

Project Summary

- Title:** Removal of Heavy Metals and Radionuclides from Soils Using Cationic Surfactant Flushing
- Project ID:** R/UW-REM-005
- Investigators:** Dr. Christine V. Evans, Professor of Geology, and Dr. Zhaohui Li, Associate Professor of Geology, Department of Geosciences, University of Wisconsin-Parkside
- Period of Contract:** 07/01/2001 – 06/30/2003
- Background/Need:** At some heavy industrial sites and DOE nuclear weapon manufacture and test sites, high concentrations of heavy metals and radionuclides in soils impose potential threat to groundwater. Soils with large surface areas and high cation exchange capacities may accumulate significant amounts of heavy metals and radionuclides, requiring eventual soil excavation and *ex situ* extraction of the heavy metals and radionuclides. Cesium and lead are two relatively common contaminants that are particularly difficult to extract from clay and oxide fractions of soils. Thus a search for an inexpensive, yet effective method, to remove heavy metals from soil becomes more imminent.
- Objectives:** The objectives of this research are to test the heavy metal removal efficiency using long chain cationic surfactants and to study the influence of surfactant chain length of several quaternary ammonium surfactants, the initial surfactant concentration, the initial heavy metal loading and initial solution pH and ionic strength on Pb and Cs removal from kaolinite and illite at batch scale, and then to conduct column leaching experiments to verify the batch results at different initial Pb and Cs loading.
- Methods:** Laboratory batch sorption was performed to determine the sorption maxima of Pb and Cs on kaolinite and illite. Then the clays were modified to 3, 15, and 100 percent of their metal sorption capacity. Desorption of Pb and Cs by cationic surfactant with different hydrophobic chain lengths (8, 12, and 16 carbons in the tail group, respectively) was determined against time, solution pH and ionic strength. For column studies, contaminated clays were leached with water and surfactant solution, and effluent metal concentrations were analyzed by atomic emission for Cs and ICP for Pb. Greenhouse studies were conducted by growing mustard and chard plants in Pb-modified soils at three levels of loading. The cationic surfactant was added to one set of replicates during normal watering procedures.

Results and Discussion:

Desorption of Cs⁺ from Cs⁺-preloaded kaolinite and illite at different loading levels followed different trends. In general, Cs⁺ was more readily removed from kaolinite than from illite. Surfactant chain lengths have strong influences on Cs⁺ desorption from kaolinite. As the surfactant chain length increased, the percentage of Cs⁺ removal from kaolinite increased. In contrast, initial surfactant concentrations have a greater influence on Cs⁺ removal from illite. As the surfactant concentration increased, the percentage of Cs⁺ desorption increased. For kaolinite, when surfactant concentrations were the same, a higher percentage of Cs⁺ desorption was achieved when Cs⁺ loading was low. As the Cs⁺ loading on kaolinite increased, the percentage of Cs⁺ desorption decreased. In contrast, a higher percentage of Cs⁺ desorption was obtained from illite when Cs⁺ loading was high. The percentage of Cs⁺ desorption decreased as the Cs⁺ loading on illite decreased. For kaolinite and illite with higher Cs⁺ loading, the percentage of Cs⁺ removal increased logarithmically with the increase in HDTMA/Cs⁺. A minimum value of 30 for the HDTMA/Cs⁺ ratio is required to achieve 80 percent Cs⁺ removal from kaolinite.

Column results show that a 100 percent increase in Cs⁺ removal was achieved when a 6 mM HDTMA solution was used as the leaching solution compared to water. Contrast to the batch study, a higher percentage of Cs⁺ removal from kaolinite was achieved by both surfactant solution and water when the Cs⁺ loading on kaolinite was high.

Plant sorption results showed that both mustard and chard absorbed Pb somewhat proportionally to the amount in the soil. For both plant types, plant sorption of Pb increased substantially at the medium and high levels of Pb-loading when the surfactant was added.

**Conclusions/
Implications/**

Recommendations: The research shows that the cationic surfactant, particularly HDTMA, drastically increase the Pb and Cs desorption from kaolinite surfaces. The greenhouse study shows that the cationic surfactant also increases plant sorption of Pb from Pb-loaded soils.

Related Publications:

Li, Z., D. Alessi, and L. Allen. (2002) Influence of Quaternary Ammonium on Sorption of Selected Metal Cations onto Clinoptilolite Zeolite. *J. Environ. Qual.* **31**,1106-1114.

Willms, C., Z. Li, L. Allen, and C. V. Evans. (2004) Desorption of Cesium from Kaolinite and Illite Using Alkylammonium Salts. *Applied Clay Science.* accepted.

Key Words: Desorption, Heavy Metal, Illite, Kaolinite, Surfactant.

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