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Adsorption and Retention of Copper Ions on Iron Oxyhydroxide Nanoparticles: Insights into Long-Term Sequestration of Metals in Aquatic Environments

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The contamination of aquatic systems with heavy metals poses a substantial risk to both humans and the environment's health. Heavy metals come from the earth’s crust and are released through activities including metal mining, fossil combustion, and metal processing. Trace metals such as lead (Pb), copper (Cu), and zinc (Zn) in aquatic environments can lead to health issues. A key process by which metal ions can be removed from the solution is through adsorption to mineral phases, including iron oxyhydroxides, although the long-term removal and kinetics of metal removal and remobilization are not well characterized.

Iron oxyhydroxides can form in the environment as nanosized particles with a high surface area-to-volume ratio and unique physical and chemical properties that render them effective sorbents to metal ions. Studying metal-nanoparticle interactions in controlled settings can provide insight into how toxic metals behave in the water and how nanophases could potentially be leveraged to clean up contaminated waters. This research aims to use iron oxyhydroxides to investigate metal ions’ adsorption and desorption processes during different exposure time intervals. Copper metal ions were introduced into an aqueous suspension of synthetic iron oxyhydroxide nanoparticles, and their dissolved concentrations measured over time using ion-selective electrodes (ISE) to assess the adsorption and desorption rates as a function of exposure time. In this study, the pH was adjusted up to 6.0 to induce the adsorption of copper ions to the iron oxyhydroxide nanoparticles, and the system was left in the adsorbed state for varying durations (1 hour - 1 week). Desorption was then induced by lowering the pH to 4.5, with the ISE measuring in real time the amount of copper ion released from the nanoparticles. Preliminary data have shown a trend where the longer the heavy metals are associated with the iron oxyhydroxide nanoparticles, the more the metals are retained and the slower the measured metal desorption rate. This has implications for long-term sequestration and reduced potential toxicity of metals sorbed to solid minerals phases in the environment.