Stabilization/solidification of hazardous powdered waste with ordinary Portland and sulfo-aluminate cements: a pilot study

F. Todaro[1], R. Annelio[1], S. De Gisi[1], M. Di Clemente[1], A. Fiorente[1], A. Petrella[1], M. Notarnicola[1]

[1]Department of Civil, Environmental, Land, Building Engineering and Chemistry (DICATECh), Polytechnic University of Bari, Bari, 70126, Italy
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Presenting author email: francesco.todaro@poliba.it

Stabilization/solidification (S/S) is typically a process that involves the mixing of waste with binders to reduce the contaminant leachability by both physical and chemical means (Tsang and Wang, 2022). S/S technologies are helpful to convert hazardous waste into environmentally acceptable material for less expensive disposal or utilization with safety environmental impact (De Gisi et al., 2020; Todaro et al., 2020). Indeed, S/S is known as the best demonstrated available technology (BDAT) in economic aspects and time.

Portland cement and lime are commonly used as binders. However, their use implies environmental concerns due to the consumption of natural resources and the high carbon footprint from production processes (Cardinaud et al. 2021; Scrivener et al., 2018). Consequently, in a vision of circular economy, the development of sustainable alternatives for the treatment of contaminated solid waste remains vital (Feng et al., 2020; Reddy et al., 2022).

This experimental study was aimed to explore sustainable alternatives for the management of industrial powdered wastes from gas treatment, both containing high concentrations of hazardous substances (i.e., European Waste Codes 10.02.07*) and not (i.e., European Waste Codes 10.02.08). In particular, experimental investigation has been carried out to explore the sustainability of S/S with Ordinary Portland Cement (OPC) or environmentally friendly binders, such as Sulfo-Aluminate Cement (SAC). Several mixtures were prepared using binders' different contents and an 0.8 water/dry matter ratio (Table 1). S/S experimentation involved the use of both bench-scale mixing reactors and the STABSOL-P pilot plant with a capacity of about 5 kg/h. The main component of the pilot plant was the mixing chamber, consisting of a cylinder containing the material to be treated and mixed by blades attached to a shaft, driven by a motor-gearbox unit.

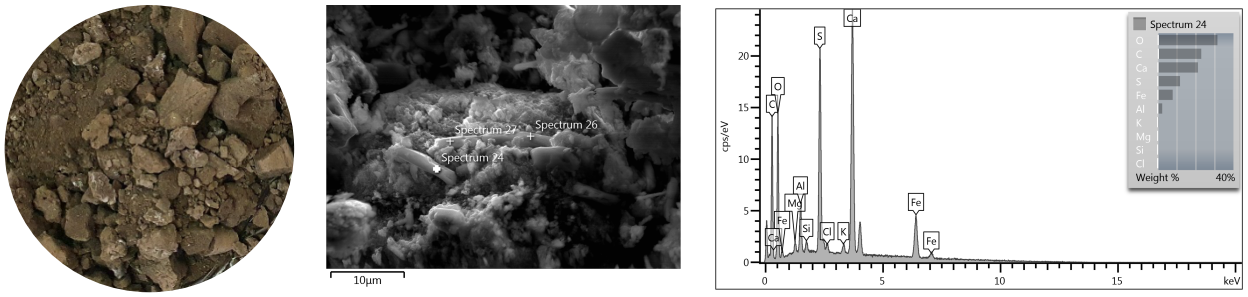
For treated samples leaching tests were carried out (according to the EN standard 12457-2) with different setting times (i.e., 1, 7, 14, and 28 days) to monitor the progressive change. Moreover, to validate the applicability of the designed mixtures, physical, mechanical, and ecotoxic investigations were carried out on the treated waste after 28 days of curing times. Also, the microstructure and mineralogy were studied by Scanning Electron Microscope (SEM) images and X-ray Spectrometry analysis (Figures 1 and 2).

Table 1. Mixture design for S/S testing (values in wt.%).

WASTE	MIX	OPC	SAC		
		DURACEM	*ALI CEM GREEN*	*ALI PRE GREEN*	*ALI FLASH*
10.02.07*	A-1	5			
	A-2	15			
	A-3		5		
	A-4		15		
	A-5			5	
	A-6			15	
	A-7				5
	A-8				15
10.02.08	B-1	5			
	B-2	15			
	B-3			5	
	B-4			15	

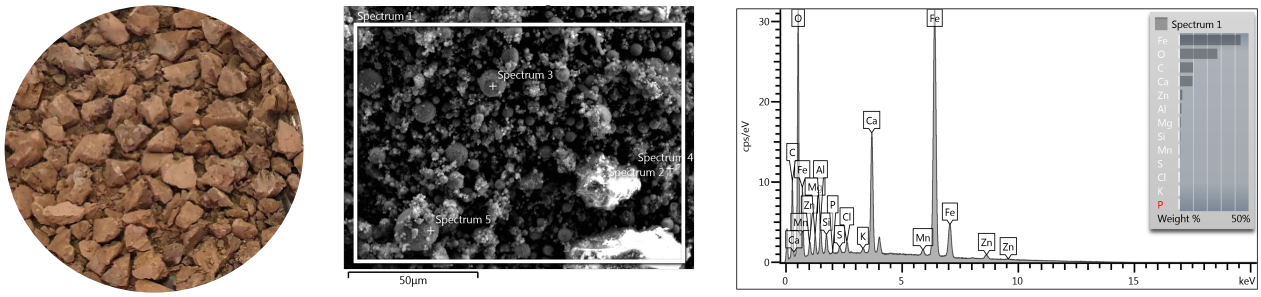
Note: DURACEM, pozzolanic cement; ALI CEM GREEN, mixture of sulphur-aluminous clinker and micronized calcium sulphate; ALI PRE GREEN, mixture of sulphur-aluminous clinker, Portland cement and calcium sulphate; ALI FLASH, sulphur-aluminous fast binder produced with reduced environmental impact.

The leaching tests show that heavy metals were released with concentrations varying with the reagent percentages. In particular, the addition of cement shows positive effects on decreasing the mobility of heavy metals. However, the addition of OPC appears to increase the leaching of vanadium (> 3 mg/L). A greater immobilization efficiency has been found for the mixture based on SAC relative to the leaching of Pb (< 1mg/L) and Se (< 0.05 mg/L), showing very promising results.



a) b) c)

Figure 1 – EWC 10.02.07* treated with 15% of ALI PRE GREEN: a) sample image; b) SEM images; c) X-ray diffraction pattern.



a) b) c)

Figure 2 - EWC 10.02.08 treated with 5% of ALI PRE GREEN: a) sample image; b) SEM images; c) X-ray diffraction pattern.

The results of ecotoxic investigations have evidence that not always the presence of contaminants in waste is a toxicity index. In fact, the treated waste has no serious effects (Effect Concentration < 250 mg/L) on *Pseudochirkneriella subcapitata* (green algae), *Daphnia magna* (crustacean), and *Danio rerio* (fish). Furthermore, the mechanical characterization demonstrated that the 28-day non-hazardous waste could be used as fill materials. Crushing resistance (0.7 N/mm^2), hydraulic conductivity (3.6 10-5 cm/s) and density (2.761 mg/m^3) suggest that treated materials should be viewed as a useful resource for civil applications such as road foundations.

The lab-scale experiment demonstrates that sulfo-aluminate binder could be considered as a green and high-performance binder for the S/S treatment of hazardous waste in comparison to ordinary Portland cement.

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