RESULTS OF THE SAFETY ANALYSIS OF THE RICHARD REPOSITORY, CZECH REPUBLIC

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Abstract
The Richard repository is located in a subsurface area of a former limestone mine in Northern Bohemia. The institutional low- and intermediate-level waste has been deposited here since 1964. The radiation situation of the near repository surrounding is monitored under inspection of the State Office for Nuclear Safety. A post-closure safety analysis has been undertaken with the aim to examine the acceptability and radioactive waste capacity of the repository against the requirements of the Czech nuclear legislation and to enable waste acceptance criteria and limits to be developed. The safety analysis considers two essential scenarios of post-closure repository behavior: a normal evolution scenario and a human intrusion scenario, as well as several variants of those. In addition seven source term scenarios and models have been defined for the dose calculations within the normal evolution scenario. The results of the safety analysis showed high level of safety of the Richard repository given by its geological and technical conditions. Some critical values of effective doses for human could be reached in case of realization of more conservative variant of intrusion scenario. The calculations resulted in derivation of new waste acceptance criteria.

Introduction
The Richard repository is situated in the subsurface area of former limestone mine in the hill Bidnice above the town of Litomerice on the River Labe in the Northern Bohemia.
The repository is situated in a part of an extensive network of tunnels and caverns (see Figure 1) in a layer of limestone. The repository is located in partially saturated rock; water table is located below the repository. Limestone as well as other rocks situated above and below the layer of limestone are believed to have relatively low permeability. Thus, infiltration of rainwater to the repository is practically negligible. The repository is currently drained. The drained water is monitored (3).
Radioactive waste has been emplaced here since 1964 year. Waste inventory is composed of a mixture of low-level radioactive waste (LLW) and short-lived intermediate-level radioactive waste (ILW) of non-nuclear origin, although the waste contains some long-lived radionuclides. Solid materials, low activity liquid waste and sludges are mostly solidified by cementation and disposed in 200l drums with a concrete liner. The inventory of radionuclides already disposed of, based on disposal records, is summarized in Table 1. The decision about the backfilling and the time of closure has not been made yet. The lifetime of the repository is estimated till 2070. At present, 61% of total disposal capacity of the repository is used for disposal.

The overall objectives of the performance assessment were to prove the long term safety of the repository by:

1. examining the acceptability and radioactive waste capacity of the repository against the requirements of Regulation No. 307/2002 Coll. of the State Office for Nuclear Safety (SUJB) on Radiation Protection Requirements,
2. allowing new waste acceptance criteria to be developed.

Regulation No. 307/ 2002 on Radiation Protection Requirements (of SÚJB) states that the dose limit for the safe disposal of radioactive waste is an annual effective dose rate of 250 μSv/y to critical group of population and an effective dose rates from intrusion scenarios of 1 mSv/y to critical group of population (4).

Methods
The post-closure performance assessment of the Richard repository was performed. Two essential scenarios of repository behavior were considered (3). <u>Normal evolution scenario</u> expects no intrusion of living organisms into the repository and continual changes in function of engineered barrier system after the institutional control period (in 2400 year). The surface water is expected to penetrate into the repository and saturate the area of the repository to 10%. Contaminated water then infiltrates out of the repository and contaminates the soil and well water of a small farm in near vicinity of the repository and well water in a town situated in a longer distance from the repository.

Human intrusion scenario assumes the remining of the limestone and further prospecting through the area of the repository after the institutional control period.
Additional variants of assessment and modeling of the repository within the normal evolution scenario were performed. Source term and seven additional variants of that were performed by using the computer program MASCOT (1). The source term has been represented in the MASCOT calculations using one or more 'solubility limited source term' (SLST) models. The SLST model represents the repository as a homogeneous compartment through which a flux of groundwater flows. It releases a flux of radionuclides into a geosphere model, or directly to a biosphere, given by the products of the calculated concentrations of radionuclides in the water in the repository and the volumetric flux of the groundwater flowing through the repository. The model allows for radioactive ingrowth and decay. The purpose of seven additional scenarios is to examine the impact of assumptions about the individual components of the repository, the inventory of radionuclides, and the volumetric flow of water into the repository, when these scenarios are realized in performance assessment calculations.
Further assessment considers scenarios associated with the releases of radionuclides from the repository to the environment in groundwater. 1D groundwater flux and radionuclide release modeling in unsaturated zone is performed by using computer code HYDRUS 5.0 and code S_1D_Dual 8.0. 1D groundwater flux in saturated zone is calculated by computer code MODFLOW based on the methods of final differences. A set of deterministic calculations with the aim of estimating possible radiological doses to critical groups - effective dose calculations - was performed with the computer program MASCOT (2). Two scenarios have been considered to test the influence of various factors to obtained effective dose to critical group: groundwater pathway scenario and bypass scenario. The geosphere was modeled in MASCOT as two units linked in series with the uniform properties of the aquifer below the repository within the groundwater pathway scenario. The Standard Geosphere model of MASCOT was applied, which is a one-dimensional model of solute transport by groundwater in a porous medium with advection, dispersion, equilibrium sorption and radioactive decay and ingrowth represented. In the Bypass Scenario contaminated water drains or leaks out of the repository bypassing the geosphere. The worst case assumption expects that the draining or leaking contaminated water would be used as a source of drinking water. All calculations were performed with the MASCOT computer program too.

Figure 1: Layout of the Richard Repository

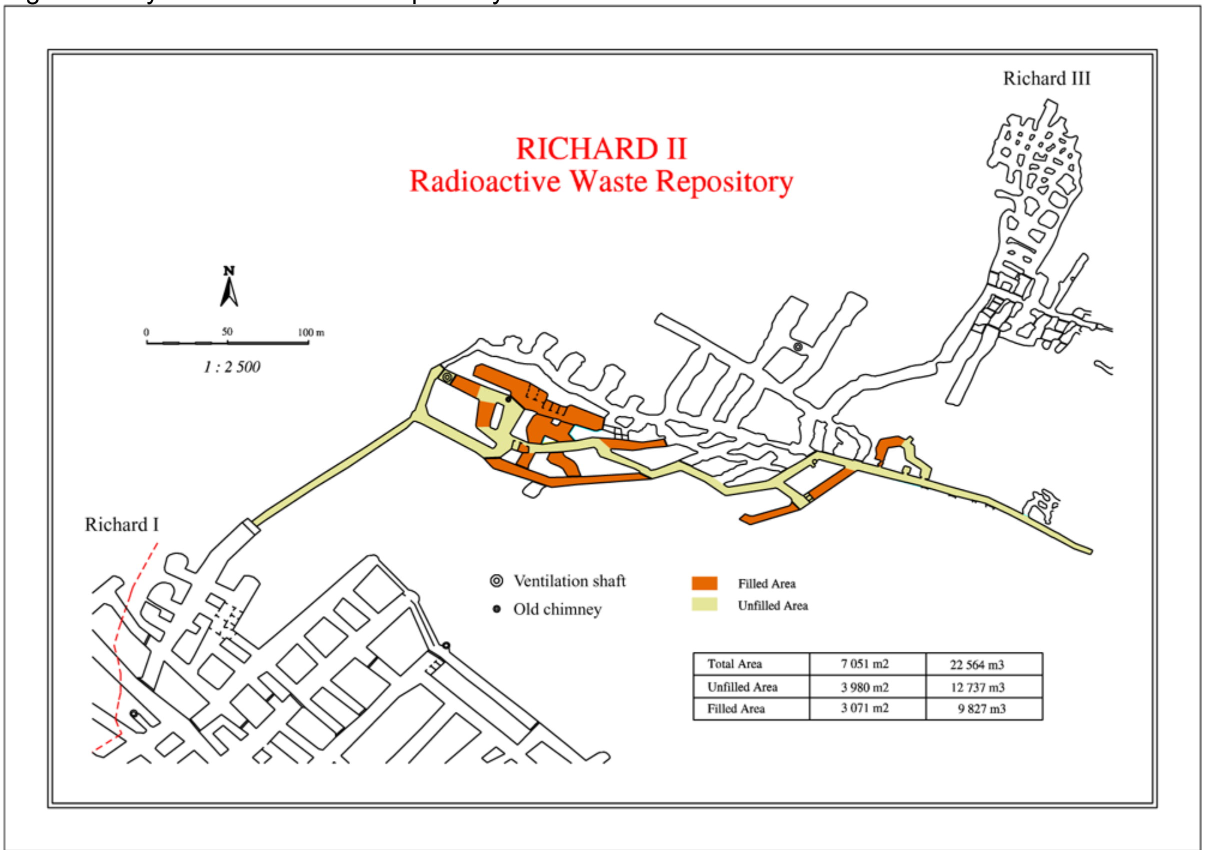


Table 1: Radionuclide inventory of the repository

Radionuclide	Total Inventory to 2000 (TBq)
H-3	**$3.367\ 10^{1}$**
C-14	**8.158 10**
Cl-36	**$7.413\ 10^{-3}$**
Co-60	**$2.544\ 10^{2}$**
Ni-63	**$8.049\ 10^{-4}$**
Kr-85	**$1.316\ 10^{0}$**
Sr-90	**$2.758\ 10^{1}$**
Tc-99	**$4.292\ 10^{-3}$**
I-129	**$2.800\ 10^{-6}$**
Cs-137	**$5.402\ 10^{2}$**
Ba-133	**$5.296\ 10^{-3}$**
Pm-145	**$8.686\ 10^{-3}$**
Pm-147	**$9.556\ 10^{-2}$**
Sm-151	**$1.547\ 10^{-2}$**
Eu-152	**$1.955\ 10^{-2}$**
Pb-210	**$1.243\ 10^{-3}$**
Ra-226	**$2.048\ 10^{-2}$**
Th-232	**$9.500\ 10^{-5}$**
U-238	**$1.507\ 10^{-3}$**
Np-237	**$1.260\ 10^{-4}$**
Pu-238	**$7.547\ 10^{-2}$**
Pu-239	**$1.615\ 10^{0}$**
Am-241	**$3.300\ 10^{1}$**
Cf-252	**$5.188\ 10^{-4}$**

Results

The results calculated suggest that the geosphere is the main factor controlling the repository safety. The calculated values of effective dose rates to critical group for all scenarios considered do not exceed the limits given by Regulation. Figure 2 shows values of effective dose rates for critical radionuclides within two essential scenarios of the repository behavior and the proposal of new waste acceptance criteria to be approved by SUJB in the end of 2003. Figure 2 shows the time dependence of critical radionuclide activity in water in case of release from the repository, normal evolution scenario.

Conclusions

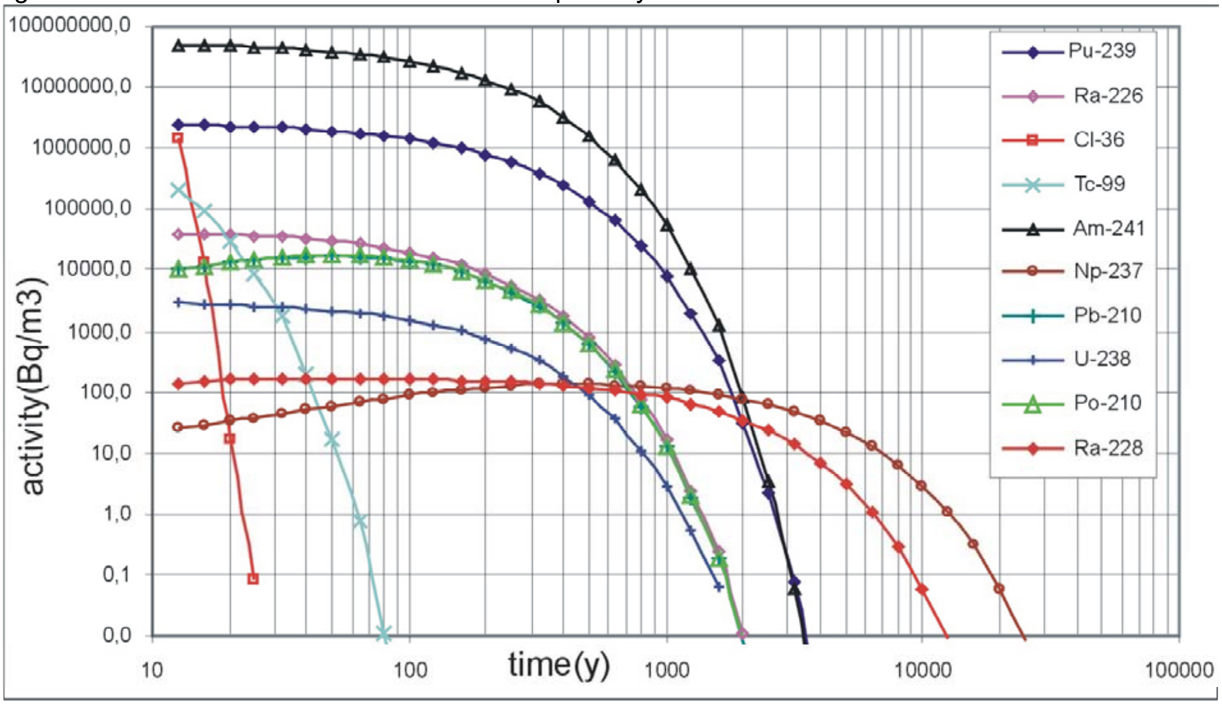
The real scenarios with various measure of conservatism were considered. The results show high safety of the Richard repository and declare the possibility to dispose radioactive waste hereafter. The transport of released radionuclides is effectively retarded by natural barriers. The new waste acceptance criteria were developed and should be approved by SUJB by the end of 2003 year.

The calculations were performed by Serco Assurance, Aquatest plc, ProGeo and RAWRA.

Table 2: The Results of Effective Dose Rate Modeling for Critical Radionuclides in Normal Evolution Scenario and Human Intrusion Scenario and Proposal of Waste Acceptance Criteria

		Normal evolution scenario		Human intrusion scenario		New Waste Acceptance Criteria	
Nuclide	Inventory to 2000 year	Effective Dose Rate	Activity Limit of Inventory in the Repository	Effective Dose Rate	Activity Limit of Inventory in the Repository	Maximal Bulk Activity	Maximal Activity in the Repository
	Bq	Sv/y	Bq	Sv/y	Bq	Bq/m^3	Bq
H-3	3,37E+13	2,00E-10	4,21E+19	3,24E-19	5E+16	1E+13	5E+16
C-14	8,16E+13	1,00E-09	2,04E+19	1,02E-09	1E+16	2E+12	1E+16
Sr-90	2,76E+13	8,00E-14	8,62E+22	5,89E-11	2E+15	5E+11	2E+15
Cs-137	5,40E+14	1,00E-35	1,35E+46	1,42E-05	1E+15	5E+11	2E+15
Pu-239	1,62E+12	2,00E-06	2,02E+14	4,03E-05	5E+12	1E+09	5E+12
Am-241	3,30E+13	7,00E-08	1,18E+17	4,90E-04	5E+13	1E+10	5E+13

Figure 2: Release of Radionuclides from the Repository



References

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(3) S. Baloun, M. Cernik, J. Slovak, Bezpecnostni analyza uloziste radioaktivnich odpadu Richard, zaverecna zprava, SoD SURAO 58/2000/Sko, (December 2002), in Czech

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