Low and Intermediate Level Waste (LILW) Repository in Slovenia

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ABSTRACT

In the paper, the activities on the project of Low and Intermediate Level Waste (LILW) repository and its disposal concept will be presented. Countries with a nuclear program have to solve the final disposal of radioactive waste. Therefore, a permanent radioactive waste repository is planning to be arranged in Slovenia. The basic purpose of LILW repository is to prevent the migration of radionuclides into the environment. After optimisation studies a near-surface silo concept for the repository was chosen with a multi-barrier approach in designing.

1 INTRODUCTION

In Slovenia, which is among the countries with a nuclear program, the project for a repository for final disposal of low and intermediate level radioactive waste (LILW) is underway. For an effective, permanent and environmentally responsible solution to the issue of LILW, Slovenia must therefore ensure their safe and final disposal.

The essential feature of the LILW repository is that, together with the natural environment in which it is located, it provides long-term prevention against discharges of radionuclides from the repository into the environment. The integrity of the repository is ensured for the period until the waste is radioactive or as long as its activity approaches the activity of natural environment. During all life phases of the repository (disposal phase, closure, long-term monitoring and free release of the site) the impact of the facility on the environment must be below the prescribed limits.

2 REPOSITORY

Slovenia started a siting procedure for a LILW repository in 2004. In the process the public has also been intensively involved, and the location Vrbina site in the municipality Krško was selected five years later. The site was accepted and confirmed by the government and several silos can be constructed on the site. In 2009, a preliminary design was prepared for the proposed concept of disposal, followed by several optimisation studies. A near-surface silo concept for the future Slovenian LILW repository was chosen. The licensing phase for one silo started and in 2014 the final detailed site investigation was finalised and a „Feasibility study“ [1] - formally approved next investment phase (until construction permit), was approved by the
Competent Ministry. An Environmental impact assessment report for a LILW repository was made in 2017, with revisions in 2018 and 2019, which represents the basis for acquiring an environmental consent for the intended activity (EIA phase) and a construction permit. Application for issuing an environmental consent was accepted by the Environmental Agency of the Republic of Slovenia. The Draft of preliminary consent for nuclear and radiation safety was issued in April 2019, which is one step in an administrative procedure for issuing an environmental consent. Now public hearing (national and neighbouring countries) is underway.

2.1 Description of the site

The location of the LILW repository is in Vrbina, in the municipality of Krško. The nearest town is Krško, which is 2.5 km away from the site, the town Brežice is 5 km away. Approximately 300 m from the western edge of the site, the Krško Nuclear Power Plant is situated. Approximately 400 m north-east of the site lies the settlement Spodnji Stari Grad (Figure 1).

![Figure 1: Illustration of the location.](image-url)

The plain on the southern side of the site is limited by the riverbed of the Sava River. To the south of the planned activity (approx. 600 m), the construction of a reservoir of the Brežice HPP was finished in 2017. In the north, the plane extends towards the hill Libna. In the east, the site is limited by the local road leading from the settlement Vrbina towards south-east, i.e. towards the bank of the Sava River. The wider area of the site is in agricultural use and is designated as the best agricultural land. At the site itself, there are landscaped fields, and on the far western edge of the site, a plantation orchard is arranged.

2.2 The disposal concept

The basic concept of LILW disposal at the Vrbina site represents the disposal of properly prepared and packaged low and intermediate level radioactive waste into the disposal units, i.e. silo, located below the groundwater level on the site itself. The disposal is carried out from the surface. In accordance with the recommendations of IAEA, the repository has been recognised as a near-surface facility. In designing, the multi-functional and/or multi-barrier approach is taken into account, with the geology of the site itself as the final barrier.
The basic principle of radioactive waste disposal is the isolation of radioactive substances from the biosphere. The basic purpose of the LILW repository is to prevent the migration of radionuclides into the environment by means of a series of consecutive natural and artificial barriers; it is designed as a complex technological unit. The multi-barrier system of the silo thus consists of the following main barriers: 1) properly prepared waste in metal drum, 2) concrete container, 3) concrete silo, and 4) geology/surroundings of the repository site (Figure 2). Geological barrier is a barrier provided by the bedrock and hydrology of the site; the insulating properties of the bedrock prevent or obstruct the migration of radioactive substances from the repository to the environment. Engineered barrier is a man-made structure or device that fulfils safety functions. Engineered barriers at repositories usually comprise sub-systems and components such as packages, canisters, backfill, embankments, seals and other artificially constructed barriers separating waste from the environment.

Figure 2: Stylized structure of the repository (GW – Grouted Waste, OP – Overpack)

2.2.1 Container

The container with reinforced concrete walls, lid, and bottom (Figure 3) performs the function of a barrier. The external dimensions of the container are 1.95 m x 1.95 m x 3.30 m; net volume is 6.31 m³; maximum weight is 40 t.

After the final disposal to the disposal silo, it must - in addition to the resilience and stability for all the foreseeable loads in the phase of filling and transport before the final disposal - also fulfil the condition of durability as the most important and most specific requirement.

The selected design of the container allows the fulfilment of all key safety functions:

− Physical retention of radionuclides or radiological shield is guaranteed with a minimum thickness of reinforced concrete walls of 20 cm.
− Chemical retention will be achieved by an appropriate chemical composition and recipe of concrete, which will correspond to the characteristics of waste and to chemical processes in radioactive waste in such a way that the migration of radionuclides from the container will be as limited as possible.
− The hydraulic shield or the prevention of water percolation into the container is ensured by choosing the high-performance concrete (HPC), which will be very poorly
permeable to water, but still sufficiently permeable to the gases that will be generated in the container.

− Human intrusion is prevented by choosing a massive reinforced concrete container with an anchored cover.
− The selected reinforced concrete structure provides structural stability.

![Figure 3: Structure of a container with TTC.](image)

2.2.2 Silo

The silo is designed as reinforced concrete cylindrical structure of 27.3 m clear diameter and about 49.2 m height (depth). The composition of the silo wall comprises a primary lining of 1.2 m and a secondary lining; their total thickness is 2.2 m. Inside the silo, there is a vertical communication tract in the form of a shaft. The central part of the communication tract consists of stairs and elevator, and the side parts are intended for the installation lines. The communication tract ends as an entry facility within the hall above the silo.

The net surface of the silo enables arrangement of 99 containers in one level, with a space increased to 20 cm between the containers. The structure height is designed so as to provide arrangement of 10 layers of containers, including the foreseen cover layer, i.e. a reinforced concrete slab and a part of the clay layer, are situated below the level of the existing aquifer, and the entire clay layer extends nearly to the surface. For the vertical communication tract, temporary exits to the interior of the silo are planned along its height, which will facilitate access to working levels during the exploitation of the repository. As the filling of the silo will progress, these exits will gradually be put out of use/filled with concrete.

The silo is intended for the following:

1. to provide disposal space in an appropriately solid building in relation to the anticipated project events and the required durability of the structure;
2. to limit access of water to the deposited waste and spreading of contamination to the environment by limiting the flow of groundwater and by favourable sorption effects;
3. to collect and retain water potentially penetrating the silo wall;
4. to provide a biological shield;
5. to provide an engineering barrier that limits water penetration after closure of the repository.

In safety analyses, the silo is considered as one of the engineering barriers (besides the container and the primary LILW package).

3 ENVIRONMENTAL ASSESSMENT

The purpose of the preparation of the Environmental impact report for the LILW repository is to assess the impacts that could significantly affect the environment and human health, both in terms of the nature and characteristics of the intended activity and in terms of the features and characteristics of the environment or its parts which could be affected by the impacts of the activity.

At the site and close to it there is no particular natural features, protected areas or areas important to biodiversity, nor are there any cultural heritage units or protected archaeological sites listed in the area.

There are no protected water resources at the LILW repository site or in its immediate vicinity, and the site lies outside water supply protection zones. All drinking water catchments are on the right bank of the Sava river. The repository site lies outside the drinking water supply protection zones; therefore, the quality of the water in this area is not relevant from the point of view of consumption.

Since the site is situated in an area of intensive agriculture, the presence of endangered and protected plant species requiring protection under special protection regimes is not expected, nor are there any floristically important areas within 500 m of the site. Dry and semi-dry grasslands are present across smaller areas. In the area close to the site, the diversity of fauna is exceptionally low, as the area comprises intensively cultivated monocultural fields separated from the surroundings by natural (Sava) and man-made barriers (road, railway line with embankments). Owing to intensive agriculture using plant protection products, a limited presence of invertebrate species (small population size of the more common species) is expected [2].

4 SAFETY CASE

General objective of a safety assessment for a radioactive waste repository is to provide a reasonable assurance to the stakeholders (governments, regulatory authorities, the general public or the technical staff) that the disposal facility will be managed and operated in such a way so as to ensure adequate protection of workers, members of the public and the environment, in all its operational stages, as well as after its closure.

Issues addressed in the safety assessment are: evaluation of the inventory of radioactive and chemically toxic materials, FEP and scenario analyses, degradation of the engineered barriers, silo resaturation flow analysis, gas generation and transport, flow modeling (basin scale), flow modeling under differing conditions of failure (near field), parameter database implementation and operational safety assessment.

The safety analysis addressed several scenarios during operation and post-closure period [3] [4]. During operation the nominal scenario (doses to workers, representative person of public) and accident scenarios were evaluated. Accident scenarios included drop of of a container (in technological building and inside the silo; from different height), fire scenario and airplane crash scenario. Calculated collective dose of all workers planned for all operations at the repository site under normal operation scenario do not exceed 21.6 man-mSv/year [3]. The effective equivalent dose of external exposure to representative person of public at the site fence
will not exceed 5 \( \mu \text{Sv} \) in one year. It can be concluded that the doses that might be incurred by members of the public and workers during an accident involving a drop of a container are sufficiently low to raise no concern. The doses to members of the public are below the doses due to natural radiation background, in all situations analysed [3]. For the workers, the total dose will depend on the time spent inside technological building or hall above the silo and the distance to the damaged container. It is observed that the doses to the workers in case of a fire scenario are 3 times lower, while the doses to members of the public are with one order of magnitude higher as calculated under the drop scenario although still below the natural radiation background. The maximum dose in the case of an air crash for a worker (at 30 m from the silo) will be 2.1 mSv, total dose for workers would be 17 mSv and for members of the public 16 mSv at 100 m from the silo.

Scenarios for a post-closure safety which were analysed are: nominal scenario with a family which lives nearby and drink water from a well and eat everything from the area of a repository, early failure of engineered barriers, river meander and surface erosion, changes in hydrological conditions and inadvertent human intrusion. In all scenarios analysed the repository has no effect on its surroundings.

5 PHASES OF A REPOSITORY

According to the basic scenario (construction of one silo), a three-year construction of the repository is envisaged after obtaining a building permit; during this period, one disposal silo, all technological and other facilities and the associated infrastructure will be built. Then a trial operation will begin when a permit for trial operation, which is a condition for the reception of radioactive waste, will be obtained. At the end of the trial operation, an operating permit will be obtained and the repository will be put into operation. After the disposal of all LILW waste produced till that time the repository will enter the standby phase (phase with no disposal or other more extensive work) until re-entering the operation in 2049 (Figure 4).

![Figure 4: The timeline of operation](image)

During the renewed operation, the remaining "Slovenian" operating waste generated in the Krško NPP will be deposited in the repository, as well as the waste generated during the decommissioning of the Krško NPP. After that the repository closes and the long-term monitoring control and maintenance of the repository is initiated. During the period of active long-term monitoring, the operator will predominantly take care of the implementation of technical monitoring of the closed repository, regular maintenance work, physical protection of the facility etc. After the end of active long-term monitoring, the repository will pass into the phase of passive control. The above-ground facilities of the repository not intended for active monitoring will be removed or submitted to unlimited use after the closure of the repository. It is assumed that the earth-filled platform of the repository will continue to remain at the site in the phase of passive control.

After the end of control phase, the surface of the repository area will pass to unlimited use, i.e. the use that will not endanger the protective functions of the repository.
REFERENCES


