Effect of dilution and ionic strength on the behavior of cerium(IV) oxide nanoparticles in the presence of fulvic acids

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Abstract

The growing consumption of products containing cerium(IV) oxide (CeO2) nanoparticles (NPs) will constantly increase their presence in the environment, including aquatic systems. One component of natural water that defines the stability, reactivity and bioavailability of NPs is fulvic acids (FAs). In our work we studied i) the formation of complexes between CeO2 and FAs and ii) the resulting stability transformation, and aging of these complexes upon pH and ionic strength changes and effect of dilution. We used scanning electron microscopy to investigate the morphology and size of FAs-CeO2 complexes, dynamic light scattering method to obtain the z-average hydrodynamic diameters, nanoparticle tracking analysis to investigate particle size distribution, electrophoretic measurements to assess the evolution of surface charge of the coated CeO2 nanoparticles as a function of FAs concentration. We report that the environmentally relevant concentration of FAs is sufficient to stabilize relatively high concentration of CeO2 NPs suspension against agglomeration. We also report that the negatively charged FAs-CeO2 electrostatic […]

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Section B: Release and transformations including its effects on aging, behavior and fate

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The growing consumption of products containing cerium(IV) oxide (CeO₂) nanoparticles (NPs) will constantly increase their presence in the environment, including aquatic systems. One component of natural water that defines the stability, reactivity and bioavailability of NPs is fulvic acids (FAs). In our work we studied i) the formation of complexes between CeO₂ and FAs and ii) the resulting stability transformation, and aging of these complexes upon pH and ionic strength changes and effect of dilution.

We used scanning electron microscopy to investigate the morphology and size of FAs-CeO₂ complexes, dynamic light scattering method to obtain the z-average hydrodynamic diameters, nanoparticle tracking analysis to investigate particle size distribution, electrophoretic measurements to assess the evolution of surface charge of the coated CeO₂ nanoparticles as a function of FAs concentration.

We report that the environmentally relevant concentration of FAs is sufficient to stabilize relatively high concentration of CeO₂ NPs suspension against agglomeration. We also report that the negatively charged FAs-CeO₂ electrostatic complexes are stable with time (up to 7 weeks) and upon important pH variation (3.0 – 10.0) despite significant changes of their electrostatic properties. We also demonstrate that FAs-CeO₂ complexes are stable upon dilution. We define the conditions that are needed to promote the aggregation of FAs-CeO₂ complexes in the presence of different electrolytes. The calculation of critical coagulation concentration values for sodium and calcium chloride salt is done. We demonstrate that the FAs coating prevents rapid agglomeration via steric and electrostatic effects in presence of monovalent salt. On the other hand the presence of divalent salt induces rapid agglomeration via cation bridging effect. Obtained results constitute an important outcome for understanding the transformation, stability and removal of engineered nanomaterials released into aquatic systems.