Development of Novel Sorbents for Uranium Extraction from Seawater

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ABSTRACT

As the uranium resource in terrestrial ores is limited, it is difficult to ensure a long-term sustainable nuclear energy technology. The oceans contain approximately 4.5 billion tons of uranium, which is one thousand times the amount of uranium in terrestrial ores. Development of technologies to recover the uranium from seawater would greatly improve the uranium resource availability, sustaining the fuel supply for nuclear energy. Several methods have been previously evaluated including solvent extraction, ion exchange, flotation, biomass collection, and adsorption; however, none have been found to be suitable for reasons such as cost effectiveness, long term stability, and selectivity. Recent research has focused on the amidoxime functional group as a promising candidate for uranium sorption. Polymer beads and fibers have been functionalized with amidoxime functional groups, and uranium adsorption capacities as high as 1.5 g U/kg adsorbent have recently been reported with these types of materials. As uranium concentration in seawater is only ~3 ppb, great improvements to uranium collection systems must be made in order to make uranium extraction from seawater economically feasible. This proposed research intends to develop transformative technologies for economic uranium extraction from seawater. The Lin group will design advanced porous supports by taking advantage of recent breakthroughs in nanoscience and nanotechnology and incorporate high densities of well-designed chelators into such nanoporous supports to allow selective and efficient binding of uranyl ions from seawater. Several classes of nanoporous materials, including mesoporous silica nanoparticles (MSNs), mesoporous carbon nanoparticles (MCNs), meta-organic frameworks (MOFs), and covalent-organic frameworks (COFs), will be synthesized. Selective uranium-binding liagnds such as amidoxime will be incorporated into the nanoporous materials to afford a new generation of sorbent materials that will be evaluated for their uranium extraction efficiency. The initial testing of these materials for uranium binding will be carried out in the Lin group, but more detailed sorption studies will be carried out by Dr. Taylor-Pashow of Savannah River National Laboratory in order to obtain quantitative uranyl sorption selectivity and kinetics data for the proposed materials. The proposed nanostructured sorbent materials are expected to have higher binding capacities, enhanced extraction kinetics, optimal stripping efficiency for uranyl ions, and enhanced mechanical and chemical stabilities. This transformative research will significantly impact uranium extraction from seawater as well as benefit DOE's efforts on environmental remediation by developing new materials and providing knowledge for enriching and sequestering ultralow concentrations of other metals.