SERDP Strategic Environmental Research and Development Program
Improving Mission Readiness Through Environmental Research

Removal and Encapsulation of Heavy Metals from Ground Water

Cleanup
CU-387

LEAD AGENCY: Environmental Protection Agency

LAB: Risk Reduction Engineering Laboratory (RREL)

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PROBLEM STATEMENT: The goals of this proposed applied research (6.2) program are to develop a unique, innovative technological approach for many of the difficult problems, found on both DoD and DOE facilities: 1) that of removing metal contamination from dilute matrix (i.e. water): 2) managing metal residuals that can not be destroyed: 3) protecting surplus equipment from environmental exposure. This effort will (1) develop high-capacity low-cost adsorbents, based on cellulose or starch, natural polymer or synthetic polymers (with functional groups) for selectively adsorbing toxic metals such as uranium, plutonium, mercury, and then (2) demonstrate permanent encapsulation of the solid adsorbent matrix by extrusion in recycled plastics such as high density polyethylene for long-term disposal, or (3) allow for temporary storage of these metals for future resource recovery or protection of surplus equipment from environmental exposure. The metal contaminants (i.e. mercury, lead, uranium) can be directly adsorbed from ground water or wastewater. If present in a solid matrix, the metals can first be leached selectively into a concentrated aqueous medium, which then will be subjected to the low-cost adsorption technique and encapsulation. Likewise, this encapsulation concept has application to solid material such as depleted uranium or plutonium found at the Y12 plant, Rocky Flats, or Aberdeen Proving Ground. The proposed research will result in a highly efficient, yet affordable technology for remediating metal contaminated water as well as protect surplus equipment from environmental exposure.

Restoration of metal-contaminated water or solids is a generic problem, with many sites belonging to both DOE and DoD. Indeed the problem is so extensive that affordable technologies are critically needed now. For ground water the dominant methods used today are of the pump-and-treat type. The treatment part usually uses activated carbon or a resin, which on saturation is regenerated by acid leaching. The metals in aqueous stream are then isolated by precipitation. The precipitate sludge is further treated, then disposed of in a hazardous waste landfill. The problem may continue over the years as the metals will gradually form leachates. It has been estimated by industry that for every one dollar of operating cost in the adsorption part of this technology, about 3 to 6 dollars are spent in regeneration. Thus developing low-cost adsorbents that do not need regeneration provides a very attractive technical approach. This is a new idea, no prior art exists.

One dominant method of metals disposal is the cement-based solidification/stabilization process. The long-term effectiveness of this technique, however, has not been determined. Alternatively vitrification has been tried, and proposed especially for radioactive wastes but does not allow for resource recovery of the encapsulated material. Encapsulating radioactive wastes in thermoplastics has been demonstrated in the U.S., U.K., France, and Israel, and no leaching has been observed for a long time (years). Metals and their compounds have no detectable diffusive transport through polymer films. In landfills thermoplastics do not begin to biodegrade in less than 400 years; in low moisture environment and in absence of microbial action, therefore, these encapsulants will last much longer. The thermoplastics are also stable to high levels of irradiation, which is important for storing radioactive compounds. The longevity of these encapsulants of course can be increased by multiple encapsulation. The Brookhaven National laboratory and the University of Cincinnati have done some preliminary work in this area. Furthermore, temporary encapsulation of surplus DoD material will alleviate many of the concerns expressed in the Office of Technology Assessment's critical report of DoD's equipment storage systems that are wasting millions of dollars due to corrosion from unprotected environmental exposure.

PROJECT DESCRIPTION: The project has several distinct parts, requiring different technical skills for their solution. First, low-cost adsorbents need to be designed and developed and produced. In the environmental restoration area, adsorbents such as carbon, zeolites, or ion exchange resins have been used. Each technology is based on the concept of regenerating the adsorbents for reuse. As has been mentioned before, even with regeneration, these adsorption processes tend to be very expensive for large dilute matrices. Moreover these adsorbents do not possess high adsorption capacity (mostly fraction of a percent), which imparts two undesirable effects on process economics, namely adsorbent cost and eventual dilution of the metals on regeneration. Highly selective adsorbents with specific ligands have made chromatography a mainstay in protein separation from very dilute solutions. In that spirit, this effort will develop low-cost adsorbents which have inexpensive but highly efficient ligands attached to them. These adsorbents will have higher capacity and high specificity for chosen metals. The resulting adsorbents will not need to be regenerated.

The technical approach consists of attaching specific amine or imine-based (or other promising) ligands on chosen adsorbents, which can be selected from cellulose, starch, saw dust, peat moss, chitin/chitosan etc., and tested for their efficacy. EPA has discussed the prospect of this approach with Prof. Jerker Porath, the famous inventor of sepharose and sephadex, the two universally used chromatography column material. Prof. Porath, who spends six months at Upsala University in Sweden and the rest at the University of Arizona, is interested in collaboration with EPA. Prof. Porath will take the prime responsibility of synthesizing the low-cost adsorbents. The engineered material most likely will be in pellets or beads form. EPA will build laboratory apparatus to demonstrate the idea of metals adsorption from contaminated water. For uranium, or plutonium, a toxic metal surrogate will be used.

In another section of the project, the separation (volume reduction) data from the laboratory will be used to design experiments for encapsulating the adsorbents or for encapsulating surplus equipment in recyclable plastics, to reduce life cycle cost. Prof. Don White, a plastics conversion specialist, and Prof. David Wolf (working at the University of Arizona) would be responsible for this effort. EPA will have access to the University extruders for demonstrating the technology. Lastly, EPA will propose demonstrating this concept at a DoD or DOE site.

Important technical issues to overcome: (i) attaching inexpensive ligands to low-cost substrate to impart high capacity, (ii) preparing appropriate engineered (thermoplastic) materials which are easily handled, (iii) demonstrating the stability of the polymers to internal or environmental effects such as radiation and (iv) demonstrating ability of resource recovery of both the encapsulated heavy metals and thermoplastic material.

EXPECTED PAYOFF: This technological approach can be tailor-made to many civilian or military site-related problems. This approach will establish a new paradigm in adsorption technology -- i.e. disposal with adsorption without regeneration.

Impact: This technology will have far-reaching impact on particularly dilute contaminated matrices for which no inexpensive alternatives exist. In addition, this technology will allow resource recovery, when needed, from solid material such as uranium. Also, millions of dollars of DoD equipment can be protected from environment exposure. Life cycle cost can be reduced if the encapsulating material is recyclable.

TRANSITION PLAN: After 24 months technical support will be provided to build prototype for demonstration of technology at a DoD or DOE site.