Volcanic tuff and its uses as geopolymer precursor: advantages, characteristics, and case studies from the radioactive waste management sector

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Keywords: zeolite chabazite, geopolymers, radioactive waste management.

Geopolymers (GPs) emerged as promising cement substitutes in the field of radioactive waste management, in addition to their commonly investigated applications in the building industry. These novel binders are obtained by the reaction of an either alkaline or acid solution, the activator, with one or more aluminosilicate sources, the precursors. The resulting material, mostly amorphous, may offer elevated mechanical performances and resistance to chemically aggressive environments (Wang et al., 2019). Moreover, GPs are considered more environmentally friendly than ordinary cement, as precursors are often either industrial byproducts (e.g. coal fly ash, ground granulated blast furnace slag, electric arc furnace slag) and/or natural materials requiring moderate-to-none processing (e.g. kaolin, volcanic ash, zeolites). In the nuclear sector, GPs offer consistent advantages for the immobilisation of challenging radioactive wastes, such as spent ion exchange resins and liquid scintillation cocktails, overcoming some limitations of cement-based binders (Mossini et al., 2023; Galluccio et al., 2024). The proposed work aims at giving an overview on the use of a chabazite-rich volcanic tuff (VT) as GP precursor and filler. Other than being a natural and abundant material, this VT contains an elevated fraction of zeolite chabazite (about 65% w/w) which, thanks to its selective ion-exchange sites can be exploited to mitigate the diffusion of specific cations particularly important for radiological safety, most of all 137Cs+ (Baek et al., 2018). Different aspects coming from a selection of studies were highlighted:

(i) The effects of the type, concentration, and pH of the activator on the stability of the VT mineralogical phases. Particular focus will be put on the effects of using an acid activator, namely phosphoric acid, on the stability of chabazite and the resulting reaction products. (ii) Advantages of using VT as precursor in terms of reduced environmental impact, in particular when compared to other common options. (iii) Applications coming from radioactive waste management studies, such as the encapsulation of VT coming from the decontamination of liquid effluents containing 137Cs. The findings were corroborated by various characterisations, such as powder X-ray Diffraction, Thermogravimetric Analysis, and Scanning Electron Microscopy. Furthermore, compressive strength and leaching tests were carried out to evaluate the performance of the GPs according to the Waste Acceptance Criteria posed by the Italian regulator. The use of VT as GP precursor revealed to be advantageous for radioactive waste management applications, in particular regarding Cs immobilisation. Although chabazite easily degraded in acidic environment, these promising performances were also confirmed for phosphoric acid-activated GPs. Being environmentally friendly and highly versatile, VT is a promising material for radioactive waste management applications.

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