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Optimizing Polymer-Grafted Amidoxime-based Adsorbents for Uranium Uptake from Seawater

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ABSTRACT:

Background: Researchers at the Oak Ridge National Laboratory (ORNL) have recently developed polymer-grafted adsorbents using high-surface-area polyethylene fibers for the recovery of uranium from seawater. Field studies conducted at the Pacific Northwest National Laboratory (PNNL) in collaboration with ORNL have demonstrated that (i) amidoxime functional groups are very effective in capturing uranium from seawater, (ii) high-surface-area polymer fibers can increase the uranium adsorbent capacity, and (iii) the capacity of the ORNL adsorbent is twice the maximum capacity reported in the literature.

Objective: The overall objective of the proposed work is to optimize the performance of amidoxime-based adsorbents developed at ORNL with respect to uranium uptake kinetics and capacity in order to improve the economic viability of the uranium-from-seawater process.

Approach: The proposed project is focused on optimizing the adsorbent morphology, adsorbent synthesis variables, and conditioning parameters with the goal to further increase the adsorbent capacity and selectivity toward uranium. A new concept combining adsorption and partitioning is also introduced to increase the uranium uptake capacity and rate. In addition, this project will develop uptake models based on microscopic- and macroscopic-level transport and reaction processes involved in uranium complexation with amidoxime, with the goal to better understand the limiting-rate mechanisms of uranium uptake from seawater and provide feedback to adsorbent-synthesis and field-testing efforts at national laboratories. The proposed work will be integrated with existing efforts, supported by the DOE Fuel Resources Program and focused on uranium recovery from seawater, through collaborations with ORNL and PNNL.

Benefits: This study will complement current efforts at ORNL, PNNL, and Lawrence Berkeley National Laboratory (LBNL). Because of the many variables involved in all the steps of adsorbent synthesis—including polymer grafting, amidoximation, and conditioning—the ORNL adsorbent has not been fully optimized. Optimization of the adsorbent performance will further increase the adsorbent capacity for uranium and improve the economics of the uranium-uptake-from-seawater process. Realistic kinetic models will be developed to describe the rate of uranium uptake as a function of model parameters that can be independently obtained. The rate-limiting step for uranium uptake can be obtained by comparing the transport and reaction kinetic rates. If diffusion is the rate-limiting step, the uptake process can be further enhanced by better engineering the adsorbent to reduce the diffusion resistance. If the reaction rate is controlling the uptake rate, the strength and longevity of the adsorbent fibers can be improved without reducing the overall uptake rate. Accurate prediction of the uranium uptake rate is also needed to estimate the duration of possible deployment of the adsorbent in the ocean. Predicting the amount of uranium adsorbed as a function of deployment duration and number of cycles has implications in the economics of the process. Thus, this project is strongly linked to the success of the uranium-from-seawater effort.