Applications of X-ray microtomography in microstructural analysis of materials resulting from waste processing

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Keywords: microtomography, porosity, water remediation, composites, waste recycling
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The complexity of samples resulting from waste processing reside in both the elemental composition and the large heterogeneity of the microstructure. Visualization and quantification of such microstructural heterogeneity can be accomplished by high resolution X-ray tomography (XCT).
We present selected cases of how XCT method and advanced post-processing of reconstructed images can be used in material characterization and optimization of waste processing. We describe also recent results obtained by tomography analysis of mine wastewater filtration, palletization of fly ash resulted by solid waste incineration and composite materials made of iron spat reinforced volcanic ash. We conclude our presentation with recent experiments aiming at quantifying changes in porosity produced by the circulation of a CO_2-rich solution that interacts with deposits of rock minerals.

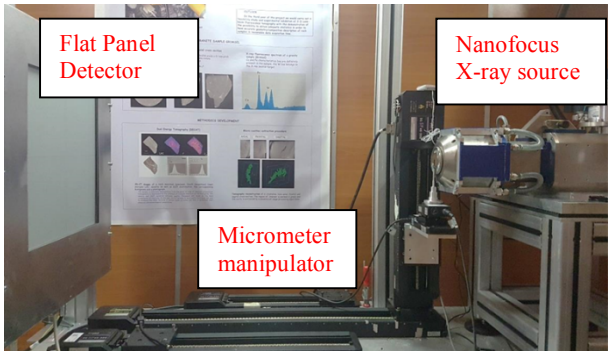

Fig 1: High resolution microtomograph

The tomography system (Fig 1) designed and built within the INFLPR Microtomography and microbeam fluorescence laboratory, is equipped with a nanofocus X-ray source with beam energy up to 225 keV and a large area, high resolution detection systems (4Kx4K @ 100 µm/pixel). It allows characterization of mineral distribution and pore system of analyzed samples down to submicron spatial resolution.

An example of the full capabilities of this advanced analysis is illustrated in Fig. 2 that shows the distribution of pores connected and insulated into a sample of Berea Sandstone™. By use of a transportation simulation model, a quasi-static fluid flow simulation in the reconstructed porous volume was performed to determine the capillary pressure. This analysis is important because the contact between the wetting and non-wetting phases is strictly influenced by the diversity of the pores, their size, shape and degree of communication.

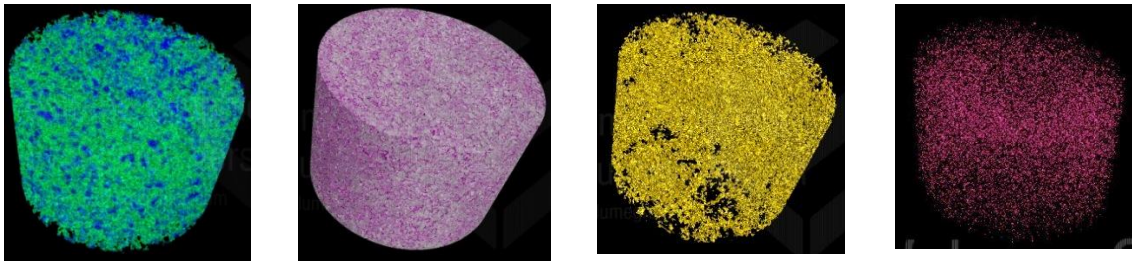
Pores spatial distribution | *Capillary infiltrated pores* | *3D representation of umwetted surfaces* | *Isolated pores*

Fig 2:Advanced volume data processing allows characterization of mineral distribution and pore system

An attempt to optimize the treatment of mine acid drainage water through rock and mineral grain filter batteries such as calcite, aragonite or dolomite of 1-2 mm by in-situ tomography analysis is shown in Fig. 3. Determination of the dynamics of passivation processes by gypsum formation and sedimentation of secondary minerals allowed the design of the granularity distribution of the filter column [F.G. Offeddu 2015].

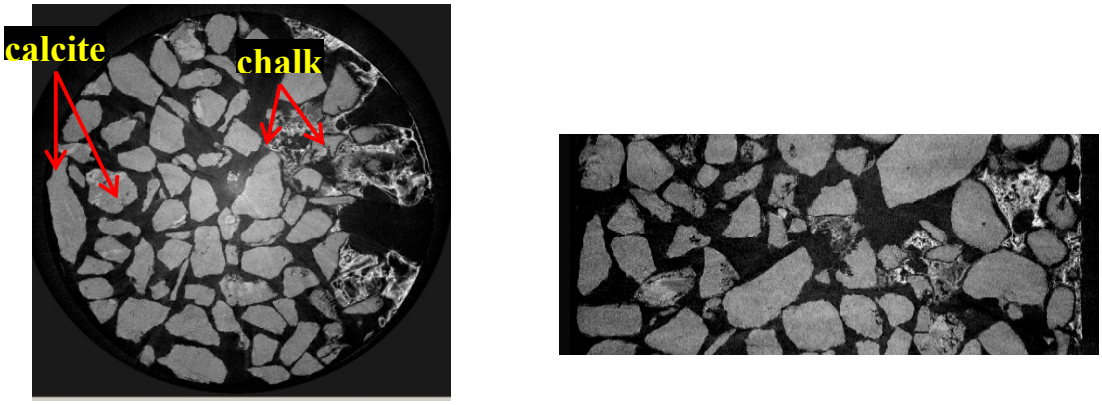

Fig 3: Tomography cross-sections of rocks and mineral grain filter (such as calcite and aragonite) with grain sizes of 1-2 mm.

The microstructural analysis of solid waste incineration samples allows the visualization of density gradients, mineral inclusions and carbonization, as can be seen in the tomography images in Fig 4.. X-ray microbeam fluorescence (microXRF) was used to interrogate the elemental composition of bright inclusions as a method to estimate the recycling value of the incinerated solid waste.

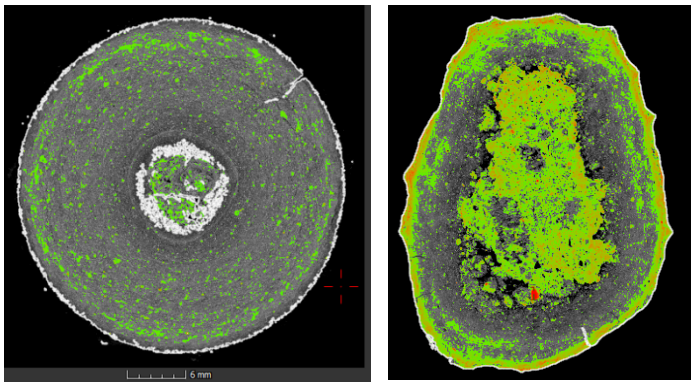

Fig 4: Fly ash pellet: inclusions, voids & carbonization: almost complete and homogeneous degree of carbonation (left); external layer of carbonated material with a limited carbonated core (right)

Development of new composite materials like volcanic ash reinforced by iron spat or recycled plastic reinforced by wood chips was also assisted by high resolution tomography (Fig. 5).

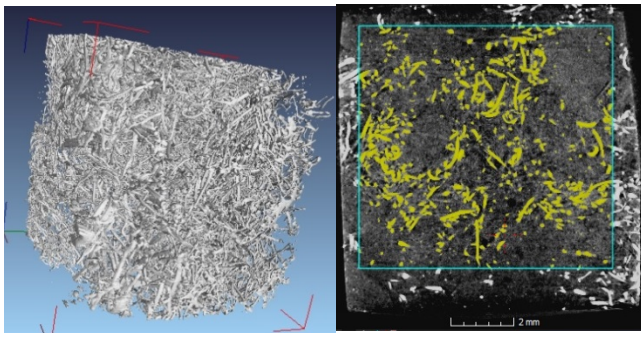

Fig 5 Tomography analysis of composite material made by volcanic ash (matrix) with iron spat reinforcement.

The homogeneity and the angular distribution of the metallic fibers can be analyzed within the post-processing software packages used in our laboratory.

F.G. Offeddu et al., Journal of Environmental Chemical Engineering Volume 3, Issue 1, March 2015, Pages 304-316