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

R. Levizzari[a], B. Ferrucci[b], A. Luce[a]
[a]ENEA, Saluggia Research Centre - Strada per Crescentino 41, 13040 Saluggia, Vercelli - Italy
[b]ENEA, Bologna Research Centre - Via Martiri di Monte Sole 4, 40129 Bologna - Italy

Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Introduction

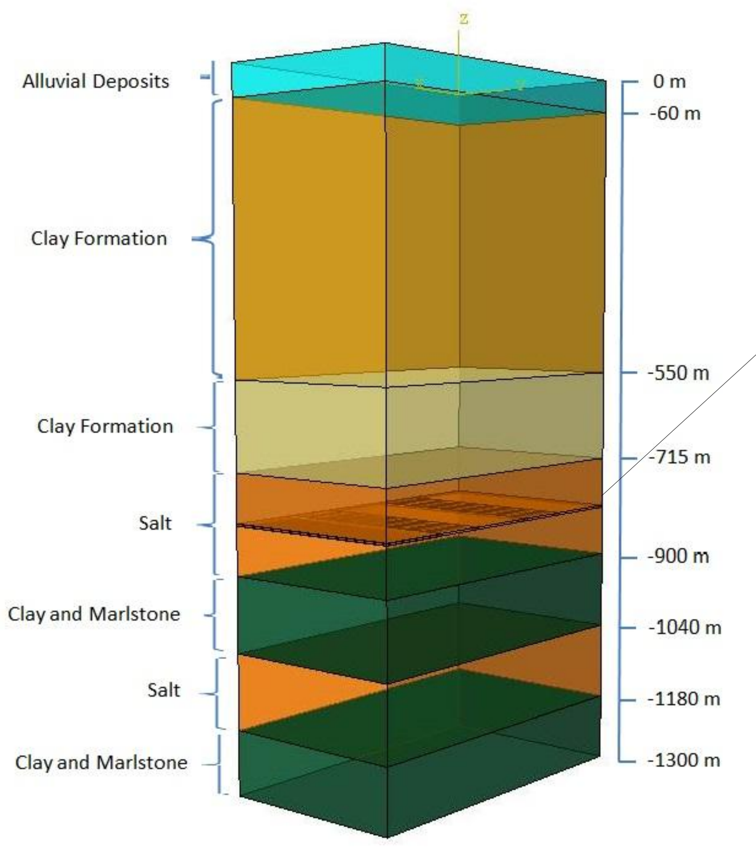
A preliminary evaluation of the radiological impact of gaseous ^{14}C under geological disposal conditions for Italian HLW-LL and ILW has been performed. Although in Italy there is still no defined project about GDF, current work may support future Safety Assessment studies for a repository in salt rock, taking into account analogies with other existing geological repository projects (e.g. WIPP). In the whole Italian context of radioactive waste, the percentage of ^{14}C bearing waste to be disposed in a possible geological repository is low; irradiated graphite is the most important radiological source. Data about radioactive HLW-LL and ILW inventory has been collected to simulate production and migration of gaseous ^{14}C in a repository hosted in a deep salt formation. The first simulation with TOUGH 2.0 code has preliminary evaluated the radiological impact referred to the whole inventory; the second simulation has evaluated the impact referred to irradiated graphite alone. A preliminary sensitivity analysis was carried out, highlighting the importance of the geometry and the distribution coefficients in materials used to seal the disposal areas within salt rock. Results of simulations have showed the possibility to correlate the K_d values, the volume and the location of sealing materials to the amount of ^{14}C emitted toward the surface facility.

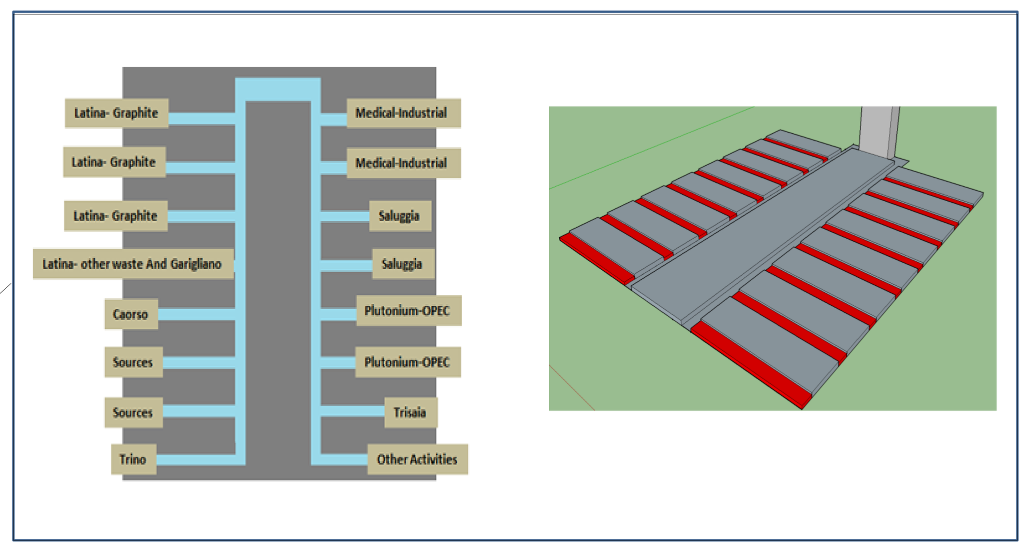
Available data and conceptual model

Inventory of Italian HLW-LL and ILW containing ^{14}C

Origin	Materials	Volume (m³)	Inventory of ^{14}C (GBq)	Quality of information Uncertainty
GCR-Magnox Reactor (Latina NPP)	Graphite	3.30E+03	2.83E+04	Estimated Moderate
NPP	Resins, metals	n.a.	3.30E+03	Estimated High
Medical, industrial, research	Conditioned sources	172.60	0.42	Estimated Moderate
	Not treated sources	6.78	92.80	Estimated Moderate
	Cemented sources	113.60	106.28	Estimated Moderate
	Solid treated sources	42.00	11.00	Estimated Moderate
	Not treated liquid waste	4.19	4.05	Estimated Moderate
	Not treated solid waste	15.06	2.36	Estimated Moderate

Geological features and conceptual model of a hypothetical repository in a deep salt formation





The repository design was performed on the basis of the US Waste Isolation Pilot Plant (WIPP). Repository would be located to a depth of ~800 meters, in a 200 m thick salt body , below clay rock, which is about 700 m tick.

Modelling by means of TOUGH2: a general-purpose numerical code for modeling flows of multicomponent, multiphase fluids in one, two and three-dimensional porous and fractured media.

Two series of simulations have carried out:

- Multi-room model, referred to the production and migration of radiocarbon due to the overall waste
- Single-room model, referred to the production and migration of ^{14}C due to the irradiated graphite.

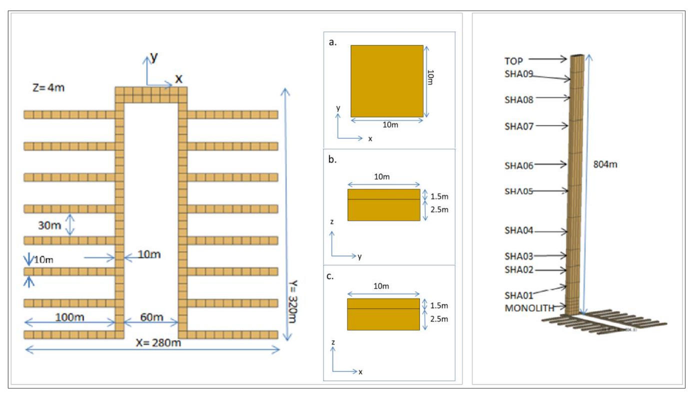
Model and results

Repository design:

- 16 rooms arranged in two panels separated by a central pillar of intact salt, 60 m thick and 4 m high;
- rooms divided by lateral pillars of intact salt, 30 m thick and 4 m high;
- room dimensions: x=100 m, y=10 m, z=4 m; volume: 4000 m³;
- each room is divided from the central pillar by a drift, 10 m width;
- in each room, waste disposed in a volume of 2500 m³ (x=100 m, y=10 m, z=2.5 m).

Two main time-steps for simulations:

- 0-300 y after the repository closure; no release of radionuclides occurs (waste package integrity);
- 300-300.000 y after the repository closure; steady-state conditions are established and waste packages corrosion starts, with consequent ^{14}C release.



Preliminary hypotheses:

- total amount of the estimated ^{14}C activity is equally distributed in the waste;
- features of waste do not affect the ^{14}C release, no overpack is considered;
- the ^{14}C release rate is constant for all waste (no IRF);
- disposed waste considered as a single compacted volume in each storage room;
- no spent fuel is considered in repository;
- only one shaft connects the underground facility to the surface;
- mechanical behavior of salt rock is not considered after the repository closure;
- EBS: waste form, waste container, backfill, shaft seal.

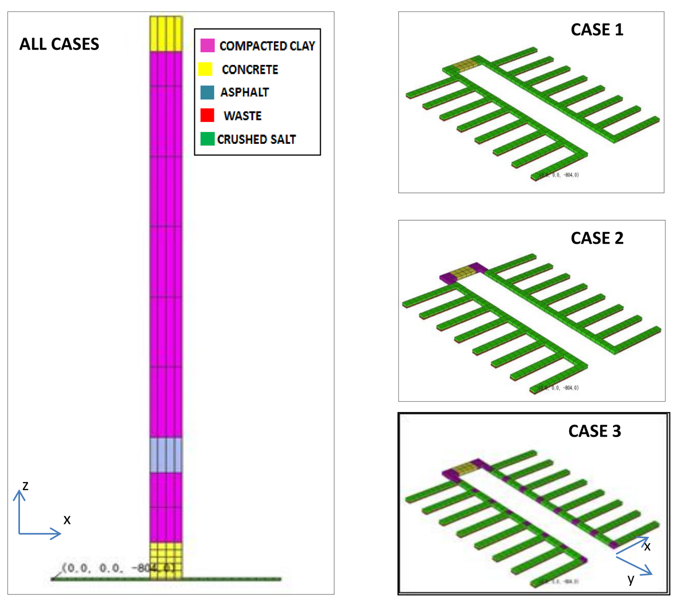
Values of ^{14}C amount have been calculated on two specific "blocks", common to the two models (single-room and multi-room): top of the shaft and monolith. The results of the two simulations are not comparable, because of the different discretization and conceptualization of the two models.

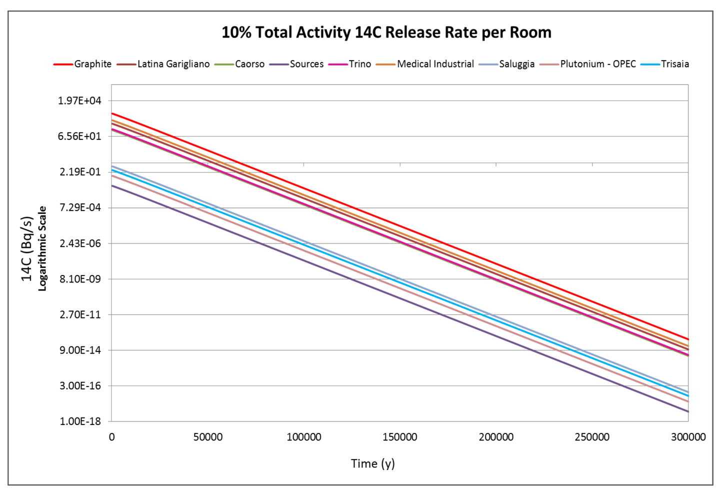
Multi-room simulation

Simulation of ^{14}C production and migration related to overall waste inventory, distributed in 16 rooms.

Five backfilling materials completely fill shaft, rooms and drifts. Three main study cases analysed (combination of materials at repository level):

- Case 1, no sealing material at repository level and K_{d_clay} = 1.0 m³/kg.
- Case 2, sealing material at the base of the shaft:
  - Case 2, K_{d_clay} = 1.0 m³/kg;
  - Case 2_a, K_{d_clay} = 1E-3 m³/kg;
  - Case 2_b, K_{d_clay} = 1E-5 m³/kg.
- Case 3, sealing material in the drifts and K_{d_clay} = 1.0 (m³/kg).

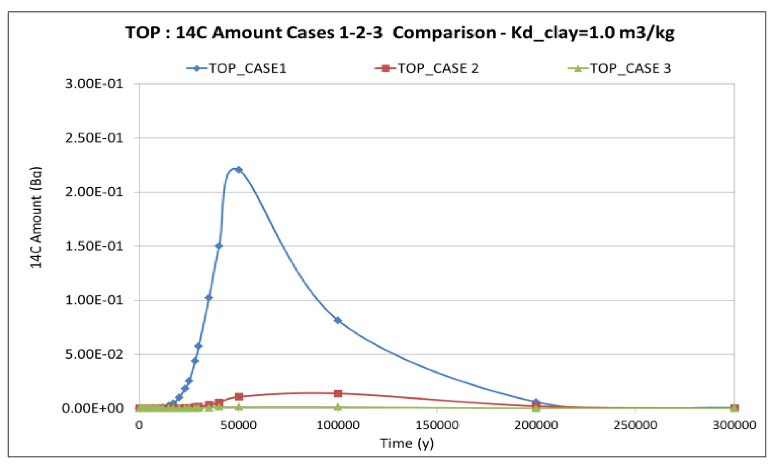


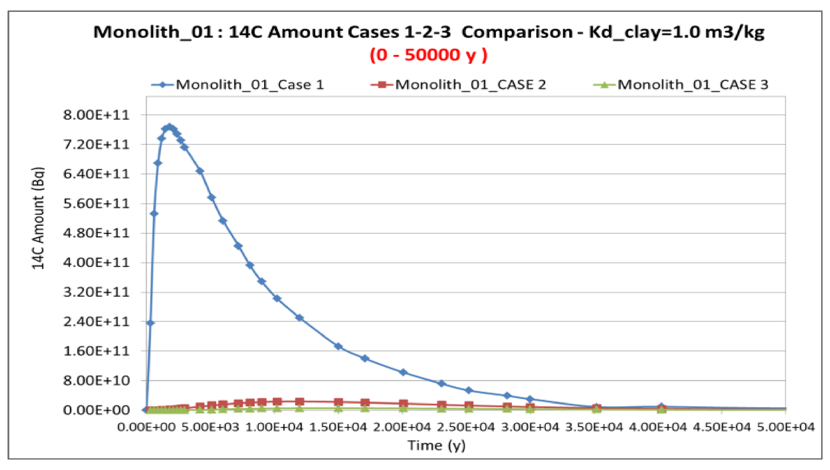


Calculation hypotheses:

- repository environment conditions are alkaline;
- corrosion rate of stainless steel: 10 nm/y;
- generated gas is H_2 calculated as produced by corrosion.

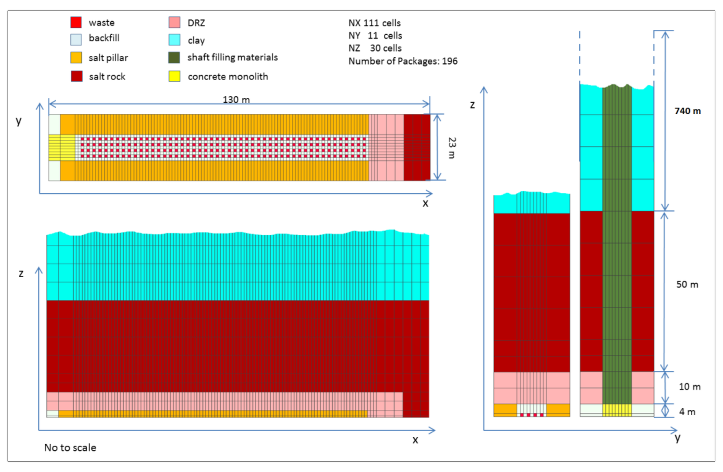
Simulation Case 2_a-b and Case 3_a-b: lowest value of clay K_d causes an increase of ^{14}C amount in all parts of the system, independently of the clay volume within the repository.
In both cases 2 and 3, decreasing the clay K_d from 1E-3 to 1E-5 m³/kg, the amount of ^{14}C at top of the shaft increases of about one order of magnitude.





Single-room simulation (irradiated graphite)

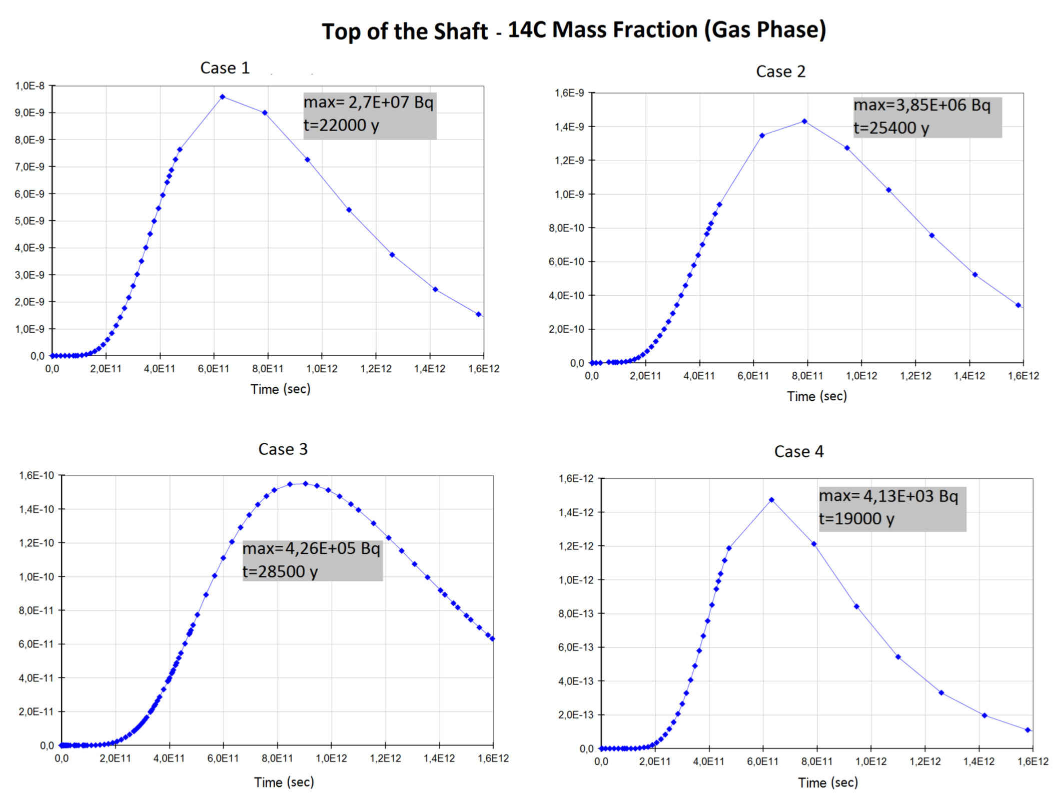
Simulation of ^{14}C production and migration related to only one storage room containing irradiated graphite.



Single storage room: 196 cubic (1 m³) waste containers, representing the graphite waste of Italian inventory. Backfilling material: crushed salt.
Source term: a congruent release of ^{14}C in the gaseous phase, with release rate 10% per year of total ^{14}C activity of the graphite.
A disturbed rock zone (DRZ) surroundings the excavated zone has been considered.

Four main cases have been simulated, varying K_d values of sealing materials.

	DRZ	Clay	Halite	Waste containers	Backfill	Shaft Sealing	Concrete (Monolith)
Case 1	0	0	0	0	0	0	0
Case 2	0	0	0	0	0	0	4
Case 3	0	0	0	1	0	0	0
Case 4	0	0	0	0	0	1	0



Results: the peak of ^{14}C amount at the top of the shaft occurs between 20.000 y and 30.000 years in the first three cases (maximum value of 2,7E+07 Bq at 22.000 years in the Case 1). After 300.000 years the ^{14}C amount at the top of the shaft become negligible in all cases, with a minimum value of 5,36E-06 Bq in the Case 4.

Conclusions

- The performed simulations provide preliminary results on the role of materials properties in delaying the migration of gaseous ^{14}C within a generic repository in salt rock.
- In order to work around the limitations due to the lack of data, some conservative assumptions have been used.
- A relationship between the total amount of gaseous ^{14}C released and the total volume of the filling material characterized by different K_d values has been highlighted. In Cases 2 and 3 of the single room model, the performance of the filling material is proportional to its volume, for equal values of K_d.
- The simulations show that the main contribution to the delay of the gaseous ^{14}C migration through the repository is obtained using filling materials characterized by a K_d value higher than 1E-3 m³/kg.
- Using the performed modelling approach with more accurate details on the repository layout, EBS materials, and host rock physical parameters, more improved and realistic results may be obtained.