Modelling of radionuclide transfer through the concrete barrier of the near-surface repository under different environmental conditions

Povilas Balčius [1] , Dalia Grigaliūnienė [1]

1 Nuclear Engineering Laboratory Lithuanian Energy Institute, Kaunas, Lithuania

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Introduction:

Radioactive waste generated by human activity, is a long term issue demanding very specific waste handling, storage and disposal requirements. One of the options for radioactive waste disposal is near-surface repositories. Such facilities can be used for low and intermediate level short-lived radioactive waste. In these waste disposal facilities, concrete barriers are arranged with the aim to prevent and/or retard radionuclide migration into the surrounding environment. These concrete barriers interact with infiltrating water and various chemical elements in the environment, and chemically degrade impacting the ability of such barriers to retain radionuclide migration.

The aim of this work is to evaluate the impact of different environmental conditions on concrete barrier degradation and their ability to retain radionuclides. Radionuclides with weak and strong sorption in concrete were considered: C-14, Cl-36, Cs-137, I-129, Pu-239. Depending on the degradation state of the concrete barriers, sorption for these radionuclides can be significantly different. To determine the effect of environmental conditions on radionuclide retention in concrete, a fractional flux out of the bottom barrier for three different cases is compared.

Radionuclide migration scenario:

After the repository closure, potential water infiltration would be through the top of the structure, as rainfall. It is assumed, that the radionuclides are leached from the waste with the infiltrated water down through the repository and through the bottom slab into the environment. The model of the repository is provided in **Fig. 1**.

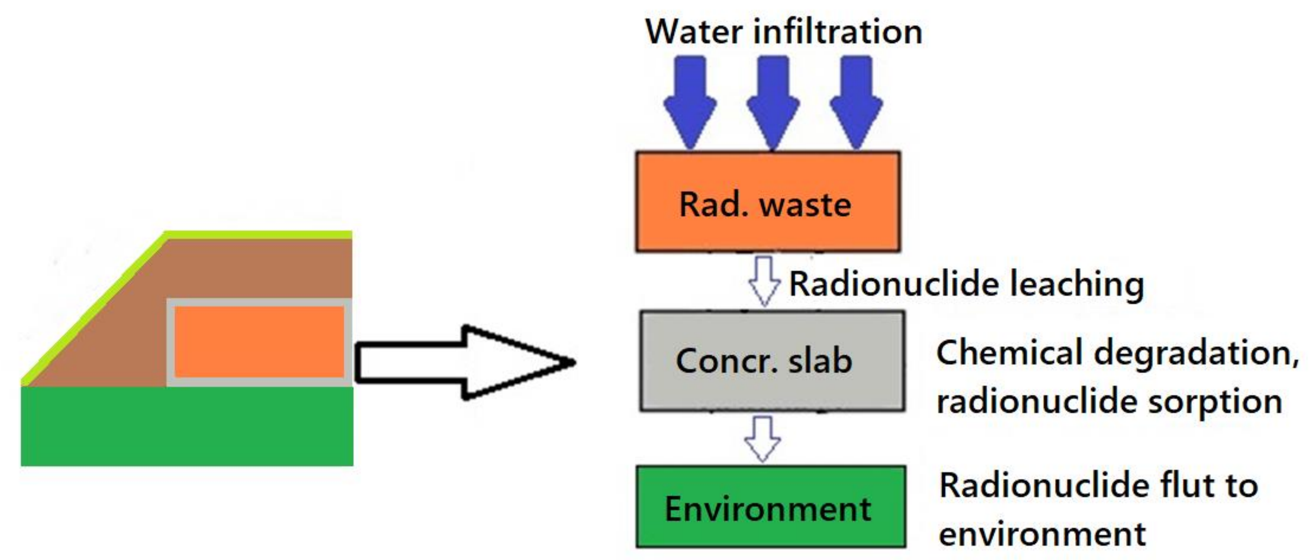

Fig. 1 Analyzed system

Modelling assumptions:

- Radionuclide migration is considered only through the bottom slab;
- Dimensionality – 1D model;
- Time frame – 1E+5 years.

Firstly, concrete chemical degradation is modelled to obtain the change in pH value in the concrete barrier and its mineralogical composition, and to determine concrete degradation stages. After this, sorption values of each radionuclide are linked to the degradation stages based on references [1-4]. Finally, radionuclide transport model is constructed and radionuclide fractional flux out of the bottom slab is estimated.

Concrete degradation evaluation:

Concrete degradation is evaluated under 3 conditions, namely, leaching with: 1) rain water, 2) rain water with increased CO_2 partial pressure (to account for microbiological activity at the top of the repository), 3) groundwater. Composition of water is based on local data [5]. The results of concrete degradation modelling are provided in **Fig. 2**. Only minerals with the most significant impact on pH evolution in concrete are presented in the graphs.

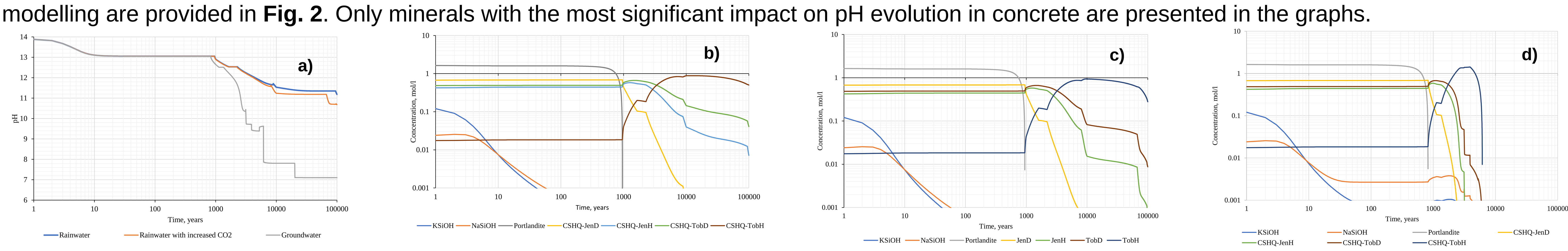

Fig. 2 Concrete degradation modelling results: a) pH change in concrete barrier under different leaching conditions, b) concrete mineralogical composition under leaching with rain water, c) concrete mineralogical composition under leaching with rain water with additional CO_2, d) concrete mineralogical composition due to leaching with groundwater.

It can be seen, that the difference for leaching with rainwater and rainwater with increased CO_2 partial pressure differ only slightly, however, leaching with groundwater leads to more rapid concrete degradation. Concrete degradation stages are provided in Table 1.

Table 1. Concrete degradation stages

	Stage 1 end	Stage 2 end	Stage 3 end
Rain water	5 years	1000 years	N/A
Rainwater +CO_2	5 years	1000 years	100000 years
Ground water	5 years	800 years	6000 years

Radionuclide flux from the bottom slab:

The results of radionuclide migration through the bottom slab into the environment for all 5 radionuclides are provided in **Fig. 3**. The results are presented as fractional flux, i.e. the ratio of radionuclide flux to its initial activity in the repository.

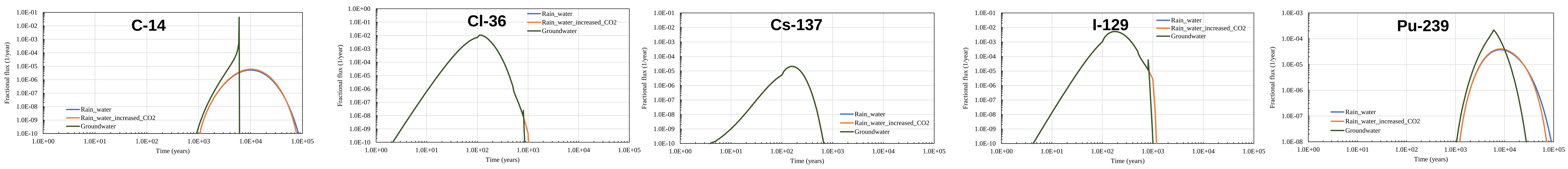

Fig. 3 Radionuclide fractional flux data from the bottom concrete barrier.

Conclusions:

- The modelling results indicate that the highest fractional flux from the repository is for mobile long-lived radionuclides Cl-36 and I-129.
- Radionuclide release from the repository in case of leaching with rainwater and rainwater with increased carbon dioxide partial pressure are very similar – the difference in maximal fluxes is less than 16%.
- Concrete leaching with groundwater causes more rapid degradation, leading to increased radionuclide migration in comparison with the rain water cases. The only exception is radionuclide Cs-137 due to its short half-life.
- The highest difference (more than one order of magnitude) between the cases can be observed for long-lived radionuclides with high sorption values: C-14 and Pu-239.

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Contact information:

Povilas Balčius

Junior associate researcher, Nuclear Engineering Laboratory

Lithuanian Energy Institute, Breslaujos st. 3, LT-44403, Kaunas

povilas.balcius@lei.lt

+370 626 43066

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