

# STATE-OF-ART IN THE IMPROVEMENT OF INDUSTRIAL WASTE MANAGEMENT WITH RADIONUCLIDE LEVELS NOT COMPLYING WITH RADIOACTIVE WASTE ASSIGNMENT CRITERIA

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*The article overviews current practice associated with the management of industrial waste with elevated radionuclide levels (IWERL) not falling under radioactive waste category. It emphasizes that the State Atomic Energy Corporation Rosatom has been actively addressing the challenge of safe IWERL management. A working group has been set featuring experts from FMBA of Russia, Rostekhnadzor, the Russian Academy of Sciences, the State Atomic Energy Corporation Rosatom and its units, as well as independent environmental organizations. The paper evaluates different trends in IWERL management presenting some proposals on the improvement of the legal framework focused on the management of industrial waste containing radioactive substances in quantities not exceeding the criteria established for waste categorization as radioactive waste. It provides IWERL management cost estimates considering various waste management options. IWERL management challenge has been discussed at Scientific and Technical Councils run by 3 government departments, also indicating the interdepartmental nature of this challenge.*

**Keywords:** industrial waste with high radionuclide levels, radioactive waste, production and consumption waste, regulatory and legal support, waste management.

During the implementation of various operations, many organizations, including those involved in the nuclear sector, generate industrial waste with increased radionuclide content that cannot be categorized as radioactive waste according to the established criteria [1]. Recently, the challenges associated with the management of such waste became quite relevant due to the intensification of nuclear decommissioning efforts potentially involving the generation of radioactively contaminated waste that nevertheless cannot be categorized as RW. It should be noted that experts dealing with practical

aspects of waste management, environmental safety and nuclear regulation come up with essentially different standpoints regarding the way in which this challenge can be addressed. There is a lively discussion on this issue in scientific journals [2, 3].

This waste has quite a diverse inventory and composition involving the following waste contaminated with technogenic radionuclides and generated during the operation and decommissioning of nuclear facilities:

- industrial and construction waste;
- wooden crafts;

- metal waste (ferrous and non-ferrous metals), cable waste;
- spent personal protective equipment;
- waste of mineral origin, soil;
- waste of rolled roofing and waterproofing materials.

Another problem should be noted, namely, the one associated with the waste generated during the operation and maintenance of equipment at organizations belonging to the fuel and energy complex contaminated with naturally occurring radionuclides, such as:

- waste from cleaning (decontamination) of oil and gas equipment with an increased content of naturally occurring radionuclides;
- scrap ferrous and non-ferrous metal contaminated with naturally occurring radionuclides.

The above list of waste is far from being exhaustive; it can be expanded accounting for various industries based on specific aspects associated with waste generation. In any case, waste contaminated with naturally occurring and man-made radionuclides that has not been released from radiation control, but are not being considered as RW, requires special safety measures during its management.

The practice of managing such waste that do not belong to the radioactive waste category reveals certain difficulties when it comes to determining the type of waste under consideration. Table 1 provides an overview of the criteria that can be used to categorize waste accounting for the most frequently occurring radionuclides.

It can be stated that as regards the waste neither being categorized as radioactive nor considered as restricted use materials, its range of activity is quite wide and for the overwhelming majority of radionuclides accounts for 1–2 orders of magnitude.

Ambiguity in the name of the considered waste should be noted in particular. Legal framework in the field of production and consumption waste management provides no specific definition for radioactively contaminated waste. Provisions of [5] designate such waste as very low-level waste (VLLW). According to [5], VLLW includes materials, products, equipment and soil not intended for further use that cannot be released from regulatory control based on the specific activity being nevertheless lower than the activity of solid radioactive waste. Provisions of [4] divide solid radioactive waste containing man-made radionuclides into 4 categories, including very low-level radioactive waste (VLRW). The similarities between the above abbreviations (VLLW and VLRW) indicate the potential for confusion, especially for non-specialists. It's considered advisable to give a short name different from VLRW to waste contaminated with radionuclides that

**Table 1. Criteria for waste categorization based on radionuclide specific activities [4]**

Radionuclide	Waste category		
	Unrestricted use materials. Specific activity, Bq/g (Appendices 3, 4 to [4])	Restricted use materials. Specific activity [4], Bq/g	Radioactive waste. Minimum specific activity allowing waste categorization as solid RW, Bq/g (Appendix 5 to [4])
<sup>3</sup> H	100	100–1·10 <sup>6</sup>	1·10 <sup>6</sup>
<sup>14</sup> C	1.0	1.0–1·10 <sup>4</sup>	1·10 <sup>4</sup>
<sup>60</sup> Co	0.1	0.1–10	10
<sup>90</sup> Sr	1.0	1.0–1·10 <sup>2</sup>	1·10 <sup>2</sup>
<sup>137</sup> Cs	0.1	0.1–10	10
<sup>232</sup> Th	0.3	0.3–1	1
<sup>235</sup> U	1.0	1.0–10	10
<sup>238</sup> U	4.0	4.0–10	10
<sup>239</sup> Pu	0.1	0.1–1	1
<sup>241</sup> Am	0.1	0.1–1	1

cannot be categorized as RW. Under the present study, industrial waste with an increased content of radionuclides and not considered as RW are named as industrial waste with elevated radionuclide levels (IWERL).

Two papers [2, 3] provide an in-depth analysis of current legal framework and regulatory legal acts (RLA) of ministries and departments covering the fields of production and consumption waste management and radioactive waste management. They present the approaches applied to implement legislative provisions and RLAs to waste contaminated with radionuclides and being categorized as RW. Since this matter has been widely discussed in other literature sources, current study does not provide any overview of relevant legal framework and RLAs.

This study aims to inform specialists and the expert community about the latest progress associated with the improvement of regulatory legal framework dealing with IWERL management.

At the initiative of the State Atomic Energy Corporation Rosatom, the task of improving the regulatory legal framework addressing the management of such waste has been reflected in the action plan for the implementation of the State Policy Fundamentals in the Field of Nuclear and Radiation Safety of the Russian Federation Until 2025 and Beyond approved by the Government order of the Russian Federation No. 139-R of February 2, 2019.

A working group has been set in Rosatom to develop the proposals on the improvement of the legal regulatory framework dealing with IWERL management. The group features representatives of the

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FMBA of Russia, Rostekhnadzor, the Russian Academy of Sciences, Rosatom and its organizations, independent environmental organizations.

The working group noted that IWERL should be managed:

- in keeping with the legislative norms of the Russian Federation and the legal regulatory acts of federal executive bodies during the management of production and consumption waste;
- given unconditional assurance of IWERL management safety;
- providing economic efficiency.

The working group has considered three focus areas for further improvement of legal framework and legal regulatory support associated with IWERL management:

Focus area 1: Improvement of regulatory and legal support system in the field of production and consumption waste management;

Focus area 2: Improvement of regulatory and legal support system in the field of radioactive waste management;

Focus area 3: Establishment of an independent regulatory and legal support system for IWERL management.

Table 2 evaluates the above areas of IWERL management.

Obviously, given the current setup when it comes to IWERL management, the highest level of safety is

achieved in case if it is managed as radioactive waste. However, as shown in [3], this approach contradicts the concept of USS RW development leading to excessive safety requirements for IWERL management actually resulting in a significant cost increase.

The idea, developed in [6], looks quite attractive. It considers the use of packages filled with IWERL in the construction of buffer zones inside radioactive waste disposal facilities (RWDF) after the completion of RW emplacement operations allowing, on the one hand, to reduce the consumption of clean materials. On the other hand, RW packages with extremely low activities or IWERL will no longer require its disposal in near-surface RWDF or other facilities. Another topic requiring further exploration are the opportunities for IWERL application as a backfill material in safety barriers at RWDF providing unconditional radiation safety.

Current legal framework suggests that IWERL are formally managed under the system of legal regulations covering production and consumption waste management. However, as practice shows, it appears quite difficult to dispose IWERL at industrial waste landfills even if these are indicated in the Federal Waste Classification Catalog (FWCC) [7]. Unlike the system of radioactive waste management with FSUE NO RAO being responsible for waste disposal and the payments made according to approved tariffs, landfills accepting industrial waste

**Table 2. Summary of IWERL management focus areas**

Focus area	Positive aspects	Negative aspects
Improvement of regulatory and legal support system in the field of production and consumption waste management	<ul style="list-style-type: none"> <li>• current legislation provides that IWERL management is implemented as part of production and consumption waste management system;</li> <li>• IWERL management is built into a system declared as operational</li> </ul>	<ul style="list-style-type: none"> <li>• safety of IWERL management is not provided at waste landfills since radioactive substances are released into the environment;</li> <li>• owners are not willing to accommodate IWERL in waste landfills (including the need for capital investments into IWERL site mapping and security systems);</li> <li>• new regulations are to be developed and approved.</li> </ul>
Improvement of regulatory and legal support system in the field of radioactive waste management	<ul style="list-style-type: none"> <li>• safety of IWERL management is provided;</li> <li>• complies with IAEA recommendations;</li> <li>• IWERL management is built into the operating system</li> </ul>	<ul style="list-style-type: none"> <li>• unavailability of disposal facilities for the generated IWERL inventory (USS RW infrastructure is not able to accept such waste amounts);</li> <li>• significant increase in the federal budget expenditures;</li> <li>• loss of the export potential for Russian nuclear technologies due to a sharp increase in the volume of RW generation due to a significant increase in the obligations under IFRS;</li> <li>• new regulations should be developed and approved (for example, requirements for IWERL disposal facilities at NFC enterprises)</li> </ul>
Establishment of a separate system for IWERL management	<ul style="list-style-type: none"> <li>• IWERL management safety is provided via its accommodation at industrial nuclear sites (including the sites where the nuclear decommissioning is actually taking place);</li> <li>• opportunities for IWERL use in the construction of safety barriers at disposal facilities designed for non-retrievable radioactive waste at nuclear sites. These provisions can be also implemented under the above two areas</li> </ul>	<ul style="list-style-type: none"> <li>• a new system of IWERL management should be built from scratch.</li> </ul>

of various hazard classes for disposal are mostly privatized and are operated under market pricing conditions. IWERL disposal at industrial waste landfills will require its owners to make certain investments in additional safety and monitoring systems. Under market conditions of the economy, to fill up the intended landfill capacities, the owners of such waste shall supply stable IWERL stream being evenly distributed over time, which is not always possible in practice. Negative public response triggered by radiophobia is seen as another factor hindering IWERL disposal at industrial waste landfills.

IWERL disposal at nuclear sites is viewed as a possible option providing unconditional safety of its management. A similar option is provided for very low-level waste by the order of the Government of the Russian Federation No. 2499-r of December 7, 2015, specifying a list of organizations that can dispose of the indicated waste in RW disposal facilities located on land plots used by such organizations. It seems feasible to consider the issue suggesting that a number of nuclear facilities can be granted the right to dispose on their territory the IWERL generated both due to the activities performed by the organization and the operation of other nuclear facilities. Such an approach seems to be quite relevant considering the expansion of nuclear decommissioning efforts, since many decommissioned facilities are located in settlements, including big cities, where operating organizations do not have the ability to dispose of the waste on their territories. It seems that in order to implement such an IWERL disposal method, the category of this waste should be formally defined under relevant legislative provisions. This can be done by adding relevant definition to the Law of the Russian Federation No. 170-FZ: "industrial waste containing radioactive substances, namely, materials and substances not subject to any further use, as well as equipment, products, the content of radioactive substances in which is below the criteria used to categorize waste as radioactive." After addressing this issue at the legislative level, appropriate criteria should be established in the same way as those set up for radioactive waste. It seems also worth to indicate possible disposal options for such waste under relevant provisions of a Government decree of the Russian Federation.

It should be noted as well that the order of the Ministry of Natural Resources No. 536 of December 4, 2014 On Approved Criteria for Categorizing Waste as the Waste of I-IV Hazard Classes According to the Degree of Negative Environmental Impact does not establish physical characteristics of waste with an increased content of radionuclides in terms of its impact on the environment. For this reason, the effect of radiation component is not considered at all during the categorization of waste according to the hazard classes.

Price component of IWERL management along with the one associated with its safe management will be considered as key factors governing the management flowcharts. The cost of IWERL management was evaluated considering three possible disposal options:

- IWERL is disposed of as RW;
- IWERL is disposed of at industrial waste landfills;
- IWERL is disposed of at industrial sites of nuclear facilities.

Table 3 presents maximum and minimum costs associated with the implementation of the above three options.

Estimates show that the cheapest IWERL management option suggests its disposal at industrial sites of NF either in storage facilities intended for IWERL (the cost of waste emplacement can vary up to 100 times depending on the costs of preliminary treatment and the emplacement itself) or at landfills for industrial waste (in this case, the cost of waste emplacement can vary up to 1,000 times, depending on the availability of landfills and relevant conditions for IWERL emplacement).

Another option suggests that IWERL are handed over to organizations that will condition them in accordance with the disposal criteria (decontamination, etc.) established for industrial waste landfills (unrestricted use materials) and dispose of the resulting radioactive waste of a significantly smaller volume (cost characteristics associated with this option were estimated as follows: the minimum cost – 17.15 thousand rubles/m<sup>3</sup>, the maximum cost – 109.931 thousand rubles/ton).

This option will be considered as a market service and its cost per IWERL unit (cubic m/t) will depend on the decontamination method, its cost and the cost of waste disposal at landfills.

It should be stated once again that since IWERL is not radioactive waste, its accommodation in RW

**Table 3. Costs of IWERL management**

Management cost	IWERL are disposed of as RW	IWERL are disposed of at industrial waste landfills	IWERL are disposed of at nuclear sites
Minimum	13.00 thousand rubles/m <sup>3</sup>	0.146 thousand rubles/m <sup>3</sup>	0.207 thousand rubles/t
Maximum	1,235.672 thousand rubles/m <sup>3</sup>	148 thousand rubles/m <sup>3</sup>	19.393 thousand rubles/t

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disposal facilities (as an item subject to disposal), on the one hand, is prohibited by law, and on the other hand, is seen as the costliest option.

IWERL generation was estimated for the period up to 2025–2030 accounting for two main streams:

Stream 1. Generation due to production activities of organizations managing NM, RS, RW.

It is highly probable (90–98%) to predict the amount of IWERL generation under this stream, since the main production processes are known and the associated generation of waste is a controlled process aimed at reducing its volume and the management costs.

Stream 2. Generation due to nuclear decommissioning.

Reduction of waste amounts and relevant costs associated with its management is seen as a key task of the waste management process during nuclear decommissioning.

Nuclear decommissioning experience shows that the share of waste management costs (radioactive waste, "clean" waste, IWERL) can reach up to 60–70% of the project budget. Moreover, at the stages of KIRO (comprehensive engineering and radiation survey), design development and decommissioning itself, the volume of waste can vary significantly (especially when it comes to low-level waste: VLRW and IWERL). In this regard, it seems quite difficult to estimate actual volumes of IWERL generation from nuclear decommissioning [8, 9].

Imperfection of the legal framework is seen as the second important aspect prompting uncertainty in the assessment of IWERL generation volumes. At present time, it appears quite challenging to provide relevant indications on IWERL amounts in the design documentation developed under nuclear decommissioning designs subject to the state environmental impact assessment, since it is often impossible to indicate their location (on the one hand, its disposal similarly to radioactive waste, as shown above, is estimated as a very costly option and contravene the law of the Russian Federation on RW, on the other hand, it will be not possible to dispose it of at industrial waste landfills since the majority of the items is missing in the FWCC).

Similar problem will arise during the decommissioning of NPP units, since in many cases the capacity of VLLW disposal facilities [5] will be insufficient to accommodate the entire volume of generated IWERL. Therefore, the envisaged IWERL generation amounts are often not reflected in the decommissioning designs.

It was estimated that by 2025 the amount of IWERL generation can amount to 123,000 m<sup>3</sup>. Pre-decommissioning and decommissioning of NPP units, as well as nuclear fuel cycle facilities, will

further increase its volume in the period up to 2030 and beyond.

IWERL management challenges were discussed in specialized publications and also considered at following STC meetings: STC No. 10 of the State Corporation Rosatom (December 17, 2019), STC section No. 3 of Rostechnadzor (February 12, 2020), session on regulation and standardization of production and consumption waste management activities under the STC run by Rosprirodnadzor (September 25, 2020). Summary documents of these meetings emphasize the inadequacy of the regulatory framework addressing IWERL management, including the radiation safety requirements also indicating the interdepartmental nature of this challenge.

To date, the State Atomic Energy Corporation Rosatom has developed relevant proposals to improve the regulatory legal framework governing the management of industrial waste containing radioactive substances in quantities that do not meet the criteria allowing to categorize it as radioactive. These proposals were submitted to interested federal executive authorities, namely those considering:

- the amendments to be introduced to the Federal law No. 89-FZ of June 26, 1998 On Production and Consumption Waste establishing the definition of industrial waste containing radioactive substances in quantities that do not meet the criteria allowing it to be categorized as radioactive waste;
- the amendments to be introduced to the order of the Ministry of Natural Resources No. 536 of December 4, 2014 On Approved Criteria for Categorizing Waste as the Waste of Hazard Classes I-IV According to the Degree of Negative Environmental Impact accounting for the physical characteristics of the waste with an increased content of radionuclides given the associated environmental impact;
- the need to develop requirements for the management of homogeneous waste groups, namely, Waste Generated from Construction and Maintenance of Radiation Hazardous Facilities, Waste with an Increased Content of Naturally Occurring Radionuclides from Radioactive Waste Decontamination, Waste with an Increased Content of Technogenic Radionuclides from Radioactive Waste Decontamination with their subsequent approval by relevant order of the Ministry of Natural Resources;
- the need to develop sanitary rules for IWERL disposal, including relevant requirements elaborating on disposal conditions and methods, design of disposal facilities, requirements for waste disposed of at disposal facilities and radiation safety;
- the amendments to be introduced to the order of Rosprirodnadzor No. 242 of May 22, 2017

On the Approved Federal Waste Classification Catalog establishing the ID of FWCC 8 85 100 00 00 for Waste from the Construction, Operation and Decommissioning of Nuclear and Radiation Hazardous Facilities.

It should be noted that by addressing the IWERL challenge at the legislative level, adequate conditions providing its safe management can be established, thus, increasing the environmental safety of production not only in the nuclear sector, but in other industries as well.

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