

X-Ray Spectromicroscopy Studies in Environmental Sciences

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Due to high resolution and the ability to study samples directly in aqueous media, X-ray microscopy is a tool very well suited to examine colloidal systems in environmental sciences. Chemical information can be obtained by tuning the X-ray energy used. Elemental mapping as well as NEXAFS spectroscopy is possible. Thus, samples can be studied with high spatial and spectral resolution at the same time. Spectromicroscopy experiments with colloidal soil systems have been performed at the X-ray microscopy station of BESSY II in the energy range of the water window and with the scanning X-ray microscope ID21 of the ESRF at the sulphur K-absorption edge.

The pedosphere is an important interface between atmosphere, anthroposphere, biosphere, lithosphere, and hydrosphere. Here numerous flows between varieties of components take place. Due to their great abundance and high surface activity colloids play an important role when describing characteristics of soils. Depending on the chemical conditions of the soil environment these particles interact, forming associations with a great variety of appearances and compositions. The physical microstructure, besides the chemical composition, determines parameters as sorption capacity, convective and diffusive mass transport or binding capacity for water. Hence the availability of natural and anthropogenic substances for chemical and biological processes is strongly influenced. A conformational change induced by changes of the environment affects strongly these soil properties. It is necessary to examine the colloidal structures directly in their aqueous environment with high spatial resolution to understand more about these properties, e.g. see fig. 1 [1]. X-ray spectroscopy capabilities can evidently be used to identify and quantify several species of certain elements reliably, e.g. sulphur with its different electronic oxidation states. Current wet chemical methods for the speciation of sulphur in soils are inaccurate and do not allow an assessment of the sulphur speciation of individual soil particles and colloids. The combination of X-ray transmission and sulphur fluorescence images with unfocused and focused NEXAFS spectra at the K-adsorption edge of sulphur taken at defined locations allows for a comparison of the distribution of sulphur species in bulk soil with that of distinct particles and colloids, e.g. see fig.2 [2]. Moreover, it is possible to assess the spatial distribution of different sulphur species on soil particles on a scale of a few hundred nanometres.

References:

[1] J.Thieme et al., BESSY Activity Report 2002

[2] J.Prietzel et al., European Journal of Soil Science, June 2003, 54, 423 433

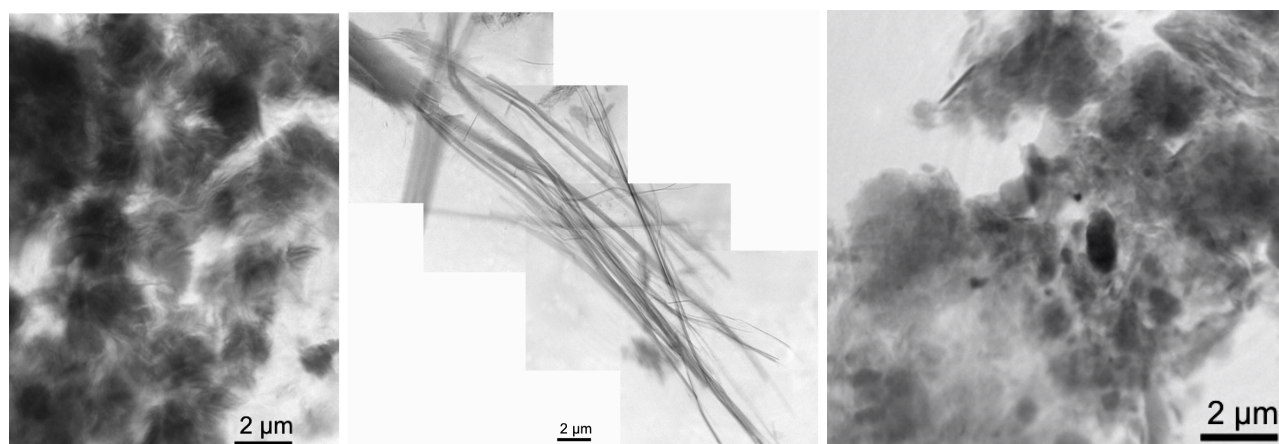


FIG. 1. X-ray microscopy images of dispersions of the clays Na^+ -Montmorillonite (left) and Nontronite (middle), and of a chernozem soil (right). The images were taken at $\lambda = 2.4 \text{ nm}$, showing structure sizes down to 20 nm. Note that the middle image is a composition of four single images.

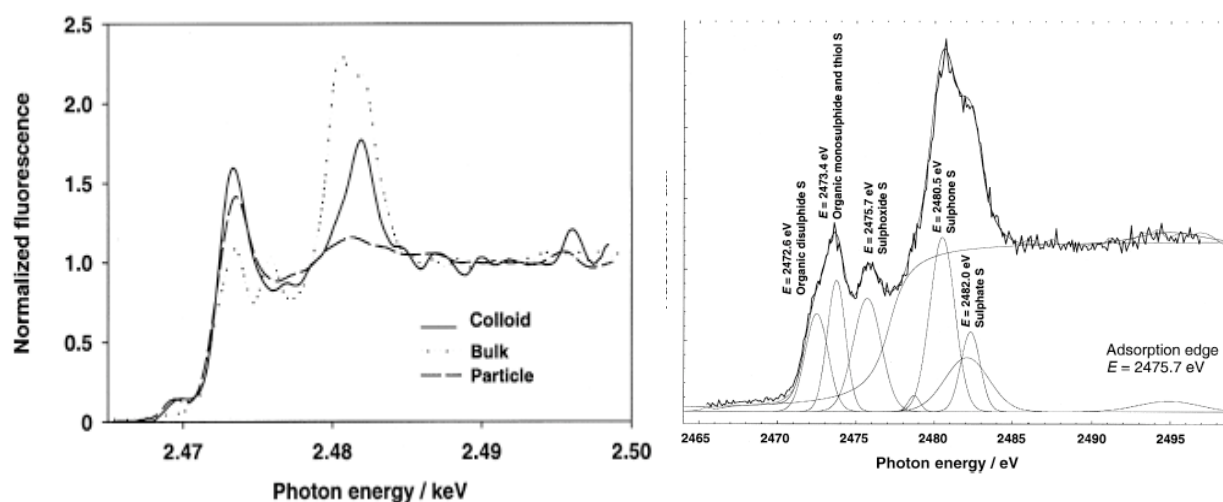


FIG. 2. Left) Comparison of NEXAFS spectra at the K-adsorption edge of sulphur taken from bulk soil, a distinct soil particle, and a colloid, normalized to the edge step. Right) Identification of different S species in a soil sample in an unfocused mode. Shown are the original scan, the smoothed scan, and isolated major components.