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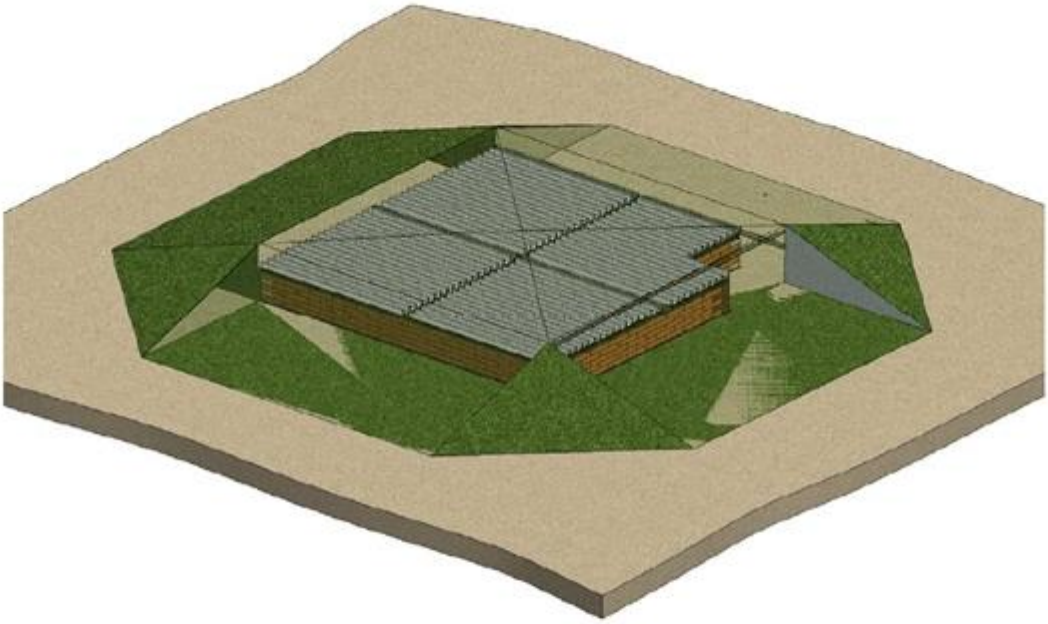

RECONSTRUCTION AND TRANSFORMATION OF IGNALINA NPP STORAGE FACILITY OF BITUMINISED RADIOACTIVE WASTE INTO REPOSITORY

ENVIRONMENTAL IMPACT ASSESSMENT REPORT SUMMARY

Kaunas, 2023

SUMMARY

During the operation of the Ignalina Nuclear Power Plant (NPP) all water discharged in the controlled area from the various technological tanks and pipelines as well as wastewater was collected in dedicated storage tanks. The collected water was evaporated in special facilities and the concentrate of the impurities present in the water was mixed with bitumen in a bituminisation facility. The resulting mixture of bitumen and evaporator concentrate (compound) was placed in the storage canyons in Building 158. During the operation of the Ignalina NPP when both Units were in operation, an average of ~250 000 m^3 of water was collected and treated per year, resulting in an average of 915 m^3 of evaporator concentrate from which 605 tons of bituminized waste was produced. Over the entire period from 1987 to 2015 (when the bituminization process was stopped) 19 415 m^3 of evaporator concentrate was generated resulting in 14 422 m^3 of bituminized radioactive waste which is stored in building 158. Bituminized radioactive waste is classified as Class B and C solid radioactive waste (short-lived, low and intermediate level activity).

Bituminized radioactive waste storage (building 158) is located at north-west part of Ignalina NPP industrial site (see Figure S1): about 200 m west from the first reactor unit and about 600 m from the south shore of the Lake Druksiai.

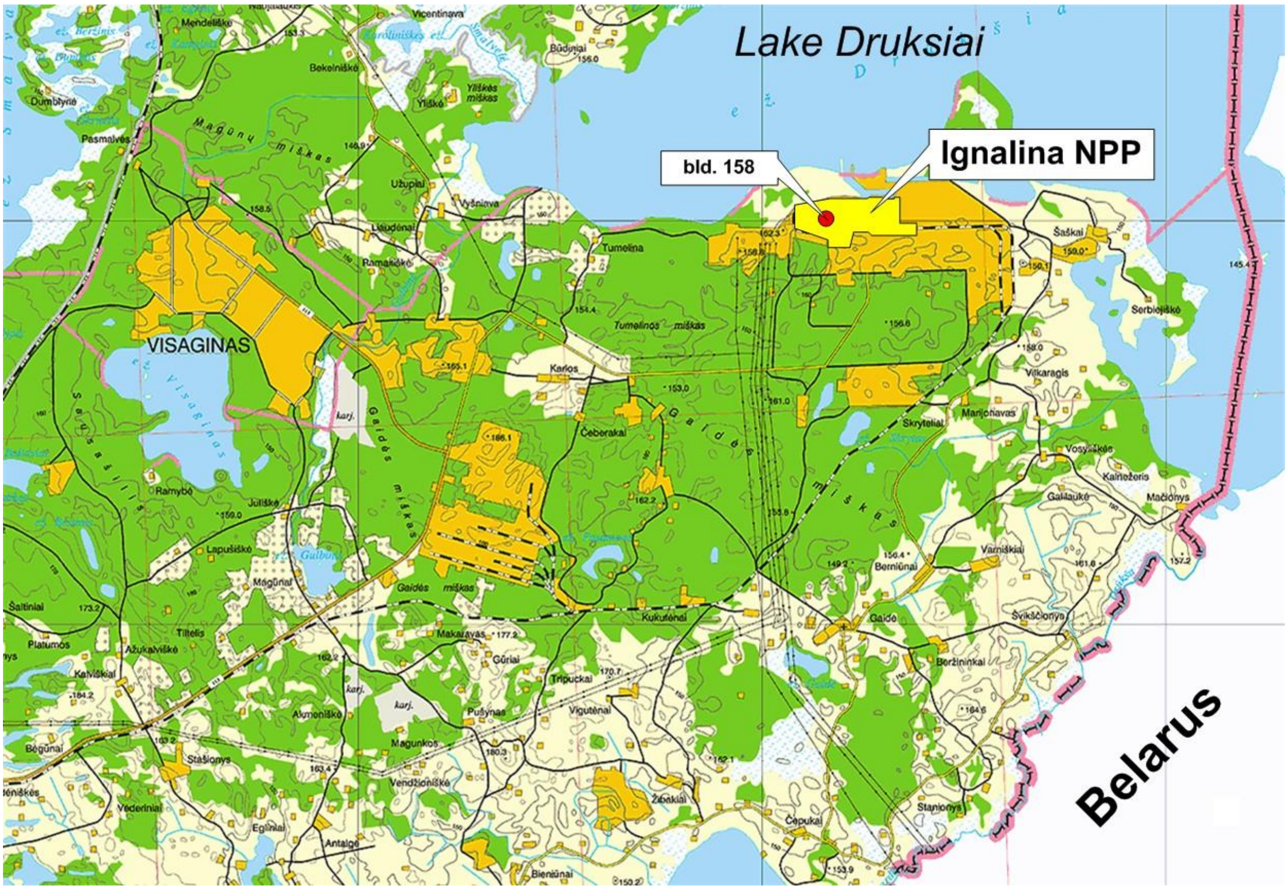

Figure S1. Location of bld.158 at the Ignalina NPP area

Retrieval of the bituminized radioactive waste from building 158 and placing it in a repository would be a complex and ambitious task – it would be necessary to develop the technology for retrieval and treatment of the bituminized radioactive waste from the storage canyons, design or find the suitable packaging, select the site for the repository, design, construct and transfer the waste to the repository. An alternative way is to transform the storage facility into a repository, such a solution would require much less financial and other resources and would be much less hazardous from the radiological impact point of view. This proposed economic activity (PEA) aims to reconstruct and transform the bituminized radioactive waste storage facility of Ignalina NPP into a repository. One of the main tasks during the transformation of the bituminized radioactive waste storage (building 158) into a repository is the installation of engineered barriers that protect the repository from ingress of water (rain, melting snow, etc.), possible external impacts caused by accidental or deliberate human activity, and limiting the ionising radiation exposure and the releases of radionuclides into the environment.

Chapters 1 and 2 of the Environmental Impact Assessment (EIA) report provide the general information of the planned surface repository and describe the main facilities and technological processes. The period of implementation of the proposed economic activity and the stages of the activity are indicated, the amount of materials required for the installation of the engineering barrier of the repository is preliminarily estimated, potential sources of pollution are named, the physical properties of bituminized radioactive waste are described, and the list of radionuclides that present in the waste and their activities are provided. The possibilities of transforming the bituminised radioactive waste storage facility at Ignalina NPP into a repository have been evaluated since 2007, when a feasibility study for transforming the storage facility into a repository was prepared [1]. Later, an International Atomic Energy Agency (IAEA) experts mission was organised in 2015 to assess the feasibility of converting the storage facility into a repository, and in 2019-2022 the conceptual design of a repository [2] was prepared, the safety justification of the repository concept [3] and an evaluation of the repository site [4] were performed. Taking into account the characteristics of the bituminised radioactive waste and the features of the site, the conceptual design of a repository considers possible technical solutions for the installation of engineered barriers during the transformation of building 158 into a repository. Engineered barriers of different thicknesses and layers were also analysed taking into account the peculiarities of the constructions of the building 158, the possible loads of engineered barriers, the requirements for ensuring radiation safety, and the external impacts of the environment. It was determined that the optimal option for the transformation of building 158 into a repository would be to install steel-reinforced concrete structures on the reinforced concrete upper cover of building 158, which would support the 5.8

m thick engineering barrier (multilayer cap) installed above the building (see Figure S2).

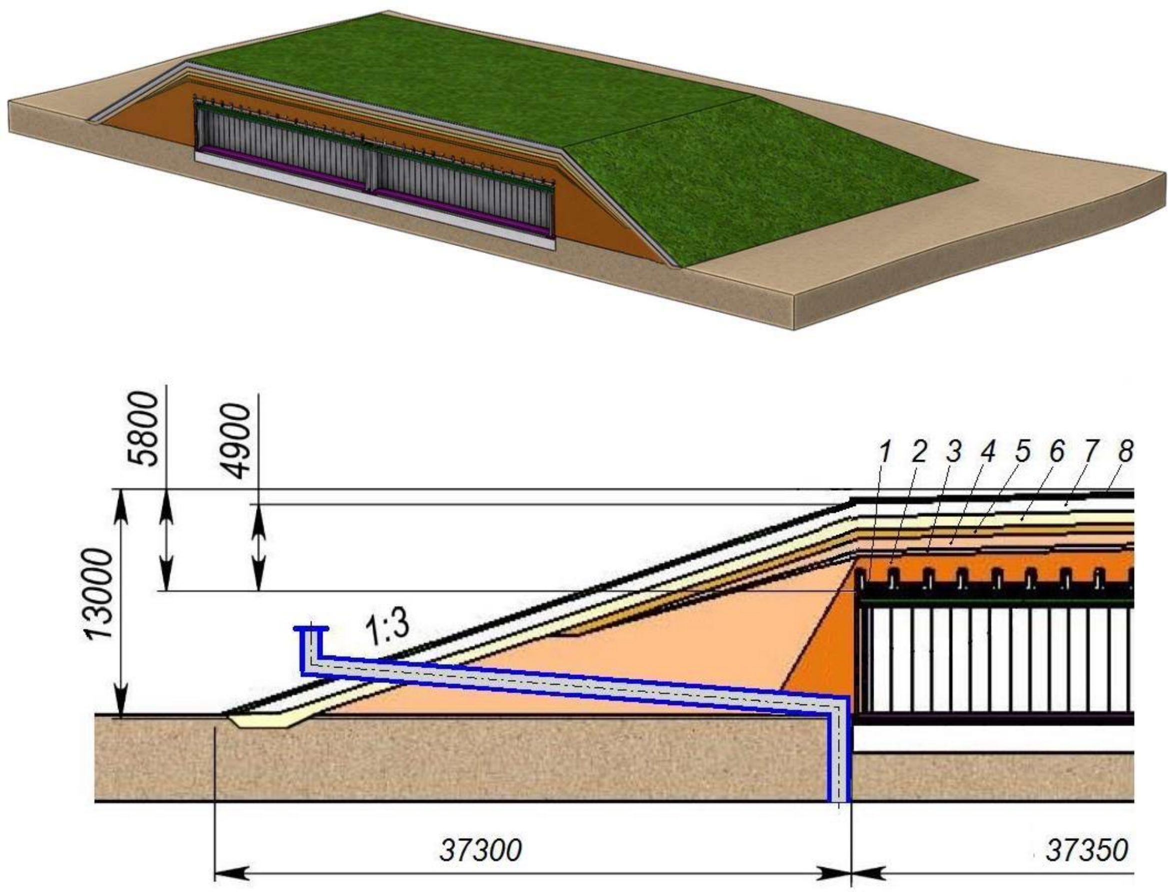

Figure S2. Image and composition (cross-section) of the 5.8 m thick engineered barrier after transformation of the storage facility (bld. 158) into the repository:
1 – drainage layer (0.2 m of sand); 2 – insulating clay layer (1.5 – 2.4 m); 3 – drainage layer (0.3 m of gravelly sand); 4 – protective clay layer (0.7 m); 5-7 – drainage layers (0.6 m of sand, 0.6 m gravel and 0.8 m of crushed stone); 8 – vegetation layer of 0.2 m thickness

Chapter 3 of the EIA report describes the waste that may be generated during the proposed economic activity, their estimated amounts and management. During the proposed economic activity, waste will be generated during the dismantling of the construction and communication structures of the 2nd floor of building 158 and the removal of unnecessary roof layers. The generated construction waste will be sorted, characterized and, depending on its activity, managed according to waste management requirements [5]. The organizer of this proposed economic activity (Ignalina NPP) strives to convert the waste generated during any decommissioning project into secondary raw materials as much as possible. This PEA is not an exception, the generated waste as much as possible will be to convert into secondary raw materials or reusable materials.

Chapter 4 of the EIA report describes the current status of the various environmental components and examines the possible impacts on these components. It should be noted that the PEA will be implemented within the closed industrial site of Ignalina NPP, locally around building 158 (see Figure S3). A sanitary protection zone (SPZ) has been established around the Ignalina NPP within a radius of 3 km, where economic activities not related to the operation and decommissioning of the Ignalina NPP are restricted and there are no permanent residents within the SPZ. Therefore, the impact on most environmental components will be negligible or absent. The main potential impact, which is examined in detail in the EIA report, is the radiological impact on the water component and public health. Non-radiological air pollution may be expected during reconstruction activities of the storage facility and construction of engineered barriers for future repository. Due to these activities, NO_x, SO_2, CO, CO_2, solid particles will be released into the ambient air, however the pollution will be local, the zone of reconstruction or installation of an engineering barrier and its surroundings within a radius of ~50 m will be impacted only. Ignalina NPP is performing chemical and radiological monitoring of the ambient air since the start of operation, according to the monitoring results the decommissioning activities at Ignalina NPP site have not had a significant negative impact on the ambient air so far.

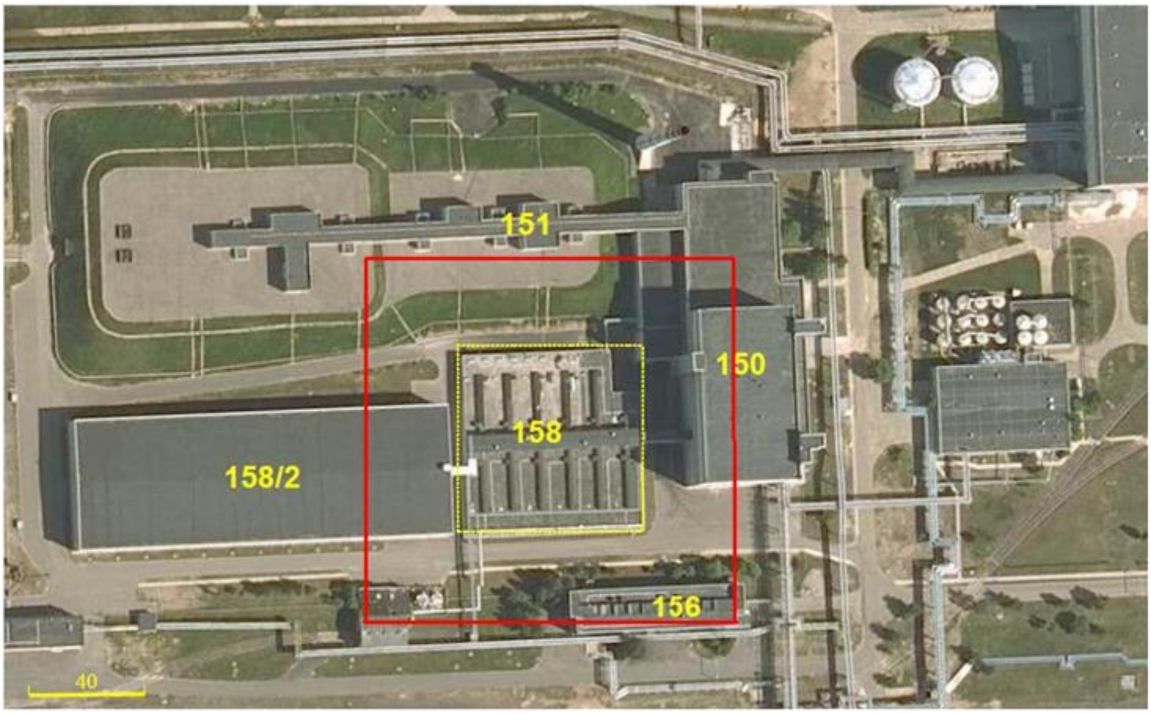

Figure S3. Reconstruction of bituminised radioactive waste storage facility (building 158) into the repository. The red line marks the 36 m wide area around the building, which will be used for the engineered barrier (multilayer cap)

bld. 150 – liquid radioactive waste treatment and bituminization facility; **bld. 151** – drainage water collection tanks; **bld. 156** – special washhouse; **bld. 158** – bituminized radioactive waste storage; **bld. 158/2** – interim storage facility for cemented radioactive waste.

The potential impact on water depends on the scenarios of the repository development (evolution of engineered barriers), which are developed according to ISAM methodology [6]. According to this methodology the disposal system is subdivided into components (the waste zone, the geosphere and the biosphere), and then possible states of the components are defined. Finally, scenarios are developed after the estimation of the possible states and their interrelation. Computer programs AMBER and COMSOL were used to model radionuclide transport through engineered barriers of the repository, ground water and in geosphere.

Two discharge points of radionuclides are investigated, exactly a well installed in the aquifer at the distance of 50 m from the repository (at the border of the supposed SPZ of the repository) and the lake Druksiai located at the distance of 600 m from the repository. The water taken from the well or the water taken from the lake can be used by the humans (members of reference group of population) for their everyday needs and, thus it can become a source of exposure. The following internal exposure pathways have been taken into account:

- inhalation of air contaminated with the dust suspended from soil during works in the garden;
- ingestion of contaminated water during drinking;
- ingestion of vegetables irrigated with contaminated water;
- ingestion of meat and milk from the cattle watered with contaminated water;
- ingestion of fish, caught in the contaminated lake;
- inadvertent ingestion of soil (e.g., particles of soil residual on vegetables).

A site dweller (in case of on-site residence scenario) consuming vegetables grown in the garden or a worker constructing a road (in case of road construction scenario) receiving a dose due to irradiation of uncovered bituminized radioactive waste would be a member of the reference group in case of inadvertent intrusion into the repository after completion of the institutional control period.

The analysis of the scenarios of the repository evolution and the dispersion of radionuclides (14 scenarios in total were analysed) has shown that the calculated annual doses to the member of the reference group are below the permissible limits. Maximum values of the exposure dose were compared with the design criterion of 0.1 mSv per year, which is less than effective dose constraint, 0.2 mSv/year, defined in Lithuanian hygiene norm requirements HN 73:2018 for operation and decommissioning of nuclear facilities [7]. The value of the design criterion was defined taking into account the fact that, in addition to the planned bituminized radioactive waste repository, other nuclear facilities are (or will be) in operation at the site of Ignalina NPP. Therefore, the exposure of the member of reference group must be distributed in such a way that the total annual dose caused by all nuclear facilities at the site cannot exceed the dose constraint. For analysis of scenarios of inadvertent intrusion into the repository the limiting dose value of 10 mSv per year is established in the VATESI (State Atomic Energy Safety Inspectorate) document [8].

Chapter 5 of the EIA report presents an analysis of PEA alternatives. “Zero”, location and technological alternatives were considered. In the case of the “zero” alternative, it was concluded that the indefinite storage of bituminized radioactive waste in building 158 is not feasible because previous assessments have shown that in the long term the structures of building 158 will start to degrade and would not provide a reliable containment of the waste. When considering the location alternative, i.e., the repository is constructed in another site, the bituminized radioactive waste from bld. 158 should be retrieved, placed in appropriate packages and transported to the disposal site. This alternative would lead to additional socio-economic challenges in the selection of the repository site, it would be necessary to develop the technology for waste retrieval, treatment and transport of the waste would lead to increased exposure of personnel and the members of population. As technological alternatives different technical solutions of the engineered barrier were considered, preliminary assessment of the advantages and disadvantages of these solutions was performed and optimal solution was selected [2].

Chapter 6 of the EIA report specifies the monitoring objectives and the conceptual description of environmental radiological monitoring. It shall be noted, that from 1987 to the present day the building 158 operates as storage facility for bituminous radioactive waste, which is monitored according to the currently valid Ignalina NPP environmental radiological monitoring [9]. In accordance with this program, groundwater samples are taken from boreholes in the vicinity of the building, dose rate values on the roof and walls of the building are measured at defined points, etc. This section of the EIA Report provides a conceptual description of environmental radiological monitoring when building 158 will be transformed into a repository, i.e., engineering barrier will be installed, a multilayer cap will be formed. Environmental monitoring of a repository includes measurements of dose rate, external absorbed dose and radionuclide activities in various environmental components. The selection of environmental objects is determined by the exposure significance of representative member due to the radionuclides they may contain. Automatic electronic devices are usually for dose rates measurements and dose-accumulating devices (thermoluminescent dosimeter) are used for measuring external absorbed dose. Environmental objects shall be sampled for radioisotopic analysis in the vicinity of drainage water and other effluent discharges and in areas of highest probable contamination. The radionuclide composition of the samples shall be determined to assess the contamination of the environment by measuring the specific activities of gamma-emitters. Contamination with beta (^{90}Sr, ^{3}H, ^{14}C, etc.) and alpha ($^{239,240}Pu$, ^{241}Am, etc.) emitting radionuclides shall be assessed by analysing a selection of representative samples.

Chapter 7 of the EIA report considers possible accidental situations (risks) that may arise during the implementation of proposed economic activity and assesses the potential radiological impact due to the accidents. The following initiating events that potentially can cause the damages of engineered barriers of the repository and radionuclide releases into environment:

- External natural, namely earthquake, ground settlement, increase of atmospheric precipitation;
- External man-induced, namely airplane crash onto the repository;
- Internal man-induced, such as a fire;
- Failure of the equipment and its components, namely malfunctioning of drainage system.

In the event of an earthquake, the engineering barriers of the repository may collapse, the concrete structures no longer perform the function of retaining radionuclides, and there would be dispersion of radionuclides into the environment. In the case of an increase in the amount of atmospheric precipitation, the infiltration of water into the technogenic soil increases and therefore the amount of radionuclides transported through the geosphere zone increases. In the event of a failure of the drainage system, water flooding of the repository is possible, which may result in the transfer of radionuclides by surface water directly into the Lake Drūkšiai bypassing the geological layers. Airplane crash probability calculations have showed that in all cases the probability is less than the screening probability level ($1 \cdot 10^{-7}$ per year for nuclear objects). The initiating events with a probability of occurrence lower than this level should not be given further consideration in spite of their consequences [10]. Despite the low probability, radiological consequences due to airplane crash onto the building 158 have been assessed and provided in the report [11]. Calculated doses for all accidental situations remain a few times below design criterion value 0.1 mSv per year. According to the evaluations, no special emergency preparedness measures are required for the reconstruction and transformation of the bituminized radioactive waste storage facility into a repository.

The impact assessment on neighbouring countries is presented in Chapter 8 of the EIA report. Two states, Belarus and Latvia, are relatively close to the site of proposed economic activity. Border between Lithuania and Belarus is about 5 km east and south-east from INPP industrial area. Lithuanian and Latvian state boarder is about 8 km north from INPP industrial area. Other states are at the distance of several hundred kilometres from INPP. It is estimated that the possible radiological impact of the proposed economic activity may be on the water component, i.e. for the Lake Druksiai, part of which is at the territory of the of Belarus. Lake Druksiai is located only within the territory of Lithuania and Belarus, and the Ricianka river, via which water connection with the Lake Rica partly located in Latvia is possible, flows towards the Lake Druksiai, but not out of it, therefore is no potential radiological impact for Latvian environment components and its population. The scenarios of inadvertent intrusion into the repository are not relevant for residents of neighbouring countries. The maximum annual dose due to the water pathway scenario to the representative member, which daily uses a contaminated water from a well (located 50 meters from the repository) and assuming the very conservative hypothetical case that lower layers, foundation, walls and top slab of the repository is cracked immediately after its closure, and the multilayer cap is also assumed to be degraded immediately after a closure, is about 10 times lower than the dose constrain of 0.2 mSv/year. Taking into account that the nearest neighbouring settlements are more distant (at 5 and 8 km distances) from the site of the proposed economic activity, i.e. further than the distance taken into account for the assessment of the radiological impact on the representative member of population (50 metres away), the health impact on the population of neighbouring countries would be even lower when considering the same water pathways as for the representative in the vicinity of the repository, as the dispersion coefficient shows that the increase in distance from the source of the discharge results in a decrease in the activity concentrations of radionuclides and the resulting doses of radiation exposure.

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