Quantitative X-ray CT of Geopolymer Wasteforms: Utilising Non-Destructive Evaluation for Formulation Validation, Deformity Detection, and Failure Prediction

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Geopolymers show promise as suitable wasteform candidates for the immobilization of a variety of radioisotopes. However, internal structure characterization remains elusive without destruction of the geopolymer for conventional characterization techniques such as microscopy; an impractical solution for inspecting wasteforms destined for final disposal. The presence of fractures and defects (air gaps, porosity, voids, and heterogenous particle distributions etc) in a wasteform leads to an increased risk of radioisotope release, particularly through leaching and radioisotope migration due to water ingress-egress, thus rendering the wasteform unsuitable for disposal. Accounting for these deformities is imperative for safe long-term disposal. X-ray Computed Tomography (CT) enables Non-Destructive Evaluation (NDE) allowing for these imperfections to be identified and quantified as part of defect metrology during wasteform formulation development quality assurance programs and prior to final disposal. In this study, X-ray CT NDE has been utilized to elucidate the internal structure of metakaolin-based geopolymer wasteforms to help identify a suitable geopolymer matrix for the eventual solidification of carbon-14 radioactive wastes. Sodium Alumino-Silicate Hydrate (N-A-S-H) or Potassium Alumino-Silicate Hydrate (K-A-S-H) pastes were prepared to which carbonates (CaCO3 or SrCO3) were loaded as representative wastes at either 20, 40, or 60 wt%. The geopolymer pastes were cast in cylindrical molds to form miniature wasteforms with a 23 mm inner diameter, 46 mm height, and a volume of 19.1 cm3. After curing, select specimens were exposed to a compressive strength load of 3.44 MPa, the minimum acceptance criteria for the Korean disposal facility, and leaching tests. The wasteform specimens were scanned, visualized, and assessed for fractures and defects as part of formulation validation and deformity detection. Further, it is envisioned that mesh generation from the X-ray CT data will enable digital twins' to be constructed to which corrosion models can be applied to understand long-term corrosion performance, as well as deformation modelling to predict points of failure.