Preliminary Design of the Vrbina LILW Repository

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ABSTRACT

Simultaneously with the siting of a repository, intensive project engineering activities relating to radwaste conditioning and disposal facility started at the end of 2004. In a Comparative Multilateral Study of Alternatives a solution of disposal in below-ground silos was proved to be the most suitable one for the Vrbina site. The solution is developed in detail in the Preliminary Design documentation.

The planned LILW repository will be located some hundred meters east of the Nuclear Power Plant Krško (NEK). The site was formally approved in the scope of the Decree on the National Spatial Plan at the end of 2009. The repository is designed for the disposal of half of the short-lived LILW from NEK and of all the remaining Slovenian short-lived LILW (9,400 m³) with a possibility of further extension of the disposal capacities to include all LILW quantity from NEK (18,200 m³).

The repository will consist of a disposal part, composed of a set of modular disposal units (silos), and other structures required for the acceptance, conditioning and storage of radioactive waste. Besides technological facilities, an information center, an administrative building and a service building are anticipated on the site as well. All buildings and disposal structures of the repository will be constructed on a platform which will protect them against floods.

Prior to disposal, all LILW will be inserted into concrete disposal containers of external dimensions 2.55 x 2.55 x 3.25 m. In an individual container, 9 tube-type containers (the most often type of package in Krško NPP) or 27 standard 200-liter drums or unpacked LILW with a volume of approximately 13 m³ will be placed. Voids in the container will be backfilled with backfilling mortar.

The containers will be disposed into a disposal silo of an inner diameter of 27.3 m and useful (net) height of 33 m. The bottom of the silo will be approximately 55 m below the elevation of the handling platform. The LILW placed in the containers will be inserted into the silo by a portal gantry crane. After each of the ten layers with 70 disposal containers is filled-up, the remaining voids between the container walls and between the containers and the silo wall will be backfilled with backfilling material. Water which will eventually seep through the silo walls will be collected in the draining basis of the silo and drained via an inspection gallery to the access shaft, where sampling will be performed prior to its pumping to the surface.
1 INTRODUCTION

Pursuant to the statutory requirements, relevant policy orientations in the fields of radioactive waste and spent fuel management, and power engineering, a low and intermediate level waste (LILW) repository should be constructed in Slovenia.

On the initiative of the Minister of Environment and with purpose of designing, engineering and siting of the repository in accordance with the foreseen time schedule on November 30th, 2004 the LILW Repository State Location Plan Development Program (Official Gazette of the RS, No. 128/04) was adopted. Following the Program, on December 1st, 2004 all Slovenian municipalities were invited to cooperate in the procedure of the repository site selection. Twelve proposed locations in five municipalities were assessed from safety, functional-technical, economic, environmental and social aspects in a Pre-comparative Study, prepared by the Agency for Radwaste Management (ARAO) from May to October 2005. The best assessed locations were confirmed by the decision of the Government of the Republic of Slovenia on November 17, 2005. Besides locations of Globoko in the Municipality of Brežice and Čagoš in the Municipality of Sevnica, the potential location of Vrbina in the Municipality of Krško was selected as well.

Activities relating to the repository project started to flourish intensively in May 2006 with the elaboration of Design Bases as one of the fundamental design engineering starting points. For the potential Vrbina site five potential disposal solutions have been identified at first: Alternative A – disposal into below-ground box-type disposal cells; Alternative B – disposal into below-ground silos; Alternative C – disposal into underground silos; Alternative D – disposal into vaults; and Alternative E – disposal into surface disposal cells. A detailed analysis of the existing geological data, results of preliminary geological research and other factors of the alternatives feasibility showed that only alternatives B, C, and E were suitable as regards technical adequacy. For the selected alternative solutions technical documents needed for the Comparative Study of Alternatives were elaborated. In the Comparative Study of Alternatives in 2006 a multilateral assessment of acceptability of the environment affecting activities was made by comparison of the alternatives from five points of view: functional, safety, environmental, spatial, economic and from the point of view of acceptability in the local area. The overall assessment result showed that the highest degree of acceptability in the location of Vrbina was attained with the solution of below-ground silos construction (Alternative B). In 2007, technical documents relating to all three suitable disposal alternatives were treated in detail within a Conceptual Design (IBE).

The solution of below-ground silos construction (Alternative B) is developed in detail in the Preliminary Design documentation of 2009 [1]. The site and the concept of the disposal solution were formally approved in the scope of the Decree on National Spatial Plan at the end of last year (Official Gazette of the RS, No. 114/09, December 31, 2009).

2 PRELIMINARY DESIGN OF VRBINA LILW REPOSITORY

2.1 Structures and arrangement

The Vrbina LILW repository is intended for the disposal of short lived LILW. Types of LILW and quantities which shall be disposed into the LILW repository are presented on Table 1. In accordance with the National Program of Radwaste and Spent Fuel Management [2] the repository shall be designed so as to provide disposal of half of the LILW from Krško Nuclear Power Plant (NEK; lifetime extension not included) and of all the remaining Slovenian LILW (9 400 m³) with possibility of further extension of the disposal capacities to include all LILW...
quantity (18 200 m³). The volume share of the LILW from NEK covers 94 % or 97 %, respectively of the overall quantity of LILW.

Table 1: LILW quantities which shall be disposed

<table>
<thead>
<tr>
<th>Type of LILW</th>
<th>Quantity of LILW (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. LILW generated in NEK</strong></td>
<td></td>
</tr>
<tr>
<td>NEK operational waste</td>
<td>3600</td>
</tr>
<tr>
<td>NEK decommissioning waste</td>
<td>13000</td>
</tr>
<tr>
<td>Other LILW from NEK</td>
<td>1000</td>
</tr>
<tr>
<td><strong>Total A</strong></td>
<td><strong>17600</strong></td>
</tr>
<tr>
<td><strong>B. Non-NEK LILW (institutional waste)</strong></td>
<td></td>
</tr>
<tr>
<td>Central Interim Storage Facility (CSRAO) waste</td>
<td>250</td>
</tr>
<tr>
<td>Decommissioning waste (TRIGA, CSRAO)</td>
<td>150</td>
</tr>
<tr>
<td>Repository operational and decommissioning waste</td>
<td>200</td>
</tr>
<tr>
<td><strong>Total B</strong></td>
<td><strong>600</strong></td>
</tr>
<tr>
<td><strong>DESIGN QUANTITY = 50% A (8800) + B</strong></td>
<td><strong>9400</strong></td>
</tr>
<tr>
<td><strong>TOTAL A + B</strong></td>
<td><strong>18200</strong></td>
</tr>
</tbody>
</table>

The repository is located some hundred meters east of NEK (Figure 1).

Figure 1: Repository site (view from N, repository on the left)

In the repository, all structures, systems and components required for its operation as an independent nuclear facility shall be provided [2]. A list of structures with the main premises is as follows (Figure 2 and Figure 3):

- Technological building (waste conditioning for disposal, laboratory, control and service area, control basin);
- Disposal structures (disposal silos – 2 silos are needed for the design quantity of LILW disposal, 4 for eventually extended capacity; access shaft, inspection galleries, temporary hall);
- Service building (workshop, storage, boiler house, water supply and fire protection);
- Administration building (security control centre, administrative part, dining area);
- Information centre; and
- Infrastructure lines and connections to utility networks.

The repository will be constructed in stages and in a modular way whereby a disposal silo will represent a modular disposal unit. Progressive construction can be roughly divided.
into two stages: in the first stage, platforms and the remaining earthworks as well as connections to commercial public infrastructure shall be performed. Moreover, non-disposal structures, an inspection shaft and the first silo shall be constructed; in the second stage, the second silo shall be constructed.

Figure 2: Repository site – structures arrangement (view from SE)

Figure 3: Repository site – structures arrangement (view from SW)

The bed of the Sava River is 400 m SE from the site. All buildings and disposal structures of the repository shall be constructed on a platform which will protect the structures against floods. The structures important to nuclear safety (technological building, temporary hall, control basin, disposal silo) will be constructed on an earth-filled platform with a top elevation height protecting the structures against probable maximum flood (PMF). The
service part of the structures will be located on a platform with an elevation height of 155.20 m above sea level which is equal to the elevation height of the NEK platform. The access part of the repository will be constructed on a platform which will protect the structures against floods with a 100-year return period.

Structures classified in the category of structures important to nuclear safety with consideration of a 100 year life time are designed in accordance with the special standard using design earthquake with a return period of 5000 years. For a closed silo (300 year life time) a design earthquake with a return period of 15000 years is considered. Structures which are not classified into the category of structures important for nuclear safety are designed in accordance with Eurocodes with due consideration of a 50 year life time.

The disposal silos are constructed in the Tertiary layer of Miocene silt (with permeability coefficients ranging between $10^{-9}$ and $10^{-7}$ m/s.) which is located under a 3 – 15 m thick carbonate sandy gravel deposit of the River Sava. Groundwater was found at a depth of approximately 4 m under the site terrain surface. In case of high waters and floods, water can rise up to the terrain surface.

2.2 Waste processing and disposal

There will be 20 to 25 persons employed in the repository. In the Preliminary Design the repository is foreseen as an independent facility operating on a continuous basis (in one 8-hour shift, five days a week, the whole year round). Other operating modes are possible as well, especially: campaign period-type operation (e.g. each year operation during a number of months) and temporary operation which would be performed in accordance with actual needs (i.e. intensive operation with interruptions).

Prior to disposal, complete waste will be filled into uniform (N3a type) disposal containers of external dimensions 2.55 x 2.55 x 3.25 m (gross volume – occupation of space is 21.13 m$^3$) and of available net disposal volume of square shape and dimensions of 2.05 x 2.05 x 2.85 m. The available gross disposal volume shall amount to approximately 12.8 m$^3$. Any diversification of the containers shape would essentially complicate the internal transport and conditioning processes, so that it has not been foreseen within the Preliminary Design. A disposal container filled with tube-type containers (TTCs, the most frequent shape of waste package in NEK and which the container is tailored to) is shown in Figure 4. Instead of 9 TTCs, 27 200-liter drums, or a suitable combination of TTCs, 200-liter and 320-liter drums, or unpacked LILW (volume 12.8 m$^3$) will be placed in an individual N3a container. The container will be qualified as an IP-2 package. Maximal gross mass is up to 60 t.

With consideration of the available data on waste and preliminary waste acceptance criteria for disposal (WAC) and on the basis of safety analysis made in the framework of the Study of Alternatives and analyses made in the initial phases of the Preliminary Design elaboration it has been assessed that conformity with a major part of the WAC will be achieved by putting the LILW packages into disposal containers. The eventually remaining unconformities shall be eliminated by basic pre-conditioning processes for which relevant capacities shall be provided in the repository, and by alternative and more complex procedures of LILW processing which shall be performed in campaigns within the repository or in locations of such procedure contractors. Basic conditioning process will be performed in the technological building.

The LILW transport from NEK and CSRAO (Ljubljana) shall be performed by roads. Packages which shall not comply with the regulatory prescriptions as regards road transport conditions shall be inserted into additional transport packaging prior to the transport start.

Unloading of the packages from the transport vehicle shall be mostly carried out in the main hall of the technological building by a five ton hoist of a bridge crane. The unloading of
packages will include incoming control, fitting of the supplied packages with missing labels and registration of packages by waste data input into the register (data base) of the repository.

Figure 4: Disposal container

After unloading and incoming registration the majority of the supplied packages shall be inserted into empty disposal containers in the area of the incoming storage facility. After filling-up of the disposal containers, these shall be closed by relevant covers. Disposal containers prepared in this way will be suitable for backfilling with backfilling mortar.

Backfilling of the container voids with backfilling mortar is a central technological process of waste conditioning in the repository. Backfilling of containers shall be performed on three backfilling positions simultaneously in several phases. The backfilling mortar shall be made of water, cement and a super-plastificator. For preparation of the backfilling mortar contaminated water can be used. The preparation will be carried out within the backfilling mortar preparation system. Mortar shall be backfilled by a pump via transport flexible hoses and an opening in the container cover. Backfilling of all voids shall be provided by self-spreadering of the mortar in the container. The repository processing equipment capacities enable conditioning of 4-5 disposal containers a week or at least 200 containers a year. For the needs of this Preliminary Design it has been assessed that the repository can accept 10 m$^3$ of LILW a day at the most.

After backfilling of voids in the containers and sealing of covers, the disposal containers will be stored in the outgoing storage facility in the main hall of the technological building in order to provide curing of the backfilling mortar (up to 28 days).

Before LILW transport from the technological building to the repository, all containers shall go through the outgoing characterization procedure which is intended especially for registration of the outgoing state of the disposal containers. It shall include dose and contamination metering on all six surfaces of the disposal container plus weighing.
The containers shall be transported from the technological building to the handling area near the silo by a road vehicle. Both the silo and the handling area will be covered by a roof of the temporary hall.

The containers shall be disposed into a disposal silo of an inner diameter of 27.3 m and useful height of 33 m. The bottom of the silo will be approximately 55 m below the elevation of the flood protective platform. The LILW placed in N3a containers shall be inserted into the silo by a portal gantry crane. The silo capacity will be 700 disposal containers, i.e. 70 containers in each of the 10 disposal layers. The disposal containers will be placed into the silo close to each other and one above the other; (Figure 5). After each of the ten layers is filled-up, the remaining voids between the container walls and between the containers and the silo wall shall be backfilled with backfilling material. In the Preliminary Design, a drainage backfilling material, i.e. sand has been foreseen.

Figure 5: Disposal silo during operation

Waters which will percolate through the silo walls will be collected in the draining basis of the silo and drained via a drainage shaft into the inspection gallery. Under the silo’s central part there will be a drained water flow and contamination metering station located in the inspection gallery. These drained waters will be routed via the inspection gallery to the access shaft. The access shaft is a cylindrical structure with an inner diameter of 5.5 m, which descends down to the depth of 65 m under the top elevation of the platform. On the bottom of the shaft basins for water collection and a pumping station will be located wherefrom all drained water will be pumped to the surface.
After filling-up of the disposal silo with LILW containers all the remaining voids shall be backfilled with backfilling material while the disposal silo shall be covered by a concrete plate and a layer of low-permeable material, e.g. clay. In the alluvial aquifer area the upper silo walls will be perforated in order to ensure the original communication of groundwater and prevent formation of a water column above the closed silo. The upper part of the silo shall be filled up with gravel or sand which will remain from the silo construction pit excavation works.

The active long-term surveillance (institutional control) period will start when all the activities regarding the repository preparation for its submittal to surveillance are accomplished and when the authorized body or the Surveillance Contractor, respectively, takes over the repository into a long-term surveillance. After the active long-term surveillance period termination all installations and devices will be removed from the inspection galleries and the access shaft and the voids will be backfilled with backfilling material. The repository will so pass to a passive long-term surveillance stage. The above-ground structures of the repository will be removed or submitted to unlimited use. The length of these phases shall be determined on the basis of safety analysis. For the special (preliminary) safety analysis needs an active long-term surveillance period of 100 years and a passive long-term surveillance period of 300 years after the repository closure was presupposed.

3 VERIFICATION AND OPTIMIZATION OF DESIGN SOLUTIONS

The Preliminary Design documentation has been reviewed by recognised IAEA experts and relevant foreign engineering companies. Their findings and suggestions are considered in the just now performing process of verification and optimization of the design solutions. Data from the revised Krško NPP Decommissioning Program (especially regarding reduced quantities of decommissioning waste to be disposed of in spite of lifetime extension) will also be included into the optimization. The process results will be checked and verified using functional and safety analyses. The optimization process shall be finished before the next step of the design documentation preparation (for obtaining Construction Permit). The optimization is especially focused on solutions regarding restricting, control and monitoring of groundwater ingression into the disposal silo.

ACKNOWLEDGMENTS

IBE has made the Preliminary Design on the basis of the Appendix 16 to the Contract signed with ARAO and covering technical support in design engineering of the LILW repository in Slovenia. The companies of NUKEM Technologies GmbH, Alzenau (for the LILW processing technology area), ZVD - Institute for Occupational Safety (for the radiology area), University of Ljubljana, Faculty of Natural Sciences and Engineering (for the area of the substructure strength analysis) and ZRMK - Civil Construction Institute (for the area of geo-mechanics) cooperated in elaboration of solutions in the capacity of duly qualified sub-contractors.

REFERENCES
