MODELLING OF NUCLIDE MIGRATION FOR SUPPORT OF THE SITE SELECTION FOR NEAR SURFACE REPOSITORY IN LITHUANIA

R. KILDA, P. POSKAS, V. RAGAISIS

Nuclear Engineering Laboratory, Lithuanian Energy Institute

3 Breslaujos str., LT-44403 Kaunas – Lithuania

ABSTRACT

Construction of the near surface repository (NSR) for disposal of short-lived low-and intermediate-level waste (LILW) is planned in Lithuania. Reference design of the repository was prepared. Site selection process is going on. Environmental Impact Assessment (EIA) Program and Report were prepared and are under review by regulators.

Releases of radionuclides to water pathway and potential human exposure after closure of the NSR have been assessed for support of the site selection for NSR installation.

Two candidate sites were taken under consideration. The assessments have been performed following ISAM methodology recommended by IAEA for safety assessments of near surface disposal facilities. The conceptual design of NSR as well as peculiarities of geological and hydro-geological environment relevant to each candidate site is taken into account. The results of the analysis as part of EIA Report are presented in the paper. It is demonstrated that estimated impact of potential radionuclide migration for both candidate sites is below dose constrain established by regulations of Lithuania.

1. Introduction

There is only one nuclear power plant in Lithuania – Ignalina NPP. Two similar units with installed capacity of 1500 MW (each) were commissioned in 12/1983 and 08/1987 respectively. But the first Unit of Ignalina NPP was shutdown December 31, 2004, and second Unit will be shutdown before 2010 taking into consideration substantial long-term financial assistance from the EU, G7 and other states as well as international institutions.

In relation with Unit 1 decommissioning implementation of new technologies for treatment and conditioning of radioactive waste are under way. Construction of the near surface repository for disposal of short-lived LILW is also planned. Reference design of the repository was prepared in 2002 [1]. Operation of the repository is planned until 2030 while the Ignalina NPP will be dismantled and the conditioning of radioactive waste will be performed.

Site selection process is going on. Environmental Impact Assessment Program and Report [2] were prepared and are under review by regulators. After geological engineering investigations North-eastern Lithuania and vicinity of Ignalina NPP in particular are identified among the best suitable regions for a near surface repository. Short distance from the Ignalina NPP, relatively favourable social-economic conditions (low population density, low land economic potential) and good level of geological characterization are the main positive features of Ignalina NPP region.

In this paper releases of radionuclides to water pathway and potential human exposure after closure of disposal facility have been assessed for support of the site selection for NSR intended to construct in Lithuania. Two candidate sites, Galilauke and Apvardai, are taken into consideration.

2. Methodology

The assessments have been performed following ISAM methodology [3] recommended by IAEA for safety assessments of near surface disposal facilities. It contains key components as follows:

1. Assessment context;

2. Description of the disposal system;
3. Radionuclide migration scenario development and justification;
4. Model formulation and implementation;
5. Calculations;
6. Analysis of the results;
7. Confidence building.

Safety assessment of candidate sites built upon framework of the ISAM is provided in the next sections.

3. Assessment context

Dose constraint of 0.2 mSv per year is required for nuclear installations in Lithuania and stands for radiological criteria in the present assessment;

The evolution of the repository within institutional control period for 300 years (100 years for active control and 200 years for passive control) and during subsequent period is considered in order to assess potential releases of long lived radionuclides.

4. Description of the disposal system

According to the concept [1], the repository would consist of 50 vaults with total disposal volume of 100 000 m^3. It is estimated that repository will occupy an area of about 40 ha including waste disposal zone of 3 ha area.

Only finally conditioned solid or solidified short-lived low- and intermediate-level waste that meet waste acceptance for disposal criteria will be disposed off in the repository. The cemented radioactive waste (cement matrixes) containing ion-exchange resins, perlite and sediments are considered in the present safety assessment. Radionuclide inventory containing *short-lived* H-3, Cs-137, Sr-90 as weak sorbing and Pu-241 as strong sorbing as well as *long-lived* C-14, I-129, Ni-59, Ni-63 as weak sorbing and Nb-94, Tc-99, Am-241, U-234, U-235, U-238, Np-237, Pu-238, Pu-239, Pu-240 as strong sorbing with total initial activity estimated to ~1.1×10^9 MBq is under investigation.

After disposal of radioactive waste the repository will be closed by constructing additional engineered barriers. The engineered barriers of closed repository consist of concrete vaults surrounded by low-permeable clay-based material and the whole system is being covered by long-lasting and erosion-resisting cap, Fig. 1. A fence at distance of 150 meters from the vaults will surround a territory of the repository. Sanitary protected zone (SPZ) of 300 m radius is planned for the facility.

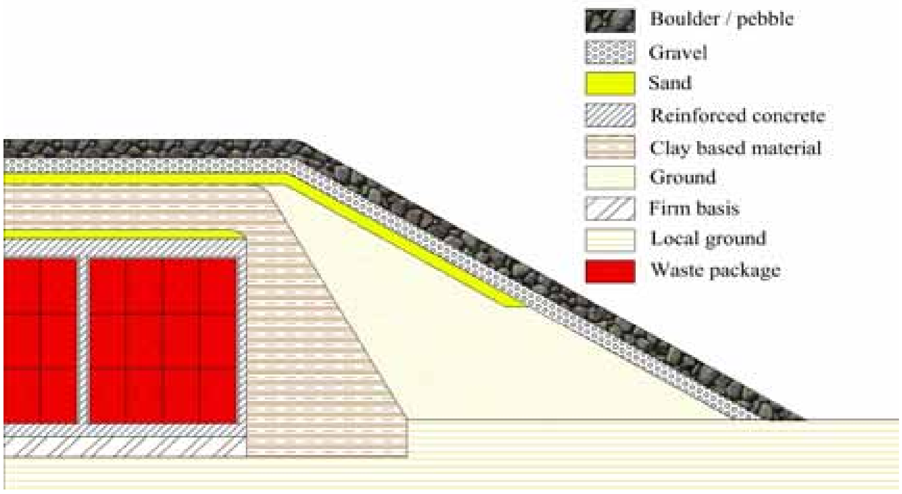

Fig. 1. Cross-section of the vault after closure of repository

A rather complex structure of the vadose zone has been assumed (generalized) as clay loam of 30 m thickness for Galilauke site, 3.5 m thickness for Apvardai site. The aquifer mainly consists of sand layer of 10 m and 2.2 m thickness at Galilauke and Apvardai site respectively.

The typical exposure pathway, exactly the well installed 150 m from the edge of the repository (next to the fence surrounding the repository), is determined for Galilauke site, but two exposure pathways, namely the well distant 150 m and the lake distant 1300 m from the edge of the repository have been determined in case of Apvardai.

5. Scenario development

Considering defined states of the engineered barriers (intact/normally degraded/completely degraded), two scenarios have been developed: *normal evolution scenario* and *barrier degradation scenario*.

The natural degradation of the barriers is assumed in case of *normal evolution scenario*. Hydraulic conductivity of clay barrier determines minimum infiltration rate (~0.02 m/yr) through the repository within analyzed period in this case.

In case of *barrier degradation scenario* the minimum infiltration rate through repository is assumed for period of institutional control (300 years) while maximum value of infiltration rate (~0.2 m/yr) is assumed after completion of institutional control due to sudden collapse of engineered barriers.

It is assumed that characteristics of geology and hydrogeology as well as biosphere remain stable within analysed period of time.

6. Model formulation

The conceptual model is developed on the basis of processes prevailing in the components of disposal system: due to water infiltration governed by state (evolution) of the engineered barriers the radionuclides leached from the waste packages (cement matrixes) through the bottom of the repository by diffusion/advection prevailing in the medium are transported toward vadose zone and further to the aquifer. Finally contaminants are discharging into well/lake water from which is used by humans for their daily needs. Radioactive decay is also taken into account.

7. Calculations

- Radionuclide migration in the repository and vadose zone has been assessed using 1-D equation of advective-diffusive transfer with respect to processes of dispersion and radioactive decay. Model is implemented in DUST computer program [4];
- Radionuclide migration through the aquifer has been assessed solving 1-D equation of advective transfer with respect to processes of dispersion and radioactive decay. Model is implemented in GWSCREEN computer program [5];
- Radionuclide transport and potential exposure to human in case of lake exposure pathway is implemented using AMMBER software [6]. 1-D differential equation modelling the radionuclide exchange between the components of the Lake system has been solved with respect to radioactive decay.

8. Analysis of the results

After assessment of migration of 18 radionuclides through the disposal system it is find out those only 12 radionuclides will reach biosphere zone. Cs-137, Sr-90, Pu-238, Pu-241, Ni-63, Am-241 will decay on the way in both cases of investigated scenarios, i.e. normal evolution as well as barrier degradation.

Normal evolution scenario
The estimated dose mainly should be resulted by C-14. After period of ~9-10 thousand years it should be of two orders of magnitude less than dose constrain of 0.2 mSv/year, i.e. negligible in case of Galilauke site. Very similar situation is revealed for Apvardai site in both cases of exposure pathways, well and lake.

Barrier degradation scenario
The estimated dose mostly should be resulted by C-14. After period of ~3-4 thousand years the maximum dose should be 0.036 mSv/year, i.e. factor of 5 less than dose constrain of 0.2 mSv/year in case of Galilauke site (Fig. 2). For Apvardai site in case of well (more important exposure pathway in comparison to lake), Fig. 3, it should be 0.16 mSv/year, i.e. ~20% below the dose constrain.

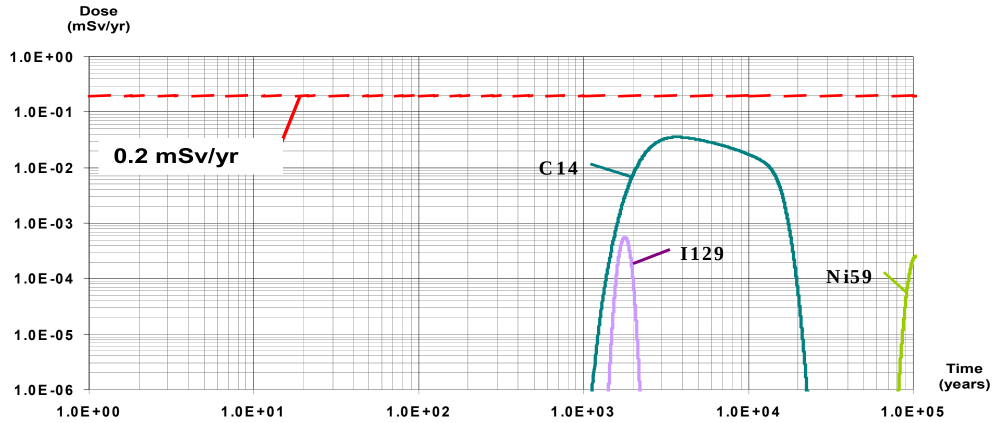

Fig. 2. Dose rate for well exposure pathway at Galilauke site in case of barrier degradation scenario

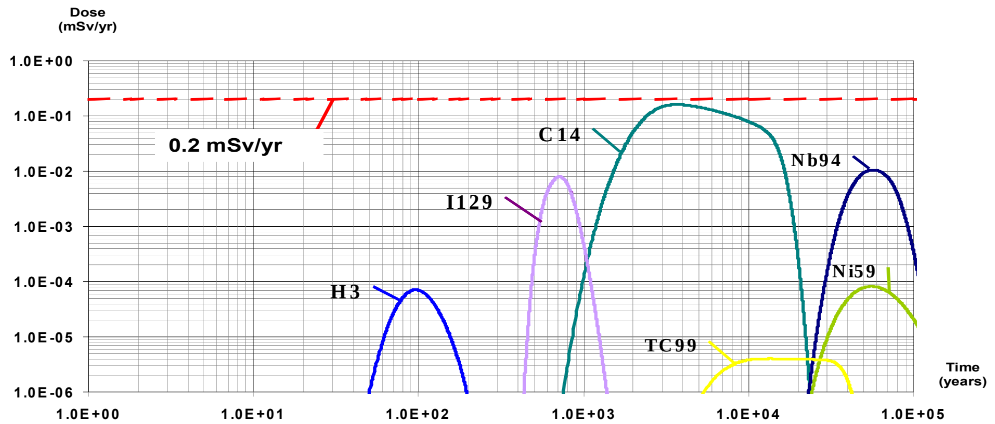

Fig. 3. Dose rate for well exposure pathway at Apvardai site in case of barrier degradation scenario

In general, the preliminary safety analysis has demonstrated that the dose constrain should not be exceeded at both candidate sites, moreover expected doses should be less at Galilauke site in comparison to Apvardai.

9. Confidence building

1. The results of the assessment should be accepted as conservative due to assumptions as follows:

- The percolation/saturation time through the repository is not taken into account;
- The radionuclide leaching from waste matrix is not modelled (instant release is assumed);
- Solubility limits of radionuclides are not taken into account;

- Initial activities of radionuclides are estimated for the beginning of operation period (not closure);
- 1-D dispersion is considered in transport analysis in aquifer zone for most radionuclides;
- Higher than average values for foodstuff consumption rates of local resident is used for dose assessment;
- Possible restrictions on activities within sanitary protection zone are not taken into consideration (i.e. well installed at the boundary of the repository).

2. Three types of uncertainties are analyzed:

(i) *Scenario uncertainties.* The alternative horizontal flow direction in vadose zone towards well has been investigated in case of Apvardai site. It appears that that dose is by 2-3 orders of magnitude less in comparison with case or vertical flow in vadose zone towards aquifer.

(ii) *Parameter uncertainties.* The variations of biosphere parameters (transfer factors, consumption rates, yield values, etc.) have been investigated for C-14 as most critical radionuclide using probabilistic simulation (Monte Carlo). The variation interval of doses is obtained and the upper bound of the interval is found within the limits of dose constrain.

(iii) *Model uncertainties.* The assessment results carried out for C-14 as most critical radionuclide using DUST for the near field and vadose zone, GWSCREEN for aquifer and, AMBER for biosphere zone are compared to the case when all components of the disposal system are modelled using only AMBER code. The difference only of 10 % in case of normal evolution scenario and 20 % in case of barrier degradation scenario is obtained.

10. Conclusions

After preliminary assessment of the potential releases of radionuclides from near surface repository to the groundwater pathway with respect to the estimated radionuclide inventory, conceptual design of the disposal facility intended to construct in Lithuania as well as peculiarities of the two candidate sites called Galilauke and Apvardai it is possible to conclude that:

1. Expected doses estimated for both candidate sites should be below the dose constraint of 0.2 mSv per year established by regulations of Republic of Lithuania.

2. Expected doses should be less in case of Galilauke site in comparison to Apvardai site.

3. Due to rather conservative assumptions taken into account for the analysis of radionuclide migration the estimated doses should be considered as overestimated.

11. References

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