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Photo-induced precipitation of uranium coupled with decomposition of fulvic acid

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The past and present mining and use of uranium lead to contamination in nature environments. Precipitation and recovery of uranium from water bodies are of interest for the environmental protection. Here we study a novel photo-induced uranium precipitation process, in which fulvic acid (FA), a group of soluble natural organic matter (NOM), serves as electron donor for uranium reduction under both oxic and anoxic conditions. Under light irradiation, 93.2% of initial uranium in uranyl-FA complexes precipitate within 6 h in the anoxic system, or 88.3% in 48 h under oxic conditions, respectively. The absence of either light irradiation or FA results in much less uranium precipitation rate (∼20-39%) within 48 h. We also characterized the precipitates to decipher the mechanism of uranium removal. Without O_2, uranium is mainly precipitated as nanoparticles of uraninite and $UO_2(OH)_2$, and the aldehyde functional groups and aromatic benzoic rings of FA are oxidized to carboxylic groups. With O_2, oxalate and carbonate are produced from FA and precipitated with uranium as tetravalent and hexavalent uranium oxalates and carbonates, indicating deeper FA degradation and efficient photocatalytic properties of uranium.

The process here takes full advantage of uranium's photochemical characteristics. In contrast to numerous previous studies focusing on heterogeneous photocatalytic reduction of uranium using solid catalysts, the process is free from the cost of synthesizing catalysts and recovering uranium from the catalysts surface. Moreover, the results suggest that, besides microbial and chemical reductions of uranium, the photo-precipitation of uranium complexed to FA could also be a relevant process in rivers and lakes where light can reach. This study provides supplementary knowledge of uranium sedimentation in surface water bodies.