Preliminary analysis of gaseous ^{14}C radiological impact in a geological repository hosted in salt rock

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In Italy there is still no defined the final disposal option for the Irradiate Graphite waste from the decommissioning of the former GCR-Magnox Reactor. However, in this work we have analyzed the potential radiological impact of gaseous ^{14}C released from the Italian irradiated graphite, disposed of in a theoretical geological repository hosted in a salt rock formation. On the basis of the layout of the shaft sealing materials of the U.S. Waste Isolation Pilot Plant (WIPP) project, a 3D model has been performed by using the THOUGH2/EOS7R code integrated into PetraSim computer program. The computational domain consists of four storage rooms and a central shaft. Not having sufficient information about the number of waste packages and their dimensions and radioactivity content, a fictitious and very conservative source term has been modeled. The analysis involves a hypothetical release scenario and two different cases of study by which evaluate the importance of the distribution coefficient, Kd, of the shaft sealing materials. The simulations have been performed setting the model input parameters on the basis of literature data. Results have showed the more effectiveness of sealing materials with Kd>0 in delaying the gaseous ^{14}C migration towards the top of the shaft, than those with Kd=0.

Conceptual Model and Assumptions

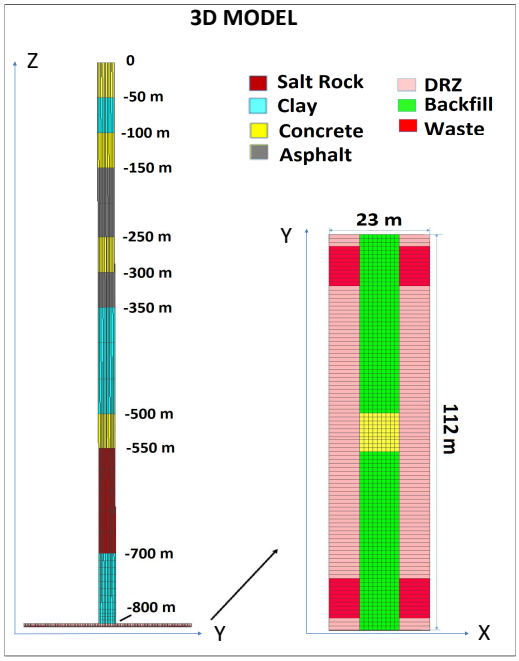
CONCEPTUAL MODEL

- The 3D model has been performed by TOUGH2/EOS7R numerical code, integrated in the PetraSim computer program;
- The shaft sealing system is made by the succession of 11 layers of 4 different materials: concrete, asphalt, compacted clay, and salt rock;
- The repository is located to a depth of ~800 meters, in a 200 m thick salt body, below clay rock, which is about 700 m tick;
- The repository contains 4 storage rooms located at 30m from a central shaft;
- Crushed Salt is used as backfill at the repository level;
- A Disturbed Rock Zone (DRZ) surrounds the excavated zone;
- No sealing materials close the storage rooms;
- Calculation time: 30000 y.

ASSUMPTIONS

- Total ^{14}C activity in the irradiated graphite: 2.83E+13 (Bq)
- The graphite waste is modeled as four monolith located to the opposite sides of the excavated zone;
- The total amount of the estimated ^{14}C activity is equally distributed in the waste;
- The consolidation of DRZ and crushed salt, and the salt rock convergence are not considered in the evolution scenario;
- The gaseous ^{14}C is released from irradiate graphite waste by leaching, due to the presence of brine in the disposal rooms;
- The source term is modelled as a constant release of gaseous ^{14}C from the solid waste, with a rate of 0.0067 % per year of the total ^{14}C activity content;
- Two main cases have been simulated increasing the Kd value of the shaft sealing materials, from 0 to 1E-3 m3/kg.

3D MODEL



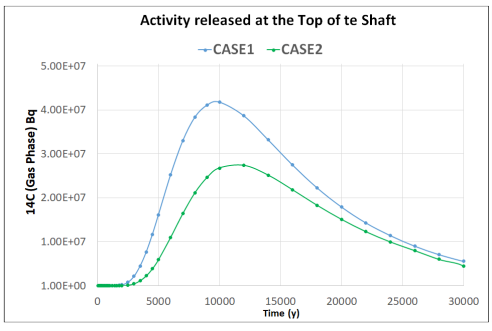
INPUT DATA

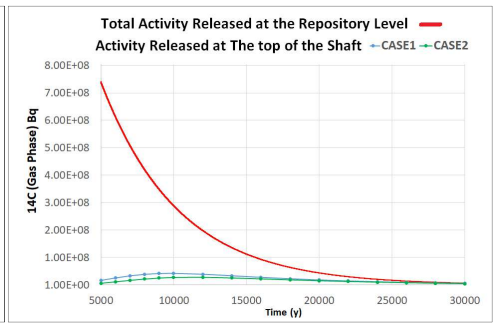
Materials	*Permeability (m^2)*	*Porosity (-)*	*Density(kg/m3)*
Concrete	*1E-18*	*0,02*	*2145*
Clay	*5E-19*	*0,24*	*2740*
Asphalt	*1E-20*	*0,01*	*1990*
Intact Salt	*1E-23*	*0,0182*	*2170*
DRZ	*1,12E-16*	*0,0129*	*2170*
Waste	*1E-13*	*0,32*	*2600*
Crushed Salt	*1E-18*	*0,35*	*2160*

SIMULATION CASES

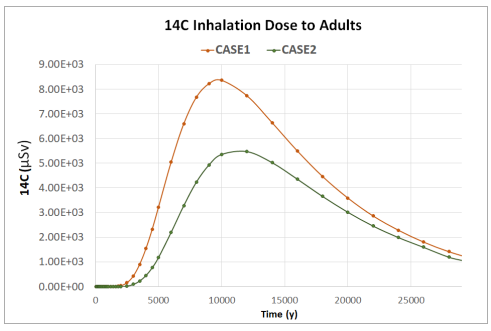
	Case 1	Case 2
	Kd_14c (m3/kg)	
DRZ	0	0
Clay	0	1.00E-03
Salt Rock	0	0
Waste	0	0
Backfill	0	0
Asphalt	0	1.00E-03
Concrete	0	1.00E-03

Results





- The peak of ^{14}C activity at the top of the shaft occurs between 5.000 y and 30.000 years;
- In Case 1 the maximum value of the ^{14}C activity reaching the top of the shaft is 5E-4% of total activity released from the waste packages, and 3E-4% in Case2.
- In Case 2 the gaseous 14C migrate toward the surface slower than in the Case1.



In both cases, at the surface level, the dose value exceeds the radiological-relevance limit of 10µSv/y imposed by the Italian regulatory:

- after 1600 y in Case 1 (whit a maximum value of 8.36E+03 µSv/y at 10000 y); and
- after 2500 y in Case 2 (whit a maximum value of 5.47E+03 µSv/y at 12000).

Conclusions

A relationship between the migration velocity of gaseous ^{14}C and the Kd value of the shaft sealing materials has been highlighted. In Case 2, the peak of the ^{14}C activity reaching the top of the shaft, occurs with a delay of about 900 y than the Case1. Assuming the release starts at repository closure (t=0), the potential inhalation dose for member of the public (adults), at the surface level, exceeds the Italian no-*radiological-relevance limit* of 10 µSv/y, after 1600 y in Case1 , and after 2500 y in Case2.
Despite the very conservative assumptions, the results highlight the effectiveness of EBS sealing materials in delaying the migration of gaseous ^{14}C from the repository level to the ground surface. These performances can be improved by using materials with favourable mechanical properties, and high Kd values.