FEDERAL ENVIRONMENTAL, INDUSTRIAL AND NUCLEAR SUPERVISION SERVICE OF RUSSIA

FEDERAL STANDARDS AND RULES IN THE FIELD OF USE OF ATOMIC ENERGY

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DISPOSAL OF RADIOACTIVE WASTE.
PRINCIPLES, CRITERIA AND BASIC SAFETY REQUIREMENTS

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DISPOSAL OF RADIOACTIVE WASTE. PRINCIPLES, CRITERIA AND BASIC SAFETY REQUIREMENTS.

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These federal standards and rules establish principles, criteria and basic safety requirements for radioactive waste near-surface disposal of radioactive waste, disposal of radioactive waste in deep geological formations and liquid radioactive waste disposal.

The regulatory document applies to solid and solidified radioactive waste disposal facilities under design, construction, operation and closure; and liquid radioactive waste underground disposal sites in operation and under closure.

The regulatory document is issued for the first time. *)

The regulatory document has been developed on the basis of the legal acts and regulatory documents of the Russian Federation, "the Joint Convention on the Safety of Spent Nuclear Fuel Management and the Safety of Radioactive Waste Management", federal standards and rules in the field of use of atomic energy, recommendations of the IAEA Safety Series N 111-F "The Principles of Radioactive Waste Management" and the ICRP and OECD recommendations.

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List of abbreviations

LRW	– Liquid Radioactive Waste
LRW DDS	– Liquid Radioactive Waste Deep Disposal Site
RW	– Radioactive Waste
RWDF	– Radioactive Waste Disposal Facility
SAR	– Safety Analysis Report
SCR	- Self-Sustained Chain Reaction
SRW	– Solid Radioactive Waste
DBE	- Design Basis Earthquake

Basic Terms and Definitions

For the purposes of this document the following terms and definitions are used.

1.	Closure of RWDF (LRW DDS) shall mean the activity implemented after RW have been emplaced in the RWDF (LRW DDS) and targeted to bring the RWDF (LRW DDS) to the state, which will remain safe during the period of potential hazard of RW emplaced in the RWDF (LRW DDS).
2.	Disposal of liquid radioactive waste shall mean LRW emplacement by injection through wells into deep-seated reservoir-beds at depths of several hundreds of meters within the established boundaries of the mining lease without intent of their further retrieval.
3.	Disposal of radioactive waste shall mean the safe emplacement of RW without intent of their future retrieval.
4.	Disposal of radioactive waste in deep geological formations (deep geological isolation of radioactive waste) shall mean the disposal of RW in the structures located at depths of several hundreds of meters without intent of their further retrieval.
5.	Integrated RWDF (LRW DDS) engineering and radiation survey shall mean the set of measures required to obtain initial data for development of RWDF (LRW DDS) reconstruction or closure project.
6.	Liquid radioactive waste deep disposal site (LRW DDS) shall mean the natural and engineered system designed for LRW disposal and located within the territory determined by the design which includes a part of subsoil – intake beds (reservoir-bed) located within a mining lease, and the complex of near-surface and underground structures, systems and equipment designed for LRW disposal.
7.	Near-field zone of RWDF (LRW DDS) shall mean the part of the natural geological formation that surrounds RWDF (LRW DDS) designed for RW disposal; and which characteristics change or can change under the disposed RW impact.
8.	Near-surface disposal of radioactive waste shall mean the disposal of RW in the structures located on the ground surface and (or) at depths from several meters up to one hundred meters.
9.	Period of potential radioactive waste hazard shall mean the period after which the specific activity of radionuclides contained in RW will be decreased up to the values that allow to exempt RW from existing Radiation Safety Standards.
10.	Physical barrier (barrier) shall mean the obstruction on the way of ionizing radiation propagation and radionuclide migration into the environment.
11.	Post-closure monitoring of the radioactive waste disposal system shall mean the integrated system of survey and control of the environmental components' state; and assessment and forecast of changes within the near-field zone of RWDF (LRW DDS) with a purpose to confirm the radioactive waste disposal safety.

12.	Radioactive waste disposal facility shall mean the stationary facility (facilities) and structure (structures) located within a territory determined by the design and equipped with systems, and equipment required for RW disposal.
13.	Radioactive waste disposal system shall mean the combination of natural geological formation, RWDF (LRW DDS) structures, and disposed RW.
14.	Radioactive waste disposal system evolution scenario shall mean one of the possible sequences of interrelated events, phenomena and factors of natural and man-induced origin and physical and chemical processes, which determine a RW disposal system evolution, migration of radionuclides into the environment and human exposure levels.
15.	Safety of radioactive waste disposal system shall mean the property of a RW disposal system to confine radiation impact to the population during the whole period of RW potential hazard within the limits established by the existing radiation safety standards.
16.	Safety of RWDF (LRW DDS) shall mean the RWDF (LRW DDS) capability under normal operation conditions and operational events, including the accidents, to confine the radiation and other associated impacts to the personnel, population and the environment within the established limits.
17.	Safe operation conditions of RWDF (LRW DDS) shall mean the specified in the design conditions as regards quantity, characteristics, operability and maintenance of safety-related systems (components). Compliance with such conditions ensures that the safe operation limits and (or) safety criteria are not violated.
18.	Safe operation limits of RWDF (LRW DDS) shall mean the values of the process parameters specified in the design, their violation may result in an accident.

Other terms and definitions used in this document are contained in the Federal Standards and Rules in the field of use of atomic energy.

1. Purpose and scope of application

1.1. This document establishes principles, criteria and basic safety requirements for RW near-surface disposal, RW disposal in deep geological formations, and for LRW disposal.

1.2. This document applies to RWDF under design, construction, operation and closure, and LRW DDS under operation and closure.

2. Safety objectives, principles, criteria and basic requirements for radioactive waste disposal

2.1. The safety objective of RW disposal shall be their reliable isolation which ensures radiation safety of humans and the environment through the whole period of potential RW hazard.

2.2. The following principles of RW disposal of shall be complied with:

2.2.1. The radiation impact associated with the RW disposal of shall be maintained as low as achievable taking account of social and economic factors (the optimization principle).

2.2.2. Long-term safety of RW disposal during the RWDF (LRW DDS) post-closure period shall be ensured through application of a system of barriers on the paths of propagation of ionizing radiation and radioactive substances to the environment. A loss of integrity of one of the barriers or a probable natural or man-induced event shall not lead to a reduction in the level of long-term safety of RW disposal (the multi-barrier principle).

2.2.3. Projected exposure levels for future generations conditioned by RW disposal shall not exceed permissible exposure levels for population established by the existing regulatory documents. Any individual of the future generations shall be protected against hazardous impact from the disposed RW to an extent that is not smaller than the extent any individual of the present generation is protected to (the principle of protection of the future generations).

2.2.4. RW disposal shall be implemented so, that unreasonable burden associated with the necessity to ensure safety in RW management shall not be imposed on the future generations (the principle of not imposing an undue burden on the future generations).

2.3. RWDF (LRW DDS) shall be considered as meeting the safety requirements during normal operation, operational events including accidents, if its radiation impact to employees, population and the environment does not exceed the exposure dose limits for the employees, population and environment established by regulatory documents for the cases of releases, discharges of radioactive substances and content of radioactive substances in the environment.

2.4. RWDF (LRW DDS) shall be considered as meeting the safety requirements in the RWDF (LRW DDS) post-closure period if:

- during normal (evolutionary) sequence of natural processes on the RWDF (LRW DDS) site (the most likely disposal system evolution scenario) its radiation impact does not result in exceeding the disposal quota for the annual effective dose limit;
- during unlikely (catastrophic) external impacts of natural and man-induced origin on the RWDF (LRW DDS) site (unlikely scenario of radionuclide propagation from RWDF (LRW DDS) individual risk limit amounting to $1.0 \bullet 10^{-5}$ $year^{-1}$ will not be exceeded.

2.5. Selection of the RW disposal method (near-surface disposal or disposal in deep geological formations), the design of the storage facility and the barriers' properties shall be

determined in the RWDF design depending on RW radiation characteristics (radionuclide composition, specific activity, potential hazard period, physical and chemical properties), taking account of natural condition of RWDF location.

The Annex 1 presents permissible content of radionuclides in RW disposed in the near-surface RWDF. RW containing radionuclides in the amount that exceeds the limits specified in the Annex1 shall be disposed in RWDF of deep geological isolation.

2.6. The deep disposal of LRW shall be executed by injection of the pre-treated LRW into the geological horizons (reservoir beds) through wells and by localization of LRW within the mining lease boundaries.

2.7. RWDF (LRW DDS) safety shall be ensured through the consistent implementation of the safety-in-depth concept based on application of a system of physical barriers on the paths of propagation of ionizing radiation and radioactive substances to the environment, as well as of a system of technical and organizational measures to protect the physical barriers and maintain their efficiency and to protect the employees (personnel), population and environment.

2.8. RWDF (LRW DDS) shall have a system of physical barriers (engineered and natural) preventing propagation of ionizing radiation and radioactive substances to the environment.

Number and purpose of the RWDF (LRW DDS) physical barriers are set forth and justified in the design taking into account investigation results of properties of barriers' materials and predictive calculation.

The barriers shall be operable during normal operation, and measures to protect them shall be in place. Should loss of operability of any barrier be detected or measures to protect it unavailable, the RWDF shall be brought to a state that meets the requirements of this document and other existing regulatory documents.

2.9. Safety of RW disposal (long-term safety) shall be ensured on the basis of the multi-barrier principle based on the barriers system on the paths of propagation of ionizing radiation and radioactive substances in the environment so that loss of integrity of one of the barriers or probable external natural or man-induced events do not result in impermissible reduction in the RW disposal system safety level. LRW

2.10.The RWDF (LRW DDS) system of barriers shall:

- ensure safety of RW disposal during the period of its potential hazard considering possible external impacts of natural and man-induced origin in the RWDF (LRW DDS) site location as well as considering the physical and chemical processes pertaining to RWDF (LRW DDS);
- retain insulating properties under possible impacts by the rock;
- retain insulating properties under heat impact by heat-releasing RW;
- prevent inadvertent intrusion of humans and animals.

2.11. RWDF engineered barriers shall prevent

- the contact of RW packages with natural water;
- damage of RW packages caused by tectonic process impacts;
- host rocks induced impacts
- radionuclide propagation into the host rocks.

2.12. The RWDF (LRW DDS) engineered barriers shall perform designated functions after RWDF closure during the period of time established and justified in the RWDF (LRW DDS) design without maintenance and repair.

2.13. For RWDF of the deep geological isolation the natural barriers (host rock) shall be the main barrier. The isolating (filtration and sorption) properties of the natural barriers shall limit:

- the ground water contact with engineered barriers; and
- radionuclide migration in case of loss of integrity of the engineered barriers.

The host rock shall be resistant to heat impact in case the heat releasing RW is disposed of; retain their insulating properties and ensure in the deep geological isolation RWDF a heat regime which does not lead to degrading of the engineered barriers' integrity.

2.14 LRW DDS the natural barriers shall have low filtration properties and limit propagation of radionuclides to the upper and lower horizons.

2.15. The capacity of the LRW DDS intake bed shall ensure emplacement of LRW within the limited rock volumes for which it is possible to determine the mining lease* boundaries.

2.16. The intake bed shall be isolated from the surface and overlaying permeable horizons in the impact region of disposed of LRW by low permeable (waterproof) rocks. These horizons shall prevent or limit subvertical migration of waste components.

2.17. Hydraulic channels connecting the intake-bed and original ground, and over-/under-laying waterbearing horizons shall not be present within the LRW DDS mining lease and the area of the projected radionuclide propagation.

A buffer horizon capable, similarly to the intake bed, of confining waste in case of its flow through the dividing low permeable layer, shall be present above the intake bed. The buffer horizon shall be overlaid with low permeable rock separating it from upper layers.

2.18. The natural ground water flow in the intake bed shall be sufficiently low to ensure confining LRW within a limited section of the host rock. The LRW DDS disposal area shall not be located within the intake bed discharge to shallow beds of the ground water. The most preferable is to use for disposal the horizons possessing collecting properties, present in hindered water cycle hydrodynamic regions, containing high salinity water, not suitable for economic purposes.

2.19. Geological and technical conditions of building LRW DDS wells shall provide for a possibility of drilling and lining of wells without accidents and significant complications; provide for reliable separation of the intake bed and overlaying horizons over the annulus of the well casting pipes.

2.20 The system of technical and organizational measures to ensure safety during disposal of radioactive waste accumulated in the near-surface reservoirs – LRW storage facilities and tailing dumps, composition of the barriers system and permissible content of radionuclides in the radioactive waste to be disposed of shall be set forth and justified in the RWSF design taking account of barriers' properties and basing on the predictive calculation for assessment of RW disposal system safety.

2.21. The system of technical and organizational measures to ensure safety during disposal shall be described in the RWDF (LRW DDS) design and reflected in SAR. The SAR shall contain the results of the RWDF (LRW DDS) safety analysis with regard to its operation and RWDF (LRW DDS) post-closure period.

2.22. Sufficiency of technical and organizational measures to ensure RWDF (LRW DDS) safety shall be justified for the whole period of potential hazard posed by RW disposed in RWDF considering possible external natural and man-induced impacts in the RWDF (LRW DDS) location as well as considering physical and chemical processes characteristic of RWDF (LRW DDS).

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* Mining lease shall mean the geometrized block of the subsoil that includes the area of the geological environment, within which RW are confined, and adjacent areas of the geological environment that are affected by disposal and which use for other purposes is subject to specific limitations.

2.23. Exemplary lists of initiating events of accidents during RWDF (LRW DDS) operation as well as for the predictive calculations for evaluation of long-term safety of disposal in RWDF (LRW DDS) are given in Appendices 2 through 6.

Final lists of initiating events of accidents during RWDF (LRW DDS) operation as well as for the predictive calculations for evaluation of long-term safety of disposal in RWDF (LRW DDS) shall be established in the RWDF (LRW UDS) design and given in SAR.

2.24. The SAR RWDF (LRW DDS) shall contain methodologies and computer codes used to justify RWDF (LRW DDS) safety along with their scope of application. The computer codes in use shall be duly certified by Gosatomnadzor of Russia.

3. Safety Requirements for Radioactive Waste Disposal

3.1. Safety requirements for siting of radioactive waste disposal facilities

3.1.1. While selecting a RWDF site, the phenomena, processes and factors of natural and man-induced origin endemic to an anticipated region of location shall be studied in accordance with the requirements of regulatory documents.

Siting of RWDF shall not be permitted in the region with active movements of the earth's crust, high seismic and volcano activity as well as in the regions with vigorous industrial activity in the regions with vigorous excavation of natural resources; and within the location boundaries of quarries, mine fields, controlled areas of underground water intake, within the regions of natural resources deposits.

3.1.2. Geologic-hydrogeologic, topographic, hydrographic, engineering-geologic, seismic, tectonic and climatic conditions of the RWDF site location shall meet the requirements of federal standards and rules in the field of use of atomic energy. While selecting a RWDF site, the site characteristics, which may affect RWDF safety, and the RWDF impact to the population and environment shall be studied and assessed.

3.1.3. The site shall be considered suitable for RWDF if there is a possibility to ensure safe disposal of RW considering natural and man-induced phenomena, processes and factors. While selecting a RWDF site a possibility of safe RW transport shall be justified. The choice of RWDF site shall be justified in the design on the basis of study and survey results obtained for the region of anticipated site location and on the basis of predictive assessments of RW disposal safety.

3.1.4. The RWDF site sizes shall provide for hosting all necessary structures designated for RW management.

3.1.5. While selecting the RWDF site, the boundaries of the controlled area shall be determined in accordance with the requirements of regulatory documents.

3.1.6. The site for near-surface RW DF shall be located, as far as possible, within positive topographic features on low-permeable soils and shall feature low ground water level. It shall not be susceptible to floods and shall not be located in the littoral region, in the river flood-plain and marshland. A RWDF shall not be located on site having signs of ongoing geological processes (erosion, subsidence, landslide, and karst etc.).

3.1.7. The RWDF of deep geological isolation shall be selected considering a combination of the following requirements:

- the host rock shall be represented by one of the potentially acceptable type (crystalline or magmatic or metamorphic rock: granite, gneiss, tuff, etc., preferably of basic or ultra-basic composition; rock salt or anhydride; clays) having sufficient volume depositing at an acceptable depth and having favorable physical and chemical properties, high composition homogeneity and low fracturing;

- the siting is reasonable on plains or slightly hilly territories which are not affected by intensive current tectonic movements;
- at the depth of RW disposal the ground water shall not be present or be in stagnant hydrological regime;
- there shall not be brine lens, permeable rock strata within the host depth;
- rock area shall not include water bearing horizons, underground water lens or fracturing zones through which inflow of water to and flooding of mining are possible.

3.1.8. When there are alternative options for siting the RWDF of deep geological isolation to meet the above requirements, the preference shall be given to those where the geological conditions meet one or several additional requirements:

- the ground water are of renewable nature and feature low alkaline reaction and low salinity;
- active fractures are not present within the site boundaries;
- depressed heat flow;
- waterproof and waterbearing horizons unsuitable for water supply are present above the planned RWDF depth;
- detected and (or) possible hydraulic channels connecting the planned RWDF location level and original ground, and over-/ under-laying waterbearing horizons including those unsuitable for water supply are not present.

3.2. Safety requirements for design and construction of radioactive waste disposal facilities

3.2.1. On the basis of the predictive calculation for safety assessment of RW disposal system and taking account of Appendix 1 of this document the RWDF design shall establish and justify:

- radionuclide composition of RW to be disposed in RWDF;
- permissible total activity of RW to be disposed in RWDF;
- total and specific radionuclides activity in RW packages (mean and maximum) in RWDF;
- permissible number of RW packages in storage and being disposed in RWDF.

3.2.2. The PWDF design shall establish conditioned RW acceptance criteria for disposal considering the following characteristics of RW packages:

- total activity of RW package, RW specific activity and RW radionuclide composition;
- equivalent rate dose of a RW package;
- RW package surface contamination;
- structural stability of RW form;
- waterproof properties of solidified RW form;
- content of corrosives;
- heat release;
- thermal stability;
- radiation resistance;
- gas generation;
- biological stability;
- RW package free moisture content;
- complexing agent contents;
- absence of explosive and pyrophoric substances;
- absence of substances which reactions with water result in heat release and generation of combustible gases;
- content of noxious substances, chemically toxic substances, pathogens and infectants;

- content of nuclear-hazardous fissile materials;
- RW package configuration;
- RW package identification.

3.2.3. The design shall establish requirements to disposed RW containers (structural materials, weight, size, design and mechanical properties), and RW packages, in whole.

3.2.4. The RWDF design shall provide for methods, engineered means and scope of the incoming inspection of the RW packages coming for disposal, including check of compliance of actual characteristics of RW packages with their certificates, and RW acceptance criteria for their disposal at RWDF.

Methods and scope of incoming inspection of RW packages coming for disposal of shall be established and justified in the RWDF design in accordance with the requirements of existing regulatory documents.

3.2.5 The RWDF design shall provide for engineered means and organizational measures for safe management of all types of RW coming for disposal of including:

- monitoring of process parameters of the system;
- conduct of transport and process operations;
- temporary storage of RW packages,
- decontamination of equipment and rooms;
- radiation monitoring and radioecological monitoring of the environment;
- management of RW generated at RWDF;
- repair and maintenance of RWDF systems and equipment;
- accounting of RW packages and their locations.

3.2.6. The RWDF design shall provide for engineered means and organizational measures aimed at preventing:

- violations of normal operation limits;
- violations of safe operation limits and conditions;
- design basis accidents and limiting their consequences.

Engineered means and (or) organizational measures shall be provided for to limit possible consequences of beyond design basis accidents if they are not excluded by inherent safety features of RWDF.

3.2.7. The RWDF design shall contain and justify:

- composition and confinement properties of the barriers;
- justification of reliability of engineered barriers;
- minimum time periods within which each of the barriers retains its properties required to ensure safety without external intervention;
- measures targeted to protect engineered barriers against damages during RWDF operation and RWDF state monitoring.

Possible changes in the confinement properties of the barriers shall be taken into account in the RW disposal system evolution scenario.

Materials of the confinement barriers shall be selected so, that interaction between components of different barriers does not result in unanticipated degradation of their confinement properties.

3.2.8. The engineered barriers of RWDF of deep geological isolation and that of near-surface RWDF shall be protected from damages associated with inadvertent human intrusion.

The engineered barriers of near-surface RWDF shall be protected from damages associated with intrusion caused by underground animals and vegetation roots.

3.2.9. The processes shall be machinery-based (automated) with remote control capabilities, as necessary.

3.2.10. The RWDF design shall provide for engineered means and organizational measures for:

- repair and maintenance of systems and equipment;
- elimination of emergency contamination of rooms and equipments with radioactive substances.

3.2.11. The design shall provide for normal operation systems (elements) including safety important and safety systems (elements).

The design developer shall attribute the elements to corresponding safety classes and shall indicate that in the documentation for design, manufacture and delivery of RWDF systems (elements) as well as in the RWDF design.

3.2.12. The RWDF design shall provide for a radiation monitoring system in RWDF premises, at its location site and in the controlled area. The radiation monitoring system shall provide for receiving and processing information on the monitored parameters describing radiation situation at RWDF and in the environment.

The following shall be established and justified: radiation monitoring objects, monitored parameters, permissible levels of the monitored parameters, radiation monitoring points, radiation monitoring frequency, engineered means and methodological support of the radiation monitoring, necessary rooms and staffing of employees carrying out the radiation monitoring.

The scope of radiation monitoring shall be established in accordance with the requirements of the existing regulatory documents.

3.2.13. The RWDF design shall provide for monitoring of engineered and natural barrier conditions providing for timely detection of loss of integrity of engineered barriers and monitoring of radionuclides migration in the environment during the RWDF operation.

Monitoring of engineered and natural barriers during RWDF post-closure period shall be implemented in a scope established in the RW disposal system design as regards the environmental monitoring taking account of the achieved level of science and technology including results of scientific studies conducted in underground laboratories.

Methods, engineered means and scope of monitoring of engineered and natural barrier conditions during RWDF operation and post-closure period shall be determined and justified in the RWDF design.

3.2.14. The design shall justify RWDF stability to external natural and man-induced impacts pertaining to the selected RWDF site and (or) to possible internal impacts resulted from accidents.

3.2.15 The design shall establish and justify RWDF equipment service life and its service life.

3.2.16. The near-surface RWDF design shall provide for engineered means preventing ingress of ground, flood and precipitation water into the disposal area; as well as possible changes in hydrogeological conditions resulted from the construction and operation of RWDF buildings and structures shall be taken into account.

3.2.17. If necessary, the RWDF design shall provide for ventilation system that prevents contamination of air in premises and the environment with radioactive substances and maintains conditions required for personnel and normal operation of equipment.

3.2.18. The RWDF design shall ensure fire and explosion safety in accordance with the requirements of existing regulatory documents.

During post-closure period RWDF fire safety shall be ensured by use of noncombustible structural materials for manufacturing of engineered barriers and that shall be justified by fire and technical calculations in the RWDF design.

3.2.19.The RWDF design shall foresee conveyances and transport and process equipment that provide for safe transportation of RW packages within RWDF along the shortest routes.

The transportation and process arrangements shall take into account:

- radiation monitoring of conveyance and routes outgoing from the possible contamination zone to the clean zone;
- acceptance of RW packages;
- emplacement of RW packages in RWDF;
- arrangements for RWDF off-shipments.

The design of transportation and process equipment shall prevent RW package from drop and damage during transportation.

RWDF shall be equipped with special engineered means for liquidation of possible emergency situations associated with RW package drop or damage.

3.2.20. The design shall provide for RW package emplacement by “addresses” in certain location in RWDF with identifiable unique location place (bay, section, cell number, location in the pile, etc.).

RW package locations shall be recorded in the RW accounting system of RWDF.

3.2.21. Should disposed RW contain nuclear-hazardous fissile nuclides, the design RWDF of deep geological isolation shall provide for measures aimed at nuclear safety ensuring, namely:

- amount of nuclear hazardous fissile nuclides in disposed RW shall be limited so that to exclude a possibility of self-sustained chain reaction due to concentration during their migration in RWDF elements and host rock;
- transport and process arrangements for loading RW packages containing nuclear hazardous fissile materials and their transport on-site RWDF shall exclude a SCR possibility.

3.2.22. The RWDF design shall consider processes going in the structures and structural materials of RWDF and RW packages during normal operation and design basis accidents including corrosion, creep, shrinking, aging, radiation induced alterations, and other possible processes.

3.2.23. The design shall provide for:

- physical protection system for RWDF and RW;
- RW control and accounting system.

A system for acquisition, systematization and reliable storage of disposed RW information shall be provided for.

3.2.24. The design of constructed RWDF shall include safety provisions for RWDF closure including the RWDF closure concept as well as:

- possibility of decontamination of premises, systems and components;
- assessment of the total amount, type and activity of RW generated during closure;
- possibility of dismantling of auxiliary systems (components);
- a list of systems required for closure-related activities;
- assessment of radiation impact caused by RWDF closure on employees (personnel), population and the environment.

A list of activities shall be updated taking account of the anticipated RWDF (LRW DDS) closure option.

3.3. Safety requirements for operation of radioactive waste disposal facilities and liquid radioactive waste deep disposal sites

3.3.1. General safety requirements for operation of RWDF and LRW DDS

3.3.1.1. Analysis of the current RWDF (LRW DDS) safety level and predictive calculation for assessment of RW disposal system safety shall be conducted for operating (closed) RWDF (LRW DDS) with a purpose to identify the required scope of implementation of technical and organizational measures aimed at ensuring safety of the personnel and population and RW disposal system safety.;

Basing on the analysis and predictive calculation results, all reasonably feasible measures targeted to implement the requirements of this document shall be taken.

3.3.1.2. The Operating Organization shall establish the organizational structure necessary for safe operation of RWDF (LRW DDS).

3.3.1.3. The Operating Organization shall provide for selection and training of employees (personnel) as well as for maintaining their professional skill and issuing permits to work independently. A system for selection and training of RWDF (LRW DDS) employees (personnel) shall be aimed at reaching, maintaining and controlling such level of professional skills that is necessary for ensuring safe operation of RWDF (LRW DDS) and for carrying out actions directed to mitigation of accident consequences.

The building up of safety culture of employees (personnel) shall be a component part of the training program.

3.3.1.4. The operating organization shall provides for development of RWDF (LRW DDS) operating documentation basing on documentation produced by developers of equipment, processes and design.

The operating documentation shall include rules and basic methods of safe operation of RWDF (LRW DDS), general procedure for performing operations relevant to safety, the safe operation limits and conditions, specified guidance for employees with regard to their actions under normal operation and operational events, including pre-emergency situations, and their actions to ensure safety in case of design basis and beyond design basis accidents.

The procedure to develop the operating documentation and to make changes to it shall be established by the Operating Organization in accordance with the requirements of the regulatory documents.

3.3.1.5. Maintenance, repair, tests and inspections of systems (components) and equipment of RWDF (LRW DDS) shall be carried out to maintain their operability and to prevent unsafe failures of systems. The mentioned activities shall be carried out according to procedures (programs, schedules, process flow diagrams) developed by the Operating Organization on the basis of design requirements. They shall be documented. Maintenance, repair, tests and inspections of systems (components) and equipment shall be carried out under conditions ensuring RWDF (LRW DDS) safety and be specified in the operating documentation

3.3.1.6. Information on failures of systems (components) and equipment and human errors shall be gathered, processed, systematized and stored during the whole period of RWDF (LRW DDS) operation. The Operating Organization shall develop periodical (annual) reports to present results of analysis and the above information as systematized.

3.3.1.7. The following shall be provided for during operation of RWDF (LRW DDS):

- effective control over all activities relevant to operation and maintenance of RW handling systems aimed at accident prevention;
- minimum generation of RW with regard to their total activity and amount;
- prevention of uncontrolled releases and discharges from RWDF (LRW DDS);
- reprocessing, conditioning and disposal of secondary RW generated during RWDF (LRW DDS) operation;
- physical protection of RWDF (LRW DDS) and RW, and control and accounting of RW.

3.3.1.8. The following activities shall be carried out during the RWDS (LRW DDS) operation:

- protection of the employees (personnel) and population against LRW radiation impact;
- prevention of LRW leakage from the process flows;
- prevention of radiation contamination of the RWDF (LRW DDS) working premises and site

3.3.1.9. The Operating Organization shall provide for continuous control over all activities important to RWDF (LRW DDS) safety. The Operating Organization shall submit periodic safety reports regarding RWDF (LRW DDS) to the Federal Environment, Industrial and Nuclear Supervision Service of Russia.

3.3.1.10. The Operating Organization shall timely inform the state safety regulatory authorities on operational events occurred at RWDF (LRW DDS). All events occurred at RWDF (LRW DDS) shall be investigated in accordance with requirements of existing regulatory documents.

3.3.1.11. The Operating Organization shall document and store information required for RWDF (LRW DDS) closure, including design and operational documentation, as well as information about:

- changes in the technology at RWDF (LRW DDS);
- reconstruction and modernization activities carried out at RWDF (LRW DDS);
- levels of surface contamination of systems, components and premises, including the RWDF (LRW DDS) site, with radioactive substances before the RWDF (LRW DDS) closure activities are started;
- amount and radionuclide composition of liquid and solid RW accumulated during operation and stored on the RWDF (LRW DDS) site, their characteristics and storage locations at RWDF (LRW DDS);
- amount of disposed RW, radionuclide composition and specific activity;
- capability of and free space in RW storages for radioactive waste emplacement;
- RWDF (LRW DDS) accidents resulted in radioactive contamination of the systems, components, premises and structures.

3.3.1.12. The Operating Organization shall ensure that RWDS (LRW DDS) systems and components required for closure remain in service or provide for the possibility of their replacement when their service life has been exhausted.

3.3.2. Safety requirements for RWDF operation

3.3.2.1. Prior to commissioning, the RWDF shall be staffed with employees (personnel) who have the necessary professional skills and permits to work independently issued according to the established procedure.

3.3.2.2. Before RWDF commissioning the start-up and alignment operations shall be carried out which shall confirm that systems (components) and equipment of RWDF were

manufactured and function as designed, and that the revealed deficiencies have been eliminated.

3.3.2.3 Plans of measures for protection of employees (personnel) and population in the case of an accident at RWDF (On-site and Off-site Emergency Plans) shall be developed and ready for implementation prior to operation of RWDF. According to the On-site and Off-site Emergency Plans, primary and back-up interaction links with organizations specially authorized in the field of protection of population and territories against emergencies shall be enabled prior to RWDF operation.

3.3.2.4. The receipt and acceptance control of RW packages shall be provided during the operation of RWDF. While receiving RW, the following shall be controlled:

- availability and completeness of the accompanying documentation;
- integrity of the RW package;
- labeling of the RW package;
- eurface dose rate (at the distance of 10 cm from the surface) and dose rate at the distance of 1 m from the outer surface;
- value of removable contamination at the outer package surface.

While receiving the RW packages they shall pass visual and radiation inspection to check compliance of the actual RW package characteristics with the data presented in their certificates, including compliance of:

- package labeling – with data from the RW package certificate;
- RW package certificate data – with actual characteristic of the RW package;
- actual characteristic of the RW package – with RW acceptance criteria for their disposal in the RWDF established by the RWDF design.

If the package does not comply with the established requirements and its characteristics cannot be brought in compliance with the acceptance criteria set forth in the design, the package shall be returned to a consignor.

3.3.2.5. A system for accounting and storage of documentation on RW management at the RWDF shall be arranged, including implementation of such functions as accounting of the of RW packages' types, their registry numbers, RW package properties, locations in RWDF.

The accounting (registry) shall be done on the basis of RW package certificates, data on the acceptance incoming control and identified specific locations in RWDF where RW packages have been accommodated.

The Operating Organization shall keep RW package certificates and registry (accounting) documents with identified locations of RW packages disposed of in RWDF until RWDF, together with the accounting (registry) information is transferred under jurisdiction and account of the federal (regional or local) executive authorities.

3.3.2.6. RW shall be transported on-site RWDF as follows:

- on special vehicles having sanitary certificates;
- along the routs specified by the design and in accordance with the flow diagrams for transportation within the RWDF site;
- inside special transport containers taking into account dimensions and mass of the transported RW, their physical state, activity, type of radiation and dose rates on the outer surface of containers.

3.3.2.7. Based on the design values of permissible gas and aerosol releases and effluents, reference levels of radioactive releases and discharges to the environment shall be set. The levels of releases and discharges set thereof shall be put on the list of the RWDF operational limits. They shall be revised periodically with consideration of the experience gained and technology development. Reference levels of releases and discharges shall be lower than permissible radioactive releases and discharges set in the design taking into account achieved safety level of the RWDF operation.

3.3.2.8. As RWDF cells (compartments, chambers, sections) are filled with RW packages, they shall be sealed.

3.3.3. Safety requirements for LRW DDS operation

3.3.3.1. Safe disposal of LRW shall be ensured by implementation of administrative and engineering measures including:

- LRW confinement in the intake beds;
- monitoring of LRW conditions and host geological environment; and also analysis of monitoring results.

3.3.3.2. The predictive calculation shall be the basis for establishing and justifying in the design:

- radionuclide composition of LRW being disposed of;
- permissible total activity of LRW in LRW DDS;
- specific activity of LRW being disposed of (mean and maximum);
- specific activity of transuranic nuclides in LRW (mean and maximum).

3.3.3.3. The LRW DDS operational documentation shall establish criteria of RW acceptance for disposal including permissible radiochemical and chemical compositions of LRW, and also LRW volumes which may be sent for disposal.

3.3.3.4. A complex of surface buildings for the following operations shall be provided for at LRW DDS:

- receipt, collection and interim storage of LRW;
- transfer of LRW to the pumping station and through the high pressure piping to the injection wells;
- recording of received LRW amounts;
- incoming inspection of LRW chemical composition and radionuclide composition indicators;
- monitoring and recording of the process parameters including pressure and injection volumes for each injection well and for LRW DDS as the whole;
- preparation of LRW for disposal;
- collection and elimination of LRW leakages from the process lines and wellhead lining of injection wells.

3.3.3.5. A complex of underground structures of the storage facility for the following operations shall be provided for at LRW DDS:

- transfer of LRW from the surface structures to the open area of the intake bed (injection wells);
- surveys, measurements and representative sampling of layer liquids from the intake bed and other monitored horizons during the disposal process monitoring (test wells and survey wells);
- intake bed discharge,(i.e. pumping out the water from discharge wells).

3.3.3.6. The LRW DDS underground structures shall ensure that the following requirements are met:

- the intake bed and monitored horizons shall be reliably separated from the surface, above and below horizons crossed by the well;
- casing pipes shall be leaktight over the whole length; the annulus and tube space shall be filled with an insulating material;
- there shall be a possibility for inspection of the technical state of wells and planned-preventive maintenance and repairs;
- the design and technical conditions of wells shall provide for elimination of wells during the LRW DDS closure.

3.3.3.7. The LRW DS operational documentation shall establish:

- a number of development and back-up wells proceeding from the condition of disposal of LRW amount as anticipated by the design and acceptable hydrodynamic interaction of wells;
- a number and arrangement of survey and test holes proceeding from the necessity to timely obtain information on the LRW disposal of progress and verification of LRW confinement within the mining lease area and control boundaries;
- methods and means of continuous measurements of flow rate (injection intensity) and pressure;
- methods and means of collection of LRW leaks from injection well canyons;
- operational service life of wells.

3.3.3.8. Engineered means and organizational measures for the following operations shall be provided for at LRW DDS:

- decontamination of equipment and rooms,
- repair and maintenance of systems and equipment;
- monitoring of parameters of process and auxiliary systems.

3.3.3.9. The following information shall be presented in the LRW DDS operations regulations:

- geological and engineering characterization of the LRW UDS;
- properties of the disposed LRW;
- standards for carrying out of processes and their monitoring;
- structure and subsurface surveillance procedure and surveillance frequency.

3.3.3.10. Wells shall be maintained and repaired according to the special programs. Upon expiration of the designed service lifetime the wells shall be inspected. The inspection results shall form a basis for making a decision whether to repair a well or to keep it as a redundant or to eliminate it.

3.3.3.11. The following shall be monitored during disposal of LRW:

- operational modes of injection and relief wells, volume and pressure values of waste injection, chemical and radionuclide composition of waste, their compliance with the design and operations regulations;
- volumes and compositions of LRW sent to disposal, total amount of disposed LRW;
- state of the ground-based LRW UDS structures, integrity of pipes, pumps and other process equipment, radiation level inside working premises, repair and other operations' bays and on the LRW DDS territory;
- technical state of underground structures: boreholes, integrity of well's casing pipes, insulation of the LRW containing intake bed from the surface and overlaying horizons over the annulus and tube space of wells;
- composition of ground water in the intake bed and monitored horizons, presence of LRW ingredients in them;
- piezometric (hydraulic pressure) area of ground water in the intake bed and monitored horizons;
- parameters of physical fields inside wells and on the surface that reflect behavior of disposal processes;
- state of water reservoirs and soils within the controlled area.

3.3.3.12. The deep disposal of LRW shall be monitored to confirm LRW disposal safety. This monitoring is aimed at:

- determination of a contour of LRW spreading in the geological environment and its changes;
- timely receipt of information on location of LRW or their ingredients in the geological environment and history of processes related to the disposal;
- assessment of the technical state of the main structures;
- early detection of signs of problems and emergences;
- documenting and keeping of the survey data and results of their processing in a form of periodically updated computerized databases.

Software and a computer model shall be elements of the system for monitoring of the LRW deep disposal. This model shall describe LRW disposal processes and shall be periodically supplemented with the results of surveys.

3.3.3.13. The Operating Organization shall produce a summary of the experience gained in LRW disposal on a periodic basis. This summary shall include an analysis of results of surveys and disposal safety assessment.

Results of surveys shall be compared with the data of predictive assessments. Basing on the obtained results the technical and organizational activities shall be implemented targeted to adjust LRW disposal modes, to carry out repair or to undertake geological and engineering measures.

3.3.3.14. Standards for LRW volumes disposed of shall be established and revised periodically on the basis of the comparative analysis results of actual compositions of LRW disposed of.

3.4. Safety requirements for closure of radioactive waste disposal facilities and liquid radioactive waste deep disposal sites

3.4.1. General safety requirements for closure of radioactive waste disposal facilities and liquid radioactive waste deep disposal sites

3.4.1.1. The Operating Organization shall implement systematic planning of RWDF (LRW DDS) closure activities at all stages of its life cycle. While developing the RWDF (LRW DDS) design the initial planning shall be conducted with the short-term planning being conducted during RWDF (LRW DDS) operation. The RWDF (LRW DDS) closure program shall include results of planning of closure-related activities.

3.4.1.2. Organizational and engineered activities carried out during RWDF (LRW DDS) operation (reconstruction and modernization) shall be implemented taking into account the forthcoming closure activities.

3.4.1.3. Organizational and engineered activities carried out during RWDF (LRW DDS) closure shall be aimed at decreasing the radiation impact on personnel, population and the environment down to the possibly low achievable levels taking account of social and economic factors.

3.4.1.4.The Operating Organization shall ensure safety of RWDF (LRW DDS) closure, including: measures targeted to prevent accidents and mitigate accident consequences, safe RW management, and also RW control and accounting, physical protection of RWDF (LRW DDS) and RW, monitoring of the environmental conditions on RWDF (LRW DDS) site, within the controlled area and surveillance zone.

3.4.1.5. The Operating Organization shall provide for development and implementation of the quality assurance program during RWDF (LRW DDS) closure and control the quality of activities implemented by organizations carrying out work and (or) rendering services for the operating organization.

3.4.1.6. Before the design (or 30-year) lifetime of RWDF (LRW DDS) is expired the Operating Organization shall provide for development of the RWDF (LRW DDS) closure program.

Development of the RWDF (LRW DDS) closure program shall be completed before RW emplacement in the RWDF (LRW DDS) is terminated. The RWDF (LRW DDS) closure program shall include possible RWDF (LRW DDS) closure options to be selected taking account of the following factors:

- RWDF (LRW DDS) features (technology, site sizes, equipment dimensions, layout decisions, characteristics of the systems, components and structures);
- availability of design and operational documentation;
- amount of RW emplaced on-site, RW radionuclide composition, specific (volumetric) and total activity;
- radiation consequences of accidents occurred during RWDF (LRW DDS) operation;
- availability of techniques, means and technologies of decontamination and dismantling of the equipment, pipelines, buildings and structures;
- possibility to use available systems, components, buildings and structures during the closure (radiation monitoring, ventilation, RW management, cranes, transport and process equipment);
- possible radiation impact on personnel, population and the environment from closure activities;
- characteristics of the RWDF (LRW DDS) site, region of the site and the environment, which can affect transfer and accumulation of radioactive substances during RWDF (LRW DDS) closure.

3.4.1.7. After RW emplacement in the RWDF (LRW DDS) has been terminated, the Operating Organization shall implement activities to prepare RWDF (LRW DDS) for closure:

- comprehensive engineering and radiation survey of RWDF (LRW DDS);
- decontamination of equipment, pipelines, systems and components in a scope necessary for preparing RWDF (LRW DDS) for closure;
- reprocessing and conditioning of RW accumulated at RWDF (LRW DDS) during its operation, and RW emplacement in RWDF.

3.4.1.8. While preparing RWDF (LRW DDS) for closure, operation of systems and components shall be implemented in accordance with the process regulations and operational manuals. Should the operational conditions for the systems and components be changed, these changes shall be incorporated into the process regulations and operational manuals according to the established procedure.

3.4.1.9. Basing on the initial data obtained by the comprehensive engineering and radiation survey (CERS) and analysis of the RWDF (LRW DDS) design and operational documentation the Operating Organization shall provide for preparation of the documentation required for RWDF (LRW DDS) closure in accordance with the terms of reference and closure program, including:

- RWDF (LRW DDS) CERS results;
- RWDF (LRW DDS) closure project;
- quality assurance program for RWDF (LRW DDS) closure;
- process regulations for RWDF (LRW DDS) closure activities;
- operational manuals for systems and components required for RWDF (LRW DDS) closure activities;
- action plans to protect employees (personnel) and population in case of an accident;
- guide on liquidation of consequences of accidents occurred at RWDF (LRW DDS) under closure;
- SAR for the RWDF (LRW DDS) closure.

3.4.1.10. The RWDF (LRW DDS) closure shall be implemented in accordance with the project. Project decisions related to the RWDF (LRW DDS) closure shall be aimed at bringing it to the state, which will remain safe during the period of potential hazard of RW emplaced in the RWDF (LRW DDS).

3.4.1.11. The RWDF (LRW DDS) closure project shall include and justify the final option of RWDF (LRW DDS) closure.

3.4.1.12. The RWDF (LRW DDS) closure project shall provide for:

- sealing (closure) of RWDF cells (compartments, chambers, sections) filled with RW packages or injection and relief LRW DDS wells;
- decontamination, dismantling or conversion of structures, systems and equipment designed for receipt of RW and temporary storage at RWDF (LRW DDS),
- monitoring of RWDF (LRW DDS) state during the time period up to 100 years after the closure activities have been completed;
- dismantling and liquidation of systems and equipment designed for RWDF (LRW DDS) state monitoring.

3.4.1.13. The RWDF (LRW DDS) closure project shall include:

- a description of the RWDF (LRW DDS) closure stages;
- a technology and sequence of activities for each stage of the RWDF (LRW DDS) closure;
- methods and means of radiation safety, including implementation of the optimization principle;
- methods and means of fire and explosion safety;
- measures targeted to ensure physical protection of RWDF (LRW DDS), radioactive substances and RW;
- techniques and means of RW management generated during RWDF (LRW DDS) closure;
- measures targeted to ensure RW accounting for and control of;
- a description of transport and process operations carried out inside the premises and on site of RWDF (LRW DDS) and process flow diagram for transportation on site of RWDF (LRW DDS);
- a description of ultimate RWDF (LRW DDS) state after the closure activities have been completed;
- a justification of required manpower, financial and technical resources.

3.4.1.14. For each closure stage the RWDF (LRW DDS) closure project shall indicate:

- technologies of activities' implementation;
- number of employees (personnel) required to implement the activities;
- activities targeted to ensure radiation safety at working places;
- required scope of individual monitoring (health physics, radiometric) of exposure of employees (personnel) and appropriate engineered means for this monitoring;
- assessment of individual exposure doses for employees (personnel) with regard to each type of activities and collective exposure dose for employees for a stage of activities on the basis of information on radiation situation;
- methods and means aimed at minimization of occupational exposure during activities' implementation;
- volume, activity and radionuclide composition of generated RW, and techniques of RW reprocessing, conditioning, transportation and storage locations;
- activities related to minimizing radionuclides releases and discharges into the environment;
- a description of RWDF (LRW DDS) state after each closure stage is completed.

3.4.1.15. The RWDF (LRW DDS) closure project shall provide for techniques and means of surface decontamination of RWDF (LRW DDS) equipment, pipelines, premises, structures and buildings.

3.4.1.16. The RWDF (LRW DDS) closure project shall provide for techniques and means for dismantling of equipment, pipelines, structures and buildings. The dismantling techniques and means shall be reliable and easy in operation and maintenance.

3.4.1.17. The RWDF (LRW DDS) closure project shall provide for rooms at RWDF (LRW DDS) and places on RWDF (LRW DDS) site for temporary storage of RW and materials to be reused, as well as techniques and means for their subsequent retrieval and removal**.**

3.4.1.18. The RWDF (LRW DDS) closure project shall provide for radiation monitoring inside RWDF (LRW DDS) premises, on-site and within the controlled area. The radiation monitoring can be implemented on the basis of RWDF (LRW DDS) radiation monitoring system designed for the facility operation. If necessary, the closure project may invoke changes to this system taking into account features of the activities being implemented at each stage of the RWDF (LRW DDS) closure.

3.4.1.19. The scope of radiation monitoring is defined in accordance with the requirements of existing regulatory documents.

The scope, techniques and means of the radiation monitoring of the RWDF (LRW DDS) under closure shall provide for:

- individual monitoring (health physics, radiometric) of occupational exposure;
- monitoring of radiation situation in the process area, inside the premises, on site and within controlled area of the RWDF (LRW DDS);
- monitoring of releases and discharges of radioactive substances;
- timely detection of changes in the radiation situation inside the RWDF (LRW DDS) premises, on site, within controlled area and surveillance area;
- radiation monitoring of materials to be reused.

3.4.1.20. The RWDF (LRW DDS) under closure shall be staffed with employees (personnel) with required professional skills who possess permits to work independently issued in accordance with the established procedure.

3.4.1.21. The Operating Organization shall provide for selecting and training of employees (personnel) as well as for maintaining their professional skills and issue permits to work independently. A system for selection and training of RWDF (LRW DDS) employees (personnel) shall be aimed at reaching, maintaining and controlling such level of professional skills that is necessary for ensuring safe closure operation of RWDF (LRW DDS).

3.4.1.22. The RWDF (LRW DDS) closure activities shall be carried out in accordance with the operating documentation developed according to the RWDF (LRW DDS) closure project**.**

3.4.1.23. All materials (fragments of dismantled equipment, biological shielding, engineering structures etc.) generated during the RWDF (LRW DDS) closure shall be subject to radiation monitoring. Basing on the radiation monitoring results, RW shall be separated from materials of limited or unlimited reuse in accordance with requirements of the regulatory documents.

3.4.1.24. When each stage of the RWDF (LRW DDS) closure has been completed, analysis of results of the carried out activities shall be conducted; additional survey of the RWDF (LRW DDS) shall be carried out in a scope required for timely revision of the design documentation and undertaking of necessary measures to ensure safe implementation of

activities at the next RWDF (LRW DDS) closure stage. Completion of the each stage of the RWDF (LRW DDS) closure shall be documented.

3.4.1.25. The Operating Organization shall provide for recording and storing of documentation related to the RWDF (LRW DDS) closure in accordance with the procedure established in the quality assurance program.

3.4.1.26. During the RWDF (LRW DDS) closure the Operating Organization shall provide for collection, processing, analysis, systematization and storing of operational events information and immediate transfer of this information to all organizations concerned according to the established procedure.

3.4.1.27. The RWDF (LRW DDS) closure activities are terminated when RWDF (LRW DDS) has reached its ultimate state established by the closure project, and the operating organization shall produce an appropriate document (report) that confirms completion of the closure activities.

The document shall demonstrate that when the closure activities have been completed, an actual RWDF (LRW DDS) state and actual site conditions comply with the ultimate state determined in the RWDF (LRW DDS) project.

3.4.1.28. After the RWDF (LRW DDS) closure the Operating Organization shall implement RW disposal monitoring which includes:

- monitoring of engineered and natural barriers' condition;
- monitoring of the host rock conditions;
- monitoring of the environmental conditions.

Duration of the RW disposal system monitoring shall be established and justified in the RWDF (LRW DDS) closure project depending on the total activity of RW disposed of and radionuclide composition.

3.4.1.29. Systems and equipment designed for monitoring of RW disposal system shall be dismantled and eliminated after the monitoring has been completed.

The monitoring of the RW disposal system is terminated when monitoring results confirm of RW disposal safety.

3.4.1.30. After the closure has been completed RWDF (LRW DDS) shall be transferred (depending on the RWDF (LRW DDS) legal status) to the account sheets of federal (regional or local authorities) which duly account for the RWDF (LRW DDS).

3.4.2. Safety requirements to RWDF closure

3.4.2.1. The closure project for the near-surface and deep geological isolation RWDF shall provide for implementing of the following activities:

- sealing of cells (compartments, chambers, sections) of the RWDF filled with RW packages;
- decontamination and dismantling of constructions, engineering structures, systems and equipment designed for receipt of RW packages and their temporary storage at the RWDF;
- monitoring of the RWDF state.

3.4.2.2. During the RWDF cells (compartments, chambers, sections) closure the following activities shall be carried out:

- dismantling of transportation and process (handling) equipment;
- dismantling of the temporary building structures (roofing, awnings, etc.) and auxiliary systems (ventilation, sewage, water supply, etc.);

- filling up the free space (hollows) between RW packages with the buffer material and other activities to bring cells (compartments, chambers, sections) of the RWDF into the ultimate state.

The RWDF closure plan specifies and justifies a scope and sequence of activities related to the RWDF cells (compartments, chambers, sections) closure to be done upon completion of RW package emplacement inside them.

3.4.3. Safety requirements to LRW DDS closure

3.4.3.1. The LRW DDS closure project shall provide for implementation of the following activities:

- sealing (closure) of injection and relief wells (well plugging);
- decontamination and dismantling of constructions, engineering structures, systems and equipment designed for receipt of LRW;
- the RW disposal system monitoring.

If necessary, construction of migration-preventing screens and other measures that provides for confinement of LRW shall be implemented in places of annulus overflows along the boreholes, and where the casing pipe sealing is damaged.

3.4.3.2 Wells that have already performed their functions or wells of unacceptable technical state shall be closed down in accordance with a special project prior to closure of the LRW DDS as a whole.

3.4.3.3. In case of LRW DDS closure, a number of survey wells shall remain operable to carry out control measurements within the frames of the regional (federal) system of the environmental monitoring. If the state of the existing survey wells is not adequate from the engineering point of view, new wells shall be bored.

4. Quality assurance in disposal of radioactive waste

4.1. According to the Quality Assurance Program of the Operating Organization, requirements of federal standards and rules in the field of use of atomic energy, and other regulatory documents, the design and reliability of the RWDF (LRW DDS) systems (components), documentation and activities regarding siting, construction, operation and closure of the RWDF and operation and closure of LRW DDS shall be subject to quality assurance activities of the Operating Organization and/or organizations executing work and rendering services to the Operating Organization.

4.2. The Quality Assurance Program for RW disposal of shall be aimed at:

- arranging for the effective system of training, retraining, advanced training and qualification of employees (personnel);
- controlling quality of the delivered equipment, component parts and materials;
- arranging for quality control of RW disposal processes;
- acquiring the reliable and complete information on qualitative and quantitative composition of the disposed RW;
- arranging for control of compliance of qualitative and quantitative characteristics of the disposed RW with RW acceptance (quality) criteria that RW shall meet to be disposed of;
- providing for the required reliability of barriers;
- organizing the effective system of records and storage of documentation during the RW disposal of;
- organizing the reliable keeping of RWDF (LRW DDS) documentation after its closure.

Annex 1. (recommended). Permissible content of radionuclides in RW disposed in the near surface RWDF

Radionuclides	Activity, Bq/m^3 (Bq/g)
Radionuclides with half-life less than 5 years	Unlimited
H_3	Unlimited
C-14	$3.0 \cdot 10^{11}$ Bq/m^3
C-14 in activated metal	$3.0 \cdot 10^{12}$ Bq/m^3
Co-60	Unlimited
Ni-63	$2.6 \cdot 10^{13}$ Bq/m^3
Ni-63 in activated metal	$2.6 \cdot 10^{14}$ Bq/m^3
Sr-90	$2.6 \cdot 10^{14}$ Bq/m^3
Nb-94 in activated metal	$7.4 \cdot 10^{9}$ Bq/m^3
Cs-137	$1.7 \cdot 10^{14}$ Bq/m^3
Tc-99	$1.1 \cdot 10^{11}$ Bq/m^3
I-129	$3.0 \cdot 10^{9}$ Bq/m^3
Pu-241	$1.3 \cdot 10^{5}$ Bq/g
Cm-242	$7.4 \cdot 10^{5}$ Bq/g
Uranium and transuranic α-emitting radionuclides with half-life more than 5years	$3.7 \cdot 10^{3}$ Bq/g

As regards the waste containing mixture of radionuclides, total concentration is determined as a “sum of fractions” by dividing concentration of each radionuclide by an appropriate permissible concentration. The sum of fractions shall not exceed 1.0.

Should RW do not contain radionuclides presented in the Table, this waste is attributed to a category to which near-surface disposal limits do not apply.

The upper (conservative) value of $3.7.10^3$ Bq/g for uranium and transuranic α-emitters with half-life more than 5 years is permitted as regards individual RW packages if their specific activity does not exceed 370 Bq/g inside the RWDF, on average.

RW bulk density equal to $2t/m^3$ is applied to estimated calculations.

Annex 2. Exemplary list of accident initiating events that could occur in operation and during closure of the RWDF

1. An exemplary list of initiating events for analysis of the design basis accidents:

1.1. External impacts of natural origin endemic to the region of the RWDF site location. DBE shall be considered in seismic analysis.

1.2. External impacts of man-induced origin (air shock wave caused by explosion that could occur at the neighbor facility, at passing by conveyance, etc.).

1.3. Facility blackout.

1.4. Fire.

1.5. Drop of individual RW packages during transport and process operations and emplacement in the RWDF structures.

1.6. Failures of equipment of RW package handling systems.

1.7. Drop of process equipment and engineering structures onto an RW package

1.8. Explosion of accumulated gas.

2. An exemplary list of beyond design basis accidents:

2.1. Aircraft crush.

2.2. Shock wave with the force of 30 kPa.

2.3. Fire with a temperature equal to or more than 800℃ during 1 hour on the RWDF structures’ surface.

2.4. Impact of the bearing (drill) on the upper covering of RWDF structures.

Annex 3. Exemplary list of accident initiating events for the LRW DDS operation and closure

1.An exemplary list of initiating events for analysis of the design basis accidents:

1.1. External events of natural origin endemic to the region of the LRW UDS site location. DBE shall be considered in seismic analysis.

1.2. Facility blackout.

1.3. Failures of equipment of LRW treatment systems.

1.4. Accumulation of radionuclides in the intake beds and heating of the bed sections up to evaporation temperatures in the strata.

1.5. Gas generation in the intake bed due to radiochemical processes or chemical reactions.

1.6. Vertical filtration of waste in the low permeable horizon overlying the LRW containing horizon and contamination of a buffer horizon in the vicinity of the injection well.

2. An exemplary list of beyond design basis accidents:

2.1. Rate of radionuclide migration in the intake bed exceeds the calculated rate.

2.2. Well unsealing due to corrosion of casing pipes, cement stone degrading, occurrence of vertical overflows along the well bores, contamination of overlying horizons.

Annex 4. Exemplary list of initiating events taken into consideration in the predictive calculation made to assess long-term safety of the near surface RWDF

1. Natural external events endemic to the region of the RWDF site location:
- seismic events;
- modifications of the intensity of the precipitations resulting from a climatic change.

2. Internal events including:
- formation of chemical compounds which degrade isolating properties of barriers;
- generation of gas due to corrosion of casks and structural materials;
- microbiological decomposition of organic RW;
- chemical decomposition of RW;
- degrading of engineered barriers due to long-term effects of radiation and physical factors;
- mechanical impact of overlaying (covering the RW disposal facility) rocks;
- physical and chemical (geo-chemical) interaction of RW with media of the near-field zone of the disposal facility.

3. Human activity including:
- agricultural activities;
- use of ground water;
- construction of settlements;
- inadvertent use of radiation contaminated media from the RWDF as raw material to fabricate construction materials;
- archeological excavations;
- various industrial activities.

4. Intrusion of animals and vegetation roots.

Annex 5. Exemplary list of initiating events taken into consideration in the predictive calculation made to assess long-term safety of the deep geological isolation RWDF

1. External man-induced effects endemic to the region of the RWDF site location including changes of geological environment: activation of tectonic processes, seismic activity. DBE shall be considered in the seismic analysis.

2. Inadvertent human intrusion, including boring and mining activities, various industrial activities.

3. Internal impacts including:

- formation of chemical compounds which degrade isolating properties of barriers;
- generation of gas due to corrosion of casks and structural materials;
- microbiological decomposition of organic RW;
- degrading of engineered barriers due to long-term effects of radiation and physical factors;
- degrading of engineered barriers due to long-term effects of thermal loads;
- mechanical impact of overlaying (covering the RW disposal facility) rocks;
- physical and chemical (geo-chemical) interaction of RW with media of the near-field zone of RWDF.

Annex 6. List of initiating events taken into consideration in the predictive calculation made to assess the LRW DDS long-term safety

1. Unsealing of wells due to corrosion of casing pipes, damage of cement stone, occurrence of vertical overflows along the well bores, contamination of the overlying horizons.

2. Inadvertent human intrusion, including boring and mining operations, various industrial activities.

3.Changes in the geological environment: activation of tectonic processes, hydro-geological regime and seismic activity. DBE shall be considered in the seismic analysis.

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