Document:	NSRAO2-POR-030	Procurer: **REPUBLIC OF SLOVENIA** **Gregorčičeva ulica 20, 1000 Ljubljana** By authorisation of: **ARAO, Ljubljana** **Celovška cesta 182, 1000 Ljubljana**
ARAO identification code:	02-08-011-004	
Date:	March 2019	
Revision:	5	
Number of copies:		
Facility:	Vrbina, Krško LILW repository	
Contractor:	ARAO, Ljubljana	
Contractor's project manager:	mag. Sandi Viršek, univ. dipl. inž. geoteh. in rud.	

Document title:

Draft Safety Analysis Report for the Vrbina Krško LILW Repository

Chapter 15 Environmental aspects

DOCUMENT HISTORY

Revision:	Date of (previous) revision:	Brief description of changes from the previous version:	Notes:
1	May 2017	Amendment of the document following review	
2	January 2018	Amendment awaiting opinion of an approved nuclear and radiation safety expert	
3	November 2018	Amendments following SNSA review	
4	February 2019	Amendments following SNSA review	
5	March 2019	Supplementing of application	

TABLE OF CONTENTS

ABBREVIATIONS AND TERMS

EMISSION
An emission is the discharge of radioactive substances into the environment over a specific period. Data on emissions gathered at the point of discharge includes data on individual activities, expressed as a becquerel (Bq) unit, of all important radionuclides contained in the discharges over this period.

IMMISSION
The concentration of all key radionuclides at the monitoring points in the environment (immission) comprises the individual specific activities, expressed as Bq/kg, Bq/m3, etc., caused by the emission.

IONISING RADIATION
Ionising radiation is the transfer of energy in the form of molecular, atomic and sub-atomic particles or electromagnetic waves with a wave length of 100 nanometres or less or a frequency of 3 x 1015 Hz or more capable of producing ions directly or indirectly.

DOSE
A dose is the measure of the amount of energy absorbed per unit of weight or damage to health. Doses are absorbed, equivalent or effective. An absorbed dose denotes the energy absorbed per unit of weight. An equivalent dose denotes the various effects that a specific type of ionising radiation has on a particular tissue or organ. An effective dose denotes the level of damage to human health from exposure to ionising radiation and is calculated as the sum of all the equivalent doses, weighted for a specific tissue or organ.

DOSE LIMITS
A dose limit is the maximum value of an effective dose (and, if appropriate, the envisaged effective dose) or the maximum value of an equivalent dose over a specific interval of time that may not be exceeded for an individual.

DOSE CONSTRAINT
A dose constraint is the maximum permissible prospective radiation dose received by an individual from a defined radiation source in the course of the performance of planned activities below which exposure must be optimised.

RADIOACTIVE CONTAMINATION LIMITS
Radioactive contamination limits are the values for specific activities derived from models of the annual intake of radionuclides into the human organism by ingestion or inhalation, from models of external exposure to ionising radiation and from conversion coefficients, i.e. dose factors. They are determined for specific radionuclides or types of radionuclides on surfaces, in substances and for reference persons.

osnVP
Draft Safety Analysis Report

JV10
Rules on the monitoring of radioactivity

NEK
Krško nuclear power plant (Krško NPP)

SNSA
Slovenian Nuclear Safety Administration

Sievert (Sv)
Unit of equivalent or effective dose One Sievert is equal to one joule per kg:
1 Sv = 1 J/kg.
1 µSv = 0.001 mSv

C – Carbon
Pu – Plutonium
Rn – Radon, radionuclide Rn-222
Sr – Strontium
^{3}H – Tritium

15 ENVIRONMENTAL ASPECTS

15.1 GENERAL

This chapter mainly addresses the radiological environmental aspects.

15.1.1 DESCRIPTION OF THE APPROACH IN RELATION TO AN ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF REPOSITORY CONSTRUCTION

The environmental aspects and environmental impact assessment are addressed in more detail in the Environmental Impact Report (PVO) [1].
The environmental impact assessment relates to the phases of construction, operation and termination of the activity, and the period following clearance. Due regard is given to the existing state, including the cumulative impacts. The description and assessment of the possible impacts include: the quality of the air, groundwater, surface waters, soil and agricultural land, nature, landscape, waste, noise, ionising radiation, electromagnetic radiation and light pollution.

15.1.2 DESCRIPTION OF ALL ACTIVITIES THAT COULD GIVE RISE TO RADIOLOGICAL IMPACTS ON THE REPOSITORY AND THE SURROUNDING AREA

15.1.2.1 Operation

Operation of the repository is addressed in the *Obratovanje* (Operation) reference document, NSRAO2-POR-020 [2].
The likelihood of radioactive substances being contained in airborne discharges during operation is low and could only occur in the event of damage to a container and the radioactive waste management operations that would follow at the repository. Discharges will be radiologically monitored.

The silo will be constructed with adequate safeguards against leakage and a collection tank will be placed below the silo to collect the water. In addition to the environment, which comprises relatively low permeable silt, the main hydraulic resistance to the percolation of water is provided by PE-HD and a secondary AB liner. Water will also arise in the silo as a result of condensation. The collection tank constitutes the first control point for the possible presence of contamination. It is envisaged that the system for draining water from the disposal silo will operate until the disposal silo is sealed. After the water has been removed from the silo, the drainage pipes through which the water is removed from silo shall be sealed.

Waste process water shall be collected by means of collectors at the point at which it is created and the level of radioactivity within it established. Waste process water not suitable for discharge into the municipal sewerage system shall be collected and held until it can be sent for processing or processed at the site. It shall be held in the floor drain sump, the sanitary tank or the collection tank and, in the case of larger quantities, in the control pool. The control pool will be additionally secured against leakage by means of a polyethylene liner and a leakage test shall be performed. In the event of contamination resulting from an emergency, it will be possible to decontaminate it. Fire water will be led into the control pool from the technological facility and platform in the hall above the silo.

Contaminated waste water collected within the waste process water drainage system and exceeding the limits for discharge into the municipal sewerage system will be processed at the repository site using leased technology (evaporation or ion exchange) or sent elsewhere for processing.

Rainwater collected from roofs, reinforced and grassy areas at the site is not expected to be radiologically contaminated; it will therefore be led to a drainage well or drain into the ground by force of gravity.

Until the construction of the second phase of the technological facility, secondary LILW will be produced as a result of the taking of samples in the course of input controls, the use of personal protection equipment, and other activities taking place within the radiologically controlled area that generate waste substances. The expected radioactive waste substances will be stored, until the measurements that are to provide the basis for the removal of controls are conducted, as secondary LILW in a storage area at the technological facility, as part of a control point that includes a decontamination area. The storage capacities will enable the temporary storage of LILW generated at the repository, along with the storage of contaminated items and equipment.

After construction of the second phase of the technological facility is completed, an area for the storage of secondary LILW will be provided in the form of a reserve storage area.

An area for the analysis of operational monitoring samples is planned for the technological facility.

The standby phase is addressed in the *Obdobje mirovanja* (Standby phase) reference document, NSRAO2-POR-021 [3]. Disposal shall not be carried out during the standby phase,

although water generated in the silo will be monitored, sampled and analysed during that phase.

Preparation of the repository for the standby phase shall include activities to establish a state that meets nuclear and radiation requirements:

a. the disposal of containers with low contact doses and low-activity LILW in the last (top) layer of containers;
b. the laying of temporary (i.e. for the duration of the standby phase) or permanent layers (e.g. concrete slabs) across the last layer of containers disposed of;
c. the removal of water from the silo or from the surface of waste already disposed of.

Preparation of the repository for the re-acceptance of waste shall include establishment of a state that enables disposal to continue.

15.1.2.2 Closure and decommissioning of the repository

The environmental radiological impacts arising from the decommissioning and closure of the repository shall not exceed the environmental impacts typical of the repository construction and operation phases.
Decommissioning of the repository is addressed in the *Program razgradnje odlagališča NSRAO* (Decommissioning programme for the LILW repository) reference document, NSRAO2-POR-003 [4].

Conditioning procedures will have to be carried out on the LILW generated during the decommissioning of technological facilities and devices at the repository prior to disposal of that waste at the repository.

Due consideration is given to the fact that, in relation to decommissioning, contamination can be expected in the waste water drainage system (control pool, floor drain sump and sanitary tank) and in the ventilation system (device filters, ducts, pipes and dampers), which is subject to radiological controls.

Service systems such as heating, cooling, fire protection, back up power supply and process management and control are not directly connected to activities in the secondary and reserve RW storage facility, the hot workshop and measurement room, and the radiologically controlled area. They are not expected to become radiologically contaminated during operation.

Detailed measurements of contamination will be conducted: of the emptied technological facility and associated technological system, the waste water collection and processing system, and the ventilation system in the radiologically controlled part of the technological facility.

If contamination is detected on the surfaces of the technological facility, in the system for the collection and processing of liquids or in the ventilation system, appropriate decontamination procedures (mechanical, chemical, electrical and other procedures for removing contamination from surfaces, concrete, metals, plastics available during the decommissioning period) will have to be carried out.

The waste generated from the decontamination process will have to be adequately processed and conditioned for disposal in accordance with the acceptance criteria. Where decontamination is not possible for components and surfaces, equipment will have to be dismantled and facilities demolished.

All radioactive waste will have to be adequately separated, measurements taken of the contamination and the dose rate, and the waste processed and conditioned for disposal in accordance with the acceptance criteria.

Repairs to contaminated equipment, decontamination procedures, the sorting of waste and other work processes for the preconditioning of LILW shall be performed in the hot workshop, which will be situated in the reserve storage area during the second phase of construction of the technological facility. Decontamination activities carried out on larger items (whereby a controlled atmosphere will have to be established) shall take place in a temporarily erected decontamination cabin equipped with local waste water capture capability.

Contaminated waste water that exceeds the limits for removal to the treatment plant shall be processed at the repository.

The conditioning of the final items of LILW from decommissioning (after the technological facility has been dismantled) is expected to take place in the hall above the disposal silo.

During decommissioning and the conditioning of waste for disposal, no radiological impacts on the environment are expected from the transport of LILW packages.

15.1.2.3 Long-term surveillance

Long-term surveillance is addressed in the *Načrt dolgoročnega nadzora in vzdrževanja po zaprtju odlagališča NSRAO* (Plan for long-term surveillance and maintenance following closure of the LILW repository) reference document, NSRAO2-POR-008 [5].

The repository has been planned and laid out for the long-term storage of LILW.

It must be able to provide an acceptable level of environmental safety.

Long-term safety of the repository will be ensured by means of a disposal system comprising:

- the repository site with the appropriate (chiefly hydrogeological) characteristics (siting of disposal facilities in a geological area with low water permeability);
- waste suitably conditioned for disposal (disposal of waste in a form that retards the discharge of radionuclides);
- disposal facilities (design solutions, materials);
- monitoring and surveillance of the repository.

The key elements of the repository are the site, the waste and the disposal facilities. Deficiencies in any of these elements of the disposal system may be compensated for by better characteristics on the part of the other two elements, whereby each of the elements must meet the minimum requirements and the three elements must ensure a sufficient level of safety at the repository.

Following the termination of operation and sealing of the silo, all the installations and devices shall be removed from the access shaft, and the bottom of the silo and all voids (including the drainage pipes) filled with material, cement mortar or concrete. The disposal silo shall be sealed by means of a concrete slab and covered with a layer of material of low permeability.

The envisaged institutional surveillance period of 300 years accords with European practice. During this period, access to the repository shall be controlled and the site will have to be maintained and monitored [6].

Because the waste is to be disposed of in an underground silo, the spread of radionuclides through water will have to be carefully monitored. The likelihood of radionuclides spreading through an airborne pathway is lower.

During the long-term active surveillance period, physical protection of the repository and repository areas will be maintained.

15.1.3 TRANSBOUNDARY IMPACTS

A report titled *Evaluation of Potential Doses at the Slovenia–Croatia Border* [7]was produced to examine the impacts during the post-closure period of the repository as part of the safety analyses and waste acceptance criteria. The report addresses the spread of radionuclides through water, taking account of the surface waters (Sava river) under conditions of low sorption or the absence of sorption in the sediments. The estimated impacts are negligible to the extent that we can say that they are non-existent. The estimated maximum doses of the population are 0.1 μSv per year (0.0001 mSv/year) and are several hundred times lower than the level of natural background radiation.

15.2 MONITORING PROGRAMME (RADIOACTIVITY)

A monitoring programme has been drawn up in the *Program monitoringa* (Monitoring programme) reference document, NSRAO2-POR-037 [8].

15.2.1 GENERAL

Monitoring of radioactivity in the environment includes continual and periodic measurements of:

– radioactivity in the ambient air;
– external gamma radiation;
– the presence of radionuclides in surface waters and groundwater;
– radioactivity of the ground and precipitation;
– radioactivity of animal feed, drinking water, foodstuffs, etc.

In the event of a sudden increase in radioactivity, monitoring of the radioactivity of the environment provides data that allows protective measures to be taken in good time.

Under the Rules on the monitoring of radioactivity [9], pre-operational, operational and post-operational monitoring of radioactivity must be carried out.

The entity responsible for radioactivity monitoring and an entity liable for operational or emergency radioactivity monitoring that monitors emissions itself must have authorisation to do so from the competent authority.

The department/manager at the ARAO organisational unit shall be responsible for activities relating to monitoring. Monitoring shall be conducted on the basis of the approved monitoring programmes to be designed in the following phases, in accordance with legislative requirements.

15.2.2 PRE-OPERATIONAL MONITORING

The purpose of pre-operational monitoring is to record the (radiological) state of the environment prior to the start of operation of the repository. It shall commence prior to the start of activities at the repository site and prior to the construction of the repository.

The performance of pre-operational monitoring of radioactivity is determined by the SNSA in the approval for the facility construction permit.

When the pre-operational monitoring programme is being determined, due regard should be given to the *Obratovalni monitoring* (Operational monitoring) reference document, NSRAO2-POR-028-00 [10].

Pre-operational monitoring is addressed in the *Program monitoringa* (Monitoring programme) reference document,NSRAO2-POR-037 [8].

Table 15-1: **Pre-operational monitoring programme**

Where monitoring activities are not necessary in light of the data already obtained, or where data will be obtained in the course of another monitoring activity, this is marked in green in the table below.

Type and description of measurement	**Sample type**	**Sampling point**	**Duration of sampling**	**Measurement frequency**	
				Initial pre-operational monitoring period	**Phase 2 of pre-operational monitoring (starts one year prior to the start of trial operation)**
A. PRE-OPERATIONAL RADIOACTIVITY MONITORING					
EXTERNAL RADIATION					
Passive dosimeter (TLD)	External radiation dose	8 locations at the site of the planned repository perimeter (in accordance with the Operational Monitoring Programme, OMP)	Continuous	Once every 4 months	Once every 4 months
AIR (IMMISSIONS)					
Track detector	^{222}Rn	4 locations at the site of the planned LILW repository perimeter (in accordance with the OMP)	Continuous	Once every 4 months	Once every 4 months
Track detector	^{222}Rn	Waste management centre, Spodnji Stari Grad	Continuous	Once every 4 months	Once every 4 months
Aerosol/charcoal filter High-resolution gamma spectrometry Radiochemical analysis Sr-90/Sr-89	I-131, aerosols Strontium Sr-90/Sr-89	1 location at the LILW repository site	4 months	/	Once a year

Type and description of measurement	**Sample type**	**Sampling point**	**Duration of sampling**	**Measurement frequency**	
				Initial pre-operational monitoring period	**Phase 2 of pre-operational monitoring (starts one year prior to the start of trial operation)**
Storm drain (S = 0.25 m^2) High-resolution gamma spectrometry Radiochemical separation Sr-90/Sr-89	Radionuclides in precipitation	1 location at the LILW repository site	4 months	/	Once every 4 months
GROUNDWATER (IMMISSION)					
High-resolution gamma spectrometry	Gamma emitters in water	Boreholes in the nearfield of the repository, in the directions of water flows, 5 deep, 5 shallow (in accordance with the OMP)	Current sample	Once every 4 months	Once every 4 months
Radiochemical isolation of Sr-90, detection using a proportional counter	Sr-90 dissolved in water	Boreholes in the nearfield of the repository, in the directions of water flows, 5 deep, 5 shallow (in accordance with the OMP)	Current sample	/	Once every 4 months
Radiochemical isolation of carbon and tritium and detection using liquid scintillation/proportional spectrometry	C-14, H-3 dissolved in water	Boreholes in the nearfield of the repository, in the directions of water flows, 5 deep, 5 shallow (in accordance with the OMP)	Current sample	/	Once every 4 months
Radiochemical separation of Pu and measurements using the alpha spectrometry method	Pu-239 dissolved in water	Boreholes in the nearfield of the repository, in the directions of water flows, 5 deep, 5 shallow (in accordance with the OMP)	Current sample	/	Once every 4 months
SURFACE WATERS (IMMISSIONS)					

Type and description of measurement	**Sample type**	**Sampling point**	**Duration of sampling**	**Measurement frequency**	
				Initial pre-operational monitoring period	**Phase 2 of pre-operational monitoring (starts one year prior to the start of trial operation)**
High-resolution gamma spectrometry	Gamma emitters in water Cs-137, I-131 in the sediment	Inlet of the channel into the Spodnji Stari Grad gravel pit (location in accordance with the OMP)	Current sample	/	Once every 4 months
Liquid scintillation spectrometry/measurement at the proportional counter	Total activity of α and β emitters in water	Inlet of the channel into the Spodnji Stari Grad gravel pit (location in accordance with the OMP)	Current sample	/	Once every 4 months
Radiochemical isolation of Sr-90, detection using a proportional counter	Sr-90 dissolved in water Sr-90 in the sediment	Inlet of the channel into the Spodnji Stari Grad gravel pit (location in accordance with the OMP)	Current sample	/	Once every 4 months
Radiochemical isolation of carbon and tritium and detection using liquid scintillation/proportional spectrometry	C-14, H-3 dissolved in water	Inlet of the channel into the Spodnji Stari Grad gravel pit (location in accordance with the OMP)	Current sample	/	Once every 4 months
CATCHMENT PUMP					
High-resolution gamma spectrometry	Gamma emitters in sources of drinking water	3 sampling points: Pump Z-1, Čele, Brezina (location in accordance with the monitoring of the zero state)	Current sample	/	Once every 4 months
Radiochemical isolation of Sr-90, detection using a proportional counter	Sr-90 dissolved in sources of drinking water	3 sampling points: Pump Z-1, Čele, Brezina (location in accordance with	Current sample	/	Once every 4 months

Type and description of measurement	Sample type	Sampling point	Duration of sampling	Measurement frequency	
				Initial pre-operational monitoring period	**Phase 2 of pre-operational monitoring (starts one year prior to the start of trial operation)**
		the monitoring of the zero state)			
Radiochemical isolation of carbon and tritium and detection using liquid scintillation/	C-14, H-3 dissolved in sources of drinking water	3 sampling points: Pump Z-1, Čele, Brezina (location in accordance with the monitoring of the zero state)	Current sample	/	Once every 4 months
SOIL					
In-situ gamma spectrometry	Contamination of soil with radionuclides	Location at the LILW repository site	Current sample	Once a year	Once a year
FOOD (garden crops, field crops, fruit, milk)					
High-resolution gamma spectrometry	Concentration of gamma emitters in food	10 samples from the surrounding area of the LILW repository (location in accordance with the OMP)	Seasonal sample	/	Once a year
Radiochemical isolation of Sr-90, detection using a proportional counter	Sr-90 in food	10 samples from the surrounding area of the LILW repository (location in accordance with the OMP)	Seasonal sample	/	Once a year
Radiochemical isolation of carbon and detection of C-14 using liquid scintillation spectrometry	C-14 in food	10 samples from the surrounding area of the LILW repository (location in accordance with the OMP)	Seasonal sample	/	Once a year

Type and description of measurement	**Sample type**	**Sampling point**	**Duration of sampling**	**Measurement frequency**	
				Initial pre-operational monitoring period	**Phase 2 of pre-operational monitoring (starts one year prior to the start of trial operation)**
B. MONITORING OF PATHWAYS					
GROUNDWATER					
Level of groundwater Level of the Sava Quantity of precipitation	Liquid	The broader area of the repository (area and monitoring points in accordance with the *Nadgradnja hidrogeološke interpretacije podatkov monitoringa podzemne vode na širšem območju odlagališča NSRAO, Vrbina* (Upgrading of the hydrogeological interpretation of the monitoring data for groundwater in the broader area of the LILW repository at Vrbina, Krško) document.	Continuous	Entire pre-operational period Annual reporting	Entire pre-operational period Annual reporting
Level of groundwater	Liquid	The narrower repository site (area and monitoring points/additional shallow and deep boreholes at the repository site in accordance with the OMP)	Continuous	Entire pre-operational period Annual reporting	Entire pre-operational period Annual reporting
Physical and chemical characteristics (prior to commencement of construction)	Liquid	Existing sampling points	/ (Values and findings taken from the reports	/ (Values and findings taken from the reports titled *Glavne raziskave*	/

Type and description of measurement	**Sample type**	**Sampling point**	**Duration of sampling**	**Measurement frequency**	
				Initial pre-operational monitoring period	**Phase 2 of pre-operational monitoring (starts one year prior to the start of trial operation)**
			titled *Glavne raziskave geo- in hidrosfere* (Main research of the geosphere and hydrosphere, IRGO, 2015) and *Poročilo o obratovalnem monitoringu onesnaževanja podzemne vode ob odlagališču Spodnji Stari Grad* (Report on the operational monitoring of groundwater contamination at the Spodnji Stari Grad landfill site))	*geo- in hidrosfere* and *Poročilo o obratovalnem monitoringu onesnaževanja podzemne vode ob odlagališču Spodnji Stari Grad*)	
Physical and chemical characteristics (after commencement of construction); scope of measurements in accordance with environmental monitoring and safety analysis requirements)	Liquid	Existing and new sampling points in accordance with the hydrogeologist's opinion	Current sample	Once a year; during the most intensive construction period	Once per year; after construction
SURFACE WATERS					
Level	Liquid	Inlet of the channel into the Spodnji Stari Grad	Current sample	Once every 4 months and in	Once every 4 months and in

Type and description of measurement	**Sample type**	**Sampling point**	**Duration of sampling**	**Measurement frequency**	
				Initial pre-operational monitoring period	**Phase 2 of pre-operational monitoring (starts one year prior to the start of trial operation)**
Flow		gravel pit (location in accordance with the OMP)		extreme circumstances	extreme circumstances
Physical and chemical characteristics (scope of measurements in accordance with safety analysis and environmental monitoring requirements)	Liquid	Inlet of the channel into the Spodnji Stari Grad gravel pit (location in accordance with the OMP)	Current sample	Once a year; during the most intensive construction period	Once per year; after construction
SOIL					
Physical and chemical characteristics (prior to commencement of construction)	Rock	Existing sampling points	/ (Values and findings taken from the report titled *Glavne raziskave geo- in hidrosfere*, IRGO, 2015)	/ (Values and findings taken from the report titled *Glavne raziskave geo- in hidrosfere*, IRGO, 2015)	/
Physical and chemical characteristics (after commencement of construction); scope of measurements in accordance with safety analysis requirements)	Rock	Existing and new sampling points in accordance with the hydrogeologist's opinion	Current sample	Once a year; during the most intensive construction period	Once per year; after construction
AIR					
Meteorological data	/	Weather observatory at Krško NPP	/ (Values and findings taken from the Krško NPP USAR or up-to-date data from the Krško NPP	/ (Values and findings taken from the Krško NPP USAR or up-to-date data from the Krško NPP weather observatory)	

Type and description of measurement	Sample type	Sampling point	Duration of sampling	Measurement frequency	
				Initial pre-operational monitoring period	Phase 2 of pre-operational monitoring (starts one year prior to the start of trial operation)
			weather observatory)		
C. ENVIRONMENTAL MONITORING					
AIR					
PM10 concentrations in the ambient air	Air complies with the SIST EN 12341:2000 standard	Area of the crossroads close to the house at Spodnji Stari Grad 2a	Continuous	Prior to the commencement of construction and during the most intensive period of construction at least every two weeks	/
GROUNDWATER					
Physical and chemical characteristics Level	/	As part of the monitoring of pathways	As part of the monitoring of pathways	As part of the monitoring of pathways	As part of the monitoring of pathways
SURFACE WATERS					
Physical and chemical characteristics Level Flow	/	As part of the monitoring of pathways	As part of the monitoring of pathways	As part of the monitoring of pathways	As part of the monitoring of pathways
SOIL					
Monitoring of the quality of the soil prior to and after construction in connection with the organisation of the construction site, the damage to the surrounding soil, pollution and the management of fertile soil	/	Area of the construction site	In accordance with special written procedures drawn up on the basis of the requirements in the tender documentation	Prior to the commencement of and during construction	After construction

Type and description of measurement	Sample type	Sampling point	Duration of sampling	Measurement frequency	
				Initial pre-operational monitoring period	Phase 2 of pre-operational monitoring (starts one year prior to the start of trial operation)
AGRICULTURAL LAND					
Monitoring of the state of agricultural land and implementation of the proposed mitigation measures in connection with the organisation of the construction site, the damage to the surrounding agricultural land, pollution and the management of fertile soil	/	Area of the construction site	In accordance with special written procedures drawn up on the basis of the requirements in the tender	Recording of the zero state and the monitoring of agricultural land quality prior to construction	Monitoring after the completion of construction
NOISE					
Noise measurements conducted in accordance with Articles 4 and 9 of the Rules on initial assessment and operational monitoring for sources of noise and conditions for the implementation of monitoring (Official Gazette of the RS, 105/08).	/	The locations of noise measurements are addressed in more detail in the *Program monitoringa* (PM) reference document	In accordance with special written procedures drawn up on the basis of the requirements in the tender	Prior to the commencement of construction and during the most extensive construction works	/
IMMOVEABLE PROPERTY					
The state of existing infrastructure must be recorded prior to the commencement of construction and the impacts of construction on the infrastructure monitored during construction	/	The scope and method of implementation is addressed in more detail in the *Program monitoringa* (PM) reference document	Scope and method of implementation (PM)	Scope and method of implementation (PM)	Scope and method of implementation (PM)

15.2.3 OPERATIONAL RADIOACTIVITY MONITORING

Operational radioactivity monitoring is:

- the monitoring of radioactive emissions from a nuclear facility, including the monitoring of permitted discharges of waste radioactive substances into the environment;
- radioactivity immission monitoring and the monitoring of the radioactivity of food and feed as a result of the environmental load placed on the environment by radiation from a nuclear facility.

Operational radioactivity monitoring covers measurements of radioactivity and the collection of radiological and other data. It includes calculations of the spread of radioactive substances into the environment using models of the spread of radioactive substances.

The operational radioactivity monitoring programme is set out in JV10 [9].

The operational radioactivity monitoring programme is compiled by the entity responsible for the operational monitoring of a radiation or nuclear facility as part of the facility's Safety Report. The SNSA shall re-review and approve the operational radioactivity monitoring programme for a radiation or nuclear facility in response to any modification in the facility's mode of operation, if the modification has an impact on radioactive discharges, in response to changes in the environment that could have a significant impact on the discharge of radioactive substances and the exposure pathways, and on the basis of the findings of reports on the implementation of operational radioactivity monitoring.

The operational radioactivity monitoring programme shall determine:

1. the types of discharge, such as atmospheric and liquid;
2. the main pathways;
3. the radionuclides most responsible for exposure;
4. the monitoring of other required data, such as meteorological and hydrological data, land use data, or data on the dietary and other habits of the population. The performance of pre-operational radioactivity monitoring is determined by the SNSA in the approval for the facility construction permit or the performance of construction or mining works on account of which nuclear or radiation safety measures have to be carried out in order to establish the initial state of radioactivity.

Preparation of the programme of implementation of the operational radioactivity monitoring programme shall take place in accordance with the following timetable:

1. determination of the type of activity and the locations of discharges of radioactive substances, and an assessment of the quantities of radioactive substances discharged;
2. determination of discharge into the environment via the atmosphere or water, as external radiation or in some other way;
3. drafting of a programme for measuring emissions of radioactive substances and the radioactivity of the environment, and the collection of other data for assessing the radioactivity of the environment;

4. determination of the pathway of exposure to radioactive radiation, such as exposure to external radiation or through inhalation or ingestion;
5. definition of the reference group from the exposed population;
6. an assessment of the exposure of reference group and a comparison with the authorised limits;
7. drafting of a programme for carrying out emergency radioactivity monitoring.

Under the Rules on the monitoring of radioactivity [9] operational radioactivity monitoring for an LILW repository encompasses the monitoring of atmospheric and liquid discharges and measurements in the environment, the basis for which is given in Annex 7. The SNSA prescribes the detailed content for an individual facility in the procedure of the issuing of an operating licence.

For atmospheric discharges from an LILW repository, emissions of the radionuclide ^{222}Rn are measured in particular.

The basis for the radioactivity programme is determined in JV10 [9], Annex 7, Table 2.

Operational monitoring for the LILW repository is addressed in the *Obratovalni monitoring* reference document, NSRAO2-POR-028 [10].

The planned operational monitoring is described in more detail in Chapter 15.2.13. Programme of measurements of radioactive substances.

15.2.4 POST-OPERATIONAL MONITORING

The scope and duration of post-operational radioactivity monitoring is determined in relation to the expected environmental impact in the vicinity of the closed repository.

Measurements or sampling are performed in the same places as operational monitoring, but less frequently. Furthermore, monitoring is not performed at all locations and for all types of samples or pathways as it is in operational monitoring. The scope of the programme is determined towards the end of the operation of the facility.

The planned post-operational monitoring is described in more detail in Chapter 15.2.13. Programme of measurements of radioactive substances.

15.2.5 PERMITTED LIMITS, OPERATIONAL LIMITS FOR DISCHARGES OF SOLID, LIQUID AND GASEOUS SUBSTANCES, MEASURES FOR ADHERING TO LIMITS

15.2.5.1 Discharge of liquid or gaseous radioactive substances

Practices involving radiation shall be performed in such a way that discharges of liquid or gaseous radioactive substances into the environment do not exceed the limits.

The Slovenian Nuclear Safety Administration shall approve the limits in the procedure of approving the Safety Report.

15.2.5.2 Limits (dose limits and radioactive contamination limit values)

15.2.5.2.1 *Dose limits*

Dose limits are the maximum values of an effective dose (and, if appropriate, the envisaged effective dose) or the maximum value of an equivalent dose that may not be exceeded for an individual.

The annual effective dose limit for exposed workers is 20 mSv.

The annual effective dose limit for members of the public is 1 mSv.

15.2.5.2.2 *Dose limits for the repository*

The dose limits for a repository are determined in JV5 [12], Annex 5 (Design bases for a radioactive waste repository), point 7. Repositories may not place a burden on a member of the public of more than 0.3 mSv/year after closure under the normal evolution scenario for the repository. In cases of alternate evolution scenarios for the repository, the following measurements should be taken into account for the implementation of measures to respond to the burden imposed on a member of the public:

a) up to 10 mSv/year: no measures to optimise the repository required;

b) above 10 mSv/year: measures required to minimise the likelihood of an alternate evolution scenario;

c) above 100 mSv/year: measures required to minimise the consequences of the alternate evolution scenario.

Alternate scenarios and doses are addressed in detail in Chapter 7 of the Draft Safety Report.

Alternate scenarios comprise undesired events or states following the closure of a repository, and caused by natural events or by human, animal or plant activity, that accelerate the long-term degradation of the repository and the migration of radioactive substances, and increase radiation (e.g. inadvertent human intrusion, water and mineral boreholes, the effects of greenhouse gases, the activation of fractures, global icing, failure of facility seals, migration that produces gases) JV5 [12].

15.2.5.2.3 *Radioactive contamination limits*

Radioactive contamination limits are the values for specific concentrations of activities derived from models of the annual intake of radionuclides into the human organism by ingestion or inhalation, from models of external exposure to ionising radiation and from conversion coefficients, i.e. dose factors, and are determined for specific radionuclides or types of radionuclides on surfaces, in substances and for individuals or for a reference population group (ZVISJV) [13].

Limits are addressed in the Decree on dose limits, radioactive contamination and intervention levels (UV2) [14] (annual intake limits, contamination limits: air, surface waters and groundwater, the human body, work environment, surfaces, work clothes, food and feed, etc.).

15.2.6 OPERATIONAL LIMITS

15.2.6.1 Operational dose limits

Operational dose limits are addressed in the *Obratovalni pogoji in omejitve* (Operational limits and conditions) reference document, NSRAO2-POR-027 [15].

Operational dose limits are expressed as operational dose limits of any radiation quantity laid down by an approved radiation protection expert for a specific practice involving radiation or a specific source of radiation. Operational dose limits can be equal to or lower than authorised dose limits.

The following limits at the site of the (outer perimeter) fence of the repository are given for all operational states of a repository (1. receipt and disposal, 2. preparedness for receipt and disposal, 3. non-operational part in the area of the silo, 4. standby phase):

15.2.6.1.1 *Dose (cumulative)*

The annual effective dose at the perimeter of the repository may not exceed 200 µSv (0.2 mSv/year).

15.2.6.1.2 *Dose from liquid discharges*

The annual effective dose from liquid discharges may not exceed 5 µSv (0.005 mSv/year).

The concentration of emitter activities in liquid discharges may not exceed the authorised concentrations for clearance under the regulations (UV1) [16].

15.2.6.1.3 *Dose from discharges into the air*

The annual effective dose from discharges into the air may not exceed 5 µSv (0.005 mSv/year).

15.2.7 CLEARANCE OF RADIOACTIVE SUBSTANCES

The Decree on practices involving radiation (UV1) [16] determines the limits for clearance of radioactive substances.

UV1 [16] shall be observed in relation to values for discharges, which may not exceed the levels laid down for the clearance of radioactive substances.

15.2.8 METHOD OF MONITORING OF DISCHARGES FROM THE REPOSITORY

The monitoring of discharges is addressed in more detail in the *Študija varstva pred sevanji* (Radiation safety study) [17] .
Radioactive discharges from the repository shall be monitored at points at which they could leak into the environment. Liquid and gas emissions are considered.
The level of radioactivity in the water collected from the silo will be monitored using the radiation counter to be installed in the collection tank. The counter will be connected to the control room, where the readings will be displayed.
Water from all the collectors will be subject to radiological control prior to removal. Samples will be taken and an analysis of radioactivity conducted using the high-resolution gamma spectrometry method.

Airborne discharges from the silo and the technological facility shall be monitored by means of continuous sampling of the air via a filter and the analysis of the filter using the high-resolution gamma spectrometry method.

Basic measurements and sampling in the environment will take place at points at which the greatest impact from the radiation or nuclear facility is expected, i.e. in the direction of the groundwater movement for underground emissions, in the direction of the water flow for emissions into surface waters and in the prevailing wind direction for any atmospheric discharges. The majority of the measurements will be conducted at those points over longer periods so as to enable trends to be observed.

Radioactivity measurements will include additional monitoring and sampling points in the opposite direction to the water flow and the prevailing wind so as to make it possible to assess the radiological conditions of the background and the nearest larger settlement.

The following controls are planned in relation to the dose at the perimeter:
The cumulative (effective) dose shall be determined at least every three months. They shall cover direct irradiation and atmospheric and liquid discharges. The dose coefficients given in UV2 [14] shall be taken into account in the calculation.
The cumulative dose of liquid and the cumulative dose of gaseous discharge shall be determined at least every three months.
The cumulative dose from irradiation shall be determined on the basis of three-month monitoring data. The highest measured cumulative value shall be taken as the value of the monitoring point.

Two measures are envisaged if the values are exceeded: reporting on the non-compliance within 30 days and the announcement of the implementation of corrective actions, and the immediate performance of activities to reduce the radiation loads.

15.2.9 MANAGEMENT AND ARCHIVING

Archiving is addressed in the *Hranjenje dokumentacij in zapisov* (Storing of documents and records) reference document, NSRAO2-POR-006 [18].

A holder that keeps, stores, discharges or disposes of radioactive waste shall keep records to this effect (Article 22 of the Rules on radioactive waste and spent fuel management (JV7)) [11].

15.2.9.1 Management and archiving of monitoring

Records on radioactivity monitoring shall include: information on sampling and the preparation of samples, the measurement conditions (time of measurements, geometry of the sample, etc.), the parameters used in the analysis and the interim results, and the measurement results and their measurement uncertainty. The records shall be arranged such that they can be used to analyse trends in the radioactivity of the environment and for other analyses.

The operator of the repository shall keep permanent records on radioactivity monitoring, and radioactivity monitoring providers shall store them for a period of five years after the measurement was performed.

ARAO will provide documentation and storage of monitoring data.

15.2.9.2 Central register

A central register (Article 23, JV7) [11] shall be maintained for radioactive waste:

- that is located with holders;
- that has been discharged into the environment;
- that has been cleared.

Data on annual forecasts of the generation of radioactive waste during the operation and decommissioning of nuclear facilities shall also be kept in the register.

The central register shall be kept by calendar year of the generation of radioactive waste.

The format of data in the central register is laid down in Annex 3 to JV7 [11] for:

- solid or liquid radioactive waste (Table I);
- radioactive waste discharged into the environment (Table II);
- the annual projections for radioactive waste (Table III).

15.2.9.3 Records of radioactive discharges

For every individual discharge, the records shall contain at least information on the origin and quantity of radioactive substances discharged, as well as information from which it can be established that the approved discharge levels were not exceeded.

15.2.9.4 Records of the clearance of radioactive substances

Records of the clearance of radioactive substances shall be maintained under UV 1 [16].

15.2.10 ALARM SYSTEMS

The SNSA shall operate and maintain a system for the continuous measurement of dose rates in the atmosphere, collect measurement results electronically, ensure quality, and maintain an early-warning system for increased radioactivity. The operator of a nuclear facility shall send the SNSA information on continuous measurements in accordance with the Rules on the monitoring of radioactivity.

Liquid and gaseous discharges shall be monitored at the repository.

Waste water shall be drained into the sewerage system if the contamination levels are below the authorised limits or if they do not exceed the levels at which radioactive substances can be cleared as laid down in UV1 [16]. Prior to discharge, samples shall be taken and analysed (using the high-resolution gamma spectrometry method).

Water shall be re-pumped from the collection tank below the silo using automatic activation and deactivation of the pumps via switches or manually. When the radiological monitor detects increased radioactivity of water in the collection tank, an alarm will be triggered in the control room and the submersible pumps in the collection tank deactivated. A change in the position of the valves will divert water to the control pool. The level of water in the collection tank shall also be monitored from the control room. Two pumps with a capacity of 5 L/s shall operate at the pumping station on the collection tank.

Measurements of the water level in the pool shall be regulated and recorded in the management and control system.

Measurements of the activity of the water in the pool prior to discharge shall be conducted by means of sampling and laboratory (off-line) measurements. Water from the control pool and sanitary tank will be sampled and discharged in the same way.
Measurements of the activity of the water in the collection tank shall be conducted in-line and with a direct link to the repository's information system. In-line measurements of the water level in the collection tank, the control pool and the sanitary tank shall also be conducted.

Airborne discharges from the silo and the technological facility shall be monitored by means of continuous sampling of the air via a filter (aerosol sampler) and the samples (filters) shall be measured using the high-resolution gamma spectrometry method. Contamination shall be established at the location of airborne discharges (on the facade of the hall on the NE side, on the roof of the technological facility Phase 1 and the roof of the technological facility Phase 2 (after construction of Phase 2, Phase 1 discharges shall be cleared and arranged for Phase 2 discharges)). Should activity be detected in airborne discharges from the technological facility's ventilation system and the silo duct, the ventilation system shall be isolated (dampers closed and the ventilation system deactivated). The status of the isolation and deactivation operation shall be shown in the management and control system.

Measurements of exhausts shall be automatic and in-line, with periodic in-line checks made of the situation at the filter. If increased contamination is detected, isolation will be triggered and the ventilation system shut down.

15.2.11 FORWARDING OF DATA TO NATIONAL AUTHORITIES AND THE PUBLIC

The operator of the LILW repository shall report the radiological monitoring results to the competent regulatory authority (SNSA) on a regular basis. By providing these reports, the operator shall demonstrate that the LILW repository is under adequate supervision and control.

Reporting is addressed by the *Poročanje upravnim organom* (Reporting to the regulatory authority) reference document, NSRAO2-POR-011 [19].

Reporting and information-provision shall take place in accordance with the provisions of JV 10 [9]. The following reporting operations shall be carried out:

- on implementation of the annual radioactivity monitoring programme;
- on operational and post-operational radioactivity monitoring and long-term surveillance;
- on the implementation of emergency radioactivity monitoring.

15.2.11.1 Notification of the nuclear and radiation safety authority

The operational radioactivity monitoring provider shall ensure that the entity responsible for operational radioactivity monitoring at the SNSA is notified immediately of any deviation in the measurement results from the authorised dose constraints and authorised limits laid down in regulations, the operating licence or the licence to perform a practice involving radiation.

The radioactivity monitoring provider shall also notify the SNSA immediately of the contamination results if it detects newly present radionuclides that were not envisaged in the radioactivity monitoring programme or the emergency radioactivity monitoring programme, and if it detects a significant increase in the concentration of radionuclides relative to the previous measurements. Similar anomalous results shall also be reported.

15.2.11.2 Provision of information to the public

The entity responsible for operational and post-operational monitoring and for long-term surveillance shall apprise the public of the content of the most recent annual report and of any special report stemming from the exceeding of the dose constraint for a reference person.

15.2.11.3 Regular and emergency reporting on operational radioactivity monitoring

The entity responsible for operational monitoring shall provide reports to the competent regulatory authority in the form of an annual report on implementation of the operational radioactivity monitoring programme for the previous year.

The annual report shall include:
1. a tabular presentation of the prescribed programme of measurements;

2. an indication of the sampling, sample preparation and measurement methodologies deployed;
3. the results of the measurements and their measurement uncertainty;
4. the geographical coordinates of the sampling or monitoring points;
5. an evaluation of the measurement results;
6. the results of comparative measurements;
7. dose estimates;
8. results of independent controls.

Information on sampling, the preparation of samples

and the auxiliary quantities should be stated in the annual report alongside the measurement results.

The activities of all recorded radionuclides should be mentioned in the results of measurements conducted using spectrometric methods.

An electronic collection of records on measurements of radioactivity should also be enclosed with the annual report, with the format prescribed by the SNSA in the annual environmental radioactivity monitoring programme.

The entity responsible for operational monitoring shall, in the report on the implementation of the operational radioactivity monitoring programme, also give details of any proposal to change the extent of operational radioactivity monitoring in the future if there are grounds for such a change.

During the implementation of operational radioactivity monitoring, the entity responsible for operational monitoring shall notify the regulatory authority if the results of the radioactivity measurements for an individual radionuclide exceed the values and authorised limits under the provisions of JV10 [9].

The entity responsible for operational monitoring of a facility that could give rise to sudden and significant discharges into the atmosphere shall provide continuous data from automated monitoring stations within the early-warning network in the area surrounding the facility or at the facility site, and provide continuous transfer of this data to the SNSA at the frequency stated in the operational radioactivity monitoring programme.

15.2.11.4 Reporting on emergency radioactivity monitoring

The emergency radioactivity monitoring provider shall, during an emergency, report the radioactivity measurements to the SNSA in electronic form as soon as possible.

The emergency monitoring provider shall, no later than 14 days after the end of the emergency, send the SNSA a report on the emergency radioactivity monitoring, containing:

- the results of the measurements and their measurement uncertainty;
- the period to which the results apply;
- the geographical coordinates of the monitoring or sampling points;
- information on sampling and samples;
- information on the auxiliary quantities for evaluation of the results;
- a short- and long-term estimate of the doses received by population groups that received the maximum doses and by the population as a whole.

15.2.11.5 Provision of public information on emergency radioactivity monitoring

The public shall be apprised of the results of emergency radioactivity monitoring in accordance with the national civil protection and disaster relief plan for a nuclear accident.

The SNSA shall ensure that the results of any emergency radioactivity monitoring are shared internationally in accordance with adopted international conventions and treaties.

15.2.12 TYPES OF DISCHARGE, THE MAIN PATHWAYS AND THE MONITORING OF DATA

When planning the operational monitoring programme, due regard shall be given to the fact that Krško nuclear power plant is located in the vicinity of the LILW repository, and that an extensive radioactivity monitoring programme is in place for the area around the former. The results of this monitoring shall be used for the monitoring of radioactivity in the vicinity of the LILW repository. The possibility of radionuclides spreading into the environment via water shall be subject to detailed monitoring. The possibility of radionuclides entering the environment chiefly via this pathway is provided for, while the airborne transfer of radionuclides is less likely (or it is expected that the radionuclides discharged this way will be considerably less radioactive).

In the event of an increased concentration of radionuclides (groundwater), data from all monitoring points will have to be analysed. It is expected that one deep and one shallow borehole will be drilled upstream from the repository so that radionuclide concentrations can be compared.

15.2.12.1 Method of transfer into the environment

15.2.12.1.1 *Airborne pathway*

Airborne discharges from the repository are possible in the event of an accident and the subsequent handling of damaged containers and radioactive materials. Emissions are monitored above the doors on the NE facade of the hall above the silo and from the radiologically controlled part of the technological facility (on the roof of the TF during Phases 1 and 2 of TF construction).

Monitoring of gamma emitters and of Sr-90 and C-14 (the two most common beta emitters in waste) is proposed.

Waste from the central radioactive waste storage facility (CSRAO) at Brinje near Ljubljana will also be disposed of at the repository. This waste includes several waste items containing Ra-226, the descendant of which is Rn-222, a gas. This means that the concentration of Rn-222 must be monitored in airborne discharges. It would be reasonable to measure the

concentration of radon in the silo itself as well as at several locations around the silo (*Obratovalni monitoring* reference document, NSRAO2-POR-028) [10].

The estimated dose of radon generated by radioactive waste disposed of and containing Ra-226 is negligible in the safety analyses.

15.2.12.1.2 *Water pathway*

Obratovalni monitoring reference document, NSRAO2-POR-028) [10]

The active water pumps and catchments, as well as the Sava river, are monitored as part of radioactivity monitoring in the area surrounding Krško NPP. Monitoring will be introduced at those locations where radioactivity could be transferred from the repository into watercourses and then into the Sava or the groundwater. Radioactivity monitoring will be conducted on garden produce around the LILW repository site. Five deep boreholes (the existing VOG-1, VOG-2, VOG-3 boreholes, with two new boreholes south and east of the silo) and five shallow boreholes on each side of the repository, or on those sides towards which water flows, are proposed. It is expected that one deep and one shallow borehole will be drilled upstream from the repository so that radionuclide concentrations can be compared. The borehole will reach to the depth of the water flows and at least one will also reach to below the lowest point at which radioactive waste is disposed of.

The surface waters in the area of the repository will flow into a drainage channel that forms part of Brežice hydroelectric plant, and will end in the area of the retention facilities for the Brežice intake. From here the surface waters will be led along channels adjacent to the storage reservoir and then flow into the Močnik stream, which empties into the Sava at Brežice. It would be reasonable to monitor the radioactivity of surface waters that flow into the Močnik stream from the repository via gravel pits and channels. The sampling point for surface waters is situated at the location of the outlet from the drainage channel in the flooded Spodnji Stari Grad gravel pit. A location on the Močnik stream above the water inlet downstream from the repository, e.g. at Zgornja Pohanca, shall be chosen as the reference location.

15.2.12.2 Radioactive substances most responsible for exposure

Among the set of radionuclides that must be monitored are those with the highest levels of activity in waste, as follows from the *Safety Analysis and Waste Acceptance Criteria Preparation for Low and Intermediate Level Waste Repository in Slovenia*, Inventory Report, ARAO, EISFI-TR-(11)-12 Vol. 1, Rev. 3, April 2012, Table 6.1) [6].

The high-resolution gamma spectrometry method allows us to monitor almost all gamma emitters, although this is not possible for beta and alpha emitters; this is because each alpha or beta emitter is determined by its own specific method, making it practically impossible to monitor all of them. The proposal is for monitoring to be conducted of those beta and alpha emitters with the greatest activity in waste: C-14, Sr-90 and Pu-239.

15.2.12.3 Data monitoring

The operational monitoring programme shall include the monitoring of required data, such as meteorological and hydrological data, data on the dietary and other habits of the population, and land use data.

The chemical parameters of the groundwater shall be monitored in connection with the hydrological data (water temperature, dissolved substances, pH value, electrical conductivity, etc.), along with the groundwater level (fluctuation).

A knowledge of the meteorological data prior to and during sampling or measurement operations is very important for a proper analysis of the data collected; such data shall be provided by the weather station. As the current plans envisage that meteorological monitoring will be provided in conjunction with Krško NPP, meteorological data from the public network of stations must be used at the repository location after the completion of the decommissioning of Krško NPP and during the active surveillance and maintenance of the repository.

15.2.12.3.1 *Programme of meteorological measurements/acquisition of meteorological data*

Table 15-2: Scope and frequency of capture of meteorological data, *Obratovalni monitoring* reference document, NSRAO2-POR-028 [10]

Data	**Frequency of capture**
Air temperature	continuous
Dewpoint temperature	continuous
Relative air humidity	continuous
Atmospheric pressure	continuous
Reduced atmospheric pressure	continuous
Atmospheric pressure tendency	continuous
Global solar radiation	continuous
Periodic quantity of precipitation	periodic
Precipitation intensity (in the most recent period)	continuous
State of precipitation in the most recent period	continuous
Duration of precipitation in the most recent period	continuous
Quantity of precipitation in the most recent period	continuous
Meteorological optical range (MOR) (10 m ... 2,000 m)	continuous
Average wind speed (ground level, reference height)	continuous
Maximum wind speed (ground level, reference height)	continuous
Average wind direction (ground level, reference height)	continuous

15.2.12.3.2 *Operational monitoring of waste water* [1]

The following parameters must be monitored:

- temperature (preliminary limit value 30 ºC);
- pH-value (6.5–9);
- undissolved substances (80 mg/L);
- total hydrocarbons (mineral oils) 5 mg/L

Operational monitoring of waste water shall be carried out on a periodic basis, at the time sampling takes place for requirements relating to discharges into the sewerage system in accordance with requirements of the operator of Vipap treatment plant.

Periodic sampling, which applies to industrial waste water and is conducted in accordance with Article 10 of the Rules on initial measurements and operational monitoring of waste water [20], will not be carried out during regular operation due to the small quantity of industrial waste

water (total quantity will not exceed 4,000 m^3 and the waste water can be considered to be municipal waste water).

In the event of the appearance of waste water as a result of an accident (e.g. fire, implementation of remedial action after the fall of a container, accidental intrusion of water into the silo, etc.), waste water shall be discharged into the public sewerage system after prior sampling and harmonisation of the requirements with the nuclear safety regulatory authority and with the operator of the sewerage system and the treatment plant.

15.2.12.4 Types of activity and points of discharge of radioactive substances

The repository and the LILW disposal system shall be arranged in such a way that prevent the discharge of radioactive substances into the environment.

Waste water management at the repository shall include:

- collection;
- processing or forwarding for processing elsewhere;
- radiological and chemical monitoring;
- drainage into the surrounding area;
- drainage into the sewerage system.

Waste water shall be removed with the water discharged into the sewerage system via the Vipap treatment plant.

At the repository site, water shall be collected from the silo in the collection tank in the lower part of the silo, water from the control point to be constructed in Phase 1 of the technological facility shall be collected in the control tank, and water from the reserve storage capacities (to be constructed in Phase 2 of the TF) in the floor drain sump (and surplus water from these two sources in the control pool). During normal operation, industrial waste water will appear only in the silo. The *Obratovalni monitoring* reference document (NSRAO2-POR-028) [10] states that, under normal operation, concentrations of radioactive isotopes in the pumped water will not exceed the authorised concentrations for clearance under the regulations (UV1) [16] .

15.2.13 PROGRAMME OF MEASUREMENTS OF RADIOACTIVE SUBSTANCES

The pre-operational radiological monitoring programme is outlined in Table 15-1.

15.2.13.1 Operational (radiological) monitoring programme

The operational programme for the monitoring of radioactivity and of radioactivity during the standby phase of the LILW repository is addressed in the *Obratovalni monitoring* reference document [10] and the Environmental Impact Report [1], and shall, in accordance with requirements, be compiled as part of the Safety Report.

Operational monitoring is conducted during the operation and standby phase of the repository, i.e. between suspension of operation and the decommissioning of Krško NPP. The measured values are compared with the values from pre-operational monitoring, which serves to assess the environmental impact of the facility and to calculate the doses for members of the public.

By conducting operational monitoring, the operator of a nuclear facility is able to demonstrate that the radioactivity of discharges in normal operation and during the standby phase do not exceed the authorised limits and limit values determined by regulations, and that the operation of facilities does not expose the population to radiation above the authorised limits and the limits determined by regulations.

Table 15-3: **Operational monitoring programme and monitoring during the repository standby phase**

Type and description of measurement	**Sample type or measurement parameters**	**Sampling point**	**Sampling frequency**[1]	**Measurement frequency**
EXTERNAL RADIATION				
Passive dosimeter	External radiation dose	Silo entrance 8 locations at the perimeter of the repository, each of the cardinal directions Reference location	Continuous	Once every 3 months
In-situ measurements (emissions) using the high-resolution gamma spectrometry method	Contamination of the area	Location at the repository	Once a year	Once a year
AIR (EMISSIONS)				
High-resolution gamma spectrometry	Aerosol filter	Exhaust from the silo duct Exhaust from the TF (control point, Phase 1 of TF or air-conditioning machine room, Phase 2 of TF) Reference location	Continuous	Once a month
Strontium Sr-90, specific analysis (radiochemical isolation of Sr-90, detection with the proportional counter)	Aerosol filter	Exhaust from the silo duct Reference location	Continuous	Once every 3 months
C-14 Radiochemical isolation of carbon and detection of C-14 using liquid scintillation spectrometry	Aerosol filter	Exhaust from the silo Reference location	Continuous	Once every 3 months

[1] "Sampling frequency" gives information on when the sample that is being measured was taken.

Type and description of measurement	**Sample type or measurement parameters**	**Sampling point**	**Sampling frequency**[1]	**Measurement frequency**
Total alpha/beta Liquid scintillation spectrometry for determining total activity of α and β emitters in water, or method with measurement at the proportional counter	Aerosol filter	Exhaust from the silo duct Exhaust from the TF (control point, first phase or air-conditioning machine room, Phase 2 of TF) Reference location	Continuous	Once a month
^{222}Rn	Air – trace detector	Exhaust from the silo or location within the silo itself 8 locations around the silo Reference location	Continuous	Once a month
^{222}Rn	Air – continuous measurements (measurements lasting at least 1 week)	Location in the silo itself	Continuous	Twice a year (winter, summer)
GROUNDWATER (IMMISSION)				
High-resolution gamma spectrometry	Liquid	Boreholes in the nearfield of the repository, in the directions of water flows, 5 deep, 5 shallow Reference location	Once every 3 months	Once every 3 months
Strontium Sr-90, specific analysis (radiochemical isolation of Sr-90, detection with the proportional counter)	Liquid	Boreholes in the nearfield of the repository, in the directions of water flows, 5 deep, 5 shallow Reference location	Once every 3 months	Once every 3 months
C-14 Radiochemical isolation of carbon and detection of C-14 using liquid scintillation spectrometry	Liquid	Boreholes in the nearfield of the repository, in the directions of water flows, 5 deep, 5 shallow Reference location	Once a year	Once a year
Pu-239 Radiochemical separation of Pu-239 and measurement using the alpha spectrometry method	Liquid	Boreholes in the nearfield of the repository, in the directions of water flows, 5 deep, 5 shallow Reference location	Once a year	Once a year

Type and description of measurement	**Sample type or measurement parameters**	**Sampling point**	**Sampling frequency**[1]	**Measurement frequency**
^{3}H	Liquid	Boreholes in the nearfield of the repository, in the directions of water flows, 5 deep, 5 shallow Reference location	Once every 3 months	Once every 3 months
LIQUID DISCHARGES (EMISSIONS)				
High-resolution gamma spectrometry	Liquid	Silo collection tank Sanitary tank (TF, Phase 1) Floor drain sump (TF, Phase 2) Control pool	Before every discharge	in-line
Phase 1: Gross alpha/beta Liquid scintillation spectrometry for determining total activity of α and β emitters in water, or method with measurement at the proportional counter Phase 2: specific analysis of α and β emitters (potentially C-14, Sr-90 and H-3 in particular)	Liquid	Silo collection tank Sanitary tank (TF, Phase 1) Floor drain sump (TF, Phase 2) Control pool	Before every discharge	in-line
^{3}H	Liquid	Silo collection tank Sanitary tank (TF, Phase 1) Floor drain sump (TF, Phase 2) Control pool	Before every discharge	in-line
SURFACE WATERS (IMMISSIONS)				
High-resolution gamma spectrometry	Liquid	Inlet of the channel into the Spodnji Stari Grad gravel pit Reference location	Continuous sampling	Once every 3 months
Gross alpha/beta Liquid scintillation spectrometry for determining	Liquid	Inlet of the channel into the Spodnji Stari Grad gravel pit	Continuous sampling	Once every 3 months

Type and description of measurement	Sample type or measurement parameters	Sampling point	Sampling frequency[1]	Measurement frequency
total activity of α and β emitters in water, or method with measurement at the proportional counter		Reference location		
Strontium Sr-90, specific analysis (radiochemical isolation of Sr-90, detection with the proportional counter)	Liquid	Inlet of the channel into the Spodnji Stari Grad gravel pit Reference location	Continuous sampling	Once every 3 months
^{3}H	Liquid	Inlet of the channel into the Spodnji Stari Grad gravel pit Reference location	Continuous sampling	Once every 3 months
SURFACE WATERS, SEDIMENT				
High-resolution gamma spectrometry	Sediment	Inlet of the channel into the Spodnji Stari Grad gravel pit Reference location	Single sample	Once a year
Strontium Sr-90, specific analysis (radiochemical isolation of Sr-90, detection with the proportional counter)	Sediment	Inlet of the channel into the Spodnji Stari Grad gravel pit Reference location	Single sample	Once a year
FOOD (GARDEN AND FIELD CROPS)				
High-resolution gamma spectrometry	Garden and field crops (if not available, samples of grass/hay)	Location (field) in the vicinity of the repository, 2 samples Reference location	1 x per year, seasonal sample	Once a year
Strontium Sr-90, specific analysis (radiochemical isolation of Sr-90, detection with the proportional counter)	Garden and field crops (if not available, samples of grass/hay)	Location (field) in the proximity of the repository, 2 samples Reference location	1 x per year, seasonal sample	Once a year
C-14 Radiochemical isolation of carbon and detection of C-14 using liquid scintillation spectrometry	Garden and field crops (if not available, samples of grass/hay)	Location (field) in the proximity of the repository, 1 sample Reference location	1 x per year, seasonal sample	Once a year
FOOD (FRUIT)				

Type and description of measurement	Sample type or measurement parameters	Sampling point	Sampling frequency[1]	Measurement frequency
High-resolution gamma spectrometry	Fruit	Location in the proximity of the repository, 2 samples Reference location	1 x per year, seasonal sample	Once a year
Strontium Sr-90, specific analysis (radiochemical isolation of Sr-90, detection with the proportional counter)	Fruit	Location in the proximity of the repository, 2 samples Reference location	1 x per year, seasonal sample	Once a year
C-14 Radiochemical isolation of carbon and detection of C-14 using liquid scintillation spectrometry	Fruit	Location in the proximity of the repository, 1 sample Reference location	1 x per year, seasonal sample	Once a year

The locations of monitoring points and monitoring boreholes are provided on the basis of the *Obratovalni monitoring* reference document, NSRAO2-POR-028 [10] and summarised in Annexes 15-1, 15-2, 15-3 and 15-4.

Radionuclides can enter food via the transfer of radionuclides from soil and water to plants and thereafter, via the food chain, into animals and human beings. Basic monitoring of radioactivity in agricultural plants is proposed, along with the monitoring of radioactivity in the edible parts of staple crops. Sampling locations will be situated in the vicinity of the repository and at the reference location.

In the event of increased radioactivity, analyses of the results of pre-operational monitoring and of samples at various locations in the area will be required.

15.2.13.2 Post-operational (radiological) monitoring programme

The post-operational monitoring programme is addressed in the *Načrt dolgoročnega nadzora in vzdrževanja po zaprtju odlagališča NSRAO* reference document, NSRAO2-POR-008 [5], and will, in accordance with requirements, be compiled as part of the Safety Report.

During the period of the transfer of the repository to long-term surveillance, the scope of implementation of measurements and of maintenance activities will be adjusted to the scope prior to the closure of the repository, and will be at least equivalent to the scope of surveillance for active long-term surveillance as set out in Table 15-5.

Table 15-4: **Monitoring programme during the active long-term surveillance phase**

Type and description of measurement	**Sample type**	**Sampling point**	**Sampling frequency**	**Measurement frequency**
EXTERNAL RADIATION				
Passive dosimeter	External radiation dose	5 luminescent dosimeters (4 sides of the area and one reference point adjacent to the disposal units)	Continuous	Twice a year
AIR (EMISSIONS)				
^{222}Rn	Air – trace detector	4 locations around the silo Reference location	Continuous	Once a year
GROUNDWATER				
High resolution gamma spectrometry	Liquid	Boreholes 5 deep, 5 shallow Reference location	Once a year	Once a year
SURFACE WATERS				
High-resolution gamma spectrometry	Liquid	Inlet of the channel into the Spodnji Stari Grad gravel pit Reference location	Continuous sampling	Once a year
Gross alpha/beta	Liquid	Inlet of the channel into the Spodnji Stari Grad gravel pit Reference location	Continuous sampling	Once a year
Strontium Sr-90, specific analysis (radiochemical isolation of Sr-90, detection with the proportional counter)	Liquid	Inlet of the channel into the Spodnji Stari Grad gravel pit Reference location	Continuous sampling	Once a year

Radioactivity monitoring shall be adjusted to the planned state of the facility after decommissioning and closure.

Measurements of the dose of external radiation from contamination of the area will not be required as any contamination during the operation and decommissioning of the repository will be remediated/removed during repository closure activities.

Because the silo and access shaft will be buried and sealed after closure, there are no plans for the monitoring of aerosol filter emissions from these facilities or continuous measurements of Rn-222 in the silo. It is proposed that measurements from the operational monitoring proposal for Sr-90, C-14 and Pu-239 in the groundwater and measurements of radioactivity in surface water sediments and of radioactivity in food (garden crops, field crops, fruit) be

discontinued during the period of long-term active surveillance, unless the results of measurements during the period of operation of the facility demonstrate otherwise [5].

Following the decontamination, dismantling and removal of the collection tank and control pool during the period of repository closure, all measurements of liquid discharges from the repository shall cease during the period of long-term active surveillance.

15.2.13.3 External radiation

Surveillance will establish the levels of external radiation in the narrower area of the repository and its immediate vicinity. Measurements of external radiation using dosimeters are envisaged at the entrance to the silo, at the repository perimeter in all four cardinal directions and at the reference point.

External radiation shall be measured using electronic dose rate counters, which are used for the in-line monitoring of external radiation, and passive thermoluminescent dosimeters.

15.2.13.4 Selected reference persons from the exposed population, assessment of the exposure of the reference person and a comparison with the authorised limits

Public exposure is assessed using models that examine the spread of radionuclides via pathways into the environment.

Regarding limits, an effective dose at the perimeter of the repository (cumulative; from direct irradiation, liquid discharges and discharges into the atmosphere) is the dose of the member of the public who has received the highest dose.

Under the ZVISJV [13], the reference person is the individual who receives a dose typical for more exposed individuals from the population, excluding persons with extreme or rare habits.

The reference person shall be defined in the operational radioactivity monitoring programme, with due regard to the provisions of JV10 [9].

The entity responsible for operational monitoring shall define one or more reference persons from the population representing the group of individuals who receive or who could receive the highest dose. Extreme habits of individuals from the population may not be taken into account when making the selection.

Reference persons from the population may differ from each other in terms of pathway so that individuals are exposed in different ways. Doses from all pathways must be added together when assessing exposure.

The entity responsible for operational monitoring shall, for a reference person from the population, collect basic data on the habits of the individuals included in the group, i.e. time spent in enclosed areas and outdoors, dietary and life habits (e.g. most common outdoor sports activities, intensive gardening, mushroom picking, river swimming, etc.).

The data from the previous paragraph shall be collected for all age groups of the population and repeated at least every five years. Any changes shall be addressed using the procedure

determined for the approval of changes as set out in the provisions of the act governing ionising radiation protection and nuclear safety.

The reference person selected for assessing doses during operation of the repository is an individual working in a field directly next to the perimeter for 2,016 hours per calendar year.

For calculating doses in safety analyses for the post-closure period of the repository, the following exposure pathways were considered for a reference person from the potentially most exposed population group: consumption of fish from rivers and plants grown in areas irrigated by river water; consumption of milk and meat from animals that have grazed in an area irrigated by river water; consumption of drinking water from a well that intercepts potential contamination at a distance of 100 m from the repository and in use after 300 years of surveillance; inhalation and exposure in the irrigated area (100% presence).

A reference person from the village of Spodnji Stari Grad, north-east of the site, is proposed as an additional reference person for monitoring purposes, taking into account exposure via the air (airborne pathway).

15.2.13.5 Emergency radioactivity monitoring programme

Emergency radioactivity monitoring shall be conducted during emergencies so that the following may be obtained in good time:

1. information on the level and type of external radiation and radioactive contamination;
2. information required by the competent regulatory authority that performs tasks under the national civil protection and disaster relief plan for a nuclear accident (hereinafter: national plan) for decisions on the remedial, corrective and other intervention measures required;
3. information required for decisions on the level and type of protection for emergency workers;
4. information required for the provision of information to the public on the level of danger;
5. information required to determine those persons who must be medically monitored for a longer period after the event;
6. information for the purposes of international information exchange.

The emergency programme of monitoring of the radioactivity of the environment and of persons shall depend on the course and extent of the emergency. A permanent state of preparedness shall be maintained for the effective implementation of emergency monitoring.

In the event of an emergency at the repository, where there is the possibility of the event involving radioactive material, emergency monitoring at the repository site is envisaged. The measures to be taken in the event of an emergency are addressed in the *Ukrepanje ob izrednem dogodku* (Measures in the event of an emergency) reference document, NSRAO2-POR-007 [21].

Not every emergency involves the occurrence of a radiological accident; it could involve a reduction in radiation safety that also requires the appropriate response. Owing to the danger of an increased level of radiation or contamination of the working environment and of some parts of the repository with radioactive material as a result of an emergency, remedial measures are required.

The level of danger for Krško NPP is defined in the national emergency plan in the event of a nuclear or radiological disaster [22].

The level of danger presented by an event shall be determined by the person in charge of response at the repository, who is a worker on constant standby. The response concept will be based on the classification and announcement of the danger level:

- a danger level whereby the event is brought under control entirely by ARAO staff and the safety department;
- a danger level for which the involvement of external intervention units is envisaged.

Emergency monitoring shall cover radioactivity measurements at the radiation source, measurements of the contamination of equipment and objects and measurements in the environment, and measurements of the exposure of the operator's workers, intervention personnel and other persons present. In the event of an emergency in which the event is brought under control entirely by the ARAO personnel present, emergency monitoring shall be conducted by the operator's radiation protection department. In the event of a danger for which the involvement of external intervention units is envisaged, the scope of the emergency monitoring shall be determined by the SNSA.

The frequency of sampling, the duration of an individual sampling or measurement operation, the number of measurements and the locations of the measurements shall be determined in accordance with the danger level and the extent of the consequences of the emergency. The sampling and measurement locations shall be determined by the repository operator's radiation protection department or else the department shall consult the SNSA.

Under the provisions of JV 10 [9] , the emergency radioactivity monitoring programme shall be drafted by the SNSA during the initial phases of the emergency. The SNSA shall immediately communicate it to all entities responsible for emergency radioactivity monitoring, update it on an ongoing basis in response to the development of events, and manage its implementation during the emergency. The guidelines given in Annex 8 to JV 10 [9] shall be taken into account during the drafting of the emergency radioactivity monitoring programme.

15.2.14 SURVEILLANCE OF THE AREA (SITE) OF THE REPOSITORY (PARTICULARLY AFTER CLOSURE)

The programme of observations shall cover:

1. facilities and building structures included in the ageing management programme (reference document NSRAO2-POR-026-01 02-08-011-003 – *Nadzor procesov staranja*/Monitoring of ageing processes);

2. other facilities and building structures important to repository safety and addressed in the *Obratovalni pogoji in omejitve* (Operational limits and conditions) reference document.

15.2.14.1 Frequency of observations

Observations shall be conducted on a regular (periodic) and emergency basis. Periodic observations shall normally be carried out twice a year, during typical seasonal periods (winter and summer). Emergency observations shall be carried out in response to emergency conditions and events:

- after an earthquake with acceleration exceeding 0.15 g;
- after a flood that has involved the leaking of flood water onto the repository site;
- after another emergency that could significantly affect the characteristics of the SSCs under observation;
- prior to every filling of voids in the silo (observation of silo);
- prior to larger encroachments into the structure of buildings for possible reconstruction purposes;
- after the detection of any anomalies in or damage to a structure that could threaten the stability and safety of a facility under observation.

During the construction period, the frequency of observations is connected to the phase of facility construction.

15.2.14.2 Types and results of observation

The types of observation shall depend on the characteristics of the SSCs being observed. They include:

- visual inspections;
- measurements of vertical shifts in the observation reference points;
- measurements of the operation and depths of cracks;
- establishment of the quality of materials with in-situ tests of materials and laboratory tests of samples taken.

The taking of samples and the laboratory analysis of groundwater are also a constituent part of the observation process (performed as part of pathway monitoring), as are the capture and analysis of any groundwater that has percolated into facilities.

All the data collected by observation shall constitute the basis for the implementation of all necessary analyses for the production of an assessment of the safety, durability and usefulness of all structures, systems and components (SSCs). The results of the observation and the analyses are entered into the report/cadastre on the state of the facilities.

15.2.14.3 Written procedures for the implementation of observation

Observation operations shall be carried out in accordance with written procedures governing:

- the technical implementation of observation and measurements;
- the requirements for measuring and other equipment;
- the requirements for those entities carrying out and organising observation operations;
- the requirements for measurement precision;
- the results evaluation procedure, including measurements of the acceptability of the established parameters (e.g. acceptable width and depth of cracks).

15.2.14.4 Starting points for the implementation of geodetic observation of vertical shifts

The observation of vertical shifts shall be carried out in accordance with the geometric levelling method. A vertical reference network shall be defined and put into operation for the implementation of observation operations, taking into account the geological and geomechanical factors. The network shall comprise well-stabilised reference points connected to each other by means of level loops and polygons.

The baseline vertical network shall be established so that it enables connections to:

- the Krško NPP levelling network;
- the national levelling network or a connection to high-precision benchmarks outside the area of the sediments.

Control points (14 are envisaged) shall be built into the concrete structure of the facilities, to at least the following extent:

- three reference points on the silo;
- two reference points on the control pool
- six reference points on the flood protection plateau;
- one reference point on the technological facility, Phase 1 (service part);
- two reference points on the technological facility, Phase 2 (technological part).

The system of geodetic observation of vertical shifts of LILW repository facilities must ensure the definition of statistically typical shifts of an order of magnitude of 1 mm.

The investor must ensure, for the implementation of geodetic monitoring:

1. the preparation of a vertical reference geodetic network project for the determination of vertical deformations and shifts of LILW facilities;
2. the stabilisation of reference and control reference points in accordance with the client-approved design from the preceding point;
3. the preparation of a vertical geodetic observations project for determining the vertical deformations and shifts of LILW facilities (geodetic datum, method, measurement method and timetable, equipment, resources, processing of observations, establishment of shift, presentation);

4. the establishment of zero measurements in accordance with the observation programme;
5. the implementation of regular periodic and emergency observations in accordance with the design output (point 3).

15.2.14.5 During construction

Technical observations shall commence during the period of construction of the repository facilities. Buildings and their components important from the standpoint of auditing the effectiveness of the implementation of construction works, implementing the safety functions of the engineered barriers and achieving of the planned (design) characteristics of the structures shall be incorporated into the observation process.[2] During the construction period, data on the geomechanical and hydrogeological characteristics of the site must also be checked or obtained; this data shall be taken into account in the strength analyses and shall be important for the subsequent stages of the repository, including in the event of any expansion of the repository with a view to constructing additional disposal units (silos). Observations during the construction phase will be directed chiefly towards the acquisition of data on:

1. movements of rocks during execution of the construction pit (for the silo, control pool and technological facility);
2. movements (subsidence) of building structures during the construction phase (for the silo, control pool and technological facility);
3. additionally for the silo, data on:
    a. the method and effectiveness of implementation of the pumping of groundwater in relief wells (after the excavation and construction phases);
    b. the permeability of the primary liner (contacts, cracks);
    c. the erosion of rock in relation to the permeability of the primary liner;
    d. the permeability of the secondary liner (contacts, cracks).

The entity responsible for carrying out observations during construction shall be the construction works contractor. The guidelines and framework criteria for observations shall be defined in the documentation for the construction works tender. The contractor shall provide details of the monitoring process in the written procedure.

[2] Monitoring demonstrates that the safety functions have been fulfilled, IAEA SSR-2/1, 4.2; Continuous and periodic monitoring of safety functions must be in place, IAEA SSR-2/2, Requirement 9.

15.2.14.6 After construction

The proposed draft plan of post-construction technical observations is provided in Table 15-5.[3]

Table 15-5 : **Draft plan of technical observation of building structures**

Facility/building structure (SSC designation)	**Type of observation**				
	Measurements of vertical shifts	**Measurements of depth of cracks**	**Measurements of operation of cracks**	**Visual inspection**	**Materials testing**
Silo (O3)	Twice a year	Twice a year	Twice a year*	Twice a year	Once a year
Control pool (O4)	Twice a year	Twice a year	Twice a year	Twice a year	Every 6 years
Flood protection plateau (O9)	Twice a year	–	–	Twice a year	–
Technological facility (T1)	Twice a year	Every 6 years	Twice a year	Twice a year	Every 6 years
Outer perimeter fence (F1)	–	–	Twice a year	Twice a year	–
Fire water tank in the administrative and service building	–	Every 6 years	Twice a year	Twice a year	–

Note: As part of the measurements of the operation of cracks, shifts in the dilatation between the silo and the base concrete platform of the hall above the silo shall also be monitored.*

Technical observations during the post-construction period shall also include laboratory tests of groundwater in the area of the silo and of water that has percolated into the silo, for the following purposes:

- establishing the aggressiveness of the water;
- measuring chlorides, sulphates, pH, aggressive CO_2, ammonia and magnesium.

The programme of post-construction technical observations shall be drafted by the repository operator prior to the completion of repository construction.

15.2.14.7 Long-term active surveillance

Surveillance of the repository shall cover the area of the repository and any immediate surroundings that could have an impact on the repository or in which the impact of the repository has been detected by means of measurement procedures.

In addition to radioactivity monitoring, smaller-scale physical and chemical monitoring of the groundwater is also envisaged during the long-term active surveillance period using the proposed shallow and deep boreholes, meteorological monitoring and geodetic monitoring.

[3] The approach is taken from the Krško NPP document titled *Program tehničnih opazovanj gradbenih objektov in konstrukcij, Postopek NEK* (Programme of technical observations of buildings and structures, Krško NPP procedure) No TD-2N, Rev. 4.

Geodetic monitoring is expected to be carried out using the extended Krško NPP geodetic network.

Table 15-6: **Proposed non-radiological monitoring during the long-term active surveillance phase**

Monitoring	**Parameters**	**Frequency (regular)**
Physical and chemical	Measurements of individual chemical parameters of the groundwater (water temperature, dissolved substances, pH value, electrical conductivity, etc.), along with the groundwater level (fluctuation)	Once a year
Meteorological	Air temperature, relative humidity, quantity of precipitation, wind direction and speed	In-line, automatic
Stability and geodetic monitoring	Monitoring of the stability of the repository and of shifts and slips of the banks of the repository flood protection plateau	Every three years if the measurements confirm the stability of the repository and its impact area or discontinuation if approved by the appropriate regulatory authority at the initiative of the operator/contractor

Access routes to the repository required for the performance of periodic maintenance work (cutting of grass and the felling of trees and shrubs at the edge of the repository, etc.) shall be maintained.

The post-closure period of the repository is addressed in the *Načrt dolgoročnega nadzora in vzdrževanja po zaprtju odlagališča NSRAO* reference document, NSRAO2-POR-008 [5].

It is envisaged that the repository will be physically secured during the active surveillance period in the area occupied by the sealed silo(s) within the outer perimeter fence; this will constitute the boundary of the protected area and will, at the same time, restrict direct access to the repository site itself. The gates or barrier barring access to the repository shall be closed and locked except when access is required.

Warning and prohibition signs shall be placed on the entrance gates and the protective perimeter. The warning signs shall contain information on the owner of the facility, the facility type, the dangers presented by the material disposed of at the facility (radiation warning, prohibition of access by unauthorised persons) and a warning that the water in the area is not suitable for drinking. Signs will also be placed in particular above the disposal section of the repository so as to prevent inadvertent human intrusion.

The repository shall be prepared for long-term passive surveillance when the long-term active surveillance period comes to an end. The passive surveillance phase will last a maximum of 300 years after closure of the repository, unless another duration is determined on the basis of a safety analysis and operational experience.

Preparation for long-term passive surveillance will include the following in particular:

- the removal of all equipment for the performance of measurements and other forms of active surveillance;
- the removal of the facilities that were required for active surveillance, or the handover of the facilities to unrestricted use;
- the removal of fences or the termination of fence maintenance.

Long-term passive surveillance of the repository will primarily be carried out for:

- the storage of information on the repository;
- maintenance of ownership of the repository land;
- the presence of signage at the repository.

At the end of passive surveillance, the repository site will pass to unrestricted use. The above-ground repository facilities shall be removed or be handed over to unrestricted use. Regarding the presence of signage at the repository, the maintenance of elements of the facilities (pillars of both entrance gates of the hall) to mark the location of the silo or the repository site is envisaged. It is also proposed that the site be marked by maintaining a series of parts of the administrative and service building.

The buried repository plateau will, if the above-ground facilities are handed over to unrestricted use and elements of the facilities are maintained, remain in part or in whole, depending on the results of safety analyses and of surveillance during operation, prior to closure and during the period of active post-closure surveillance.

Warning signs will be placed in the area occupied by the silo(s). The warning signs shall contain information on the owner of the facility, the facility type, the dangers presented by the materials deposited at the facility, and basic information on and the properties of the LILW disposed of there.

15.2.14.8 **Monitoring of the use of space**

Activities shall be restricted in the area of restricted use of the repository (broader area of controlled use of the repository) in accordance with UV3 [23].

The area of restricted use of space resulting from the presence of the repository shall be located in the area of restricted use of space resulting from the presence of Krško NPP.

After closure of the repository, an area of restricted use under UV3 [23] is envisaged, encompassing an area of 50 m around the repository area in which activities are restricted in accordance with UV3 [23].

An area of restricted use of space is proposed following closure of the repository with a radius measured from the centre of the silo (1 and 2) and at a distance of 50 m from the outer edge of the silo, or a circle at a radius of 65 m from the centre of the silo.

The technological facility following decommissioning and the administrative and service building may remain in use for requirements relating to long-term active surveillance and maintenance, or may be temporarily passed over to other activities, taking the activities permitted under UV3 [23]into account.

The agreement of the SNSA and ARAO shall be required for activities in the area of restricted use of space.

15.3 OTHER IMPACTS

15.3.1 OTHER IMPACTS

15.3.1.1 Construction

Measures shall be carried out at the construction site to prevent leakage. Technically faultless construction machinery shall be used, and the seals of machine assemblies and hydraulic connections checked. Fuels and lubricants for machinery shall be stored on a reinforced, limited and covered surface capable of retaining the entire quantity of stored substances without the possibility of inflow of rainwater and precipitation. Portable collecting containers and absorbent materials must be available at the construction site. The cleaning of machines and vehicles shall be carried out on a sealed surface.

A safety plan shall be drawn up under the provisions of the Decree on the implementation of health and safety at work requirements at temporary and mobile construction sites [24].

15.3.1.2 Operation

Rainwater from the plateaus and driving surfaces, where motor vehicles and machinery are expected in greater numbers, shall be drained via an oil separator with a coalescing filter into the rainwater runoff system and then, via a drainage field, into the ground.
Oil separators must be checked and maintained (emptied) on a regular basis.
The runoff system must be maintained on a regular basis.
Programmes for the monitoring of the state of the environment must be adhered to.

15.3.1.3 Decommissioning and closure

Decommissioning is addressed in the *Program razgradnje odlagališča NSRAO* reference document, NSRAO2-POR-003 [4].

Decommissioning of nuclear facilities includes decontamination and dismantling procedures, and the removal of radioactive waste. It encompasses a sequence of measures that lead to the closure and then termination of surveillance of a nuclear facility. Non-radiological impacts are the same as they are for the construction period.

15.3.1.4 Long-term surveillance

Long-term surveillance is addressed in the *Načrt dolgoročnega nadzora in vzdrževanja po zaprtju odlagališča NSRAO* reference document, NSRAO2-POR-008 [5].

No activities are envisaged as taking place at the repository that would have non-radiological impacts on the repository and the surrounding area during the long-term surveillance period.

15.3.2 AREA OF RESTRICTED USE OF SPACE

15.3.2.1 Area of restricted use of space and restrictions on the use of space resulting from a nuclear facility

Under point 4 of Article 5 of UV3 [23] (Decree on areas of restricted use due to nuclear facilities and on the conditions of construction), an area of restricted use of space shall be of such a size that a person present on the external boundary of the area following a maximum design discharge of radioactive substances from the nuclear facility throughout the passage of a radioactive cloud during an emergency does not receive a total dose greater than 250 mSv or a thyroid dose greater than 3 Sv.

In determining the areas of restricted use of space, the SNSA shall consider the potential impacts of activities within these areas on the nuclear facility and on the implementation of emergency plans in accordance with the regulations governing protection against natural and other disasters in the event of an emergency at a nuclear facility.

Under the provision of point 7 of Article 3 of UV3 [23], any practices or activities that may, through deep interventions below the surface of the soil, compromise the protective functions of the geological layers surrounding the repository shall be prohibited in areas of restricted use of space resulting from an LILW repository.

An LILW repository shall be located within a broader area of controlled use of space (area with a radius of 1,500 m from the centre (reactor) of Krško NPP).

In an area of restricted use of space resulting from a nuclear facility, the activities under Annex 1 to the Decree on areas of restricted use due to nuclear facilities and on the conditions of construction (UV3) [23] are permissible provided that the impacts on radiation and nuclear safety are verified and deemed acceptable during the procedure of acquiring design conditions, consents, guidelines and opinions.

Under point 5 of Article 3 of UV3 [23], the area of the restricted use of space is outlined for informative purposes in the Conceptual Design Rev. C, [25], Main file (Graphical section: Overview, Overview of land parcels and repository facilities, Graphical presentation of location, size and forms of land parcels).

Under point 5 of Article 3 of UV3 [23], the minimum extent of the area of restricted use resulting from an LILW repository, i.e. the minimum extent of the broader area of controlled use of space resulting from a repository, is defined as the area within a circle with the centre in the centre of the nuclear facility and a radius of 500 m, and the minimum extent of the broader area of

controlled use of the repository after closure is the area of the nuclear facility, extended by a band 50 m wide around the repository.

15.3.2.1.1 *Area of restricted use of space resulting from a repository*

The area of restricted use of space resulting from an LILW repository is the broader area of controlled use defined as a circle with a radius of 500 m from the centre of the repository.

Under the provisions of the *Praktične smernice za vsebino varnostnega poročila za odlagališče NSRAO* (Practical guidelines for the content of the Safety Report for the LILW repository), PS 1.03, 2012 [26], the centre of the repository is defined as the centre of gravity of the floor areas of all the planned disposal units and technological facilities.

The calculation includes Silo 1, Silo 2 and the technological facility (Phases 1 and 2).

15.3.2.1.2 *Area of restricted use of space resulting from a closed repository*

The area of restricted use of space resulting from an LILW repository after closure is the broader area of controlled use, which is defined as a circle with a radius from the centre of the silo and clearance of 50 m from the silo, or a circle with a radius of 65 m from the centre of the silo.

15.3.2.1.3 *x,y coordinates*

Centre of the repository: 88324.87, 541158.13

Centre of silo 1: 88318.32, 541131.54

Centre of silo 2: 88347.48, 541065.62

The area in question (area of restricted use of the repository and area of restricted use of the repository after closure) are shown in the graphical annex to the Draft Safety Report (15.4).

15.3.2.2 Proposed smaller area of restricted use of space resulting from a repository

Under point 8 of Article 3 of UV3 [23], the extent of the broader area of controlled use of space resulting from a repository defined by the SNSA in its preliminary consent may be reduced provided that the environmental impact assessment report [1] demonstrates that the implementation of radiation and nuclear safety measures in the reduced area of restricted use of space remains unimpeded.

With regard to the provisions referred to in the first to third paragraphs of point 15.3.2.1 and based on the results of the safety analyses in Chapter 7, an area of restricted use of space resulting from an LILW repository smaller than that laid down in point 5 of Article 3 of UV3 [23] is proposed. It follows from the Draft Safety Report (Chapter 7) **that the doses received by persons present at the perimeter of the LILW repository would be considerably lower than set out in Article 3 of the Decree on areas of restricted use due to nuclear facilities and on the conditions of construction (UV3), i.e. considerably lower than 250 mSv or a thyroid dose of 3 Sv. We therefore propose that the boundary of the area of restricted use be the outer perimeter of the LILW repository**. **Radiation and nuclear measures shall remain unimpeded in the reduced area.**

15.4 ANNEXES

15.4.1 GRAPHICAL ANNEX 15-1
Location of monitoring points and monitoring boreholes in the area of the repository

15.4.2 GRAPHICAL ANNEX 15-2
Location of meteorological monitoring points and monitoring boreholes outside the repository

15.4.3 GRAPHICAL ANNEX 15-3
Surface water sampling locations

15.4.4 GRAPHICAL ANNEX 15-4
Fruit and field crop sampling locations

15.4.5 GRAPHICAL ANNEX 15-5
Area of restricted use of space resulting from a repository, M 1:2000, IBE, July 2016

The area of restricted use of space resulting from a repository and the area of restricted use of space resulting from a closed repository are shown.

EXPLANATION: Graphical Annex 15-5 shows the area of restricted use of space in accordance with point 5 of Article 3 of UV3 [19], which enables identification of the parcels (parcel no) and coordinates of the vertices of the polygons that demarcate the area of restricted use of space resulting from the repository (the coordinates are given in point 15.3.2.1.3).

NOTE: **A proposal for a reduced area of the restricted use of space resulting from an LILW repository is made. It is defined as the outer perimeter of the repository (see point 15.3.2.2).**

15.5 REFERENCES

[1] Environmental Impact Report for the LILW repository *(Poročilo o vplivih na okolje za odlagališče NSRAO), NSRAO2-PVO-001*. ERICo d.o.o. and HSE Invest d.o.o.

[2] Reference document, Operation (*Referenčna dokumentacija Obratovanje*), Rev. 1, NSRAO2-POR-020. IBE d.d.

[3] Standby phase (*Obdobje mirovanja*) Rev. 1, NSRAO2-POR-021-01. IBE d.d.

[4] Reference document, Decommissioning programme for the LILW repository (*Referenčna dokumentacija Program razgradnje odlagališča NSRAO*), Rev. 1, NSRAO2-POR-003.

[5] Reference document, Long-term post-closure surveillance and maintenance plan (*Referenčna dokumentacija Načrt Dolgoročnega nadzora in vzdrževanja po zaprtju odlagališča*) Rev. 1, NSRAO2-POR-008.

[6] Safety Analysis and Waste Acceptance Criteria Preparation for Low and Intermediate Level Waste Repository in Slovenia, EISFI, 2012, 2015, 2016.

[7] Evaluation of Potential Doses at the Slovenia–Croatia Border, Technical Report, NSRAO2-PCS-018 (Safety analysis and waste acceptance criteria preparation for low and intermediate level waste repository in Slovenia), EISFI consortium, October 2016.

[8] Reference document, Monitoring programme (*Referenčna dokumentacija Program monitoringa*), Rev. 1, NSRAO2-POR-037, IBE d.d. 2018.

[9] Rules on the monitoring of radioactivity (*Pravilnik o monitoringu radioaktivnosti*) (JV10). (Official Gazette of the RS, 27/18).

[10] Reference document, Operational monitoring (*Referenčna dokumentacija Obratovalni monitoring*), Rev. 1, NSRAO2-POR-027. IBE d.d.

[11] Rules on radioactive waste and spent fuel management (*Pravilnik o ravnanju z radioaktivnimi odpadki in izrabljenim gorivom*) (JV7). (Official Gazette of the RS, 49/06, 76/17 [ZVISJV-1]).

[12] Rules on radiation and nuclear safety factors (*Pravilnik o dejavnikih sevalne in jedrske varnosti*) (JV5) (Official Gazette of the RS, 74/16).

[13] Ionising Radiation Protection and Nuclear Safety Act (*Zakon o varstvu pred ionizirajočimi sevanji in jedrski varnosti*) (ZVISJV). (Official Gazette of the RS, 102/04 [official consolidated version], 70/2008 [ZVO-1B], 60/2011, 74/2015).

[14] Decree on dose limits, reference levels and radioactive contamination (*Uredba o mejnih dozah, referenčnih ravneh in radioaktivni kontaminaciji*) (UV2). (Official Gazette of the RS, 18/18).

[15] Reference document, Operational limits and conditions (*Referenčna dokumentacija Obratovalni pogoji in omejitve*), Rev. 1, NSRAO2-POR-027. IBE d.d.

[16] Decree on radiation activities (*Uredba o sevalnih dejavnostih*) (UV1). (Official Gazette of the RS, 19/18).

[17] Vrbina Krško LILW repository, Conceptual Design (*Odlagališče NSRAO Vrbina, Krško, Idejna zasnova*), Rev. C., January 2016, IBE d.d., Study of radiation protection (*Študija varstva pred sevanji*).

[18] Reference document, Storage of documentation and records (*Referenčna dokumentacija Hranjenje dokumentacij in zapisov*), Rev. 1, NSRAO2-POR-006.

[19] Reference document, Reporting to regulatory authorities (*Referenčna dokumentacija Poročanje upravnim organom)*, Rev. 1, NSRAO2-POR-011.

[20] Rules on initial measurements and operational monitoring of waste water (*Pravilnik o prvih meritvah in obratovalnem monitoringu odpadnih vod*) (Official Gazette of the RS, 94/2014, 98/2015).

[21] Reference document, Measures in the event of an emergency, (*Referenčna dokumentacija Ukrepanje ob izrednem dogodku*), Rev. 1, NSRAO2-POR-007.

[22] National emergency plan in the event of a nuclear or radiological disaster (*Državni načrt zaščite in reševanja ob jedrski ali radiološki nesreči*), Version 3.0, No 84300-4/2010/3, Slovenian government, 2010.

[23] Decree on areas of restricted use due to nuclear facilities and on the conditions of construction (*Uredba o območjih omejene rabe prostora zaradi jedrskega objekta in o pogojih gradnje objektov na teh območjih*) (UV3). (Official Gazette of the RS, 36/04, 103/06, 92/14).

[24] Decree on the implementation of health and safety at work requirements at temporary and mobile construction sites (*Uredba o zagotavljanju varnosti in zdravja pri delu na začasnih in premičnih gradbiščih*) (Official Gazette of the RS, 83/05, 43/11 [ZVZD-1]).

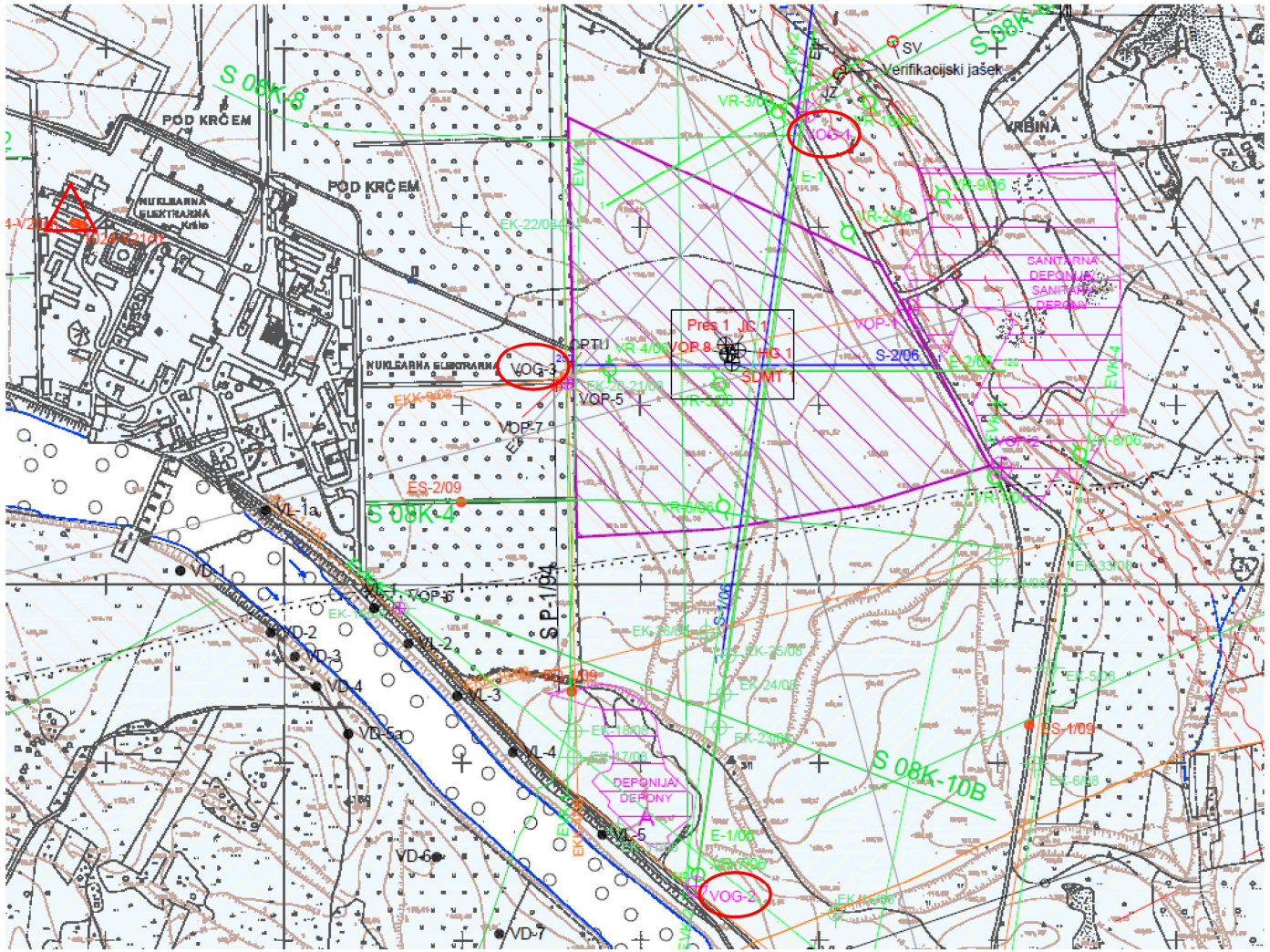
[25] Vrbina Krško LILW repository, Conceptual Design (*Odlagališče NSRAO Vrbina, Krško, Idejna zasnova*), Rev. C. 2016.

[26] Practical Guidelines – Content of the Safety Report for the low- and intermediate-level radioactive waste repository (*Praktične smernice – Vsebina varnostnega poročila za odlagališče nizko in srednje radioaktivnih odpadkov*). 2012.

GRAPHICAL ANNEX 15-1 Location of monitoring points and monitoring boreholes in the area of the repository

LEGENDA	KEY
Zunanje sevanje – pasivni dozimeter	External radiation – passive dosimeter
Zunanje sevanje – in situ gama	External radiation - in situ gamma
Zrak – aerosolni filter	Air - aerosol filter
Zrak – Rn detektorji sledi	Air - Rn trace detector
Zrak – Rn kontinuirne meritve	Air - Rn continuous measurements
Podtalnica – plitve vrtine	Groundwater - shallow boreholes
Podtalnica – globoke vrtine	Groundwater - deep boreholes
Tekočinski izpusti	Liquid discharges
Opomba: Referenčne lokacije niso prikazane	Note: Reference locations are not indicated.

GRAPHICAL ANNEX 15-2 Location of meteorological monitoring points and monitoring boreholes outside the repository



LEGENDA

Globoka vrtina

Meteorološki stolp

LEGENDA	KEY
Globoka vrtina	Deep borehole
Meteorološki stolp	Meteorological tower

GRAPHICAL ANNEX 15-3 Surface water sampling locations

LEGENDA

Površinske vode in sediment
1 – Vtok kanala v gramoznico Spodnji Stari Grad
2 - Referenčna lokacija

LEGENDA	KEY
Površinske vode in sediment	Surface waters and sediment
1 – Vtok kanala v gramoznico Spodnji Stari Grad	1- Inlet of the channel into the Spodnji Stari Grad gravel pit
2 – Referenčna lokacija	2 – Reference location

GRAPHICAL ANNEX 15-4 Fruit and field crop sampling locations

LEGENDA

★ Hrana - povrtnine, poljščine

★ Hrana - sadje

Opomba: referenčna lokacija (npr. Dobova) ni prikazana

LEGENDA	KEY
Hrana – povrtnine, poljščine	Food (garden and field crops)
Hrana – sadje	Food (fruit)
Opomba: referenčna lokacija (npr. Dobova) ni prikazana.	Note: The reference location (e.g. Dobova) is not indicated.