2009 [21]	Federal Law No. 384-FZ of December 30, 2009 Technical Regulations on the Safety of Buildings and Structures	Increased level of construction responsibility	–
SP 2.6.6.2572-2010 [22]	Radiation Safety in the Management of Industrial Wastes from Nuclear Power Plants Containing Technogenic Radionuclides. Sanitary regulations	–	The document applies to VLLW generated at NPPs
Order of the Government of the Russian Federation No. 2499-r of December 7, 2015 [23]	The list of organizations engaged in mining and milling of uranium ores and resulting in RW generation, and organizations operating particularly hazardous radiation and nuclear productions and facilities and performing activities resulting in VLRW generation that are allowed to dispose this waste in RWDF located on the land plots operated by such organizations	–	–
MU 2.6.5.08-2019 [24]	Category of a facility determined based on its potential radiation hazard level. Guidelines	-	–
GD No. 1494 of December 30, 2012 [25]	Decree of the Government of the Russian Federation No. 1494 of December 30, 2012 Regulation on the segregation of nuclear facilities into separate categories and establishing the composition and the boundaries of such facilities	RWDF is a nuclear facility	–

Continuation of Table 1

Document ID	Name of the document	Classification and categorization of RWDF for VLRW	Note
SanPiN 2.6.1.2523-09 (NRB-99/2009) [26]	Radiation safety standards	–	–
–	Facilities for the final disposal of very low-level waste. General atomic energy requirements	–	Development of this regulatory document is recommended after a most cost-effective and safe design option is selected for VLRW disposal with relevant scientific demonstration provided.

Disposal designs for VLRW

Figures 1 and 2 present the designs for VLRW disposal facilities implemented in Sweden and France [27, 28]. International experience in the disposal of this waste category was briefly summarized in [29].

The Swedish regional disposal facility for very low-level waste at the Oskarhamn NPP site is an impervious concrete 0.5 m thick base installed above a two-meter-thick natural moraine layer filled with a mixture of pebbles and stone chips. Waste packages shape an extended mound. The voids are backfilled with sand and a cap is installed on the top, including the following layers: a mixture of pebbles and stone chips, a 0.4 m-thick hydraulic barrier made of bentonite with stone chips, bentonite textile, pebble drainage layer, geotextile material, a 1.2-meter-thick layer of clay moraine with vegetable soil placed on top [27].

Figure 1. VLRW disposal method applied at the Oskarhamn NPP site (Sweden) during the construction of a covering cap [27]

Figure 2. VLRW disposal method applied in the Cires facility at the Morvilliers site (France) [28]

A centralized disposal facility for VLRW is operated in France: its layout involves a network of trenches reaching a depth of up to 8 m excavated in the near-surface clay layer with a temporary mobile roof installed above and kept in place during waste emplacement operations. After the trenches are filled with waste packages and a mound-type structure is formed with the gaps backfilled with sand, a cap is installed above the mound. The cap involves a few layers, namely, 2 mm-thick high-density polyethylene, a layer of clay extracted during trench excavation (from 1 to 5 m), clay-based buffer material (2.5 m), vegetable soil layer (0.3 m) [28].

Buried structures are recommended to be used in case of waste disposal in clays, if the clay excavated during trench construction can be used to build a cap and also given that the groundwater flows are far away from the ground surface. In other cases, above-ground RWDF structures are considered a most acceptable design option. In Russia, surface VLLW repository designs were implemented at the Kursk NPP and BREST-OD-300 sites: positive statements were issued based on the national state review of these designs (authors of this article were engaged in the design development). Figure 3 presents the designs of VLLW disposal facility for BREST-OD-300. Similar VLLW disposal designs were developed for the Kursk NPP.

System of safety barriers at the disposal facilities shown in Figures 1—3 can be largely reduced to two barriers: underlying and covering engineered

systems. Buffer material used to backfill the waste packages (sand) do not prevent the spread of radionuclides. The buffer basically fills the voids avoiding subsidence of the covering layers and the accumulation of water, which in the winter season causes rapid degradation of the installed barriers.

Plastic bags, barrels, big bags, metal and polymer containers are used to ship the waste to the disposal site: these may not be considered as safety barriers after being emplaced into a repository. Bulky waste can be also disposed of without any packaging.

Table 2 presents the main elements of very low-level waste disposal facilities and their functions.

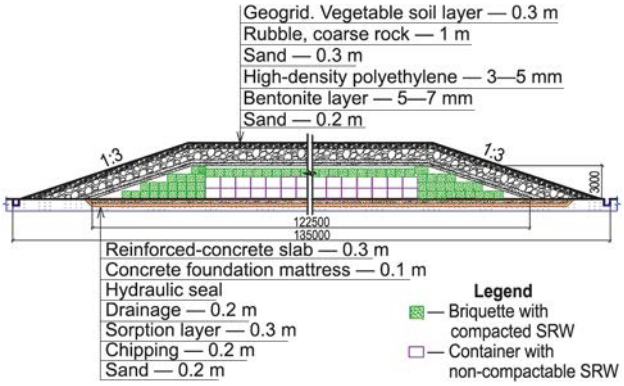

Figure 3. Designs of a VLLW disposal facility for BREST-OD-300 [30]

Table 2. Main structural elements of a disposal facility for VLRW and their functions

No	RWDF element	Function
1	Underlying screen (base)	Bears mechanical loads from waste packages, buffer materials and the covering screen; prevents groundwater flows to waste packages; drains water in case of waste flooding; retards the spread of radionuclides released from waste packages.
2	Waste form and waste packaging	Provides the integrity of the waste emplaced into a package at least until the covering screen is installed (in accordance with Table No. 4 NP-093-14).
3	Buffer material	Fills voids preventing subsidence of the covering screen; prevents water accumulation due to waterproofing properties (clay) or due to filtration (sand); provides stable (chemically and biologically neutral) conditions considered favorable in terms of waste package integrity.
4	Covering screen	Prevents technogenic and natural impacts; provides waterproofing capacity; prevents freezing of the disposal massif; prevents capillary rise of water from the disposal cells (in case of waste flooding); adsorbs radionuclides released from waste packages; prevents gas accumulation in the disposal mass.
5	Mobile roof installed above the working area	Protects against precipitation at the stage of RW package emplacement.
6	Natural barrier (host rock)	Prevents radionuclide migration due to engineered barrier degradation.
7	Observation wells	Are used to monitor groundwater flows and identify the presence of a radioactive contamination. Provide indirect control over the safety barriers.
8	Fencing (security system)	Prevention of unauthorized intrusion into RWDF.

The above functions of RWDF elements provide safe operation of waste disposal facilities abroad, namely for the waste the activity level of which corresponds to the VLRW waste category adopted under the Russian waste classification system. At the same time, high economic efficiency of waste disposal is provided due to:

- the absence of load-bearing building structures in RWDF designs;
- simplified approaches to waste processing (or no processing at all);
- the use of inexpensive common industrial packaging for waste.

According to [31], at the final stages of RW management the highest costs are those associated with RWDF load-bearing structures, RW processing and waste disposal containers.

Best international practices in VLRW management should be considered in Russia as well. Discussed below are the requirements of Russian regulatory documents (RD) in the field of RW disposal with relevant legal obstacles analyzed obstructing the construction of facilities similar to very low-level waste disposal facilities operated in Sweden or France.

Preconditions for amendments to be introduced to the regulatory and legal framework in the field of VLRW disposal

Regulatory requirements to RWDF designs

Although provisions of [1] and [2] distinguish VLRW as a separate RW category, RWDF requirements for LLW and VLRW repository designs actually were not differentiated under the Russian regulatory framework since they belong to a same waste class.

In accordance with Article 12 [1], "solid very low-level waste can be disposed of in near-surface disposal facilities for radioactive waste with no

preliminary conditioning provided" (i. e. in an unpackaged form, unlike LLW and ILW requiring conditioning and the use of packaging[1]).

NP-069-14 presents the design development requirements for near-surface RW disposal facilities (NSDF) [8].

According to paragraph 8 of Section II [8], the following engineered safety barriers should be installed at NSDFs depending on RW characteristics, as well as the method and conditions of waste disposal:

- RW packaging and its individual elements (RW form, container);
- NSDF building structures and their individual elements;
- materials used in the construction of RW disposal cells;
- buffer materials;
- elements of structurally isolated structures or parts of NSDF structures purposely equipped for the disposal of spent sealed sources of ionizing radiation (SSSR);
- underlying screen;
- covering screen.

NP-055-14 also provides some general requirements on the composition and functions of the safety barriers [7]. However, to date, the regulatory framework of the Russian Federation provides no specific purpose-oriented requirements concerning the EBS structures. These have been elaborated in detail only as regards packages accepted for disposal [9], however, only minimal requirements have been established to date for Class 4 RW (LLW, VLRW) [9].

According to paragraph 12 of Section II [7], "RW disposal method (near-surface or deep RW disposal), disposal designs, the composition and properties of safety barriers are selected and validated in the design documentation."

Obviously, the set of barriers from [8] proposed for VLLW disposal is generally redundant. At the same time, the simplified RWDF design for VLRW (without building structures, with common industrial packages) does not contradict the requirements from [7] and [8] provided that the feasibility of the proposed design options have been properly demonstrated in the design documentation.

In 2010, sanitary rules [22] (hereinafter referred to as the Rules) were developed for the management of VLLW from NPP providing relevant requirements for the design development of VLLW disposal facilities. Despite a narrow scope of this document, it provides no specific requirements on the design features of disposal facilities. Paragraph 6.2.1 of the Rules [22] requires VLLW to be disposed of in near-surface repositories. Appendix 2 of the Rules presents some general requirements for the safety barrier structure and functions. At the same time, according to paragraph 6.2.2, specific engineering solutions proposed for the construction of disposal facilities should be specified and justified in the design documentation.

Generally, design organizations developing documentation for VLRW disposal facilities have no specific regulatory requirements at hand and experience in the design development and construction of VLRW repositories. Thus, non-optimal engineering solutions may be proposed under RWDF designs with no unification provided especially given the large VLRW inventory.

In this regard, a national standard (for example, GOST Facilities for the Final Disposal of Very Low-level Radioactive Waste. General Requirements) may be reasonably developed in the future taking into account the best international practices in the construction and operation of RWDFs for very low-level waste. This standard may provide some specific requirements or recommendations regarding VLRW disposal designs (for example, number of layers, materials and thicknesses of the covering and underlying screens and buffer materials, sketch drawings of standard repositories design layouts, recommendations regarding the repository service life, specific requirements regarding the functions of the main safety barriers and structural RWDF[2] elements). A study should precede the development of such a GOST standard to demonstrate the feasibility of the selected optimal design option for a VLRW repository, as well as relevant efforts associated with the development and examination of design documentation for VLRW disposal facilities.

Following the development of the above GOST, amendments or additions to [7] and [8] may be required.

On the recognition of RWDF for VLRW as particularly hazardous, technically complex and unique facilities

Figure 4 shows a flowchart according to which VLRW repositories are formally recognized as particularly hazardous, technically complex and unique facilities in keeping with the urban planning code [20] and as facilities of high responsibility level

[1] Author's note is given in brackets

[2] Considering the design features of disposal facilities intended for VLRW, GOST should provide for an approach currently implemented under existing federal norms and rules, according to which the ultimate decision on the structures proposed under VLRW disposal designs should be made at the design development stage taking into account natural and climatic conditions in the siting region, as well as the radionuclide compositions of VLRW handed over for disposal.

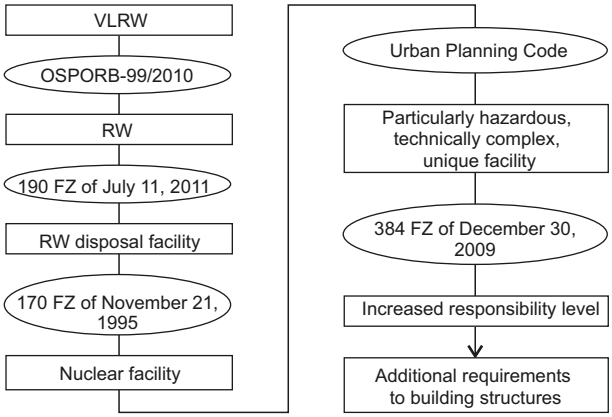

Figure 4. Flowchart followed to recognize a RWDF for VLRW as a particularly hazardous, technically complex and unique facility according to the Urban Planning Code of the Russian Federation

according to the classification system provided in Federal Law No. 384-FZ of December 30, 2009 [21].

According to [21], additional requirements are imposed on structures with an increased responsibility level (engineering surveys, mechanical safety of structures). These requirements are seeking to protect the life and health of people and the environment from dangerous consequences of accidents that can occur during construction, operation, isolation and demolition (dismantling) of such facilities.

Some requirements regarding facilities with an increased responsibility level, namely, on the accounting of emergency design situations provided in the Federal Law No. 384-FZ of December 30, 2009 [21] are elaborated in a number of regulatory documents, in particular:

- SP 20.13330.2016 Loads and impacts. Updated edition of SNiP 2.01.07-85 [32];
- SP 286.1325800.2016 Construction of facilities with increased responsibility level. Rules for detailed seismic zoning [33];
- GOST 27751-2014 Reliability of building structures and foundations [34];
- SP 14.13330.2014 SNiP II-7-81 Construction in seismic regions [35].

In accordance with Federal law No. 384-FZ [21], failure of an element constituting to load-bearing structures should not cause collapse of the entire structure. Depending on the design solutions proposed for a particular structure, the requirements [21, 32–35] may significantly increase the cost due to the required duplication of load-bearing beams, reinforcement strengthening, etc.

However, as it comes to facilities similar to the one shown in Figure 3 with no beams, walls, columns, roofing, etc., these requirements may basically affect the design of the foundation used for container installation. Obviously, this should not lead to a significant increase in the VLRW disposal cost, especially considering the fact that:

- RWDF foundation is not required under the French VLRW disposal concept;
- Swedish VLRW disposal practice has shown that containers are recommended to be installed not on a reinforced concrete base, but on clayey soil capable of absorbing radionuclides eventually released from RW packages.

Classification of temporary structures that can be erected above RW disposal cells for the period of RW emplacement into the repository to prevent the seepage of atmospheric precipitation is still considered as a debating point.

If the collapse of temporary structures on a stack of VLRW packages results in a contamination of the repository site, then it is necessary to impose increased requirements on such structures, which therefore would increase the cost.

To address this issue, pneumatic frame structures, the collapse of which cannot damage the waste packages, may be considered.

On the external influences considered in the development of disposal designs for VLRW

At nuclear facilities, decisions on the measures implemented against external impacts are made based on the category of a facility according to its potential radiation hazard level established in accordance with OSPORB-99/2010 [3] and MU 2.6.5.08-2019 [24] provisions.

According to the materials supporting license applications for Class 3 and 4 RW disposal facilities (LLW/ILW) at the sites of JSC UEIP, FSUE PA Mayak and JSC SCC [36—38], these NSDF were attributed to Category III according to the corresponding potential radiation hazard levels. Obviously, VLRW repositories should be assigned to the same category since they cannot pose greater potential hazard than the repositories for low- and intermediate-level waste.

In case of an accident at such facilities, the radiation impact will be limited to their sites. NP-064-17 [13] requirements should not be accounted for when it comes to facilities attributed to category III according to the corresponding potential radiation hazard levels (they apply only to facilities belonging to categories I and II in accordance with paragraph 1.2 of NP-064-17). In particular, no engineering solutions should be provided to protect relevant RWDF from an aircraft crush, thus, avoiding additional costs that would've been required to reinforce the RWDF structures. The same applies to seismic impacts with DLE intensity and explosive shock wave (no measures are required to

be implemented to protect the facility from these impacts).

Regulatory requirements on the VLRW transfer for disposal and RW disposal tariffs

General requirements regarding RW transfer for disposal (and, in particular, VLLW) are established in [1]. If the general procedure stipulated in this law provides for the transfer of RW packages to the National Operator, who accepts the RW meeting the criteria established for particular repositories for waste disposal in purposely developed disposal facilities, then in keeping with the provisions of Article 27 [1], VLRW may be disposed of in structures sited on land plots operated by such organizations according to the Government Decision of the Russian Federation. The Government Decree of the Russian Federation [23] has approved a list involving 12 organizations that were allowed to dispose of this waste in RWDFs sited on the land plots operated by these organizations. However, in a number of cases, VLRW disposal is practically hindered by the requirement of Article 40 [1], according to which, a legal entity acquiring ownership over a RWDF shall within one year alienate it to FSUE NO RAO. These regulatory contradictions have already been noted earlier [39].

RW disposal tariffs were established by orders of the Federal Antimonopoly Service and are given in [6]. In accordance with [2], VLRW, along with LLW, belongs to RW Class 4: when the waste is transferred to the National Operator, uniform tariffs are set for LLW and VLRW providing no opportunities for VLRW disposal cost optimization today. Since LLW and VLRW are characterized with different specific activity levels, which may differ by 1—2 orders of magnitude, VLRW management costs should be obviously lower.

To solve the above problems, appropriate amendments should be introduced to [2] and [1], in particular, elaborating on the way the ownership right over VLRW disposal facilities may be transferred and VLRW treatment as a separate RW class according to the RW classification for disposal purposes.

Regulatory requirements concerning the service life of RWDF for VLRW

Regulatory framework of the Russian Federation does not specify any particular service life for RW disposal facilities. The service life of the engineered safety barriers in a disposal system depends on the disposal safety and is directly related to the period of potential hazard characteristic for the waste subject to final disposal. In case of near-surface disposal facilities for short-lived LLW and ILW, this time period commonly accounts for several hundred years [40, 41]. It governs the requirements concerning the restrictions imposed on the specific activity of long-lived radionuclides (especially considering the content of transuranic elements), as well as the robustness and the performance of RWDF structures.

The potential hazard period assumed for the RWDF for VLRW in Sweden amounts to 100 years [27] given the restrictions imposed on the amount/concentration of long-lived radionuclides. This period corresponds to the service life of modern nuclear enterprises taking into account their decommissioning schedule and eliminates the need for costly engineering designs. Assuming such a timeframe in case of VLRW disposal, its safety can be relatively easily provided and demonstrated given the restrictions imposed on the content of long-lived radionuclides. However, to date, this period has not been specified in the federal norms and rules.

Maximum allowable specific and volumetric activities of radionuclides contained in waste are given in [2]. Long-term safety assessments for RWDF at the sites of JSC UEIP, FSUE PA Mayak and JSC SSC [36—38] showed that the content and activity of radionuclides were taken conservatively according to the limits established for the corresponding classes of removable RW specified in [2]. If calculations reveal that at the post-closure stage the dose limits for the population established by radiation safety standards [26] are exceeded due to the radionuclide migration in the environment, the limits for the specific/volumetric activity of some radionuclides can be calculated by solving the inverse problem. Subsequently, restrictions on the content of radionuclides in waste sent for disposal should form the basis of local acceptance criteria established for individual disposal facilities.

This approach may be applied in case of VLRW disposal facilities. In this case, for a RWDF with a potential hazard period of 100 years, only local acceptance criteria should be developed. However, if design solutions for VLRW disposal facilities characterized with the same potential hazard period are replicated, it seems reasonable to limit the content of long-lived radionuclides in VLRW and introduce necessary amendments to the Government Decree of the Russian Federation No. 1069 of October 19, 2012 [2].

Regulatory requirements on the long-term safety assessment of RWDF

Recommendations concerning the long-term safety assessment of near-surface disposal facilities for radioactive waste (including VLRW) are set forth in [10], and those concerning the structure and content of the RWDF safety analysis report in

[19]. However, these are only general requirements; no particular assessments are discussed in the regulations. At the same time, the requirements of [10] and [19] apply mainly to design development stage having no direct and significant impact on the RWDF designs and its cost. These regulations also provide no requirements and recommendations obstructing final VLRW disposal in repositories of a simplified design. In this regard, amendment or review of these regulations is not considered required.

Necessary and sufficient amendments to the legal regulation in the field of VLRW disposal

As shown above, regulations addressing RW disposal provide some requirements and recommendations impeding full-scale implementation of the key VLRW management task, namely, cost-effective final disposal of this waste given the unconditional observance of all existing safety principles.

To address this challenge, regulatory documents requiring some amendment should be identified.

First of all, the problems associated with the transfer of ownership over VLRW disposal facilities and the establishment of RW disposal tariffs should be resolved. At the same time, the problem of tariffs is directly related to the RW classification system for disposal purposes, which requires certain amendment of [1] and [2] providing the conditions necessary to launch practical efforts on VLRW disposal.

Although, no specific regulatory document specifying the requirements for VLRW repository designs is in place and these are listed among general requirements for near-surface disposal facilities, no important restrictions could be identified in the regulations preventing the final VLRW disposal in repositories of a simplified design, since decisions on repository designs are validated and justified in the design documentation.

Nevertheless, absence of specific requirements for VLRW repository designs also results in different interpretations of the general regulatory requirements. Therefore, certain amendments should be introduced to [7] and [8] to promote favorable conditions for the introduction of the international disposal practice with VLRW repositories of simplified designs in the Russian Federation, namely: these should be supplemented with requirements on the selection of such RWDFs, recommendations for a differentiated decision making on EBS considering the potential hazard level of the waste; and also, probably, with requirements concerning the temporary structures protecting the disposal cells from atmospheric precipitation during the implementation of RW emplacement operations.

Further improvement and unification of VLRW final disposal approaches may require the development and approval of a new specialized regulatory document setting forth the requirements on VLRW disposal facilities.

On the opportunities for the joint disposal of VLLW and VLRW

Since it appears quite difficult to distinguish between VLLW and VLRW categories, some publications [39, 42] propose the concept of their joint disposal. An expert assessment of this concept and its prospects are presented in article [43]. In brief, findings of this paper can be boiled down to the fact that VLLW should not be included to the RW category to avoid additional burden placed on the USS RW. In fact, authors of this article do agree with this point.

However, the basic principle supporting the separation of VLLW category (basically reducing the volume of low-level waste transferred to the National Operator for disposal) may be also extended to the waste of the VLRW category.

In case of direct in-situ disposal of VLLW and VLRW, the applied VLLW and VLRW disposal approaches maybe may be identical, similar to the repository designs.

At the same time, during the disposal process, accounting and control should be provided separately for VLLW and VLRW (VLLW and VLRW may be disposed of in separate repositories, thus, one will be able to distinguish between the disposal facilities for production and consumption waste and those intended for radioactive waste).

On the opportunities for VLRW disposal in facilities subject to decommissioning

At present time, scientific and design development communities are discussing the option of VLRW disposal in buildings and structures at the sites of existing nuclear facilities subject to decommissioning (DE), but, nevertheless, not being considered as facilities holding non-removable RW. Summarized below are the prerequisites for such discussions:

- such structures are actually available at NF sites (in the vicinity of VLRW generation sources), with their areas cleared from equipment during decommissioning;
- no need for costly dismantlement of such buildings/structures;
- no need for the decontamination of building structures;
- good condition and high reliability of building structures, namely, constituting to some buildings and facilities subject to decommissioning

(DE is required not due to the degradation of building structures, but due to the depreciation of equipment);
- absence of requirements for the building structures acting as engineered safety barriers for VLRW disposal purposes (as shown above, VLRW disposal does not require any building structures at all).

To date, no regulatory obstacles have been identified by the authors of this article preventing the use of building structures not originally intended for VLRW disposal as a basis for RWDF. At the same time, this option seems feasible provided that the NF site complies with the safety requirements on the repository site selection.

In accordance with paragraph 36 [19]: "for the developed RWDF, information on the alternative siting options shall be provided along with the materials demonstrating the advantages of the selected site." Separate feasibility studies are recommended to evaluate the economic efficiency of VLRW disposal in existing buildings and structures at NF sites subject to decommissioning and to meet relevant requirements [19].

Conclusion

A new group of VLRW was established to eliminate excessive requirements and restrictions imposed at further RW management stages involving various RW inventories accumulated and generated by the nuclear industry. First of all, this was supposed to benefit the final disposal process rendering it much easier. Brief analysis of the general RW disposal requirements showed that this goal has not been achieved so far, and to develop more cost-effective VLRW disposal solutions, appropriate amendments are to be introduced to [1] and [2] to deal with the issues of VLRW repository ownership and the disposal tariffs.

If these issues are addressed, the practice of VLRW disposal in the RWDF complying with the best internationally available analogues may start being implemented.

Given the needs of the Russian Federation, issues related to the designs of VLRW disposal facilities can be comprehensively addressed provided that:
- the requirements for VLRW repositories presented in [7, 8] are elaborated more precisely;
- restrictions limiting the specific/volumetric activity of long-lived radionuclides in VLRW are introduced in [2] to specify the potential hazard period of VLRW repository of about 100 years;
- standardized unified designs of VLRW repositories are developed based on international best practices with appropriate scientific and engineering basis provided, which can later become a basis for the development of GOST Facilities for the Final Disposal of Very Low-level Radioactive Waste. General Requirements;
- the VLRW disposal concept is evaluated considering the nuclear decommissioning tasks at hand, as well as the feasibility of using existing building structures non intended for any further operation as a basis for VLRW disposal facilities.

References

1. Federal'nyi zakon ot 11 iyulya 2011 g. No. 190-FZ "*Ob obrashchenii s radioaktivnymi otkhodami i o vnesenii izmenenii v otdel'nye zakonodatel'nye akty Rossiiskoi Federatsii"* [Federal law of July 11, 2011 No. 190-FZ "On Radioactive Waste Management and Amendments to Certain Legislative Acts of the Russian Federation"].

2. Postanovlenie Pravitelstva Rossiyskoy Federatsii ot 19.10.2012 No. 1069 *"O kriteriyah otneseniya tverdyh, zhidkih I gazoobraznyh othodov k radioaktivnym othodam, kriteriyah otneseniya radioaktivnyh othodov k osobym radioaktivnym othodam i k udalyaemym radioaktivnym othodam i kriteriyah klassifikacii udalyzemyh radioaktivnyh othodov"* [Decree of the Government of the Russian Federation of 19 October 2012, no. 1069 "On the criteria of designation of solid, liquid and gaseous waste as radioactive waste, criteria of radioactive waste designation as special radioactive waste and removable radioactive waste and criteria of classification of removable radioactive waste"].

3. SP 2.6.1.2612-10. *Osnovnye sanitarnye pravila obespecheniya radiacionnoj bezopasnosti (OSPORB-99/2010)* [Basic sanitary rules for radiation safety].

4. Sorokin V. T., Pavlov D. I. Tekhnologii okonchatel'noi izolyatsii radioaktivnykh otkhodov: evropeiskii opyt i tendentsii [Technologies of Radioactive Waste Disposal: European Experience and Trends]. *Radioaktivnye otkhody — Radioactive Waste,* 2018, no. 4 (5), pp. 24—32.

5. Ekidin A. A., Antonov K. L. Primenenie udel'nogo pokazatelya dlya otsenki ob"emov obrazovaniya RAO pri normal'noi ehkspluatatsii AEHS Rossii [Application of a Specific Indicator for the Estimation of Radioactive Wastes Generation Volumes During Normal Operation of Nuclear Power Plants in Russia]. *Radioaktivnye otkhody — Radioactive Waste,* 2020, no. 2 (11), pp. 66—74. DOI: 10.25283/2587-9707-2020-2-66-74.

6. *Tarify na zakhoronenie radioaktivnykh otkhodov na period s 2018 po 2022 gody* [Tariffs for Radioactive Waste Disposal for the Period from 2018 to 2022]. — URL: http://www.norao.ru/about/tarify/ (accessed on 01.02.2021).

7. NP-055-14. *Zakhoronenie radioaktivnykh otkhodov, printsipy, kriterii i osnovnye trebovaniya bezopasnosti* [Disposal of Radioactive Waste. Principles, Criteria and Basic Safety Requirements].
8. NP-069-14. *Pripoverkhnostnoe zakhoronenie radioaktivnykh otkhodov, trebovaniya bezopasnosti* [Near-Surface Disposal of Radioactive Waste. Safety Requirements].
9. NP-093-14. *Kriterii priemlemosti radioaktivnykh otkhodov dlya zakhoroneniya* [Acceptance Criteria for Radioactive Waste Disposal].
10. RB-117-16. *Otsenka dolgovremennoi bezopasnosti punktov pripoverkhnostnogo zakhoroneniya radioaktivnykh otkhodov* [Long-term Safety Assessment of Near-Surface Radioactive Waste Disposal Facilities].
11. GOST R 52037-2003. *Mogil'niki pripoverkhnostnye dlya zakhoroneniya radioaktivnykh otkhodov. Obshchie trebovaniya* [Near-Surface Disposal Facilities for Radioactive Waste. General Requirements].
12. NP-058-14. *Bezopasnost' pri obrashchenii s radioaktivnymi otkhodami, obshchie polozheniya* [Radioactive Waste Management Safety, General Provisions].
13. NP-064-17. *Uchet vneshnikh vozdeistvii prirodnogo i tekhnogennogo proiskhozhdeniya na ob"ekty ispol'zovaniya atomnoi ehnergii* [Consideration of External Impacts of Natural and Man-made Origin Produced on Nuclear Facilities].
14. NP-016-05. *Obshchie polozheniya obespecheniya bezopasnosti ob"ektov yadernogo toplivnogo tsikla (OPB OYATTS)* [General Safety Provisions for Nuclear Fuel Cycle Facilities].
15. NP-031-01. *Normy proektirovaniya seismostoikikh atomnykh stantsii* [Standards for the Design Development of Earthquake-Resistant Nuclear Power Plants].
16. Federal'nyi zakon ot 21 noyabrya 1995 g. No. 170-FZ *"Ob ispol'zovanii atomnoj energii"* [Federal Law of November 21, 1995 No. 170-FZ "On Atomic Energy Use"].
17. Postanovlenie Pravitel'stva Rossiiskoi Federatsii ot 19 noyabrya 2012 goda No. 1185 *"Ob opredelenii poryadka i srokov sozdaniya edinoi gosudarstvennoi sistemy obrashcheniya s RAO"* [Decree of the Government of the Russian Federation of November 19, 2012 On the Approved Procedure and Schedule for the Development of a Unified State System for Radioactive Waste Management].
18. Postanovlenie Pravitel'stva Rossiiskoi Federatsii ot 10 sentyabrya 2012 goda No. 899 *"Ob utverzhdenii polozheniya o peredache radioaktivnykh otkhodov na zakhoronenie, v tom chisle radioaktivnykh otkhodov, obrazovavshikhsya pri osushchestvlenii deyatel'nosti, svyazannoi s razrabotkoi, izgotovleniem, ispytaniem, ehkspluatatsiei i utilizatsiei yadernogo oruzhiya i yadernykh ehnergeticheskikh ustanovok voennogo naznacheniya"* [Decree of The Government of the Russian Federation of 10.09.2012 On the Approved Provision Regulating the Radioactive Waste Transfer for Disposal, Including Radioactive Waste Generated from Activities Related to the Development, Manufacturing, Testing, Operation and Disposition of Nuclear Weapons and Nuclear Power Defense Units].
19. NP-100-17. *Trebovaniya k sostavu i soderzhaniyu otcheta po obosnovaniyu bezopasnosti punktov zakhoroneniya radioaktivnykh otkhodov* [Requirements on the Structure and the Content of the Safety Analysis Report for Radioactive Waste Disposal Facilities].
20. Federal'nyi zakon ot 29 dekabrya 2004 goda No. 190-FZ *"Gradostroitel'nyi kodeks Rossiiskoi Federatsii"* [Federal Law No. 190-FZ of 29.12.2004 Urban Planning Code of the Russian Federation].
21. Federal'nyi zakon ot 30 dekabrya 2009 goda No. 384-FZ *"Tekhnicheskii reglament o bezopasnosti zdanii i sooruzhenii"* [Federal Law No. 384-FZ of 30.12.2009 Technical Regulations on the Safety of Buildings and Structures].
22. SP 2.6.6.2572-2010. *Obespechenie radiatsionnoi bezopasnosti pri obrashchenii s promyshlennymi otkhodami atomnykh stantsii, soderzhashchimi tekhnogennye radionuklidy. Sanitarnye pravila* [Radiation Safety in the Management of Radioactive Waste from Nuclear Power Plants Containing Technogenic Radionuclides. Sanitary Rules].
23. Rasporyazhenie Pravitel'stva Rossiiskoi Federatsii ot 07 dekabrya 2015 goda No. 2499-r *"Perechen' organizatsii, v rezul'tate osushchestvleniya deyatel'nosti kotorykh po dobyche i pererabotke uranovykh rud obrazuyutsya RAO, i organizatsii, ehkspluatiruyushchie osobo radiatsionno opasnye i yaderno-opasnye proizvodstva i ob"ekty i osushchestvlyayushchie deyatel'nost', v rezul'tate kotoroi obrazuyutsya ONRAO, kotorye mogut osushchestvlyat' zakhoronenie ukazannykh otkhodov v PZ RAO, razmeshchennykh na ispol'zuemykh takimi organizatsiyami zemel'nykh uchastkakh"* [The list of organizations generating radioactive waste due mining and milling of uranium ores and organizations operating particularly radiation-hazardous and nuclear-hazardous production facilities and implementing activities resulting in VLLW generation that are allowed to dispose of such waste in RW disposal facilities located at the sites operated by such organizations: Order of the Government of the Russian Federation of 07.12.2015 No. 2499-r].
24. MU 2.6.5.08-2019. *Ustanovlenie kategorii potentsial'noi opasnosti radiatsionnogo ob"ekta. Metodicheskie ukazaniya* [Evaluating the Category of a Radiation Facility According to the Corresponding Level of Potential Hazard].
25. Postanovlenie Pravitel'stva Rossiiskoi Federatsii ot 30 dekabrya 2012 goda No. 1494 *"Polozhenie ob otnesenii ob"ektov ispol'zovaniya atomnoi ehnergii k otdel'nym kategoriyam i opredelenii sostava i granits takikh ob"ektov"* [Resolution of the Government

Russian Federation of 30.12.2012 No. 1494 Regulations on the Assignment of Nuclear Facilities to Specific Categories and on the Approval of their Composition and Boundaries].
26. SanPiN 2.6.1.2523-09 (NRB-99/2009). *Normy radiatsionnoi bezopasnosti* [Radiation Safety Standards].
27. Rybalchenko I. L. *Obrashchenie s otkhodami ochen' nizkogo urovnya aktivnosti. Shvedskii opyt* [Management of very low level radioactive waste. Swedish experience]. — Saint-Petersburg, 2009. 36 p.
28. Torres P., Cahen B., Dutzer M. The Cires Facility in Morvilliers: from a VLL Waste Disposal Facility to the Development of Industrial Activities. *WM2015 Conference,* USA, Arizona, March 15—19, 2015.
29. Abalkina I. L. Opyt zakhoroneniya ONAO: perspektivy dlya Rossii [VLLW Disposal Experience: Perspectives for Russia]. *Radioaktivnye otkhody — Radioactive Waste,* 2018, no. 4 (5), pp. 15—23.
30. Demin A. V., Nemtsova A. V., Klyukvin S. A. *Predproektnye prorabotki ehnergokompleksa BREST-OD-300. Varianty sozdaniya ehnergokompleksa, vklyuchaya ehtapnost' vvoda, planirovochnye resheniya i ehkonomicheskie otsenki* [Pre-design studies of the BREST-OD-300 energy complex. Options for creating an energy complex, including stages of commissioning, planning solutions and economic assessments] : R&D Report JSC Head Institute "VNIPIET", Saint-Petersburg. No. 4095. 2012.
31. Pavlov D. I., Ilina O. A. O sistemnom podkhode k vyboru bar'erov bezopasnosti dlya zakhoroneniya RAO klassov 3 i 4 [On a System Approach to the Selection of Safety Barriers for the Disposal of Radioactive Waste Class 3 and 4]. *Radioaktivnye otkhody — Radioactive Waste,* 2020, no. 3 (12), pp. 54—65. DOI: 10.25283/2587-9707-2020-3-54-65.
32. SP 20.13330.2016. *Nagruzki i vozdeistviya (aktualizirovannaya redaktsiya SNIP 2.01.07-85)* [Loads and Impacts (updated version of SNiP 2.01.07-85)].
33. SP 286.1325800.2016. *Ob"ekty stroitel'nye povyshennoi otvetstvennosti. Pravila detal'nogo seismicheskogo raionirovaniya* [Building Structures of Increased Responsibility. Rules for Detailed Seismic Zoning].
34. GOST 27751-2014. *Nadezhnost' stroitel'nykh konstruktsii i osnovanii* [Reliability of Building Structures and Foundations].
35. SP 14.13330.2014, SNiP II-7-81. *Stroitel'stvo v seismicheskikh raionakh* [Construction in Seismic Areas].
36. *Materialy obosnovaniya litsenzii na ehkspluatatsiyu pervoi ocheredi statsionarnogo ob"ekta, prednaznachennogo dlya zakhoroneniya radioaktivnykh otkhodov — pripoverkhnostnogo punkta zakhoroneniya tverdykh radioaktivnykh otkhodov, otdeleniya "Novoural'skoe" filiala "Severskii" FGUP "NO RAO" (vklyuchaya materialy otsenki vozdeistviya na okruzhayushchuyu sredu)* [Materials of an operational license application for the first section of a stationary facility designed for RW disposal — a near-surface disposal facility for SRW, Novouralsk devision of FSUE NO RAO's Seversky branch]. — URL: http://www.norao.ru/ecology/mol/ (accessed on 01.09.2021).
37. *Materialy obosnovaniya litsenzii na razmeshchenie i sooruzhenie pripoverkhnostnogo punkta zakhoroneniya tverdykh radioaktivnykh otkhodov 3 i 4 klassov, Chelyabinskaya oblast', Ozerskii gorodskoi okrug* [Materials of a Siting and Construction License Application for a Surface Disposal Facility for SRW Class 3 and 4, Chelyabinsk Region, Ozyorsk City District]. — URL: http://www.norao.ru/ecology/mol/ (accessed on 01.09.2021).
38. *Materialy obosnovaniya litsenzii na razmeshchenie i sooruzhenie pripoverkhnostnogo punkta zakhoroneniya tverdykh radioaktivnykh otkhodov 3 i 4 klassov, Tomskaya oblast', gorodskoi okrug, ZATO Seversk* [Materials of a Siting and Construction License Application for a Surface Disposal Facility for SRW Class 3 and 4, Tomsk Region, Urban District ZATO Seversk]. — URL: http://www.norao.ru/ecology/mol/ (accessed on 01.09.2021).
39. Ivanov E. A., Sharov D. A., Kuryndin A. V. Aktual'nye problemy klassifikatsii udalyaemykh tverdykh radioaktivnykh otkhodov, obrazuyushchikhsya pri ispol'zovanii atomnoi ehnergii [Challenges Related to the Classification of Radioactive Waste Generated from Nuclear Power Uses]. *Yadernaya i radiatsionnaya bezopasnost' — Nuclear and radiation safety,* 2018, no. 2 (88), pp. 11—23.
40. Specific safety requirements No. SSR-5. Disposal of radioactive waste. IAEA Safety standarts. Vienna, 2011.
41. Specific safety guide No. SSG-29. Near surface disposal facilities for radioactive waste. IAEA Safety standarts. Vienna, 2014.
42. Asmolov V. G., Barchukov V. G., Ivanov E. A. Ochen' nizkoaktivnye radioaktivnye otkhody v sisteme bezopasnogo obrashcheniya s radioaktivnymi otkhodami [Very Low-Level Radioactive Wastes in the Radioactive Waste Management System]. *Promyshlennye vedomosti — Industrial Statements,* 2014, no. 5. — URL: https://www.promved.ru/articles/article.phtml?id=2759&nomer=91 (accessed on 01.09.2021).
43. Abramov A. A., Bolshov L. A., Gavrilov P. M., Dorofeev A. N., Igin I. M., Linge I. I., Mokrov Yu. G., Pechkurov A. V., Utkin S. S. Ob ideyakh rasshireniya sistemy obrashcheniya s RAO na promyshlennye otkhody, soderzhashchie tekhnogennye radionuklidy [About the Ideas on Expanding the RW Management System to Cover Industrial Waste Containing Man-made Radionuclides]. *Radioaktivnye otkhody — Radioactive Waste,* 2019, no. 4 (9), pp. 6—13. DOI: 10.25283/2587-9707-2019-4-6-13.

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