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Geopolymer as a potential sustainable technology for a safe radioactive nuclear waste management: Design, synthesis and characterization

Proper radioactive waste management is one of the critical issues for a successful and safe nuclear application. Engineered or technical barriers to contain such waste should be performed with the objective of ensuring adequate safety and protection of both the environment and the human health. Cementitious materials have been widely utilized as a solution for radioactive waste disposal. Nonetheless, this technique presents numerous technical challenges, particularly regarding long-term durability. One of the main concerns revolves around the possibility of these cementitious materials to degradation over time, potentially leading to the release of radioactive contaminants. One of the promising materials that can be used as an alternative cementitious material is geopolymers. These emerging materials can offer high encapsulation capacity, durability, and lower CO2 emissions, making it a sustainable and eco-friendly solution compared to conventional Portland cement-based materials. This study aims to assess the physical and chemical barrier effect of geopolymer material on leaching behavior of cesium and strontium. Phosphate mining waste rocks and metakaolin were used as aluminosilicate agents. Microstructure, structure analysis and thermal analysis were performed using Scanning Electron Microscopy (SEM), energy-dispersive X-ray spectroscopy (EDAX), X-ray Diffraction (XRD), Fourier Transform InfraRed (FTIR),) and Thermogravimetric Analysis (TGA). The long-term leaching performance of simulated radioactive cesium and strontium from geopolymers was evaluated according to ANSI/ANS-16.1, which showed that the diffusivity of cesium and strontium in geopolymer specimens was significantly lower than in Portland cement by a factor of 103 and 106, respectively, demonstrating significantly improved immobilization performance. A pilot plant design with a details structure design have been proposed as a potential project for intermediate and low level nuclear waste immobilization.

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