Study and characterization of zeolites for the removal of artificial radionuclides in wastewater samples from nuclear power plants

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Goal and Phases of the Work

Goal

Use of zeolites for the decontamination of wastewaters from former Garigliano nuclear power plant (Italy), containing artificial radionuclides after cooling and storage of irradiated fuel elements.

Work phase 1

Radiological characterization of wastewater by γ-spectrometry using HpGe detector.

Work phase 2

Characterization of zeolites adsorption with batch experiments using simulated aqueous solutions with not radioactive isotopes.

Work phase 3 (in progress)

- characterization of zeolite adsorption with column experiments,
- setup of an in-situ pre-pilot plant to carry out tests with contaminated wastewater at the Garigliano facility.

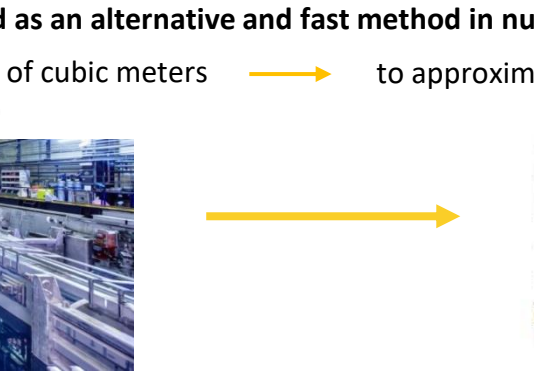
Work phase 1: radiological characterization of wastewater

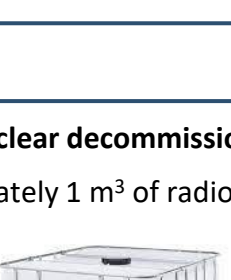
Results

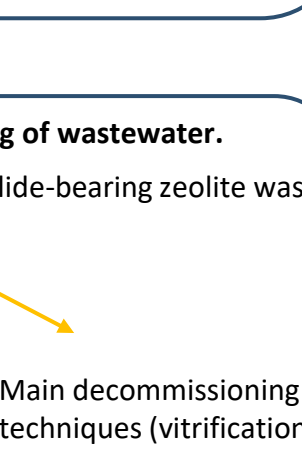
	Activity concentration (Bq/L)	Concentration (ppm or mg/L)
^{60}Co	121.8 ± 1.9	$2.86 \cdot 10^{-9} \pm 4.46 \cdot 10^{-10}$
^{137}Cs	2914.5 ± 8.2	$8.80 \cdot 10^{-7} \pm 2.48 \cdot 10^{-8}$

D.Lgs 101/2020 ^{60}Co and ^{137}Cs limit:
$^{60}Co/100 + {}^{137}Cs/100 < 1$

^{60}Co: ^{59}Co neutron activation in reactor
^{137}Cs: byproduct of ^{235}U nuclear fission





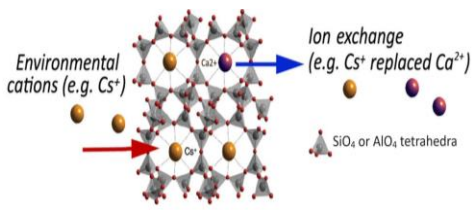


Efficiency of 48%
Sensibility < 100 keV
Resolution: 2.16 keV at 1.33 MeV

Zeolite material

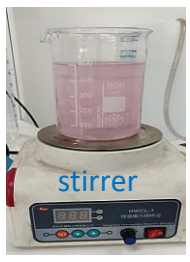
- Naturally occurring mineral group (family of aluminosilicates) characterized by microporous crystalline structure.
- Features: cost-effectiveness, ion exchange and adsorption capability, ion selectivity, stability against thermal and radiation influences.
- Structure: TO_4 tetrahedra (where T stands for *Si* or *Al*) embedded in an open framework.

Work phase 2: characterization of zeolites with batch experiments

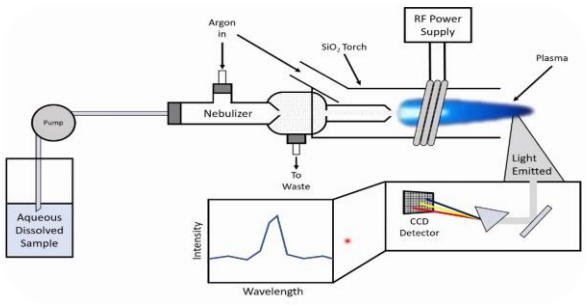


Powdered zeolites
- synthetic (4A, 13X)
- phillipsite-rich tuff

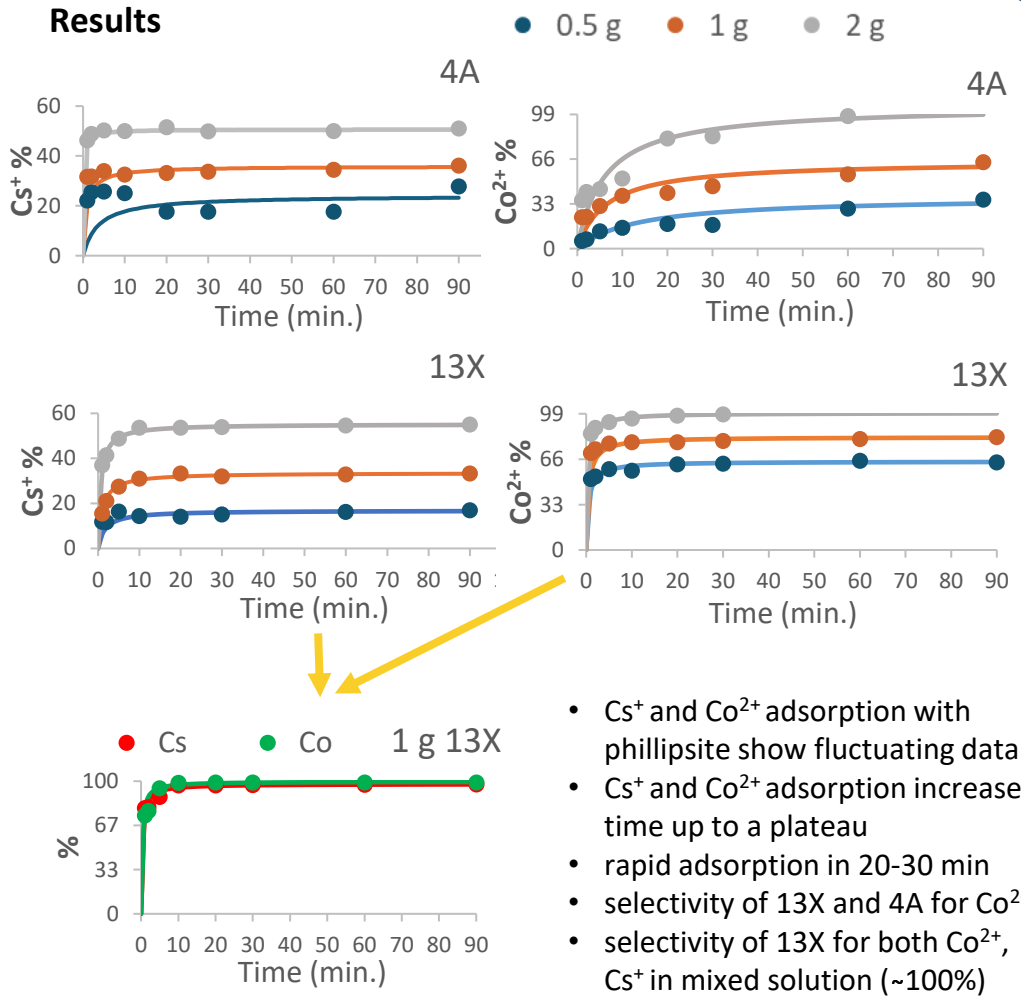
Aqueous solution
- normality 0.01 eq/L
- Cs^+ nitrate powder $CsNO_3$ [0.975 g]
- Co^{2+} nitrate powder $Co(NO_3)_2 \cdot 6H_2O$ [0.725 g]



Experimental setup
- solid-liquid ratios: 0.5 g, 1 g, and 2 g for 13X and 4A, 1 g, 2 g, and 4 g for phillipsite
- sampling times: 1, 2, 5, 10, 20, 30, 60, 90 min
- Cs^+ and Co^{2+} concentration by inductively coupled plasma – optical emission spectroscopy (ICP-OES)



Results



- Cs^+ and Co^{2+} adsorption with phillipsite show fluctuating data
- Cs^+ and Co^{2+} adsorption increase in time up to a plateau
- rapid adsorption in 20-30 min
- selectivity of 13X and 4A for Co^{2+}
- selectivity of 13X for both Co^{2+}, Cs^+ in mixed solution (~100%)

Conclusions

Zeolites could be effectively used as an alternative and fast method in nuclear decommissioning of wastewater.

Reduction of wastewater volumes from thousands of cubic meters (~ half capacity of an olympic pool) → to approximately 1 m^3 of radionuclide-bearing zeolite waste

Main decommissioning techniques (vitrification cementification)