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Ga(III) behavior at the soil-water interface

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The development of new technologies in the recent years has increased the use and demand of elements classified as technological critical elements (TCE). Among these elements, gallium (Ga) is one for which the fate and impact remain poorly studied to properly assess these concerns, whereas Ga is commonly used in microelectronic components notably in semiconductors, and also in nuclear medicine as radioactive species (^{67}Ga) to detect and localize malignant tumor cells. This increased use of Ga results in its inevitable discharge into the environment where its fate is not well understood. Because Ga is not an essential element for living organisms, concerns about the environmental risk and threat to human health related to Ga contamination have been frequently raised. A better insight into Ga behavior at the soil-water interface is therefore needed in order to assess its (bio)availability.

We present in this study the adsorption behavior of Ga onto two natural soils with different properties, using a multiscale approach combining the batch adsorption technique and X-ray Absorption Spectroscopy (XAS). To better understand the processes involved, similar experiments were also conducted onto isolated soil phases such as goethite, organic matter, clay minerals, and onto a synthetic soil constituted of a mixture of these isolated phases. First, Ga(III) adsorption was studied on these different systems using adsorption experiments as a function of contact time and pH to obtain macroscopic data. Then several solid samples were characterized at molecular scale to record X-ray Absorption Near Edge Structure (XANES) spectra and to perform linear combination fitting.

The particular speciation of Ga(III) in solution, which forms the anionic species $Ga(OH)_4^-$ in basic medium, leads to a systematic decrease at alkaline pH of its adsorption onto the different systems, with 95% adsorption on both soils between pH 2.5 and 6.5. The results evidence, depending on the system, the major role of clay minerals and goethite in the Ga(III) retention, and a less important involvement of OM and a low contribution of Ga precipitation. These results provide a pertinent set of data that could be used in geochemical models to predict the fate of Ga(III) in soils.