Effects of extracellular polymeric substances on the aggregation of CeO_2 nanoparticles

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Engineered CeO_2 nanoparticle (CeNP) is widely used for industrial application such as catalyst, whereas the environmental impacts have been still in debate. The dispersion of CeNPs is a key process that depends on the aggregation affected by various factors including the adsorbed organic compounds. Extracellular polymeric substances (EPS) derived from microorganisms ubiquitously occur in environments and can potentially affect mobility of the CeNPs. The objective of this study is to elucidate the adsorption processes of EPS onto CeNPs and the effects on the aggregation based on laboratory-scale experiments.

100 ppm of CeNPs with < 7 nm in size were contacted with (i) ultra-pure water with 1 mM NaCl at pH of 6.0, (ii) 0.16 mM phosphate in (i), or (iii) EPS from *S. cerevisiae* in (i). Scanning transmission electron microscopy (STEM) and energy dispersive X-ray spectrometry (EDX) and atomic force microscopy (AFM) were utilized to characterize EPS and CeNPs aggregates. Zeta potential and average hydrodynamic diameter of CeNPs were also measured using Zetasizer nanoZEN 5600.

In the solution (iii), the particle size of CeNPs aggregates ranges 100–300 nm and EPS with the size of 20–30 nm was associated with the aggregates at pH 6 after 24 h. The EPS components of adsorption on CeNPs at the same condition were found mainly inorganic phosphate and protein by FT-IR.

Zeta potentials of (iii) gradually decreases from 0 mV to -30 mV at pH from 3 to 10, which are plotted slightly lower than that of EPS and higher than those of (ii). The average hydrodynamic diameters at pH 7 after 24 h, which is around point of zero charge (pzc) of (i), are >~1000 nm in (i) and 100–200 nm in (ii) and (iii). Also the average hydrodynamic diameters at pH 3, which is around pzc of (ii) and (iii), are <~200 nm, >~1000 nm and 300–500 nm in (i), (ii) and (iii), respectively. These results suggest that adsorption of EPS suppresses the aggregation of CeNPs by forming steric repulsive force due to adsorption of the macromolecular onto the CeNPs namely at near pzc. Consequently, the EPS derived from microorganisms modifies the surface properity of colloid aggregates and remarkably constrains the pH dependence of further aggregation.