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Electromagnetic Mixed Waste Processing System for Asbestos Decontamination

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DISCLAIMER

PI.1 Electromagnetic Mixed Waste Processing System for Asbestos Decontamination

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Introduction

DOE sites contain a broad spectrum of asbestos materials (cloth, pipe lagging, sprayed insulation and other substances) which are contaminated with a combination of hazardous and radioactive wastes due to its use during the development of the U.S. nuclear weapons complex. These wastes consist of cutting oils, lubricants, solvents, PCB's, heavy metals and radioactive contaminants. The radioactive contaminants are the activation, decay and fission products of DOE operations. The asbestos must be converted by removing and separating the hazardous and radioactive materials to prevent the formation of mixed wastes and to allow for both sanitary disposal and effective decontamination. Currently, no technology exists that can meet these sanitary and other objectives.

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Objectives

The overall objective of this project is to develop and demonstrate a cost-effective technology for converting contaminated asbestos to a form suitable for disposal in a sanitary landfill or to a form which stabilizes inorganic, radioactive and heavy metals in a solidified silica suspension for disposal as low-level waste.

The electromagnetic mixed waste processing system employs three patented technologies to convert DOE asbestos to a non-hazardous, radionuclide-free, sanitary waste: high-shear acid decomposition (ABCOV Method), metals separation (Westinghouse STC), and radio frequency (RF) heating (KAI Electromagnetic Process). The asbestos is decomposed to an amorphous silica suspension using the high-shear acid process. Radionuclides and heavy metals are separated from this suspension by ion exchange and physical separation processes. The suspension is then heated with radio frequency energy to remove the organic volatiles. Finally the amorphous silica is solidified with sodium silicate for disposal.

The objectives of Phase 1 were to establish the technical feasibility of asbestos decomposition, inorganic radionuclide and heavy metal removal, and organic devolatilization. The technical feasibility involved separate bench-scale testing of:

1. Decomposition of asbestos to an amorphous silica suspension using the ABCOV technology described in U.S. Patent Number 5,041,277; performed by Ohio DSI Corporation in Columbus, OH.

2. Removal of inorganic radionuclides and heavy metals designated as hazardous by the Resource Conservation and Recovery Act (RCRA) using ion exchange and physical separation processes; performed by WSTC in Pittsburgh, PA.

3. Devolatilization of organics using RF-based technology described in U.S. Patent Number 5,065,819; performed by KAI Technologies, Inc. in Portsmouth, NH.

Technical Approach

Apply techniques that have already proved successful in the mining, oil and metal processing industries to the development of a multi-stage process to remove and separate hazardous and radioactive materials from asbestos. This process uses three methods: acid attack which converts the asbestos to a sanitary waste; electrochemical processing for the removal of heavy metals, RCRA wastes and radionuclides; and dielectric heating to volatilize the organic materials. This process will result in the destruction of over 99% of the asbestos; limit radioactive metal contamination to 0.2 Bq alpha per gram and 1 Bq beta per gram; reduce hazardous organics to levels compatible with current EPA policy for RCRA delisting and achieve TCLP limits for all solidified waste.

Technologies

The electromagnetic mixed waste processing system employs three patented technologies to convert DOE asbestos to a non-hazardous, radionuclide-free, sanitary waste; high shear acid decomposition (ABCOV Method), radio frequency heating (KAI Electromagnetic Process) and electrochemical separation(Westinghouse STC). The asbestos is decomposed to an amorphous silica suspension using a high-shear acid process. Radionuclides and heavy metals are separated from this suspension by an electrochemical process and radio frequency heating is employed to remove organics. Finally, the amorphous silica is solidified with sodium silicate for disposal.

The ABCOV Method is a non-burning, simple and economical, chemical and mixing treatment of friable asbestos-containing material (ACM) that renders it harmless in a period of two hours or less. The ABCOV process was developed after years of extensive research at Battelle Laboratories and Georgia Institute of Technology. It uses several chemical formulations to effectively improve the removal of asbestos-containing materials (ACM) and chemically converts asbestos into a non-hazardous substance. It offers the following advantages over conventional removal and disposal methods:

- Removal time is reduced by applying ABCOV-T directly to the ACM, achieving improved wetting and initiating the conversion process. Some studies have documented removal times to be reduced by as much as 40 percent, allowing for labor savings .In addition, after removal of ACM, ABCOV-T can be used to clean substrates of any remaining fibers, eliminating the need for scrubbing the wire brushes.

•Depending on the type of filler material in the ACM, the volume of waste may be reduced by as much as 80%. The removed ACM is immersed in a vat containing formulation ABCOV-C. After 30 or more minutes of agitation using a high-speed dispersion mixer, the mixture may be analyzed for the presence of asbestos fibers. Several previous demonstrations of the process by major utilities and federal institutions have confirmed conversion into a non-ACM substance.

•Since a hazardous substance no longer exists, it becomes unnecessary to transport the remaining material to a required ACM landfill.

Thermal processing is the most effective approach to removing organics from the mixed waste matrix. As thermal processing candidates, both direct incineration and vitrification processing would destroy any organics present in the asbestos, and in particular, vitrification can result directly in a stable waste form for disposal. The KAI radio frequency (RF) desorption technology was selected over these processes for the following reasons:

•Incineration - a) requires more complicated licensing for on-site, mobile operations ;b) requires more expensive off-gas processing/particulate collection system to contain airborne contaminants for an ALARA design for nuclear application (this includes other asbestos fibers and radionuclides); and c) may condition metals present in the asbestos decomposition residue to make radionuclide and heavy metal extraction more difficult.

•Vitrification would destroy organics condensing the asbestos and metals into a single vitrified waste form, but in so doing generates no potential waste minimization through release of a "sanitary" fraction in the form of the ABCOV product silica suspension.

By contrast, RF desorption meets both the needs of the DOE PRDA for a decontaminated, (potentially) sanitary waste form and the EPA requirements for a pollution prevention and (secondary) waste minimization in any waste treatment.

Because RF dielectric heating "couples" directly with the waste at the molecular level, it does not rely on convective or conductive mechanisms for heat transfer. Such coupling is an intrinsic advantage of both radio frequency and microwave heating approaches (for materials with which they couple and which, otherwise, may resist conventional heating due to their insulating characteristics).

This asbestos is, by definition, an insulation material, and so bulk-scale, thermal desorption processing by convective or conductive heating of the asbestos matrix will be extremely inefficient. Through the use of radio frequency coupling, the proposed process system penetrates the asbestos matrix effectively and results in rapid, even heating of organic molecules. Because RF coupling is a "non-invasive" heating process which injects energy directly into the substrate's atoms and molecules, RF-driven desorption reduces the risk of airborne contamination with the results:

•An ALARA design is maintained, critical for all nuclear operations

•Man-ran exposure decreases through reduced maintenance and reduced material handling.

•Risk of asbestos fiber release is reduced.

Westinghouse technology for the various

metals and radionuclide extraction includes a multi-step approach:

- Removal of metals and metallic oxides by flotation or other gravimetric approaches.
- Filtration of the solids from the processing liquor.
- Ion exchange and/or electrochemical processing to process the liquids.

One processing alternative to address hazardous and radioactive metals is direct plasma vitrification of the asbestos matrix (without separations). While feasible (and may even be cost-effective), direct vitrification does not support direct discharge of a sanitary waste product; therefore, we have discarded it for meeting the PRDA constraints.

Another alternative is using chemical lixiviants (based on commercial mining experience) to dissolve the metal contaminants from the asbestos matrix (or its ABCOV decomposition products) as opposed to our proposed physical processing. The primary issue for chemical leaching is the potential mismatch between the contaminant lixiviant chemistry and of the ABCOV decomposition chemistry. In addition, the leaching approach requires additional solid/liquid separations to segregate the decomposition and extraction reagents resulting in
:

- Risks of release/spill
- Increased process complexity
- Greater secondary waste generation

Accordingly, we have discarded leaching for this specific application as well - recognizing that it may well be the process of choice for other applications.

Waste Forms

The potential waste forms for the stabilization operation after metals extraction from the asbestos include the following:

- A "fine fraction" consisting of metallic ions adsorbed into the ABCOV generated silica suspension is a possible but unlikely form since we do not anticipate any chemical binding between the asbestos/silica and the contaminants. Further we anticipate that the metallic contaminants will have hydrolyzed to metallic oxides prior to the asbestos removal and D&D operations. The contaminants were originally metal chlorides of U, Ra, Th and others - all of which hydrolyze readily on exposure to moisture or oxidizing conditions. As a result, these oxides should have been separated by the density/gravimetric operations based on density differences since the density of silica is approximately 2.2 g/cc compared to thoria at 9.86 g/cc and urania at 8.3 to 11g/cc; some combination of either floatation classification or magnetic separation should produce a separate, contaminant fraction.

- The metallic oxides fraction from the density/gravimetric separation is likely.

- The "clean" or "sanitary" residue of the asbestos decomposition process - only approximately one-tenth to one-eighth of the original asbestos volume is the major constituent.

- Any ion exchange or filtration media generated during the process must be included as the process secondary waste.

Note that all these streams are compatible with standard LLW radwaste stabilization media - grout, epoxies, polyesters and/or silicates.

Accomplishments

Based on the "success" criteria established in the Phase 1 Laboratory-Scale Test Plan, the objectives of the bench scale testing of the KAI RF organic process were achieved in that a near optimum treatment temperature was achieved for PCE and that the laboratory testing demonstrated that over 90% of an organic contaminant (PCE) could be removed from the silica suspension (converted ACM). During the test a heating rate of 20°C/hour was achieved for the silica suspension using 200 watts of RF power. These tests achieved significant removal of PCE operating near its boiling point of 121°C. The electromagnetic energy required to accomplish the removal of the organic contaminant was quite reasonable at 1.2 kilowatts per kilogram of the silica suspension. The residence time can be significantly reduced by increasing the RF power level. For example, 30 minutes or less is a realistic goal for RF power levels in the range of 2 kilowatts. The total number samples analyzed under EPA method 601 was 30 (2 samples from Test 2 (Control); 14 samples each for Test 3 and Test 4).

A PCB surrogate RF plasma destruction feasibility study was undertaken as an addition to the objectives described in the Phase I KAI Test Plan. The PCB surrogate chosen was 1,2 - dichlorobenzene, and glass wool was chosen as a surrogate for asbestos. RF energy was used to both volatilize and begin decomposition of the PCB surrogate. A Bronson Model PM-310 RF glow plasma discharge chamber operating at the ISM (Industrial, Scientific, Medical) frequency of 13.56 MHz was employed. The reactor vessels were small, 15 cm long x 10 cm in diameter, and the residence time was limited for these preliminary experiment, therefore limiting the extent of destruction possible for the dichlorobenzene. However, the key reactions leading to the fracture of the benzene ring were initiated in the first experiment. This was evidenced by the compounds detected by an independent laboratory evaluation of the products produced using the cold plasma. The initial reactions involve removal of hydrogen and chlorine obstruction from the dichlorobenzene creating free radicals.

These radicals can then combine with gas-phase radicals or lead to fracture of the aromatic ring. Decomposition of the rings (desired result) occurs by additional energy absorption from collisions with photons, ions, electrons and excited atoms and molecules. The additional compounds collected or trapped provide evidence that these reactions are beginning to take place.

The Westinghouse Phase 1 Laboratory-Scale Program established the technical feasibility of inorganic heavy metal and radionuclide removal at the laboratory scale using ion exchange and physical separation technologies. Test results lead WSTC to propose a revised integrated mixed waste processing system design for remediation of contaminated asbestos.

The success criteria for Phase 1 were met:

1.) The feasibility of ion exchange to remove metals from the process stream was demonstrated by obtaining:

- 92% uranium removal in single-contact tests with a commercial ion exchange resin.
- 0.6 equivalents/l resin loading with uranium.
- lead retention in the solid phase for stabilization, allowing separation of the radioactive materials from hazardous contaminants.

2.)The potential to regenerate the ion exchange resin was demonstrated by obtaining 52% regeneration of the resin in one-cycle screening tests.

Ohio DSI Corp. (OHIO) performed a series of asbestos-destruction runs. The purpose of the runs was to demonstrate destruction and to generate treated material for experimental operations by KAI Technologies, Inc. (KAI) and Westinghouse Science & Technology Center . OHIO was tasked to initially analyze the ACM, wet it using ABCOV-T and treat it using ABCOV-C. The resulting solution and solids were then provided to KAI and Westinghouse. OHIO was tasked to provide each contractor with 30 liters of solution resulting from the treatment of 4.1 kilograms of asbestos. The following results were achieved:

- *Thirty-three runs were made to treat ACM* with ABCOV-C solution. In all 33 cases, the fibers were converted in 45 minutes.

- The final fluoride content, final pH and final volume varied with each run.

- The average amount of make-up ABCOV-R for each run was 310 grams, or 2.77 grams per gram of dry-weight asbestos (1.84 grams per gram of ABCOV-T-wetted material).

- Runs 1 through 32 were packaged into two containers. Runs 1 through 16 were delivered to KAI in Woburn, MA on October 11, 1994. Runs 17 through 32 were delivered to Westinghouse in Pittsburgh, PA on October 11, 1994.

Applications

Laboratory-scale tests on each processing operation have provided the basis to conceptually design a cost-effective, integrated process for remediation of asbestos-containing material (ACM) that is contaminated with organics, heavy metals and radioactive metals. Process characteristics include:

Flexibility: Although the target remediation material for the system is asbestos, the process for inorganic removal has been applied to other types of contaminants. Concrete, demolition debris and soil are material types that could also be remediated using the basic system elements being developed in this program.

Demonstrated Unit Operations: The overall process uses unit operations and technologies that have a proven track record for related remediation problems. For example, the metals separation process is based on Westinghouse soil washing experience. Successful soil washing of uranium-contaminated solution mining site at Bruni, Texas *demonstrated the application of* similar metals removal processes for soil remediation.

Economic Potential: The process offers significant economic advantage over high-temperature vitrification and mixed waste disposal options for the mixed waste asbestos containing materials.

Environmental Benefits: The process will be designed to have zero fugitive emissions. It will eliminate the need to consider incineration or other high-temperature processes that require stacks and gas cleaning systems. The converted asbestos is a nonhazardous material.

Future Activities

The overall objective of this project is to develop and demonstrate a cost-effective technology that converts contaminated asbestos to a form suitable for disposal in a sanitary landfill, or to a form which stabilizes inorganic radioactive and heavy metals in a solidified silica suspension for disposal as low-level waste.

The objectives of Phase 2 are to optimize the Electromagnetic Mixed Waste Process for removal of inorganic radionuclides and heavy metals from contaminated asbestos and to develop commercial-scale designs and system economics of the Electromagnetic Mixed Waste Process.

The objectives of Phase 3 are to demonstrate the Electromagnetic Mixed Waste Process for removal of inorganic radionuclides and heavy metals in a full-scale system, to gain regulatory acceptance to update system economics, to conduct a market analysis and to develop a commercialization plan.

Contacts

KAI Technologies, Inc. is actively engaged in the innovative use of electromagnetics for this and other environmental problems. For information regarding this project, please contact:

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DOE's Morgantown Energy Technology Center (METC) supports the Environmental Management (EM) Office of Technology Development by contracting research and development of new technologies for wast site characterization and clean-up. For information regarding this project, the DOE contact is: DOE Project Manager, James Longanbach, 304-285-4659