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Overview of the nuclear fuel resources –seawater uranium recovery program sponsored by the U.S. Department of Energy

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For nuclear energy to remain a sustainable energy source, there must be assurance that an economically viable supply of nuclear fuel is available. One major goal of the Fuel Cycle Technology Research and Development (R&D) Program in the United States Department of Energy (DOE), Office of Nuclear Energy (NE) is to develop sustainable fuel cycles options. The development of technology to recover uranium from seawater has the potential to fulfill this program goal. Seawater uranium recovery technology is identified in the U.S. DOE NE Roadmap as an area most appropriate for federal involvement to support long-term, "game-changing" approach.

Seawater contains more than 4 billion metric tons of dissolved uranium. This unconventional uranium resource, combined with a suitable extraction cost, can potentially meet the uranium demands for centuries to come. The challenge, however, is the low concentration of uranium in seawater –approximately 3.3 ppb. A multidisciplinary team from the U.S. national laboratories, universities, and research institutes has been assembled to address this challenge.

Polymeric adsorbents materials containing amidoxime ligands, developed at the Oak Ridge National Laboratory (ORNL), have demonstrated great promise for the extraction of uranium from seawater. These ORNL adsorbents showed adsorption capacities for the extraction of uranium from seawater that exceed 3 mg U/g adsorbent in testing at the Pacific Northwest National Laboratory Marine Sciences Laboratory. A key component of this novel technology lies in the unique high surface-area polyethylene fibers that considerably increase the surface area and thus the grafting yield of functional groups without compromising its mechanical properties. In addition, high surface area nanomaterial adsorbents are under development at ORNL with the goal of increasing uranium adsorption capacity by taking advantage of the high surface areas and tunable porosity of carbon-based nanomaterials.

Structure-based computational design methods are being used to identify more selective and stable ligands. The most promising candidates are being synthesized, tested and evaluated for incorporation onto a support matrix. Fundamental thermodynamic and kinetic studies are being carried out to improve the adsorption efficiency, the selectivity of uranium over other elements, and the durability of the adsorbents. Understanding the rate-limiting step of uranium uptake from seawater is essential in designing an effective uranium recovery system.

Economic analyses have been used to guide the technology development and highlight what parameters, such as capacity, recyclability, and stability, have the largest impact on the cost of extraction of uranium from seawater. Initially, cost estimates by Japanese researchers for extraction of uranium from seawater with braided polymeric fibers functionalized with amidoxime ligands were evaluated and updated. The economic analyses were subsequently updated to reflect the results of the U.S. program while providing insight for cost reductions in the adsorbent development through "cradle-to-grave"case studies for the extraction process.

… see attachment for full abstract

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