Modelling of ^{14}C Migration from RBMK-1500 Reactor Graphite Disposed of in a Potential Geological Repository in Crystalline Rocks in Lithuania

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Lithuanian Energy Institute

Main research directions:

- Development of energy economy planning methods, investigation of safety and reliability of the power plants, their impact on the environment, efficient energy consumption and the renewable energy sources;
- Investigations in the fields of thermal physics, fluid mechanics and metrology;
- Simulation of complex systems, development of their control methods and technologies;
- Investigation of energy systems' construction elements aging and development of new multifunctioned materials;
- Investigations of combustion and plasma processes in the fields of fuel saving, reduction of environmental pollution and thermal decontamination of materials.

Nuclear Engineering Laboratory

Main research areas:

- Safety of spent nuclear fuel management: modelling of fuel characteristics, safety and environmental impact assessment of storage and disposal facilities, normative and legislative base;
- Safety of radioactive waste management: strategy, safety and environmental impact assessments of treatment, storage and disposal facilities, normative and legislative base;
- Evaluation of different factors related to decommissioning of nuclear power plants: planning and cost estimation of decommissioning and dismantling, radiological characterisation of buildings, systems and facilities, safety and environmental impact assessment, normative and legislative base;
- Fire hazard analysis in nuclear power plants and other facilities;
- Research related to the construction of new nuclear power plant in Lithuania;
- Heat transfer and hydrodynamics investigations for nuclear and non-nuclear applications.

Introduction

There are two RBMK-1500 type reactors at the Ignalina NPP in Lithuania where graphite was used as a neutron moderator and reflector. These reactors are under decommissioning now and Lithuania has to find a solution for safe disposal of the irradiated graphite (i-graphite). A deep geological repository (DGR) is analysed as an option for disposal. Initial evaluation of ^{14}C migration from the RBMK-1500 graphite in the case of disposal in crystalline rock was performed with very conservative assumptions.

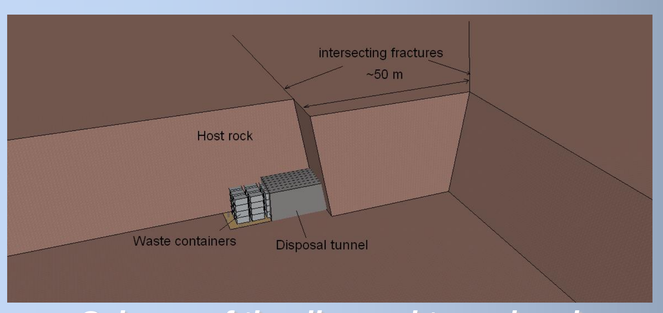
The aim of this work:

- to perform updated evaluation of ^{14}C migration from the i-graphite disposed of in a potential DGR in crystalline rocks and of the impact on humans based on the outcomes of the research performed under the CAST Project;
- to compare the results of the previous and updated assessment;
- to identify the potential for conservatism reduction.

System Description

Graphite waste is placed in metal containers and disposed of in a separate tunnel of a DGR in crystalline rock in Lithuania. Two alternatives are analysed:

- Alternative 1 – graphite waste inside metal containers disposed of without an encapsulant;
- Alternative 2 – disposal of encapsulated waste.



Scheme of the disposal tunnel and intersecting fractures

After emplacement, the tunnel is filled with cementitious backfill.

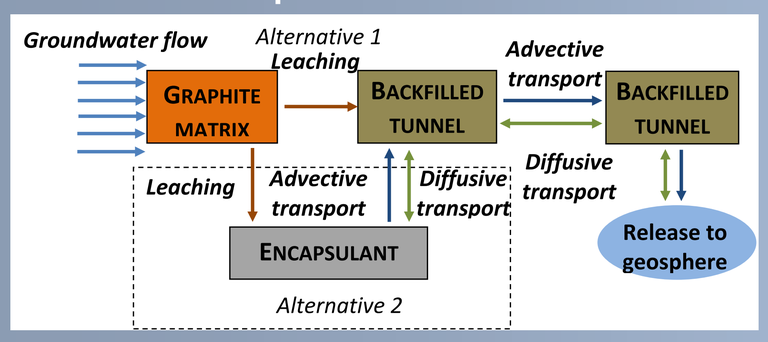
The crystalline rock is covered with a sedimentary cover, more than 600 m thick.

^{14}C Migration Scenario and Conceptual Models

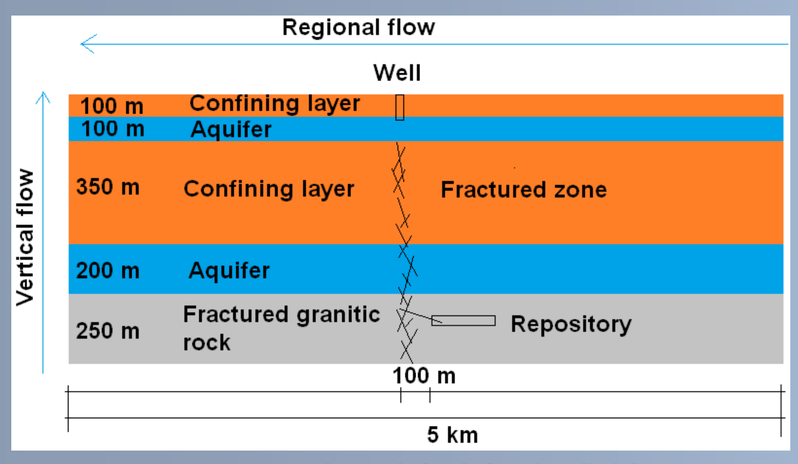
Scenario

A normal evolution scenario with ^{14}C leaching from i-graphite and transfer through the engineered barriers and the geosphere up to the biosphere by the water pathway is analysed.

Conceptual models



Conceptual model of the disposal system



Conceptual model of the far field

Source term

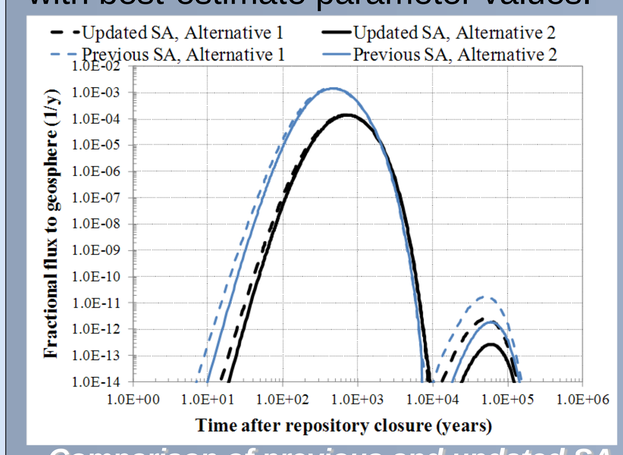
Comparison of the assumptions in the previous safety assessment (SA) and in the updated safety assessment with integrated CAST project results

Parameter	Hypothesis used in previous SA (before CAST)	Hypothesis used in updated SA (based on CAST)
Inventory	Based on conservative modelling. No sensitivity and uncertainty analysis.	Based on updated modelling and experimental results.
Release rate		
Releasable inventory	Total	Fraction from total inventory based on experimental results.
Rapid release fraction	For 10 years with release rate of 0.1 1/y.	Based on experimental results.
Rapid release rate		Instant.
Long-term (slower) release fraction	Variant calculations with different release rate based on measurements and modelling.	Based on experimental results, depends on releasable inventory and rapid release fraction.
Long-term (slower) release rate		Based on experimental results.
Speciation	Not considered.	Organic compounds: CH_4; inorganic compounds: $^{14}CO_2$/carbonate.
		Ratio between organic and inorganic compounds based on measurements.
Sorption in cement	Two calculation cases analysed: in one case all released ^{14}C is non-sorbed and in another case all released ^{14}C is well-sorbed.	Inorganic compounds: well sorbed.
		Organic compounds: no sorption for the best estimate calculations; weak retention for uncertainty analysis.

Results

Base case (best estimate)

The effect of incorporation of the findings from the CAST project in the updated SA was evaluated by comparison of the fractional release rate into the geosphere in the case of the previous SA and the updated SA with best-estimate parameter values.

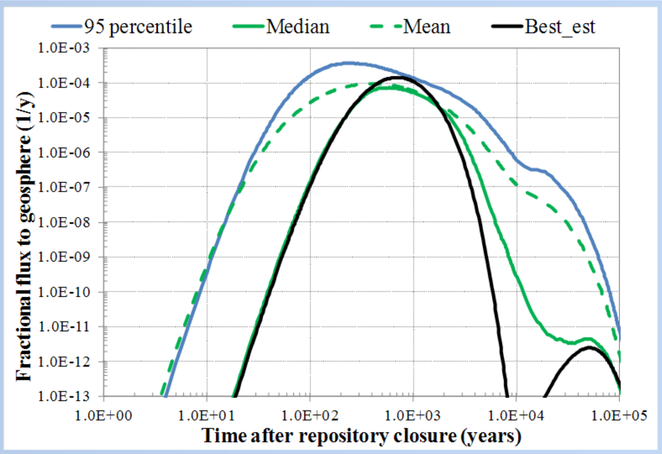


Comparison of previous and updated SA

The maximal fractional flux into the geosphere in the updated SA is reduced by about one order of magnitude, and therefore substantiated more realistic assumptions could significantly reduce the conservatism.

Impact on human

The estimated maximal doses to human in both alternatives are very similar, since the main contributor to the maximal dose is organic ^{14}C. The doses make about 5.5 % from the dose constraint (0.2 mSv/y).



Results of the uncertainty analysis, Alternative 1

Uncertainty analysis

The maximal fractional flux values corresponding to organic ^{14}C release differ between the median value and the 95th percentile by about factor of 5. For inorganic ^{14}C release, it varies in a much wider interval (from 2.5E-12 1/y to 3.2E-07 1/y). The uncertainty analysis demonstrated that further investigations in partitioning of the released ^{14}C between organic and inorganic compounds and sorption of the released compounds in cementitious environment could reduce the range of uncertainties and provide a more realistic picture of the system.

Conclusions

- ✓ Comparison of the updated SA base case results with the results from the previous SA indicates that the maximal fractional flux into the geosphere in the updated SA is reduced by about one order of magnitude.
- ✓ The estimated maximal dose to human in both alternatives makes about 5.5 % from the dose constraint (0.2 mSv/y).
- ✓ Uncertainty analysis demonstrated that further investigations in partitioning of released ^{14}C between organic and inorganic compounds and sorption of these compounds in cementitious environment could significantly reduce the range of uncertainties.