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ABOUT SOME PRACTICAL ASPECTS OF HANDLING WITH RADIOACTIVE WASTE FROM SMALL MODULAR REACTORS PARTICIPATING IN THE "FIRST" PROGRAM

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This article provides an examination of approaches to the management of radioactive waste generated by small modular reactors. These approaches are based on the IAEA principles and take into account the experience of pilot and commercial operation of nuclear installations based on small modular reactors. The article contains comparative aspects of the production of radioactive waste at various types of nuclear installations and approaches to managing radioactive waste data.

Keywords: *small modular reactors, radioactive waste, nuclear power, reactor electric power, types of radioactive waste, nuclear fuel.*

INTRODUCTION

Within the framework of a joint project with the International Science and Technology Center, activities are being carried out to support energy innovation and develop technical cooperation with partner countries in the field of reliable and safe nuclear energy infrastructure. This cooperation includes support for the implementation of advanced nuclear technologies, including small modular reactors (SMRs), in accordance with the approach of the International Atomic Energy Agency (IAEA) to the implementation of a responsible nuclear energy program. The President of the Republic of Kazakhstan, Kassym-Jomart Tokayev, emphasized the need to build additional NPPs after the first one, while emphasizing interest in the construction of NPPs based on small modular reactors (SMRs) for the purpose of decentralizing the energy infrastructure [1]. Thus, Kazakhstan is considering the possibility of constructing and using small modular reactors in the energy sector [2].

Since 2012, the IAEA has been keeping records of small modular reactor (SMR) projects. The latest edition presents eighty-three projects [3, 4]. Although there are about a hundred projects in the world as of 2024, only active projects with demonstrated sustainable performance were selected for the catalog, but some of them will not even turn into real commercial products, since some projects are developed as proofs of concept or educational material.

ABOUT POTENTIAL CANDIDATE SMR TYPES FOR THE REPUBLIC OF KAZAKHSTAN

Candidate SMR sites

Existing SMR designs are grouped into four different technology lines: water-cooled reactors, high-temperature gas-cooled reactors, liquid metal fast reactors and molten salt reactors, and have two additional categories – floating nuclear power plants and microreactors, which can rely on the above technology lines.

Each group of SMRs has its own distinctive features.

The land-based water-cooled SMR family includes a variety of light water reactor (LWR) and heavy water reactor (HWR) designs for land-based grid applications: integral PWRs, compact PWRs, loop PWRs, BWRs, and pool-type reactors for district heating. These designs represent mature technology, given that most large power plants in operation today use water-cooled reactors. There are currently 15 water-cooled SMR designs.

The offshore water-cooled SMR family includes concepts that can be deployed in the offshore environment, either as a floating barge-mounted unit or a submersible underwater unit. The group includes 6 offshore water-cooled SMR designs, some of which have been deployed as nuclear icebreakers. The High Temperature Gas Cooled SMR family features 14 modular HTGR designs currently under development and construction. HTGRs produce high temperature heat (≥750 °C) that can be used for more efficient power generation, a variety of industrial applications, and cogeneration.

The Fast Spectrum SMR family features 10 reactor designs that utilize the fast spectrum with a variety of coolant options including sodium, a heavy liquid metal (such as lead or lead-bismuth), and helium-gas.

The Molten Salt SMR family features 12 designs derived from advances in molten salt reactor (MSR) technology. MSRs promise many benefits, including improved safety due to the inherent properties of salt, a low-pressure, single-phase cooling system that eliminates the need for a large containment vessel, a high temperature system that provides high efficiency, and a flexible fuel cycle. The micro-SMR group includes 13 reactor designs designed to generate electricity, typically up to 10 MW(e). Micro-reactors can serve future niche electricity and district heating markets in remote regions, mining, manufacturing, and fisheries that have been served for decades by diesel power plants.

One of the promising areas of SMR technology development involves replacing existing and aging coal-fired plants with SMR plants. The main advantages of this direction of SMR technology implementation are the use of existing infrastructure, as well as the reduction of greenhouse gas emissions, which is relevant in light of the country's goals to achieve carbon neutrality.

Kazakhstan has a fairly large fleet of thermal power plants (TPPs) operating on coal and fuel oil (Figure 1).

Figure 1. Distribution of thermal power plants with a capacity of over 10 MW across the territory of the Republic of Kazakhstan

Most thermal power plants in Kazakhstan were commissioned in the 60s and 70s of the last century, and some even earlier. Many of them have not undergone major repairs and equipment modernization for decades. As a result, today the wear and tear of the main equipment at power plants reaches more than 50%. More than a third of the plants have a wear and tear of 70%–90% [5]. Therefore, considering the issue of constructing nuclear power plants with SMR in Kazakhstan in the context of replacing outdated thermal power plants is relevant and promising.

An alternative zone for the placement of SMR is Western Kazakhstan. Units with a capacity of 200–600 MW(e). This choice is dictated by the fact that the existing infrastructure will not allow higher-capacity units to operate stably and, in the event of an emergency with their disconnection from the power grid will lead to the disconnection of a large number of consumers at once [6].

SMR Selection Criteria

To identify promising SMR projects for their implementation in the energy system (ES) of the Republic of Kazakhstan, a preliminary ranking of the installations can be made according to the following criteria:

− technology: a water-cooled thermal neutron reactor (as the most common and proven technology) or a high-temperature gas-cooled reactor.

− design: ground-based (based on the specifics of the reactor's applicability in Kazakhstan).

− capacity: 50–300 MW(e) – for the possibility of use in industrial complexes) or up to 600 MW(e);

− project development: stage of completion of the licensing process, stage of construction, operation (preference for reference technology or expected by 2035).

− service life: at least 60 years;

− campaign: more than 24 months (the frequency of refueling is on average higher than for high-power reactors);

− enrichment of the core fuel: no more than 20% (in accordance with non-proliferation requirements);

− safety: seismic resistance (more than 0.2 g), presence of passive protection elements, possibility of natural circulation of the coolant.

Financial and economic parameters are not considered at this stage, since there is no reliable information on this issue, taking into account the current status of development of most SMR projects.

SMR Acceptability Analysis for the Republic of Kazakhstan

According to the IAEA [1], there are currently 6 reactor plants at advanced stages of construction that are considered preferred technologies in the subject area under consideration (participation in the FIRST program) and are in the specified range of generated electric power: BWRX-300 (GE-Hitachi Nuclear Energy and Hitachi GE-Nuclear Energy, USA-Japan), NuScale Power Module (NuScale Power LLC, USA), SMART (KAERI, South Korea and K.A. CARE, Saudi Arabia), Rolls-Royce SMR (Rolls-Royce, UK).

Table 1 below provides detailed characteristics of the SMRs under consideration.

Table 1. Technical and economic indicators of small and medium-power modular reactors [7–18]

Indicator Name	Magnitude (characteristic)			
Reactor	**BWRX-300**	**NuScale**	**SMART**	**Rolls-Royce SMR**
Reactor type	BWR	PWR	PWR	PWR
Coolant/moderator	H_2O	H_2O	H_2O	H_2O
Reactor thermal power, MW	870	200	365	1276
Installed electric power, MW	270–290	60	107	443
Fuel Type	UO_2 (array 10 × 10)	UO_2 (square 17 × 17)	UO_2 (square 17 × 17)	UO_2 (square 17 × 17)
Enrichment on U-235, %	3.4 (avg.) 4.95 (max.)	<4.95	<5	<4.95
Number of fuel assemblies, pcs	240	37	57	121
Average burnup GW-day/tU	49.5	>30	<54	55–60
Fuel reloading, month	12–24	24	30	18–24
Reactivity control mechanism	reactor protection control system and solid absorbers (B_4C, Hf, Gd_2O_3)	reactor protection control system and Boron	reactor protection control system and Boron	reactor protection control system and Gd_2O_3 solid burnable absorber
Safety Systems	passive	passive	passive	combined passive and active
Plant service life, years	60	60	60	60
Plant area, m^2	8 400	140 000	90 000	10 000
Reactor vessel height/diameter, m	26 / 4	17.7 / 2.7	18.5 / 6.5	11.3 / 4.5
SSE seismic resistance	0.3 g	0.5 g horizontal 0.4 g vertical peak ground acceleration	> 0.3 g & 0.18 g automatic shutdown	> 0.3 g
Approach to the final stage of the NFC	dry underground/ 5 600 $м^3$	a nuclear power plant spent fuel pool that provides storage of spent nuclear fuel for up to 10 years	interim storage of spent nuclear fuel at nuclear power plants	temporary storage in a NPP spent fuel pool before sending to a dry spent fuel storage facility

At this stage of considering the possibility of implementing SMRs in the Republic of Kazakhstan, the following reactors can be recommended from the technologies that are being considered within the framework of a joint project with the International Scientific and Technical Center: BWRX-300, NuScale, SMART.

In case of positive experience in construction and operation, as well as confirmation of economic parameters that meet the conditions of the Republic of Kazakhstan to ensure energy production in the medium power range (300–600 MW), the Rolls-Royce SMR reactor can be recommended for consideration.

As noted in Table 1, each of these SMR projects already has a ready-made approach to the final stage of the nuclear fuel cycle – sending irradiated nuclear fuel to temporary storage at the NPP site, then to a separate storage facility or to a spent nuclear fuel reprocessing plant, and ends with the final removal of high-level waste after SNF reprocessing.

They are discussed in more detail below.

WASTE MANAGEMENT AND DISPOSAL PLAN FOR SELECTED PLANTS

BWRX-300 (GE Hitachi, USA-Japan)

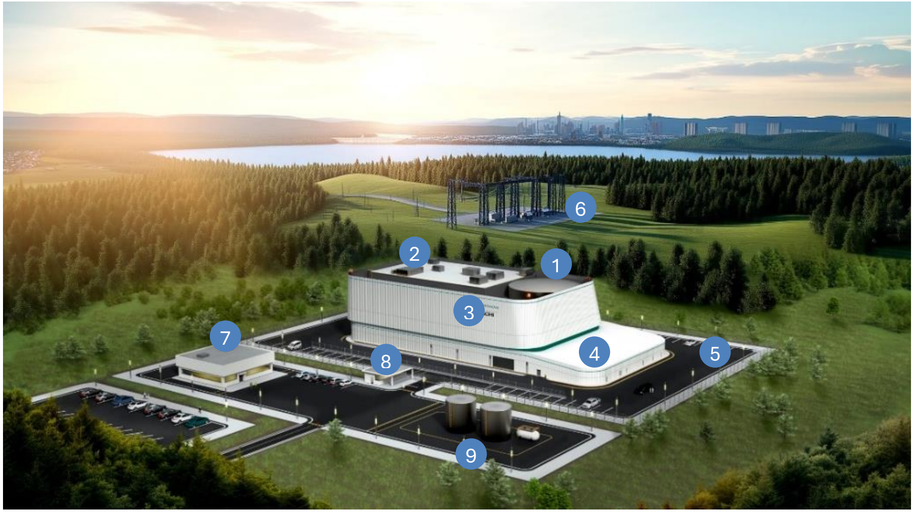
The BWRX-300 plant layout includes a central reactor building (RB) with a cylindrical shaft, surrounded by a control building (CB), a turbine building (TB), and a radioactive waste building (RW). The RB, a seismic category 1 structure, houses the reactor vessel and primary containment. The CB contains the control systems, the TB contains the turbine and generator systems, and the RW contains the radioactive waste systems.

The BWRX-300 uses a standard approach to the BWR fuel cycle with an emphasis on efficiency and safety. It uses low enriched uranium (LEU) fuel assemblies. The plant design supports fuel cycles ranging from 12 to 24 months.

The BWRX-300 is designed for optimal resource utilization and waste management, with the goal of minimizing the consumption of non-renewable resources and reducing the generation of radioactive waste. The plant is equipped with advanced systems such as the Liquid Waste Management System (LWM) and the Off-Gas System (OGS), to minimize emissions to the environment and ensure low radiation doses to workers.

NuScale (NuScale Power Inc., USA)

The NuScale Power Module™ (NPM) is a small pressurized light-water reactor (PWR). The NuScale plant is scalable and can be built to accommodate varying numbers of NPMs to meet customer energy needs. The 77 MW(e) NPM delivers power in increments that can be scaled up to 925 MW(e) gross in a single twelve-module plant. The twelve-module configuration is the reference plant size for design and licensing. Each NPM is a standalone module that operates independently of the other modules in a multi-module configuration. All modules are controlled from a single control room.



1 – Reactor Building; 2 – Turbine Building; 3 – Radwaste Building; 4 – Control Building; 5 – Protected Area; 6 – Switchyard; 7 – Admin Building; 8 – Security Building; 9 – Tanks & Skids

Figure 2. BWRX-300 SMR Power Plant

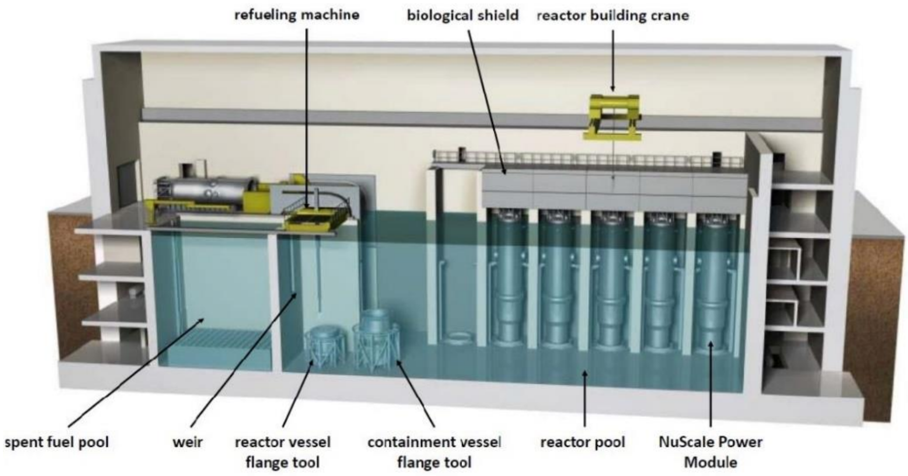


Figure 3. SMR Power Plant with NuScale NPM

The spent fuel is stored in a stainless steel lined concrete pool adjacent to the reactor pool. Its location below ground level significantly reduces the potential for cooling water loss. The NuScale spent fuel pool provides storage for up to 10 years of spent fuel, as well as temporary storage of new fuel assemblies. The pool water volume provides approximately 150 days of passive cooling of the spent fuel assemblies after the loss of all electrical power without the need for additional water.

The cleaning system reduces contaminant buildup. After about 5 years, the thermal load of the spent fuel assemblies is significantly reduced and they can be moved to a safe dry storage facility. The power plant site layout includes the allocation of space sufficient for dry storage of all spent fuel for the 60-year life of the plant.

SMART (KAERI – KEPCO and K.A. CARE, South Korea and Saudi Arabia)

The reactor name is an abbreviation for System-integrated Modular Advanced ReacTor. This is a light-water reactor with a thermal capacity of 330 MW. In the power generation mode, the station with such a reactor has a capacity of 90 MW. In the desalination station mode, the unit with the SMART reactor will produce up to 40 thousand tons of drinking water daily. Another possible application of SMART is heating of nearby areas. The SMART project combines both proven technologies and innovative solutions. The former include, for example, the use of a standard 17 × 17 square fuel assembly with uranium dioxide fuel, the presence of a large dry containment, the design of the control and protection system drives, and reactivity control using rods and boric acid. Among the innovative solutions, an integral layout stands out – all the main components of the primary circuit are located inside the reactor vessel. ASMM SMART actively uses the modular principle, which simplifies its construction. The station's control systems are completely digital.

Figure 4. SMART SMR Power Plant

The SMART NPP is designed with a water intake structure and other buildings including the on-site chlorination building. The power unit houses the reactor containment and auxiliary buildings (RCAB), the turbogenerator buildings and one complex building common to the two SMART units.

The RCAB houses the reactor containment, auxiliary and fuel areas to accommodate the small and modular plant concept.

The reactor containment area consists of the LCA and the UCA.

The SMART fuel cycle is 30 months. KEPCO-NF can provide SMART fuel with its fuel fabrication capacity increment schedule. SMART spent fuel is stored in a spent fuel pool using storage racks. The current storage capacity of the spent fuel storage racks is 30 years, which can be changed depending on the owner's requirements.

SMART has several design solutions to minimize the generation of radioactive waste. All liquid radioactive waste will be treated with a demineralization package, which can simplify the system design and minimize the transportation of solid waste. The gaseous radioactive waste system ensures sufficient contained decay of radioactive waste and controlled release of gases. The solid radioactive waste disposal system uses polymer curing technology, which can minimize the volumes of resin shipped.

Rolls-Royce SMR, Rolls-Royce, Great Britain

The Rolls-Royce SMR project is a medium power reactor project with an electrical power of 443 MW(e) and a thermal power of 1276 MW(t).

The Rolls-Royce SMR reactor is a pressurized light water reactor. The reactor plant is a three-loop, dual-circuit reactor with centrifugal pumps in the primary circuit.

Uranium enrichment is within the limits available for commercial light water reactors – up to 4.95%. The reactor campaign is from 18 to 24 months. The maximum burnup is 55–60 GW·day/t.

Both active and passive safety systems are assumed. The design service life of the reactor is 60 years.

The steam generator is vertical, with U-shaped tubes.

The design features include a compact site, a modular approach to construction, and "austere and functional external systems that are resilient to hazards". The Rolls-Royce SMR project provides for the highest possible standardization and serialization (repeatability). The production time for block modules for one block is 500 days, and the modular approach minimizes construction time on site.

The block modules can be transported by any means – roads, railways, waterways. In particular, due to this condition, the diameter of the UK SMR reactor vessel was limited to 4.5 meters in order to be able to transport it on British railways.

As it approaches equilibrium, the Rolls-Royce SMR operates on an 18-month fuel cycle with a three-batch equilibrium active bed. The spent fuel is subsequently transferred to a spent fuel pool adjacent to the containment building for storage prior to transfer to long-term dry cask storage.

Rolls-Royce SMR waste treatment systems are based on proven technologies and best available techniques. Industry lessons learned and best practice have been incorporated into the design of the systems to minimize active and inactive waste and discharges through both accepted design and operational practices.

Standardized waste treatment system components and modules are used to achieve the flexibility required for waste-informed design. Operation without soluble boron in the primary coolant allows for significant reductions in environmental discharges while simplifying the waste treatment systems.

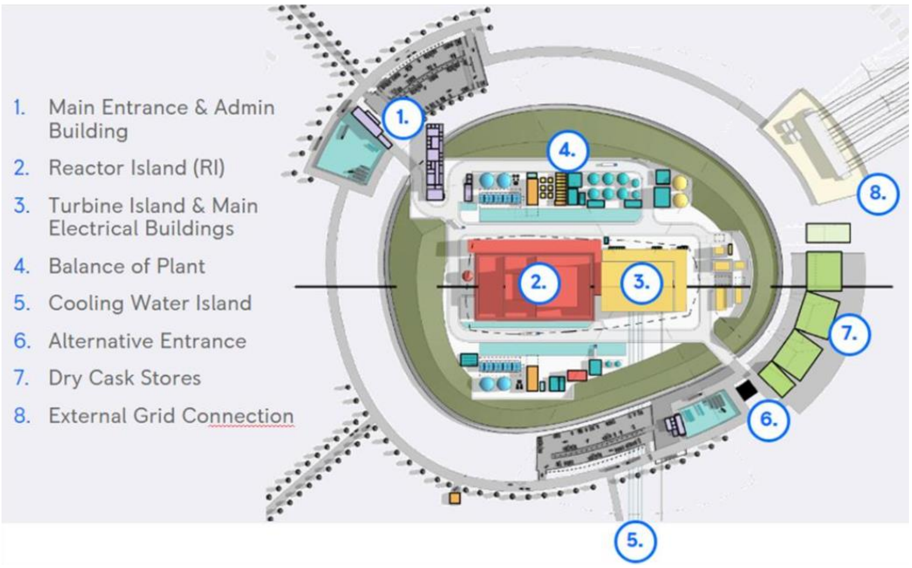


Figure 5. Rolls-Royce SMR Power Plant

It should also be noted that the design and construction of nuclear facilities, such as nuclear power plants, also require compliance with very stringent safety requirements, particularly nuclear security. These requirements are driven by the need to prevent threats inherent to facilities using nuclear materials, including potential theft of nuclear material and sabotage related to both the material itself and the nuclear facility as a whole [19].

FEATURES OF FORMATION OF RADIOACTIVE WASTE USING SMR TECHNOLOGY

Classification of radioactive waste

In principle, NPPs with high-power units do not differ from SMR stations. Therefore, the production and sources of RW formation for both types of stations can be considered similar.

The source of NPP RW is the processes of fission of fuel nuclei (^{235}U, ^{233}U, ^{239}Pu) and neutron activation of various materials present in the reactor core and near-reactor space, corrosion products of structural materials, coolant and moderator impurities, fuel nuclei themselves, air in reactor rooms, etc. The overwhelming majority of radioactive substances formed during reactor operation are concentrated in the fuel.

A small portion of the fission products released during normal reactor operation from the fuel into the coolant, and a portion of the neutron activation products formed outside the fuel elements, as a result of certain technological operations, are continuously or periodically discharged into the plant's processing and storage systems and form operational NPP RW.

NPP RW also includes waste from NPP decommissioning (dismantling of equipment, dismantling of buildings and structures, etc.).

RW is classified at all stages of RW handling: at the time of formation, during processing, during storage, transportation, when determining the method of final disposal.

NPP RW are classified in terms of their potential hazard by several parameters (Figure 6):

− by aggregate state;
− by activity and heat emission levels;
− by the half-life of radionuclides, which determines the time of their potential hazard;
− by the nature of the predominant radiation – α-emitters, β-emitters, γ-emitters (Table 2).

There are both qualitative and quantitative systems for classifying radioactive waste, developed taking into account the requirements of radiation and environmental safety, technological features of processing, transportation, storage, disposal.

Table 2. Categorization of solid and liquid radioactive waste by specific activity of radionuclides

RW Category		Specific activity, Bq/g			
		Tritium	β-emitting radionuclides (excluding tritium)	α-emitting radionuclides (excluding transuranic)	Transuranic radionuclides
SRW	Low-level	from 10^7 to 10^8	from 10^3 to 10^4	from 10^2 to 10^3	from 10 to 10^2
	Intermediate-level	from 10^8 to 10^{11}	from 10^4 to 10^7	from 10^3 to 10^6	from 10^2 to 10^5
	High-level	more than 10^{11}	more than 10^7	more than 10^6	more than 10^5
LRW	Low-level	up to 10^4	up to 10^3	up to 10^2	up to 10
	Intermediate-level	from 10^4 to 10^8	from 10^3 to 10^7	from 10^2 to 10^6	from 10 to 10^5
	High-level	more than 10^8	more than 10^7	more than 10^6	more than 10^5

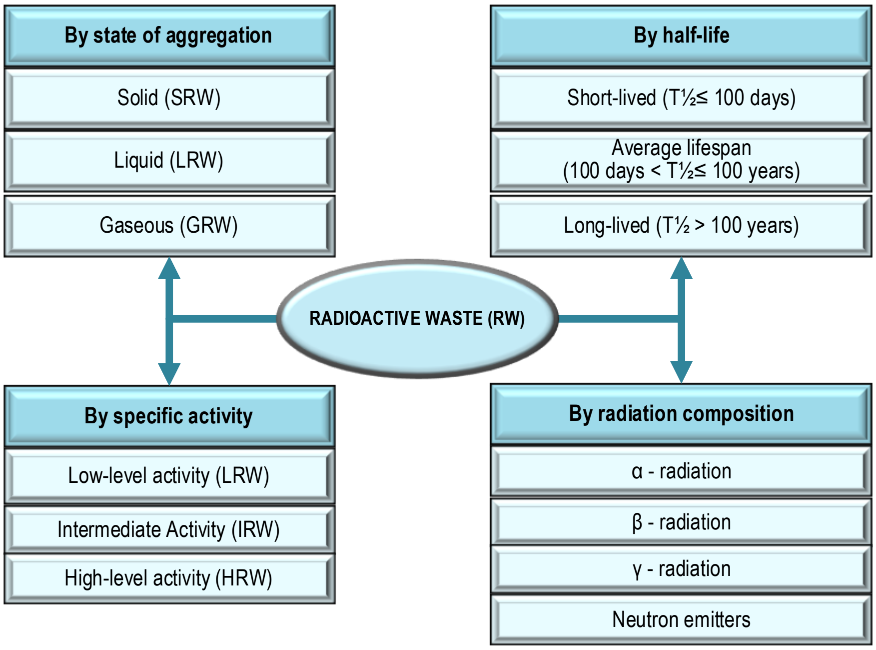


Figure 6. Classification of radioactive waste

Preliminary sorting of SRW is performed using the categorization of SRW by the level of surface radioactive contamination, as well as by the dose rate of γ-radiation at a distance of 0.1 m from the surface of the RAW:

1) low-level RAW – from 0.001 to 0.3 mSv/h;
2) medium-level RAW – from 0.3 to 10 mSv/h;
3) high-level RAW – more than 10 mSv/h.

Methods of handling and processing of radioactive waste

At the operational level, in addition to the mandatory classification of radioactive waste according to the degree of its potential danger, additional separation of waste into streams within each class is carried out, which allows not only the effective use of existing processing and conditioning technologies, but also ensures the safety and quality requirements for the final forms and packaging of waste (these requirements are determined by the requirements for transportation, storage and disposal for each class of waste).

Based on these parameters, the classification of waste from the operation of NPPs in the general case is presented in Figure 7. Before final isolation, radioactive waste is processed. The known methods used at NPPs are shown in Figure 8.

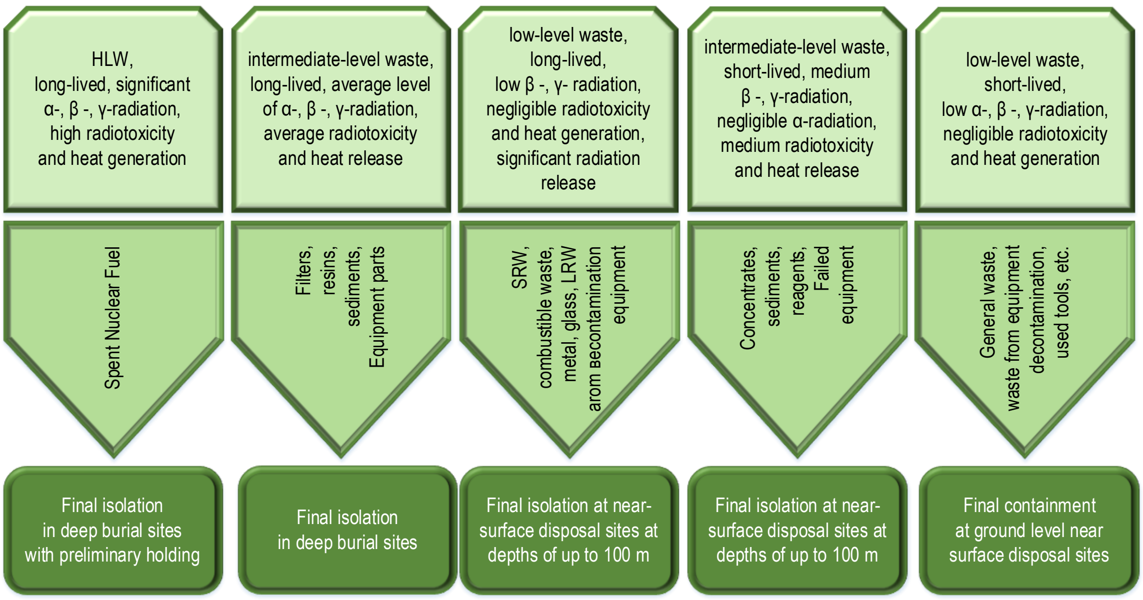


Figure 7. Scheme of handling radioactive waste of different categories

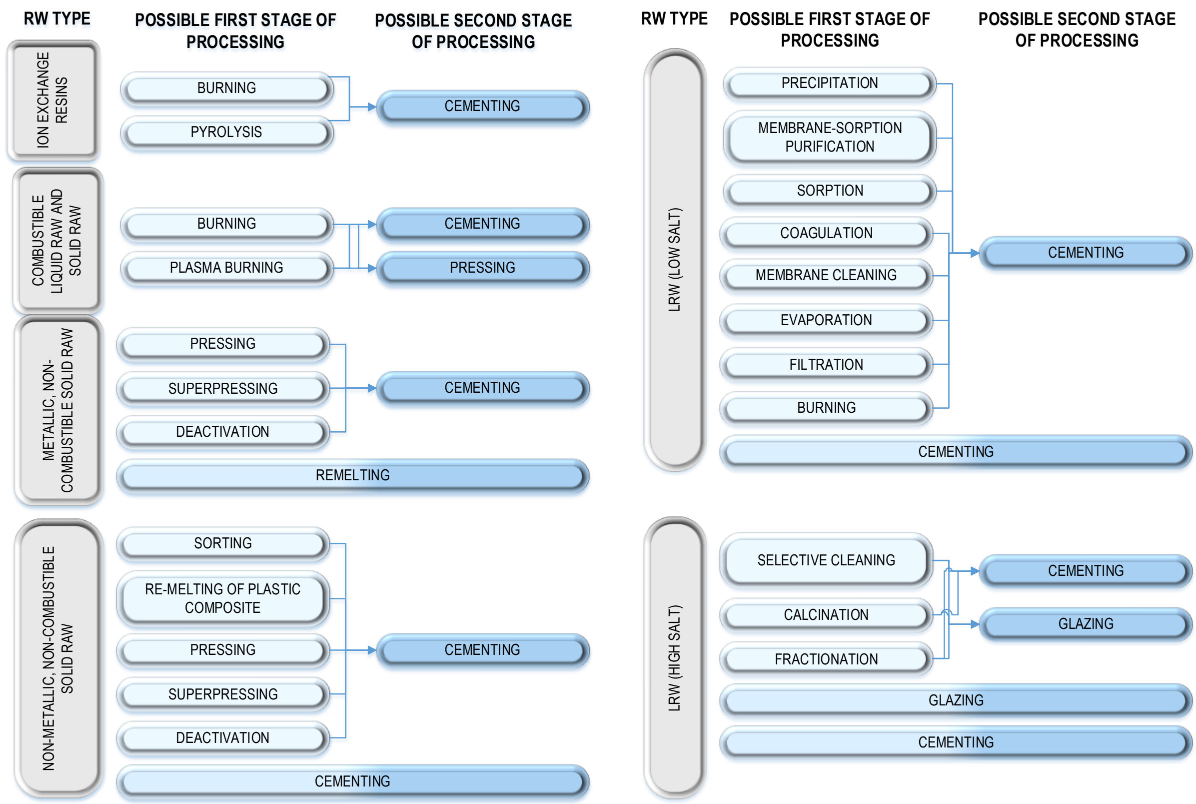


Figure 8. Methods of RW processing

RESULTS AND DISCUSSION

In general, the amount of radioactive waste generated during the operation of a nuclear power plant and during its decommissioning strongly depends on the applied handling technologies and on the country's regulatory requirements for RW handling. The figures given in various literature and sources differ by orders of magnitude.

The assessment of the generated RW volumes at SMRs was performed using the median RW generation rate for water-cooled reactors given in [20, 21] (see Table 3).

Table 3. Median RW generation rate calculation, m³/GW·h

RW Category	Total amount	
	LRW	SRW
Very low-level	0.0005	0.014
Low-level	–	0.009
Intermediate-level	0.018	0.0013
High-level	–	0.000023

The volume of radioactive waste generated during normal operation of SMRs based on water-moderated reactors is given in Table 4.

For each type of SMR, the volume of radioactive waste was calculated for the entire period of operation of the plant (Table 5).

It was considered that during the operation of a 1 GW NPP with a water-moderated reactor, the total volume of RW for the entire period of operation is ≈90·10³ m³, of which:

- ILW – 65·10³ m³;
- LLW – 25·10³ m³.

When decommissioning a NPP, the total volume of RW is ≈100·10³ m³, of which:

- ILW – 12·10³ m³;
- LLW – 88·10³ m³.

According to other data, on average, depending on the capacity and type of the reactor installation, it was indicated that from 0.15 to 0.35 m³ of liquid and from 0.1 to 0.3 m³ of solid RW per 1 MW are formed per year. When recalculated for 50 years of operation, this amounts to 7,500–17,500 m³ of liquid RW and 5,000–15,000 m³ of solid RW.

Table 4. Calculation of the volume of different types of generated radioactive waste per 1 MW(e), m³/year

RW Category		SMR Type			
		BWRX-300	NuScale	SMART	Rolls-Royce SMR
LRW	Low-level	1.23	0.26	0.46	1.94
	Intermediate-level	44.15	9.46	16.87	69.85
	TOTAL	**45.37**	**9.72**	**17.34**	**71.79**
SRW	Very low-level	34.34	7.36	13.12	54.33
	Low-level	22.08	4.73	8.44	34.93
	Intermediate-level	3.19	0.68	1.22	5.04
	High-level	0.06	0.01	0.02	0.09
	TOTAL	**59.66**	**12.78**	**22.80**	**94.39**

Table 5. Calculation of the amount of radioactive waste that can be generated at SMR, m³

RW Category		SMR Type			
		BWRX-300	NuScale	SMART	Rolls-Royce SMR
LRW	Low-level	73.58	15.77	28.12	116.42
	Intermediate-level	2 649.02	567.65	1 012.31	4 191.13
	TOTAL	**2 722.61**	**583.42**	**1 040.43**	**4 307.56**
SRW	Very low-level	2 060.35	441.50	787.35	3 259.77
	Low-level	1 324.51	283.82	506.15	2 095.57
	Intermediate-level	191.32	40.99	73.11	302.69
	High-level	3.38	0.73	1.29	5.36
	TOTAL	**3 579.57**	**767.05**	**1 367.90**	**5 663.39**

With the introduction of strict environmental requirements and high tariffs for RW disposal by developed countries, reactor designers began to pay more attention to RW management and, at present, the European Utility Requirements require the accumulation of SRW of no more than 50 m^3 per year per 1000 MW at new NPPs. For example, the average estimated amount of SRW (per year) based on the experience of Russian NPPs using the VVER-1200 reactor as an example is 51.5 m^3 per year, including:

- low-level radioactive waste, m^3 – 40;
- medium-level radioactive waste, m^3 – 11
- high-level radioactive waste, m^3 – 0.5.

As can be seen, modern data on the amount of radioactive waste generated at nuclear power plants differs by an order of magnitude from the data used previously.

CONCLUSION

The potential use of small modular reactors (SMRs) opens up new prospects for nuclear power, but the issues of radioactive waste management remain critical.

At the same time, the urgency of solving the problem of developing nuclear energy is dictated by the fact that Kazakhstan occupies a leading position in the global market for the extraction and export of uranium, the country operates research reactors, produces uranium fuel for nuclear power plants, as well as experimental nuclear fuel [25].

As noted in this article, the main sources and categories of radioactive waste at SMRs are not fundamentally different from those at traditional NPPs. The differences lie in the volumes of waste, their specific activity, and the possibilities for optimizing processing and storage systems. SMR-based plants do not create fundamentally new challenges in the field of radioactive waste management, but require adaptation of existing practices. Their widespread implementation should be accompanied by the development of a regulatory framework and processing technologies in order to ensure nuclear physical, environmental, and radiation safety throughout the entire life cycle of a nuclear facility.

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«FIRST» БАҒДАРЛАМАҒА ҚАТЫСАТЫН ШАҒЫН МОДУЛЬДІ РЕАКТОРЛАРДЫҢ РАДИОАКТИВТІ ҚАЛДЫҚТАРЫН БАСҚАРУДЫҢ КЕЙБІР ПРАКТИКАЛЫҚ АСПЕКТІЛЕРІ ТУРАЛЫ

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Бұл мақала шағын модульдік реакторлар түзетін радиоактивті қалдықтарды басқару тәсілдерін қарастырады. Бұл тәсілдер МАГАТЭ қағидаттарына негізделген және шағын модульдік реакторлар негізіндегі ядролық қондырғыларды тәжірибелік және коммерциялық пайдалану тәжірибесін ескереді. Мақалада сондай-ақ ядролық қондырғылардың әртүрлі түрлерінде радиоактивті қалдықтардың түзілуі және радиоактивті қалдықтардың деректерін басқару тәсілдері салыстырылады.

Түйін сөздер: *шағын модульдік реакторлар, радиоактивті қалдықтар, атом энергетикасы, реакторлық электр энергиясы, радиоактивті қалдықтардың түрлері, ядролық отын.*

О НЕКОТОРЫХ ПРАКТИЧЕСКИХ АСПЕКТАХ ОБРАЩЕНИЯ С РАДИОАКТИВНЫМИ ОТХОДАМИ МАЛЫХ МОДУЛЬНЫХ РЕАКТОРОВ, УЧАСТВУЮЩИХ В ПРОГРАММЕ «FIRST»

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В настоящей статье приводится рассмотрение подходов к обращению с радиоактивными отходами, которые образуются в результате деятельности малых модульных реакторов. Данные подходы основываются на принципах МАГАТЭ, учитывают опыт опытной и коммерческой эксплуатации ядерных установок на базе малых модульных реакторов. В статье содержатся сравнительные аспекты по наработке РАО на различных типах ядерных установок и подходы по управлению данными РАО.

Ключевые слова: *малые модульные реакторы, радиоактивные отходы, атомная энергетика, электрическая мощность реактора, типы радиоактивных отходов, ядерное топливо.*