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Mobility of Technology-Critical Elements in groundwater systems: Influence of citrate and humic substances on the transport of Indium and Gallium in saturated sand columns

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We investigate indium and gallium transport in laboratory column experiments using quartz sand as a model porous medium. Indium and gallium are metals of very low abundance in the Earth's crust and, correspondingly, the biosphere is only adapted to very small concentrations of these elements. However, in modern semiconductor industries both elements play a central role and are incorporated in devices of mass production such as smart phones and digital cameras. The resulting considerable increase in production and discharge of indium and gallium throughout the last ten years raises questions regarding the fate of both elements in the environment, as both are known to pose potential health hazards. However, the transport behavior of these two metals in soil and groundwater systems remains poorly understood to date. The experimental strategy focused on quantifying the transport and retention behavior of these two metals. Saturated soil column experiments were performed under controlled and relevant environmental conditions to study the transport and fate of indium and gallium in quartz sand. The impact of trisodium citrate – as a representative of small organic molecules – and humic acids – as a representative of natural organic matter – on the transport of these elements was studied. Column experiments demonstrate that the binding capacity differs between indium and gallium, being stronger for indium. For both metals, the presence of humic acid has an effect on the sorption dynamics. For indium, the binding capacity on quartz sand decreases significantly in the presence of humic acid and consequently its mobility is enhanced substantially. In contrast, a slightly higher sorption affinity and lower mobility in the presence of humic acid is observed for gallium. However, in all cases, it is shown that the binding capacity of gallium to quartz is much weaker than that of indium. These results are consistent with the assumption that indium and gallium form different types of complexes with organic ligands; in this context, it was observed that gallium complexes appear to be more stable than those of indium.