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Draft Safety Analysis Report for the Vrbina Krško LILW Repository

Chapter 12 Closure of the repository

DOCUMENT HISTORY

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

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ABBREVIATIONS AND TERMS

ARAO – Agency for Radwaste Management

IDP – Conceptual Design

JV5 – Rules on Radiation and Nuclear Safety Factors, Official Gazette of the RS 74/16

JV9 – Rules on Operational Safety of Radiation and Nuclear facilities, Official Gazette of the RS 85/09, 8/10, 87/11
JV10 – Rules on the Monitoring of Radioactivity, Official Gazette of the RS 20/07, 97/09

NEK - Krško nuclear power plant

LILW – Low and intermediate level waste

SNSA – Slovenian Nuclear Safety Administration

ZVISJV – Ionising Radiation Protection and Nuclear Safety Act, ZVISJV-UPB2, Official Gazette of the RS 102/04 with amendments

Backfill – (Backfilling) grout for filling voids in the silo

Disposal facility - disposal silo

Disposal container – Container filled with LILW and ready for disposal

12 CLOSURE OF THE REPOSITORY

The chapter addressing the closure of the entire repository (as a nuclear facility) and the closure of the disposal facility (silo) is a summary of the reference document for the LILW repository – Closure of the repository. [1] It also describes the activities and procedures for the decontamination, dismantling and removal of all radioactive waste from the non-disposal part of the disposal facility (the silo and the hall above the silo).
The objective of the closure is the closing of the repository. The closure of the repository is the completion of all measures that must be carried out to ensure the long-term safety of the repository. Following closure, the repository will acquire the status of a closed repository, for which long-term monitoring and maintenance must be provided. A decision on the status of the closed repository following its closure is issued by the SNSA along with the issuing of a decision on termination of the status of nuclear facility. [2]

The LILW repository is a nuclear facility at which all activities will be carried out that are directly linked to the disposal of radioactive waste.
The wider surroundings of the repository contain:

- the entrance to the repository,
- the core area of the repository,
- vacant surfaces of the repository, and
- areas for connection to utilities infrastructure.

Scope of the closure programme

The programme includes the closure of the entire repository (as a nuclear facility) and the technical and other procedures for closure of the disposal facility (disposal silo). The document also describes the activities and procedures for the decontamination, dismantling and removal of all radioactive waste from the non-disposal part of the facility. The decommissioning of the (non-disposal part of the) repository is covered in the reference document Decommissioning programme for the Vrbina Krško LILW repository. [3]

List of facilities and mechanical and electrical systems that are the subject of the programme:

1. Disposal facility – disposal silo (R)
2. Hall (above the silo) (R)
3. Control pool (R)
4. Physical security facilities
    a. Outer perimeter fence
    b. Inner perimeter fence
5. Plateau and facilities of exterior and landscape arrangements
    a. Plateaus and compacted surfaces around the silo
    b. Planted areas

Note: facilities in the controlled area that could be contaminated and will be subject to closure are marked (R).

Systems and devices in the area of the disposal unit

Mechanical and technical systems and devices

Systems:

1. System for removing water from the area of the disposal silo (R)
2. Ventilation (R)
3. External hydrant network

Devices:

1. Devices for providing internal transport
    a. Gantry crane above the silo with container gripper (R)
    b. Personnel lift in the silo access shaft (R)

Note: systems and devices in the controlled area that could potentially be contaminated and will be subject to closure are marked (R).

Electrical systems and devices

1. Power supply (R)
2. Backup power supply (R)
3. Lightning arresters (R)
4. Grounding (R)
5. Lighting (R)
6. Exterior lighting (R)
7. Security lighting (R)
8. Process management and monitoring (R)
9. Radiological monitoring (R)
10. Fire alarm system (R)
11. Safety/access monitoring (R)
12. Paging (R)

Note: All electrical systems and devices partly run through the non-disposal part of the repository and will potentially be contaminated. These parts of the systems will be subject to decommissioning.

Closure strategy

In the event of a decision on the final closure of the repository after the decommissioning of the Krško NPP, the closing of the repository will be initiated when the decommissioning of Krško NPP is completed. The activities for decommissioning of the technological facilities (first step) and the closure of the repository (second step) will be implemented on the basis of the authorisation of the competent authority [4] and will be carried out in accordance with the Decommissioning Programme and the Closure Programme. The decommissioning will be carried out only for technological facilities and/or facilities in the controlled area. Technical procedures that are an integral part of the decommissioning (decontamination, dismantling, disassembly, etc.) will also be carried out (in accordance with the closure programme) in the area of the disposal unit (silo). [4] After the closure of the repository, in accordance with the Programme the administrative authority will issue a decision on the status of the closed repository and at the same time a decision on the termination of the status of nuclear facility. [4] Main elements of strategy and characteristics of closure:

- Following the decommissioning of non-disposal facilities at the repository, all LILW from decommissioning is placed in the disposal silo.
- A review is conducted of the radiation parameters of the structures, systems and components in the disposal part of the repository that are not expected to be integral

parts of the closed and sealed silo, along with preliminary decommissioning of these SSC. The SSC that exceed the threshold values for discontinuation of monitoring and which cannot be decontaminated will be conditioned for disposal and placed in the disposal silo.
- Disposal of LILW in the silo is concluded.
- The disposal silo is closed (voids in the silo are filled, and the top slab is placed over the waste disposal containers along with a confinement barrier). The silo is drained of any seep water.
- Pumping out of seep water is terminated.
- All systems and devices are decommissioned (monitoring is discontinued for them) and all systems and components are permanently disposed of.
- All voids in the disposal silo (drainage pipes, etc.), the machine rooms in the bottom storey of the silo and in the access shaft are sealed.
- The above-ground sections of the silo and access shaft and hall above the silo are permanently decommissioned (monitoring discontinued) and dismantled.
- The flood control plateau on which the facilities are built is preserved.

<u>Decommissioning and closure timeline</u>

The decommissioning of the technical non-disposal facilities will be carried out in accordance with the final Repository Decommissioning Programme in 2061, and the disposal silo and the repository will be closed in accordance with the Repository Closure Programme in 2062. The sealing of voids in the silo will also be carried out during the closure of the repository. The pumping of seep water will be terminated within a short time after the filling of the silo with waste and the closure of the silo. Waste generated from the decommissioning of the repository facilities will be conditioned for disposal in the hall. After the removal/disposal of all LILW, the hall, which will be decontaminated after the conditioning of the LILW from decommissioning, will also be dismantled, and any waste from the decontamination process will be disposed of as the final LILW.

The decommissioning and closure procedure will be managed and carried out by ARAO in cooperation with external contractors. All work positions at the repository will be included in the procedure of decommissioning the disposal part of the repository, which will carry out: general service activities, technical service activities, radiation safety activities and physical security activities.
The external contractors will be responsible primarily for: construction works, dismantling and disassembly, major decontamination measures and conditioning waste from decommissioning for disposal.

<u>Closure activities</u>

Decontamination
In the case of normal operation of the repository, the contamination of structures, components and systems is not expected. All areas and surfaces in the controlled part of the repository will be maintained in a clean (uncontaminated) state. In the event of contamination (e.g. due to accident) decontamination will be carried out immediately and a clean state will be re-established.
Therefore no major decontamination will be carried out during the period of closure. Together with the conducting of clearance measurements, only the decontamination of surfaces (e.g. installed piping, drain channels, etc.) which could not be decontaminated during the period of

operation will be carried out as needed. Decontamination will be carried out in particular through the use of chemical decontaminants and through the removal of contamination using absorbent materials. The decontamination of the concrete surfaces through the removal of the upper layers is in principle not planned.

Dismantling and disassembly

Continuous measurements of contamination will be conducted during the dismantling of all systems and components that could be contaminated (marked R in the list). All systems and components in the silo and in the hall above the silo and in the control pool will be dismantled and removed.

Among the concrete structures, only the upper part of the access shaft in the silo (in the area of the construction of the containment barrier), the concrete elements in the hall and the control pool with its shafts for removing water from the silo will be dismantled.

The hall will also be decommissioned.

Removal of waste and rubble

In total, two N2b containers of LILW are expected to be generated as a consequence of the operation and decommissioning of the LILW repository, which will have to be placed in the repository (the net volume of a container is 6.31 m^3) – estimate based on reference [5]. The majority of this waste will be the result of the decommissioning of the non-disposal part of the repository.

The following will be removed from the silo before sealing: the metal parts of the staircase, landings and other metal structural supports, the personnel lift, the mechanical installations including the pumps, and the electrical installations and components.

The volume of the removed equipment will amount to several 10 m^3, and the weight from 5 to 10 t. The major portion of the equipment will be defined as non-radioactive waste and transferred to the authorized organisation. A smaller portion (30%) will be possible to save for further use (e.g. the personnel lift). The dismantled steel structure of the hall (total weight approx. 220 t) will also be possible to save for further use. We assume that 10% of the dismantled structure will be defined as construction waste. The entire roof (30 t) and 20% of the facade lining (total weight 65 t) will also be defined as construction waste.

The gantry crane and the crane track will also potentially be saved for further use. After removal of the lift and hall, the floor slab of the hall at the location of the silo will also be removed (around 800 m^3 or 1,980 tons of RC), along with the asphalt surfaces around the former hall (1,570 m^2 or 320 t), the pertaining kerbs (170 m, 5 t) and walkway slabs (190 m^2, 16 t). [6]

Isolation of structures from the environment

Upon filling up the silo with LILW containers, all the remaining voids are filled with filler (cement grout or concrete) and the disposal silo is covered with a concrete slab and a layer of low-permeability material, which is to reach almost to the landscaping layer at the surface. The works will be performed by external construction contractors.

Following the adoption of the decision to terminate the pumping of seep water from the silo, all the installations and devices will be removed from the access shaft and the bottom of the silo (where the collection tank with the pump will be installed), and all voids (including the drainage pipes) filled with filler (cement grout or concrete). This will limit the inflow of groundwater, ensure the long-term stability of the site and prevent the destruction of the underground spaces. Works will be performed by external construction contractors under the supervision of repository staff.

Remediation of the site

After the closure of the repository, the administrative and service building and the technological facility with the adjacent compacted surfaces, access routes and green areas will be transferred into different, unrestricted use, i.e. they will be managed in accordance with the Closure Programme.

It will be possible to remove the outer perimeter fence around the repository, i.e. it will be managed in accordance with the Closure Programme. The same applies to the internal fence, except around the area of the disposal silo. This fence will be maintained throughout the period of active monitoring.

Revegetation with indigenous plant species

The areas from which structures and the asphalt surfaces were removed will be replanted. In the area of the conducting of active long-term monitoring, the grass will be kept cut throughout the period of active long-term monitoring.

In the other areas there are no restrictions with regard to revegetation.

Handling of secondary radioactive waste during closure

Part of the secondary waste will be generated during the repository closure procedure i.e. the decommissioning of the non-disposal technological structures and components at the repository. This waste will be treated in part in the way described in general terms for primary waste, while part of this waste will have to be processed and conditioned for disposal outside Krško NPP and the TF (since these are planned to be already decommissioned at the time of processing). This last waste deriving from decommissioning will be conditioned in the hall above the disposal silo.

The waste will be placed directly into a disposal container, or first into a 200-litre cask.

12.1 LONG-TERM MONITORING

This chapter is a summary of the LILW repository reference document Long-term Post-Closure Monitoring and Maintenance Plan for the Vrbina Krško LILW repository. [7] A summary of the post-closure safety analyses is also given. [8]

<u>Summary of post-closure safety analyses for the LILW repository</u>

In conducting the safety analyses in question, which concern the repository after closure and are presented in detail in Chapter 7 of this report, the administrative restrictions set out in the JV5 Rules, [9] the ICRP reports, [10], [11] the Rules on Drinking Water [12] and other recommendations, which are presented in detail in Chapter 7 of this report, were taken into consideration.

The safety analysis for the LILW repository was conducted for the entire inventory of LILW generated in Slovenia (Scenario SA.2), but the impact of the disposal of smaller or larger quantities of waste was also assessed in the section on uncertainty. The parameters of the water flow through the disposal system and the site were obtained through the use of detailed models of the immediate and wider surroundings. These were then taken in the system model, which was used to conduct the sensitivity analysis. In the system model it was assumed that the entire inventory is disposed of in one disposal silo, where the following assumptions also applied:

- Due to the conservative use of a one-dimensional vertical flow through the repository, the impact of the construction of the second silo on the vertical flow is negligible.
- Distributing the waste between the two silos would lower the specific concentration i.e. specific activity, however, in the models none of the radionuclides are restricted by any solubility limits, so that the distribution does not have any effect on the model.
- Distributing the waste between the two silos would increase the surface area for potential discharges (it would double), which would mean a reduction in the pollution concentration in both the well and the atmosphere.

In light of the above reasoning, it can be concluded that the assumed disposal of the entire inventory in a single silo is the conservative approach, and the results thus obtained constitute the upper envelope of the impact of the repository on the environment and on people.

From the results of the deterministic safety analysis, it follows that:

- The results of the safety assessment for the nominal scenario of development of events are significantly lower than the prescribed limit of 0.3 mSv/year per representative of a critical population group, despite the conservative assumption of consumption of water from the well.
- The results obtained under the scenario without the use of water from the well disclose much lower doses, of the order of 10^{-6} mSv/year. This indicates a major contribution of water from the well to the total estimated dose. With a more realistic consumption of water in the nominal scenario, the estimated dose for the nominal scenario would be much lower, meaning that the safety margin for the repository would be much larger than indicated in the nominal scenario at first glance.
- The results of the scenario of alternative failure of engineered barriers (sequential failure of barriers) show later and lower maximum doses than under the nominal scenario. It is thought that the use of this sub-scenario is more realistic than the nominal scenario itself, which further increases the safety margin of the repository.
- Taking account of the scenario of early destruction of the engineered barriers, the maximum estimated dose is 3.24 mSv/year, which is still lower than the legal limit of 10 mSv/year for alternative scenarios of the development of the repository, for which additional measures are required. This scenario could also be described as a scenario without engineered barriers, as no combination of FEPs leads to the realisation of such a scenario.
- The result of the river meandering and surface erosion scenario is a very low estimated dose of 10^{-6} mSv/year.
- The dose results under the scenario of change to the hydrological conditions are comparable to the doses under the nominal scenario at the time of 10,000 years after the closure of the repository. These results indicate that the nominal scenario represents a good basis for decision-making by the regulatory body.

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The probabilistic analysis and calculation for the period of 10,000 years after closure show:

- The deterministic results for the nominal scenario constitute a conservative safety assessment, but not extremely conservative, taking account of the unreliability of the parameters used. Moreover, the calculation of the nominal scenario is below the permissible limits in the 95th percentile for the analysed parameters.
- The results of the sub-scenario without using the well indicate a very small dose throughout the entire period covered in the safety analyses, and constitute a large safety margin in comparison with the permissible regulatory limit.
- The results for the meandering river and erosion scenario indicate a large safety margin in the calculations in the 95th percentile for the analysed parameters.

Within the framework of the sensitivity analysis, the following conclusions can be drawn:

- In a period longer than 10 000 years after the closure of the repository, the change in the sorption coefficient for Ra-226 indicates a non-linear relationship between the maximum and the sorption.
- The effect of the degradation rate of the engineered barriers on the maximums in a period longer than 10 000 years after the closure of the repository was shown to be fairly insignificant.
- The groundwater flow velocity in the aquifer was a significant parameter in the period up to 10,000 years after the closure of the repository. Higher velocities lead to greater dilution and lower doses. The rate used in the nominal scenario was shown to be conservative and credible.
- For the period longer than 10 000 years after the closure of the repository, the parameter of sorption in the immediate vicinity of the repository is significant.
- The discretisation of the system model of the farfield proved to be an insignificant parameter.
- The dose rate is directly proportional to the size of the inventory, which is the result of the choice of generic solvency parameters, which yield a conservative assessment of the solvency limits used and a conservative assessment of the final results.

An analysis of the effect of non-radioactive toxic metals indicated that the repository with its potential discharges meets the Slovenian standards for drinking water. The evaluation of the repository's impact on non-human organisms indicates a very low dose rate in comparison with the current ICRP recommendations.

The results of the analysis of inadvertent human intrusion show that the highest dose rates in the event of intrusion are faced immediately after the end of institutional controls. In this case the estimated dose for the intruder is 0.05 mSv/year, and the maximum dose per local inhabitant after the intrusion is slightly over 10 mSv/year. Intrusions that occur after the discontinuation of monitoring will result in lower dose rates. The estimated results indicate that radionuclides contained in activated metals at the repository will have the greatest effect on the dose rate in the event of intrusion. The analysis does not take account of the problems (unfeasibility) of intrusion (drilling through metal with equipment used for geotechnical drilling). Due to the repository design concept, the likelihood of an intrusion event is also extremely low, and the analyses conducted can be defined as conservative. The estimated impact is still below the limit of 100 mSv/year, at which additional optimisation would have to be performed in accordance with the requirement. Therefore it is assumed that additional optimisation (measures to mitigate the consequences for the Vrbina Krško LILW repository) are not required, and that 300 years is a suitable duration of institutional controls for the LILW repository.

The safety margin in the security analysis comes from the conservative approach taken to safety analysis. This is reflected in several areas:

- the scenarios were selected with conservative assumptions despite the low likelihood of occurring,
- several sub-scenarios were selected,
- tested models were used,
- the parameters used in the models were selected conservatively.

The minimum safety margins deriving from the above assumptions are thus presented for the deterministic calculations in the individual chapters, which represent the results of the individual scenarios.

In the safety analyses it was therefore estimated that the impact of the repository after closure is below the prescribed limits and is negligible. [8]

Long-term monitoring of the LILW repository

After the closure of the repository, the repository will enter the period of long-term monitoring as quickly as possible, as ARAO will also conduct the long-term monitoring. During this period, the operator identifies and monitors the effectiveness of the performed activities for closure and carries out the necessary maintenance and corrective measures that bring the repository to a state appropriate for the repository to be transitioned to post-closure monitoring. [13] After the period of transition to post-closure monitoring and maintenance, the repository will to enter the period of active long-term monitoring.

In the event of the detection of an excessive impact of the repository on people and the environment, a remediation programme will be carried out depending on the findings. An excessive impact for the closed LILW repository assumes a dose in excess of 0.3 mSv.

The criteria that form the basis for a decision on the performance of maintenance work at the repository in response to the results of monitoring and of inspection and supervision operations will use the criterion set out in the applicable ZVISJV at that time (currently Article 37) as the benchmark for evaluation of the measure. The reference level for emergencies is set out in Article 27 of the UV2, [14] which set out the limit values for surface contamination (100 mSv per year). The regulatory authority can also lower this value. At the same time, point 8 of Appendix 5 to the JV5 rules [9] stipulates that no measures to optimise the repository are required up to a level of 10 mSv/year.

Active long-term monitoring is planned to commence at the beginning of 2066, when all preparatory activities have been performed for a transition to monitoring following the period of transition of the repository to long-term monitoring and maintenance (2063–2065) and after the monitoring and maintenance provider has taken over the repository for long-term monitoring and maintenance. Active long-term monitoring and maintenance will last 50 years

(2066–2115), unless another duration is determined in subsequent revisions of the document and on the basis of a safety analysis and operational experience.

After the end of active long-term monitoring and maintenance, the repository will pass into the phase of passive long-term monitoring. The above-ground facilities of the repository will be removed or transferred to unrestricted use. The passive monitoring phase is planned to last a maximum of 250 years after the end of active long-term monitoring of the repository (2116-2365), unless another duration is determined in subsequent revisions of the document on the basis of a safety analysis and operational experience.

During the period of the transfer of the repository to long-term monitoring, the scope of measurement taking and 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 monitoring for active long-term monitoring.

During the period of preparation and transfer of the repository to long-term monitoring, trend monitoring will be carried out with 2-3 measurements per year over all three years of that period. These measurements will serve as the basis for a more precise subsequent situation analysis and the development or updating of the long-term monitoring plan as envisaged in this document.

Owing to the disposal of the waste in a silo that will be nearly 60 m deep, the water-borne spreading of radionuclides into the environment will have to be closely monitored. We can expect the possibility of radionuclides entering the environment chiefly via this pathway, while the airborne transfer of radionuclides is less likely (or it is expected that the radionuclides discharged this way will be considerably less radioactive). [15]

The physical security of the repository will be carried out inside the outer perimeter fence for all facilities and structures that are not decommissioned and for the area of the disposal units.

Activities during the period of preparation of the repository for transfer to long-term monitoring shall be carried out in accordance with the monitoring and maintenance programme for the storage units and for the repository's drainage system after closure of the repository, and in accordance with the requirements of the JV9 rules. [16]

This period is expected to last three years, from the beginning of 2063 to the end of 2065.

Monitoring of the repository shall cover the area of the repository surrounded by the outer perimeter fence, the auxiliary structures, the plateau near the disposal facilities and any immediate surroundings that could have an impact on the repository or in which the impact of the repository can be detected by means of measurement procedures. The precise area for monitoring the environment outside of the repository fence will be determined in subsequent revisions of the document.

The technological facility following decommissioning and other non-technological facilities at the repository may also be used for requirements relating to active long-term monitoring and maintenance, or may be temporarily used for other activities.

The land in use during the different phases of the repository is shown in Table 12-1 and Figure 12-1.

Table 12-1: Land in use. [13]

Repository time period – state	Land in use dimensions
Termination of operations (standby phase) or active long-term monitoring (area of the structures)	500 x 200 m (outer perimeter fence)
Passive long-term monitoring	30 x 30 m (silo)
After transfer into unrestricted use	0

Figure 12-1: Layout of repository structures with repository borders (fences) marked. [6]

meja območja DPN	boundary of the DPN area
meja parcele namenjene za gradnjo NSRAO	boundary of the lot intended for construction of the LILW repository
gradbena meja	construction boundary
LEGENDA	KEY
ASFALT	ASPHALT
MAKADAMSKE POVRŠINE	UNPAVED AREAS
TRAVA	GRASS
DREVESA	TREES
ZUNANJA OGRAJA	OUTER PERIMETER FENCE
NOTRANJA OGRAJA	INNER PERIMETER FENCE
MEJA OBDELAVE NAČRTA	BOUNDARY OF THE PLAN UNDER CONSIDERATION
LEGENDA OBJEKTOV:	KEY FOR THE FACILITIES:
HALA – HALA NAD SILOSOM	HALA - HALL ABOVE THE SILO
TO – TEHNOLOŠKI OBJEKT	TO - TECHNOLOGICAL FACILITY
USO – UPRAVNO-SERVISNI OBJEKT	USO - ADMINISTRATION AND SERVICE BUILDING
TP – TRAFO POSTAJA (obseg načrta – Infrastrukturni objekt)	TP - TRANSFORMER STATION (plan coverage - Infrastructure facilities)
K.B. – KONTROLNI BAZEN	K.B. - CONTROL POOL

When determining the land in use, during the preliminary design phase [17] it was assumed that during the standby phase and the active long-term monitoring phase all of the structures will remain in use by the repository or the repository operator, and that during the passive long-term monitoring phase all of the structures would be removed from the site or transferred to unrestricted use. [13] Through the development of the repository design and taking into account the possibility of the conditioning of LILW for disposal at Krško NPP, in the upcoming phases of the project and the updating of this programme, in addition to the programme and strategy for the decommissioning of the repository, it will be necessary to determine the status of the individual structures during all of the repository time periods.

12.1.1 ACTIVE LONG-TERM MONITORING

Active long-term monitoring is expected to begin in 2066, when all preparatory activities are performed for transfer to monitoring and when the provider of long-term monitoring takes over the repository for management and long-term monitoring. In the period of active long-term monitoring, the provider of management, long-term monitoring and maintenance of the repository will provide, in accordance with the confirmed and valid safety analysis report, in particular the following:

- the technical monitoring of the closed repository, in order to monitor the provision of the safety functions,
- the maintenance of the physical protection of the facility,
- regular maintenance works and cleaning on systems that will still be functioning, including measuring equipment,
- any necessary repairs and maintenance of covering, filling and service elements of the repository,
- monitoring the growth of vegetation at the repository and prevention of forest growth on the grassy area.

Monitoring and maintenance of the repository and the surrounding environment

Within the scope of monitoring radioactivity at the repository and monitoring the surrounding environment during the period of active monitoring, it will be necessary to conduct measurements of external (gamma) radiation, measurements of the groundwater characteristics and measurements of liquid discharges from the system for removing water from the disposal part of the repository (Table 12-2).

Table 12-2: Design of radioactivity monitoring programme at the LILW repository during the active long-term monitoring phase 2066-2116. [18], [19], [15]

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	borehole 5 deep, 5 shallow Reference location	Once a year	Once a year
SURFACE WATER				
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 per year

The design of the radioactivity monitoring programme, as envisaged in the requirement for carrying out operational radioactivity monitoring for the LILW repository under the JV10 rules [18] is adapted to the planned state of the facility after decommissioning and the planned scope of operational monitoring, [15] for which a final determination will be made with the help of the safety analyses and the other required design documentation.

Measurements of the dose of external radiation from contamination of the soil will not be required, as any contamination during the operation and decommissioning of the repository will be remediated/removed during repository closure activities. [20]

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 all measurements from the operational monitoring proposal for Sr-90, C-14 and Pu-239 in the groundwater be conducted once a year during the period of long-term active monitoring or discontinued, unless the results of measurements during the period of operation of the facility demand otherwise.

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 monitoring.

Measurements of radioactivity in surface water sediments and of radioactivity in food (garden crops, field crops, fruit) will be discontinued during the period of long-term active monitoring, unless the results of measurements during the period of operation of the facility demand otherwise.

Figure 12-2: Location of monitoring points and monitoring boreholes at the repository site. [15]

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.

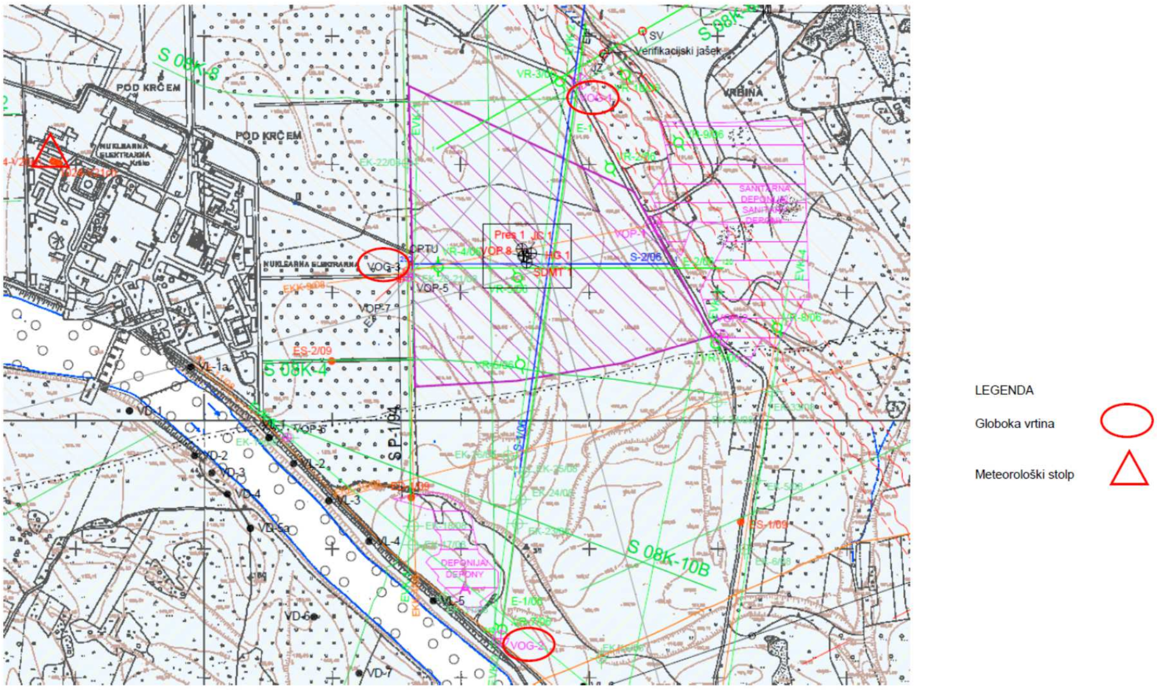

Figure 12-3: Location of meteorological monitoring points and monitoring boreholes outside the repository site.

LEGENDA	KEY
Globoka vrtina	Deep borehole
Meteorološki stolp	Meteorological tower

A system of sampling boreholes is planned for monitoring of the migration of radionuclides from the repository. Five shallow boreholes (10 – 20 m) are planned in the immediate vicinity on each side of the repository, or on those sides of the repository on which watercourses flow, and two deep boreholes (approx. 100 m) in the area of the repository. The three existing deep boreholes located outside the area of the repository site (Figure 12-3) will also be used for monitoring. This will ensure that at least one of the deep and shallow boreholes will be upstream and several of the boreholes will be downstream from the repository disposal unit. In addition to water sampling and analysis, this will allow a comparison of the radionuclide concentration before and after the existence of the repository, including during the period of active long-term monitoring, in accordance with the proposal for operational monitoring, during the first phase of disposal of LILW. The exact locations of the boreholes will be determined on the basis of safety analyses, which will indicate the important areas for conducting monitoring.

[15] According to the analyses to date, the same boreholes that are used for operational monitoring will be used for subsequent monitoring.

Among the set of radionuclides that must be monitored are those with the highest levels of activity in waste, as follows from the documents for conducting the safety analyses [8] and for preparing the acceptance criteria. [21] In addition to radioactivity monitoring, smaller-scale physical and chemical monitoring of the groundwater is also envisaged during the long-term active monitoring period using the proposed shallow and deep boreholes (Table 12-2), meteorological monitoring, geodetic monitoring and monitoring the stability of the repository and the banks of the repository's flood-control plateau (Table 12-3). No biological monitoring of the surrounding environment is planned during the period of long-term monitoring.

Table 12-3: Other types of monitoring of the repository and the surrounding environment [18], [15]

Monitoring	**Activity/measurement**	**Frequency (regular)**
Physical and chemical	Measurements of individual chemical parameters of the groundwater (water temperature, dissolved substances, pH, electrical conductivity, etc.), groundwater level (fluctuation)	once per year
Meteorological	Air temperature, relative humidity, precipitation, wind direction and speed	Continuous, automatic
Stability and geodetic monitoring	Monitoring of the stability of the repository and of shifts and slips of the banks of the repository flood-control 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

Routine inspections of the repository will be carried out once a year, i.e. it is reasonable to carry out routine inspections at least occasionally during periods of heavy precipitation, in order to check the functionality of the systems for removal of surface runoff water from the repository surface. Routine inspections will also be carried out after major earthquakes in order to check the condition of the repository, and primarily the condition of the planned controls, such as natural and engineered barriers, the sealing of the silo, the condition of the access roads, etc.

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. [18] As the current plans envisage that meteorological monitoring will be provided in conjunction with Krško NPP, [6] meteorological data from the public network of stations must be used at the repository site after the completion of the decommissioning of Krško NPP and during the active monitoring and maintenance of the repository.

Geodetic monitoring will be carried out using the expanded geodetic network of Krško NPP.

The repository will be physically secured in the area occupied by the sealed disposal units within the outer perimeter fence; this will constitute the boundary of the controlled 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 security fence. The warning signs shall contain information on the owner of the facility, the facility type, the dangers presented by the material deposited 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 part of the repository so as to prevent inadvertent human intrusion.

During the transitional period before the beginning of long-term monitoring and maintenance, it will be necessary to arrange and later also to maintain access routes to the repository, which will be required for the performance of periodic maintenance work (cutting grass, cleaning channels and trenches, and felling trees and shrubs at the edge of the repository) and the remediation of any damage to the flood-control plateau.

Active long-term monitoring is planned to last for 50 years after the period of the transfer of the repository to long-term monitoring and maintenance. The exact length of the active long-term monitoring period shall be determined on the basis of a safety analysis and included in the revision of this document.

12.1.2 PASSIVE LONG-TERM MONITORING

The repository shall be prepared for long-term passive monitoring when the long-term active monitoring period comes to an end. The preparations will include in particular:

- the removal of all equipment for the performance of measurements and other forms of active monitoring;
- the removal of the facilities that were required for active monitoring, or the transfer of the facilities to unrestricted use; and
- the removal of the fence or the discontinuation of fence maintenance.

Long-term passive monitoring 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 geodetic warning signs at the repository.

For purposes of storage of repository records, at least two types of information will be archived for as long a period as possible and for potential use:

- Information, data, records and documents relating to activities during operation and decommissioning, data on disposed waste, data on emergencies, site data, site maps, photos of the repository and the surrounding environment, etc.

- Data obtained through the conducting of monitoring of the repository and the surrounding environment (radiological, meteorological, etc.)

Pursuant to Article 7a of the ZVISJV, [2] the details regarding the types and scope of the documentation and the method of security and storage of documentary materials shall be determined by the minister responsible for the environment.

The above-ground facilities of the repository will be removed or transferred to unrestricted use. The buried repository plateau will remain or will be removed, depending on the results of safety analyses and of operational monitoring, prior to closure and during the period of active post-closure monitoring.

Warning signs and signs of prohibition as a warning against unintended entry to the disposal facilities will be placed in the area occupied by the disposal facilities. 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 the LILW deposited there and its properties.

The start of long-term monitoring will signal the termination of physical security [23] under the Rules on the physical protection of nuclear facilities and nuclear and radioactive materials, and the transport of nuclear materials. [22]

Passive long-term monitoring will last for several decades after the end of the active long-term monitoring period, provisionally for 250 years. The scope of passive long-term monitoring will be determined in accordance with the Safety Analysis Report.

12.2 REFERENCES

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