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Chemical imaging of Metal(loid)s in Environmental Sciences on LUCIA beamline

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The LUCIA microfocused beamline dedicated to X-ray fluorescence (XRF) and X-ray absorption spectroscopy (XAS) experiments has been designed to cover the energy range from 0.8 to 8.5 keV. With such an energy range, the beamline is optimized to characterize the speciation of light elements such as Na, Mg, Al, Si, P, S, etc., essential to study in bio-geo-environment. However, the beamline can also observe heavy metal(loid) pollutants such as Pd, Ag, Cd, Sn, Sb, Pb, etc. right up to the lanthanide erbium (Er). Using a pair of Kirkpatrick-Baez (KB) mirrors, the photon beam can be focused, enabling the elements in a heterogeneous sample to be mapped (Flank et al., 2006, Vantelon et al, 2016). At present, the size of the focused beam is typically 2.5 x 2.5 µm, but an upgrade to LUCIA in 2026 will make it possible to work with an 800 x 800 nm beam in a dedicated chamber.

LUCIA's strength lies in its ability to couple XRF imaging with X-ray absorption near edge spectroscopy (XANES) and extended X-ray absorption fine structure (EXAFS) analysis at the micrometric (soon nanometric) scale. This makes it possible to determine the speciation variability of a given atom as a function of its elemental environment. As XRF maps can be collected in fly-scan mode, it is possible to obtain hyperspectral data, stacking the images using a Jupyter notebook developed at SOLEIL. This allows to collect a XAS spectrum in each pixel of the elemental map. Thanks to liquid He and N_2 cryostats, such experiments can be performed in cryo-conditions, on hydrated samples if needed. In addition, LUCIA can accommodate dedicated microfluidic chips to enable in situ observations of reactions, the quality of these measurements being enhanced by XAS data collection in fly-scan mode.

These LUCIA beamline capabilities will be illustrated by various examples, such as the oxidation hydrolysis of Fe(II) in presence of organic matter in a microfluidic chip or the Cr speciation in an environmentally altered plastic using XANES hyperspectral maps.