Effects of organic molecules on the aggregation of CeO_2 nanoparticles

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Groundwater colloids play a key role on migration of low soluble toxic elements. The process is dependent on the aggregation that can be affected by various factors including adsorbed organic compounds. Extracellular polymeric substances (EPS) derived from microorganisms are one of the important organic matters in sub-surface environment, which is typically composed of proteins, polysaccharides, nucleic acids and inorganic ions. Despite of the ubiquitous occurrence of EPS, the impact on colloid aggregation has not been explored. The objective of this study was to elucidate the effects of saccharides and phosphate on the aggregation of non-soluble nanoparticle based on the laboratory experiment.

100 ppm of CeO_2 nanoparticles (< 7 nm; CeNPs) were contacted with NaCl solution (1 or 10 mM; control) at pH of 6.0, adding 0.12 mM saccharide (type S), adding 0.16 mM phosphate (type P), or adding 0.12 mM saccharides and 0.16 mM phosphate (type S+P). Four different saccharides; D-glucose, D-maltose, stachyose, and α-cyclodextrin were used in the present experiment. The turbidity was analyzed by UV-vis. Solution analysis was conducted using ICP-AES and TOC. Zeta potential of CeNPs was also measured.

In the types P and S+P, the aggregation of CeNPs was inhibited, while type S exhibited no inhibition. The aggregation inhibition was attributed to the electrostatic repulsion by the adsorbed phosphate. The amounts of stachyose and α-cyclodextrin adsorbed on the CeNPs were reduced by 50% in the presence of phosphate, most likely because the number of adsorption sites for saccharides decreased by the adsorbed phosphate.

Zeta potential of the type S showed almost the same value as that of control. In the type S+P the amount of phosphate adsorbed on CeNPs was 1.1~1.5 times greater than that in the type P, despite the zeta potential of the type S+P, -40 ~ -41 mV, was almost same as that of the type P. In the type S+P, adsorption of saccharides lead to the increased the area of the sliding surface of CeNPs, and the electrostatic repulsive forces between CeNPs and aqueous phosphate were reduced, resulting in the increased amount of adsorbed phosphate. Consequently, phosphate in EPS inhibits nanoparticles aggregation, while saccharides do not modify the aggregation behavior but moderate the increased surface charge.