Contaminated phyllosilicates colloids separation by particulate flotation foams for excavated or in-situ soils decontamination

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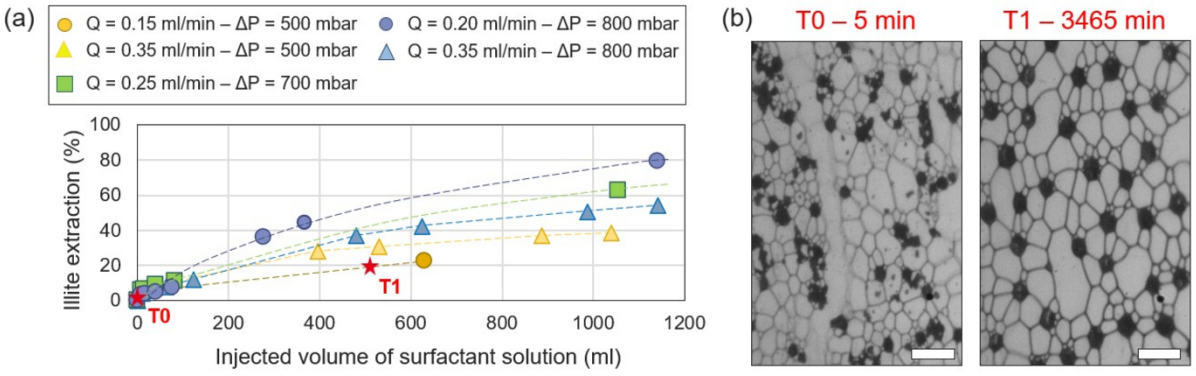
Both colloidal phyllosilicates and organo-mineral clay-humic complexes microparticles are able to adsorb permanently in soils various chemical pollutants or even radionuclides, inducing long-term contaminations over several decades. The main contaminants fixed on these microparticles resist to water lixiviation such as metallic cations (lead, copper...) or, in the case of nuclear accidents, cesium-137 (^{137}Cs) with a half-life of 30.1 years. All these contaminated microparticles (1 to 100 µm) are most often located in the top of clay-sandy soil (0-30 cm depth) with low permeability coefficient (10^{-5} to 10^{-6} m/s). Two treatment strategies to decontaminate the soils are studied by CEA.

First, to treat large contaminated top soil areas (from 100 m^2 to 10 ha), the first step requires to excavate the topsoil (0-30 cm) to separate the finest granulometric part containing major contamination. More particularly in the case of radioactive Cs soil decontamination, CEA developed these latest years an environmentally friendly process with flotation foams operating in continuous mode that limits the production of secondary wastes and reduces the high volumes of contaminated soil [1]. The flotation foam process allows the selective extraction of the smallest phyllosilicates particles containing cesium in a flotation foam column. Soil is suspended in water (10 to 15% by mass) and CEA found that cationic TTAB surfactant is the best to selectively absorb on negatively charged phyllosilicate particles increasing their hydrophobicity. Ascending air bubbles injected at the bottom of the column capture selectively the hydrophobic phyllosilicate particles or aggregates and transfer the contaminated particles in a stable foam generated at the top column. The drying residue of the foam concentrates the contamination in a reduced volume divided by 3 to 7. Last year, a new foam flotation column was designed to use on real radioactive soils and confirmed the recovery of a major part of Cs in the foam residue with TTAB.

Secondly, for smallest surfaces called hot spots (<100 m^2), one innovative method developed more recently is to generate ascending flotation foam flow directly in the soil through aspiration [2]. Over the last two years, CEA has studied the detachment and transport of foam-raw illite micrometric particles in model porous media made of glass beads. The *in-situ* generated foam properties are first evaluated with a non-ionic surfactant thanks to image analysis and conductance measurements (Foamscan© device, Teclis Instruments) under varying foam generation parameters (foaming solution flow rate Q and pressure gradient ΔP). The geometry of the porous medium, coupled with various flow rates and pressure difference, deeply influences the foam characteristics (liquid fraction, lamellae apparent thickness, bubble density) which may then result in different particles transport and extraction efficiencies. This method is relevant to precise the role of surfactant, i.e. TTAB, on the transport of adhered microparticles by lamellae thanks to surface charge modification.



(a) Recovery curves for illite particles in 0.5 mm glass beads-packed column under different conditions of in-situ foam generation. (b) Snapshots at different recovery times. Grains, illite aggregates (first snapshot) and lamellae appear in black, the porous area is in light gray. Scale is 0.5 mm.

References:

[1] A. Ben Said, F. Frances, S. Faure, A. Grandjean, C. Latrille, Chemical Engineering and Processing, Process Intensification, Vol 142, 2019, 107547.

[2] Faure S., Gentil T., Frances F., Method for recovering an element from a porous substrate via an in-situ generated aqueous transport foam, CEA Patent, WO/2025/133330 (2025).