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Adsorption of rare earth elements to gibbsite: experimental measurements and surface complexation modeling

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Rare earth elements (REEs) are integral components of modern technology such as lasers, consumer electronics, and magnets. A growing demand for these products necessitates a constant supply of REEs, rendering them critical materials for medical, transportation, and aerospace industries, among others. One of the most common REE sources is ion adsorption deposits, which primarily host REEs through adsorption to secondary minerals. These deposits are abundant in kaolinite and other clay minerals, and they also contain gibbsite ($Al(OH)_3$). Lateritic bauxite deposits are another promising but underexplored source of REEs, which is abundant in aluminum (hydr)oxide minerals such as gibbsite. Consequently, an improved understanding of REE adsorption to gibbsite can provide insights into REE enrichment and mobility in weathering environments where REEs and gibbsite co-occur. Moreover, increasing use of REEs in high-tech products contributes to their increasing levels in the environment; REEs are sometimes considered emerging contaminants. Whether REEs are considered as a resource or as a contaminant, studying adsorption in the gibbsite-REE system will aid in predicting REE fate and transport.

This study aimed to investigate how REE adsorption to gibbsite changes as a function of varying water chemistry conditions and to interpret REE surface speciation on gibbsite using modeling. We conducted batch adsorption experiments over a broad range of water compositions (pH, background electrolyte concentration, and total REE concentration) with three REEs covering a range of atomic weights (Nd, Dy, and Yb). Adsorption of REEs to gibbsite increased with pH, with a major rise occurring at pH 6-7. Adsorption was barely affected by electrolyte concentration, which indirectly suggests that REEs adsorb via inner-sphere complexation. Data from the batch adsorption experiments were used to develop a surface complexation model that reproduced the experimental data using a set of surface complexation reactions involving the REEs and the hydroxyl functional groups on gibbsite's edges. Our surface complexation model can complement reactive transport models and help improve the current understanding of the mobility of REEs in environments rich in aluminum (hydr)oxides and clay minerals.