Sorption of Perchlorate from Water using Surfactant Modified Clays and Zeolite

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Over the past decade, the United States has become increasingly concerned about water contamination by perchlorate (ClO_4^-). Anthropogenic sources of perchlorate in the environment include ammonium perchlorate (NH_4ClO_4) which is used as an oxidizer in propellants for rockets, missiles, explosives, pyrotechnics, and fireworks. Also, perchloric acid and perchlorate salts are used extensively in many commercial and industrial processes, such as wet digestions, organic syntheses, aluminum refining, animal feed additives, and herbicides. Natural sources of perchlorate include certain fertilizers (e.g., Chilean nitrate) and evaporite mineral deposits. Perchlorate is highly soluble and recalcitrant and has been detected in drinking water in 35 states, human milk, dairy milk, and in crops exposed to perchlorate-contaminated water. The anion perchlorate poses potential environmental concerns because its ionic radius and charge can competitively block thyroid iodine uptake. Iodine is an essential element for thyroid function. At relatively high doses, perchlorate is known to interfere with the thyroid's ability to produce hormones and regulate metabolism.

Currently, perchlorate-contaminated drinking water is treated using ion exchange processes, reverse osmosis, sorption with granular activated carbon and nanofiltration. The cost of treating perchlorate and other emergent contaminants in water using ion exchange and granular activated carbon is a growing financial burden to many municipalities. To alleviate the high cost of treating perchlorate-contaminated water using expensive filtration media, the USEPA and American Water Works Association/Research Foundation are seeking sustainable low-cost treatment technologies.

We have prepared and tested low-cost surfactant-modified (or tailored) clays (SMC) and zeolites (SMZ) that effectively sorb perchlorate in aqueous solutions. A very rapid approach to sorption equilibrium was observed in batch sorption tests conducted using low (ppb) and high (ppm) perchlorate concentrations. Specifically, the approach to sorption equilibrium was two hours for experiments conducted with the powdered SMC and less than four hours with the 30 – 50 mesh size (pelletized) SMZ. Batch sorption isotherms for experiments conducted in freshwater were described by the Langmuir sorption model, meanwhile the partition model described the sorption of perchlorate from brine solutions. The sorption capacity for perchlorate to SMC and the pelletized SMZ was 14,000 mg/kg and 6,500mg/kg, respectively.

The effectiveness of SMC and SMZ as sorbents for the very miscible perchlorate ions in water offers great promise that we can develop a low-cost sustainable treatment technology for perchlorate-contaminated drinking water. Additional research is needed to manufacture pellets of the water stable SMC for use in water filtration canisters.