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Electromagnetic Mixed Waste Processing System for Asbestos Decontamination

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ELECTROMAGNETIC MIXED WASTE PROCESSING SYSTEM FOR ASBESTOS DECONTAMINATION*

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Introduction

Department of Energy (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. These wastes consist of cutting oils, lubricants, solvents, polychlorinated biphenyls (PCBs), heavy metals and radioactive contaminants. The radioactive contaminants are the activation, decay, and fission products of DOE nuclear weapons complex operations.

In order to reduce the volume of mixed waste needing treatment and disposal, it may be desirable to separate radioactive and hazardous portions of the waste. The ability to segregate and minimize hazardous and radioactive waste may allow waste disposal costs to be significantly reduced.

Objectives and Status

The overall objective of this three-phase program is to develop an integrated process for treating asbestos-containing material (ACM) that is contaminated with radioactive and hazardous constituents. The integrated process will attempt to minimize processing and disposal costs.

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The objectives of Phase 1 were to establish the technical feasibility of asbestos decomposition, inorganic radionuclide and heavy metal removal, and organic volatilization. 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 5,041,277; performed by Ohio DSI Corporation in Columbus, OH.

2. Removal of inorganic radionuclides and heavy metals by extraction with a recyclable solution using a variety of technologies developed and tested at Westinghouse Science & Technology Center (STC) in Pittsburgh, PA.

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

The Phase 1 Asbestos Decontamination Project resulted in the successful bench-scale demonstration of the elements required to develop a mixed waste treatment process for asbestos-containing material (ACM) contaminated with radioactive metals, heavy metals, and organics. Using the Phase 1 data, a conceptual process was developed.

The Phase 2 Program, currently in progress, is developing an integrated system design for ACM waste processing.

The Phase 3 program will target demonstration of the mixed waste processing system at a DOE facility.

Description of Process

The electromagnetic mixed waste processing system employs patented technologies to convert DOE asbestos to a non-hazardous, radionuclide-free, stable waste. The dry, contaminated asbestos is initially heated with radiofrequency energy to remove organic volatiles. Second, the radionuclides are removed by solvent extraction coupled with ion exchange solution treatment. Third, the ABCOV method converts the asbestos to an amorphous silica suspension at low temperature (100°C). Finally, the amorphous silica is solidified for disposal.

The conceptual process flow diagram for asbestos decontamination is provided in Figure 1. The first step in the process is RF treatment to remove organics. The dry ACM material exiting the RF process is then washed to remove the radioactive metals in a system that includes physical and chemical separation steps. The process segregates a small radioactive stream for transport to a radioactive disposal facility. ACM solids that no longer contain radioactive metals are processed in the commercially available ABCOV process in order to convert the asbestos into

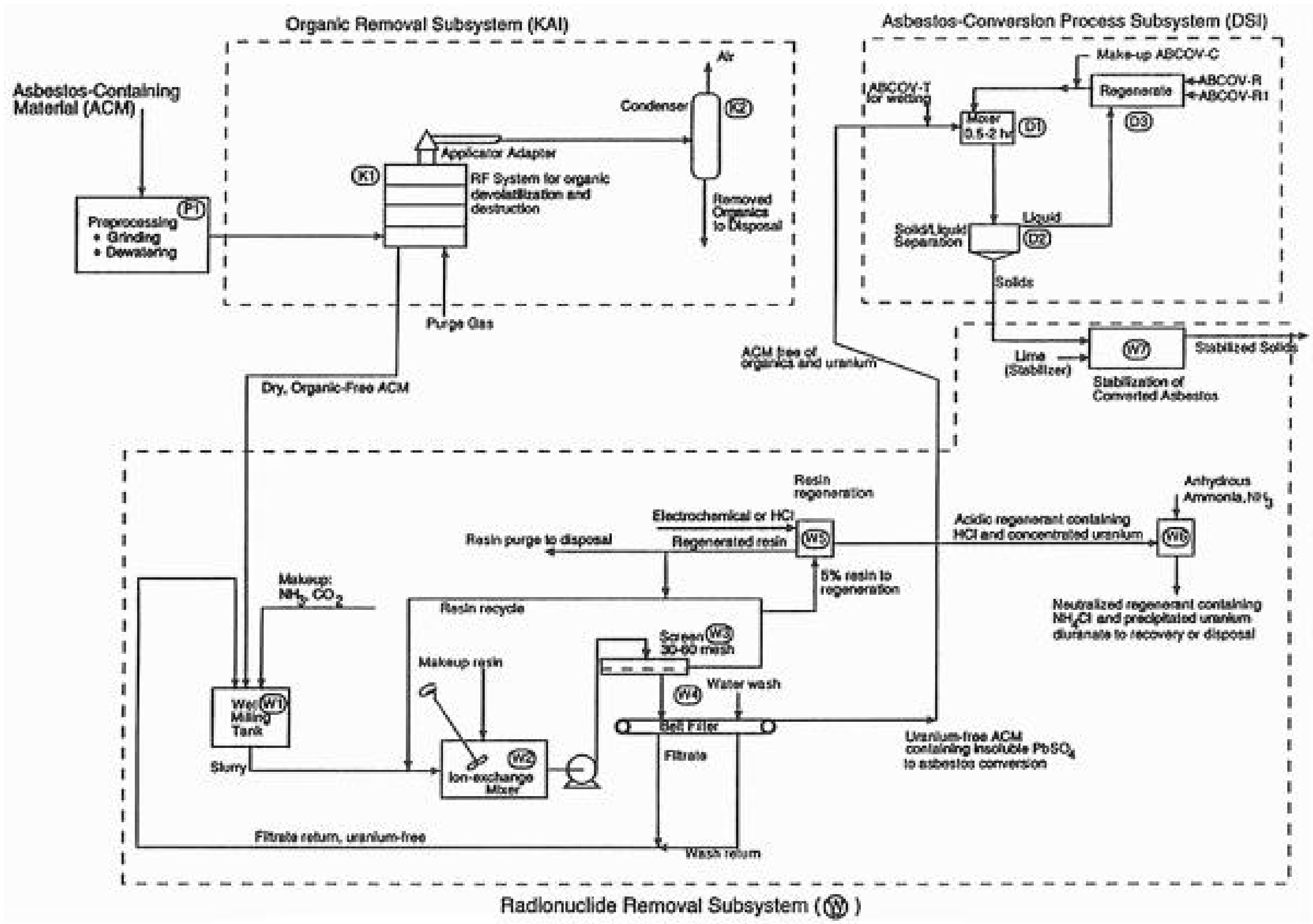


Figure 1: Phase 1 resulted in the development of a proposed process flow diagram for processing ACM contaminated with soluble uranium, lead, and organics.

amorphous solids. These amorphous solids are then stabilized for disposal as nonradioactive, nonhazardous waste.

The ACM enters the stirred reactor, W2, where it is contacted with slightly alkaline ammonium carbonate solution, the solvent, supplied from W1, the solvent make-up tank. The ammonium carbonate solution solubilizes anionic and cationic uranium compounds, as well as uranium oxide. The resulting slurry contains solubilized uranium in the anionic form of uranyl carbonate, $[(UO_2)(CO_3)_3]^{-4}$, and insoluble ACM, contaminated with nonradioactive heavy metals.

A slurry pump, W3, moves the ACM-solution slurry to the belt filter W4, which separates the ACM from the carbonate solution carrying the uranium ions. A low-volume carbonate wash on the belt filter captures residual uranium in solution and provides make-up solution. At this process point, the radioactive contaminants are separated from the nonradioactive, hazardous materials. The liquid stream contains the uranium in the ionic form of uranyl carbonate $[(UO_2)(CO_3)_3]^{-4}$. This stream must be processed to concentrate the uranium into a low volume waste and allow solution recycle. The solid stream consists of wetted ACM and the nonradioactive contaminants.

The solid stream, moist ACM containing nonradioactive heavy metals, moves from W4 to the commercially available ABCOV asbestos conversion system where the asbestos is converted to amorphous silt-like fines under the chemical action of ABCOV reagents. The converted asbestos, along with nonradioactive heavy metals, are stabilized for disposal as a nonhazardous, nonradioactive solid waste.

The radioactive liquid stream is treated by ion exchange to remove the uranium, present in the uranyl carbonate form $[(UO_2)(CO_3)_3]^{-4}$, returning uranium-free solvent to the make-up tank W1. The ion exchange resin is regenerated either chemically or electrochemically, producing a small volume, concentrated uranium stream for disposal. The use of electrochemical regeneration may facilitate the ion exchange process, and provide the minimal volume of residual radioactive waste.

Technical Approach

This process uses three major technologies: dielectric heating to volatilize the organic materials, solvent extraction with solution treatment for the removal of radionuclides, and acid attach which converts the asbestos to a nonhazardous waste. Process goals are to convert 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.

Westinghouse's technical approach to the current Phase 2 integration program is twofold:

1. As a base case, the process shown in Figure 1 is being developed using the assumed waste characteristics developed in Phase 1. Solution treatment and waste minimization options are being tested and evaluated.
2. Actual samples of radioactively-contaminated ACM materials are being characterized. Based on the contaminant forms found in these samples, additional integrated approaches for radionuclide removal from the ACM sample matrix are being proposed and tested.

Technologies

The program integrates two commercial technologies with technologies under development at Westinghouse STC.

KAI Technology

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) 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 and 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 destroys organics, condensing the asbestos and metals into a single vitrified waste form, but it does not necessarily minimize waste.

By contrast, RF desorption meets all the needs of the DOE PRDA for decontamination, EPA requirements for pollution prevention, and waste minimization.

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 radiofrequency 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 in 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-rem exposure decreases through reduced maintenance and reduced material handling.
- Risk of asbestos fiber release is reduced.

<u>ABCOV Technology</u>
The ABCOV method is non-burning, simple, economical, 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 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 exits, it becomes unnecessary to transport the remaining material to a required ACM landfill.

<u>Westinghouse Technology</u>
Westinghouse STC has tested and developed a range of technologies for radionuclide and heavy metal removal including:

- chemical extraction using solvents selected to remove target radioactive species in the ACM
- filtration of the solids from the extractant

- extraction solution treatment by ion exchange or electrochemical ion exchange
- resin regeneration via chemical and electrochemical processes.

In addition, Westinghouse is performing the process integration, developing conceptual flow sheets for integrated mixed waste processing options.

Accomplishments

<u>KAI Phase 1 Testing</u>
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 the 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 of samples analyzed under EPA method 601 was 30 (2 samples from Control Test 2; 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 1 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 experiments, 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.

Ohio DSI Phase 1 Testing

Ohio DSI Corporation (OHIO) performed a series of asbestos destruction runs. The purpose of the runs was to demonstrate destruction and to generate treated material for experimental operation by KAI Technologies, Inc. (KAI) and Westinghouse STC. OHIO was tasked to initially analyze the ACM, wet it using the 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 the ABCOV-C solution. In all 33 cases, the fibers were converted in 45 minutes.
- 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 1, 1994.

Westinghouse Phase 1 Testing

Westinghouse established the technical feasibility of inorganic heavy metal and radionuclide removal in Phase 1, using and assumed radioactive and heavy metal contaminant forms. An extractant was selected, and preliminary ion exchange screening tests indicated a path forward for recycle of the extractant solution.

The success criteria for Phase I 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.

Test results lead Westinghouse to propose the revised integrated mixed waste processing system design, shown in Figure 1, for remediation of contaminated asbestos.

Westinghouse Phase 2 Testing

In Phase 2, Westinghouse is developing the metals removal system design, including the solution recycle option, using waste specifications determined during Phase 1. In addition, Westinghouse is characterizing actually contaminated asbestos from two sites in order to define waste processing options appropriate for actual mixed waste asbestos samples.

Metals Removal Solution Treatment Testing

During Phase 2 , this metals removal system design base is being developed, using the assumed contaminate forms approved in Phase 1. The planned testing focused on developing solution treatment options for ammonium carbonate extraction process. Batch ion exchange tests were used to screen commercial resin performance. Column ion exchange tests have verified the solution treatment option, achieving better resin performance that commercially reported. Figure 2 compares ion exchange breakthrough data obtained to reported commercial resin performance.

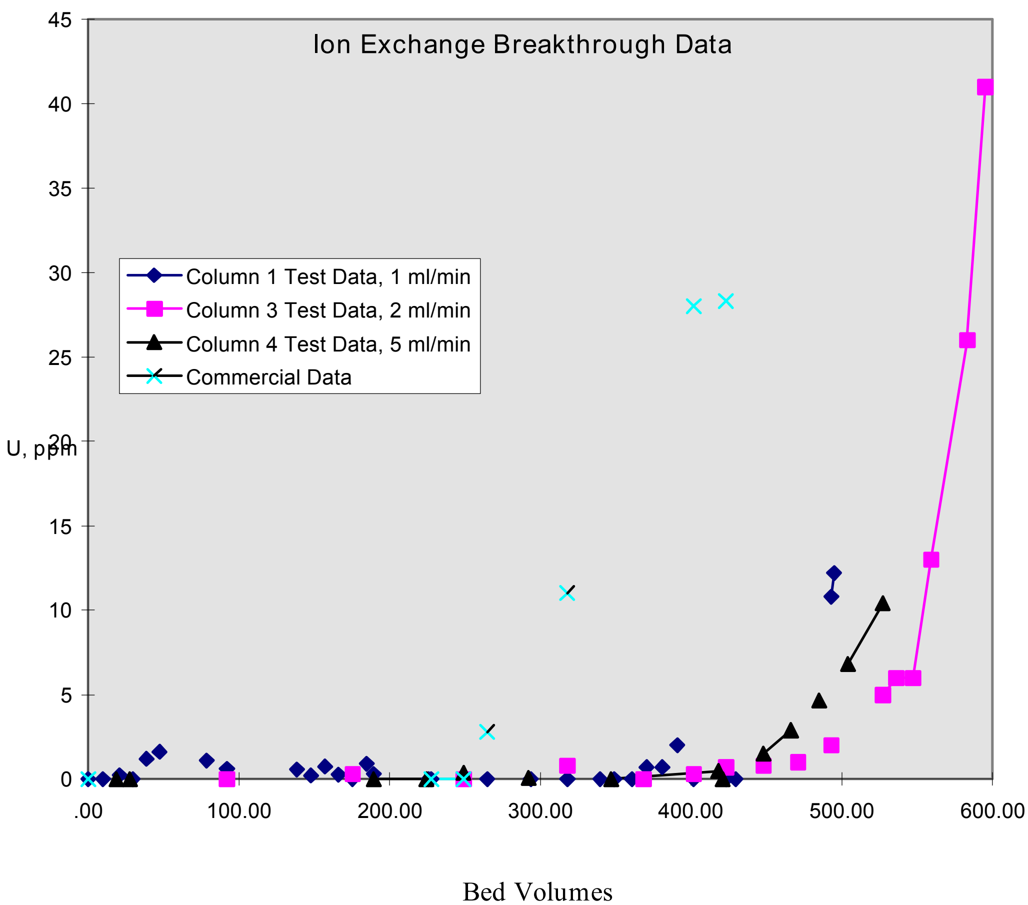


Figure 2: Ion exchange column tests illustrated robust uranium capture until more than 400 bed volumes of solution were processed.

Resin regeneration tests, currently in progress, are determining whether chemical or electrochemical regeneration options will be most cost effective by comparing the performance, waste volumes generated, and the raw material costs of each process.

ACM Characterization

Waste characterization is an important aspect in developing any waste treatment process. In order to allow waste characterization, Westinghouse received two samples of actually-contaminated ACM, one from the FERMCO weapons site and the other from the Yankee Atomic Power Plant. The characterization and testing of these materials shows that waste processing designs will need to be specifically tailored to the ACM contamination characteristics.

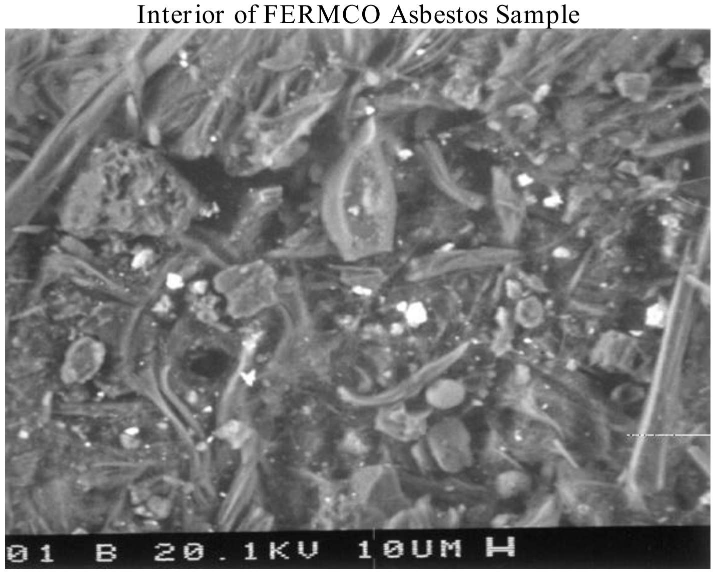
Fermco Asbestos from the Weapons Production Facility

Samples of uranium-contaminated asbestos pipe insulation were received from a metal casting area of the FERMCO Weapons Production Facility. The asbestos samples are shown in Figure 3.

Figure 3: Asbestos pipe lagging samples from FERMCO contained discrete layers of asbestos wrapped in tar paper and aluminum foil.

The samples were chemically assayed for uranium; 100 to 500 ppm uranium was present in the samples. Asbestos layers were segregated and inspected using a scanning electron microscope (SEM) equipped with a backscattered electron detector that interfaces with an energy dispersive X-ray spectrometer (EDS). Elemental scans (Figure 4) show the uranium contamination is isolated in particles of less than 10 um diameter. Semiquantitative analysis of the spectrometer data indicate the atomic ratios present are consistent with the presence of uranium in the forms of U_3O_8 and UF_4. Given the insoluble nature of these species, we tested extraction with aggressive acids. Only concentrated nitric acid was an effective extractant for the FERMCO ACM samples.

Interior of FERMCO Asbestos Sample



Uranium Scan

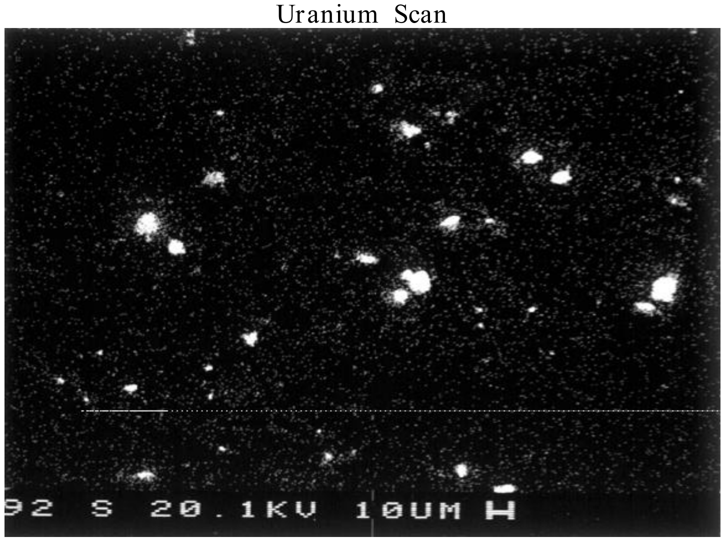


Figure 4: SEM analysis, including EDS analysis, was be performed to determine the material's general morphology, structure, and elemental composition.

Yankee Atomic ACM from Primary Coolant Loop Pipe Lagging

A sample of ACM pipe lagging from the main coolant loops in the containment was received from Yankee Atomic Power Plant (Figure 5). The radioactive contaminants identified in scans of this Yankee Atomic ACM material were Co60, Cs134, Cs137, Sr90, Am241, Pu238, Pu239, Pu240, Pu241, Fe55, Ni63, Ce144, Cm243, and Cm244. Westinghouse is performing extraction tests to define radionuclide separation options.

Figure 5: The asbestos portion of pipe lagging from Yankee Atomic was coned and quartered to provide test samples.

Summary

Developing a process for decontaminating mixed waste asbestos-containing materials will require specific attention to the waste being evaluated including:

- characteristics and form of the actual mixed waste
- contaminant form and its required removal level
- secondary streams generated and their treatment requirements
- waste disposal regulations, options, and costs.

Phase 2 is developing an integrated, mixed waste process for removal of inorganic radionuclides and heavy metals from contaminated asbestos. The system design and economics is being assessed.

Phase 3 will demonstrate the Mixed Waste Process for removal of inorganic radionuclides and heavy metals in a full-scale system.

Contacts

KAI Technologies, Inc. is actively engaged in the innovative use of electromagnetics for this and other environmental problems. For information regarding the 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 waste site characterization and clean-up. For information regarding the project, the DOE contact is: DOE Project Manager, John Duda, 304-285-4217.