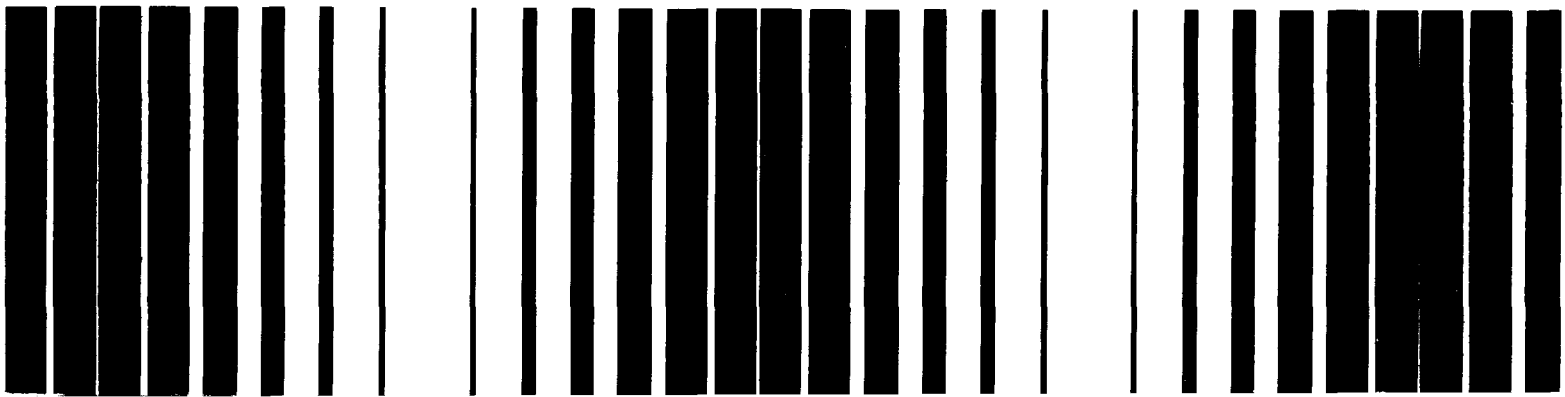




Radioactive Site Remediation Technologies Seminar

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Summer 1992



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APPROACHES TO SAMPLING RADIOACTIVE HETEROGENEOUS WASTE

**Mr. Terence Grady
U.S. Environmental Protection Agency
Las Vegas, Nevada**

Both the U.S. Environmental Protection Agency and the U.S. Department of Energy are faced with characterizing and remediating sites contaminated with hazardous chemicals and/or radionuclides. Much of the waste on these sites is of varied composition ranging from uncontainerized waste in landfills to drummed or boxed waste. Investigators experience severe difficulties when attempting to design sampling strategies, collect representative samples, and identify and select appropriate field and laboratory methodologies for radioactive heterogeneous waste. The problem of method selection is further compounded by personnel safety considerations.

Recent work at the Environmental Monitoring Systems Laboratory-Las Vegas developed a logical approach to designing a sampling and analysis program for debris and heterogeneous wastes, both hazardous and radioactive. The approach begins with determining data quality objectives (DQOs) and progresses through formulating a site model, statistical considerations of sampling design and, finally, selecting sampling and measurement procedures. Recommended for this last phase are semi-invasive sampling followed by fully invasive sampling if sufficient information is not obtained by semi-invasive procedures. The use of pilot sampling is recommended as a guide to planning future sampling activities.

The process is illustrated by reference to actual sampling situations.

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SOIL CHARACTERIZATION METHODOLOGY FOR DETERMINING APPLICATION OF SOIL WASHING

**Dr. James Nelheisel
U.S. Environmental Protection Agency
Washington, D.C.**

The Office of Radiation Programs (ORP), in compliance with the Superfund Amendments and Reauthorization Act (SARA) of 1986, has evaluated radioactively contaminated soils from sites on the National Priority List (NPL) for potential application of soil washing as a viable remediation technology. In these investigations, a laboratory methodology for soil characterization has been developed which is essentially an additional step to existing RI/FS procedures. This methodology separates representative soil samples from the site into several size fractions with each soil fraction tested for mineralogical, physical, and radionuclide content by detailed petrographic and radiochemical techniques. The protocol provides (1) a grain size distribution curve which relates weight percent versus particle size, (2) relationship of specific radionuclide activity levels versus particle size, (3) identification of the mineral/material composition of the radioactive contaminant waste forms and their physical properties, and (4) mineral/material identification of the host medium and its specific physical properties. Differences found in the physical and chemical properties of the radioactive contaminants and host materials are used in providing essential data to determine the potential feasibility of volume reduction by soil washing.

The application of the soil characterization protocol for radioactive soils is described for the potential remediation of thorium contaminated soils at the Wayne and Maywood, New Jersey, FUSRAP sites and for the radium contaminated soils of the Maywood and Glen Ridge, New Jersey, sites on the National Priority List.

SOIL CHARACTERIZATION METHODOLOGY FOR DETERMINING APPLICATION OF SOIL WASHING

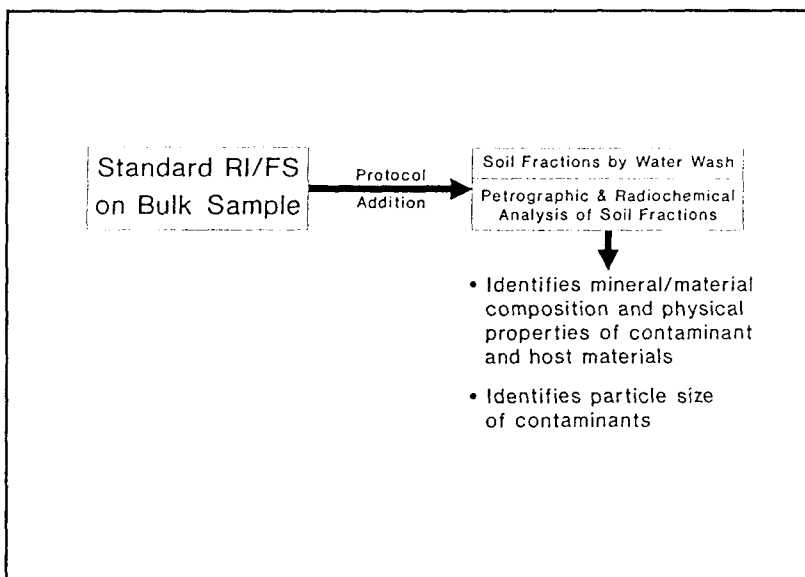
**James Neiheisel
EPA Office of Radiation Programs
Washington, D.C.**

During the FS process, soil characterization assists in the detailed analysis of individual remedial alternatives against the 9 NCP evaluation criteria:

- Protection of human health and the environment
- Compliance with ARARS
- Long-term effectiveness/permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State Acceptance
- Community Acceptance

Innovative Soil Characterization Protocol for Radioactive Contaminated Soils has Application to all tasks of the
RI/FS Process

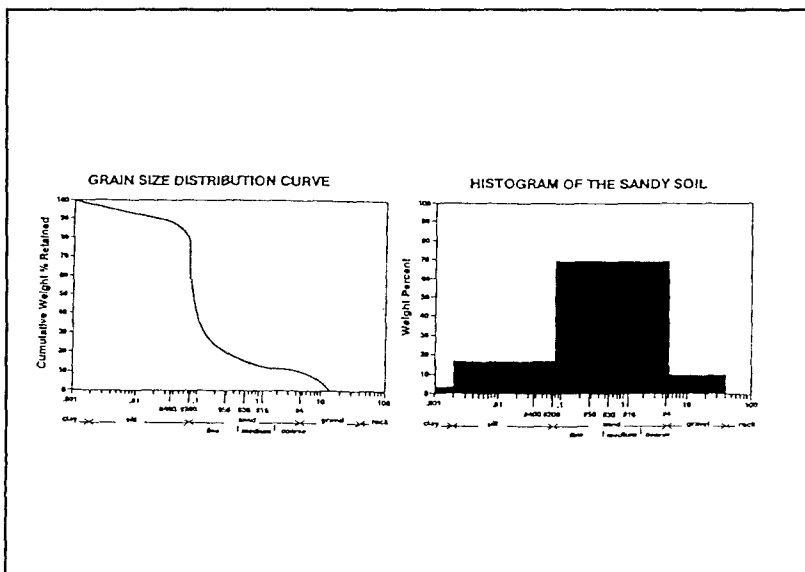
- Utility has been demonstrated at Wayne/ Maywood, NJ, FUSRAP sites and Montclair/ Glen Ridge, NJ, NPL sites.
- Potential application for additional NPL sites (45) and FUSRAP sites (26).



Utility of Protocol Data for RI/FS Tasks

Determination of potential effectiveness of soil remediation alternatives.

- Grain size in relation to Radioactivity Levels
- Minerals or materials containing radionuclides
- Minerals or materials comprising host media
- Physical properties of contaminants and host media



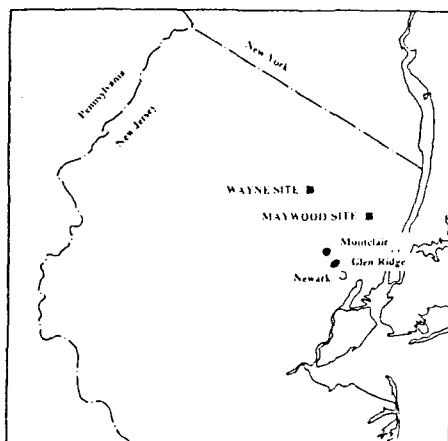
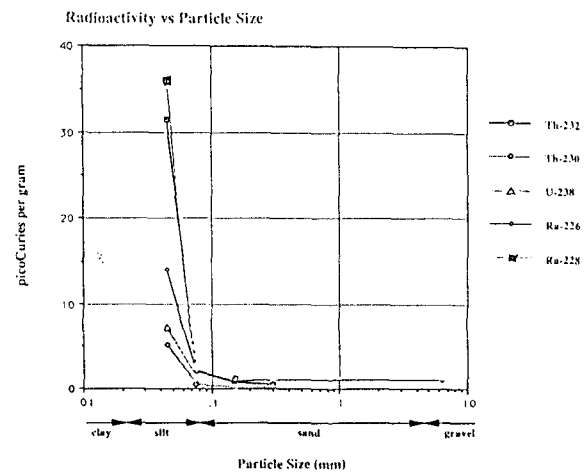
STAGES OF PETROGRAPHIC EXAMINATION

Tier 1

- Course (0.60 mm and greater) — Megascopic
- Medium (0.038 mm to 0.60 mm) — Petrographic Microscope
- Fine (less than 0.038 mm) — X-Ray Diffraction

Tier 2

- Additional Size Fractions
- Sedimentation and Centrifugation for Fine Fractions
- SEM/EDX of Fines



Location of Wayne and Maywood FUSRAP sites and Montclair and Glen Ridge NPI Sites.

Application of Protocol to Radioactive Sites on NPL
and Formerly Utilized Sites Remedial Action Program
(FUSRAP) Sites

- Wayne and Maywood, NJ, FUSRAP sites
- Montclair and Glen Ridge, NJ, NPL sites

Wayne and Maywood, NJ, FUSRAP Sites

Prior to March '91
Standard RI/FS Procedures

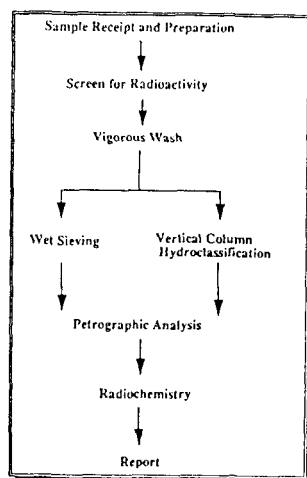
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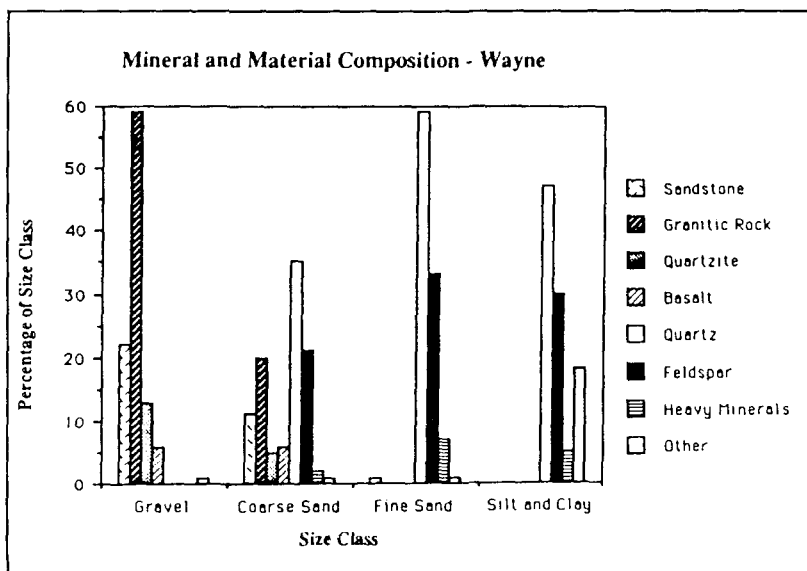
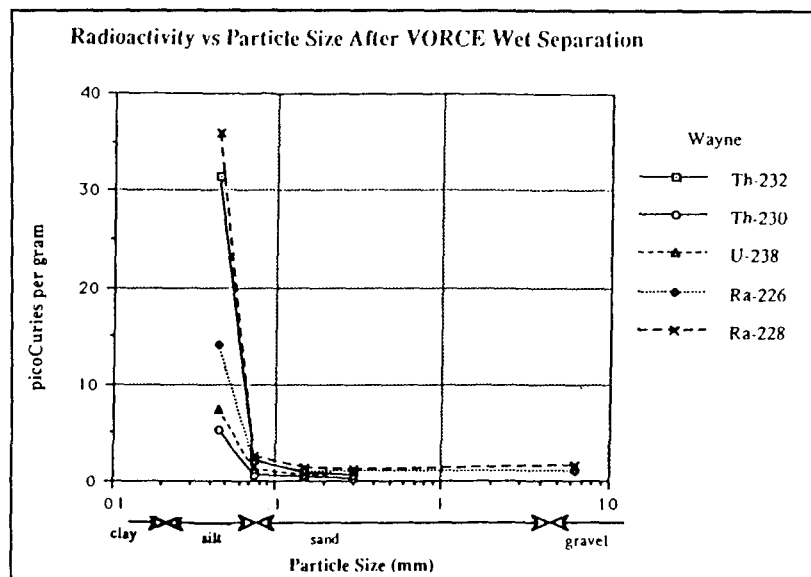
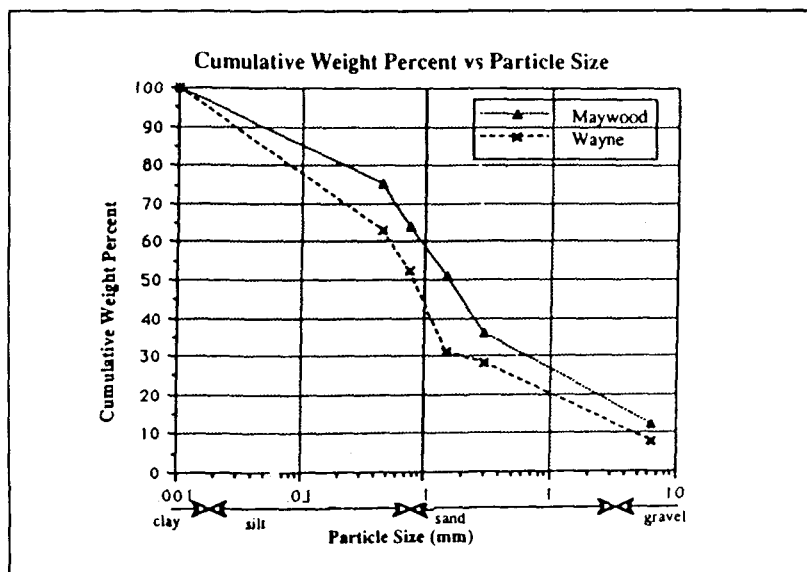
- Mineralogy or physical nature of contaminants
- Grain size range of contaminants

March '91
Protocol Additions

Protocol Key Additions:

- Identification of Monazite and Zircon as contaminants
- Size range of contaminants
- Feasibility of volume reduction





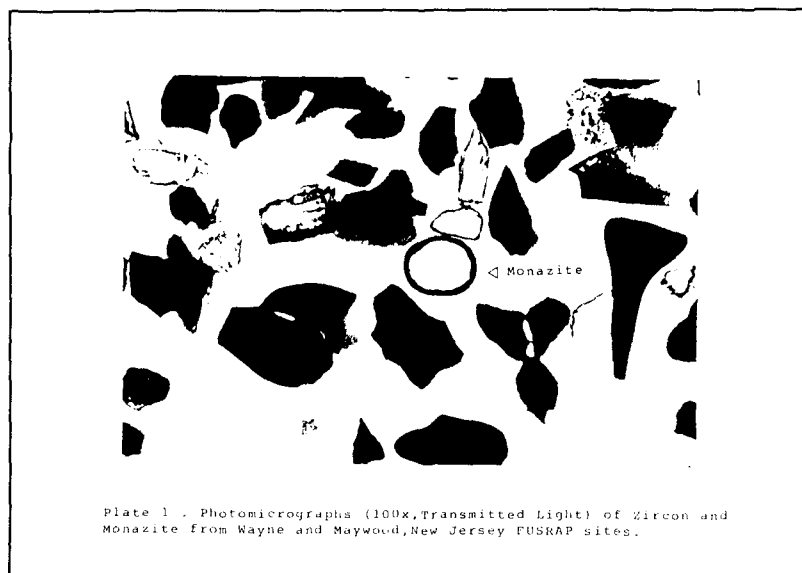
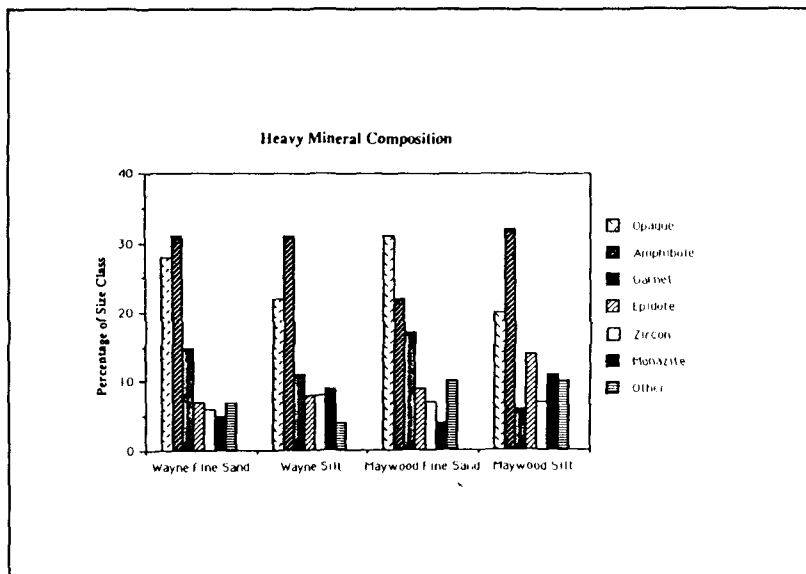
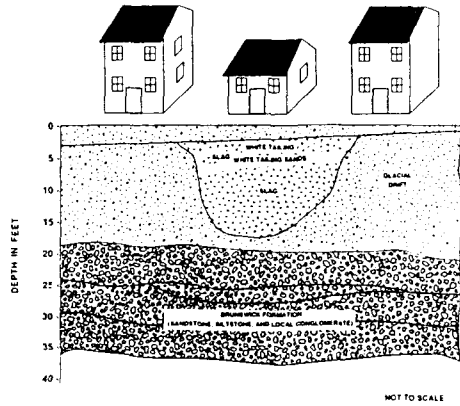


Plate 1 . Photomicrographs (100x, Transmitted Light) of Zircon and Monazite from Wayne and Maywood, New Jersey FUSRAP sites.

Wayne and Maywood, NJ, Sites Application of ORP Soil Characterization Data in Relation to RI/FS Process

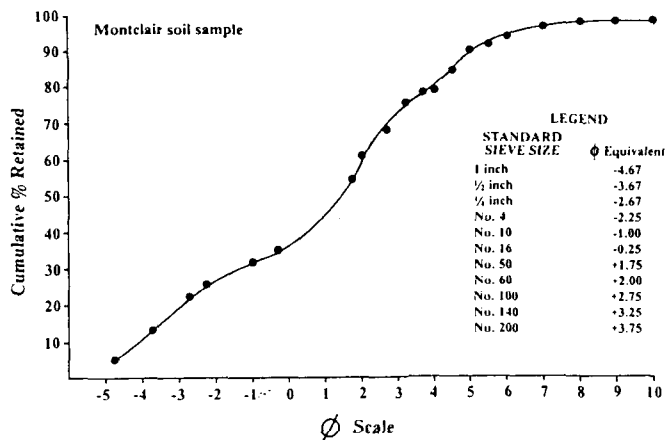
Task 1	Task 2	Task 3
<ul style="list-style-type: none"> Monazite identified as highly insoluble source of Thorium 		
Predictor of Retention onsite	Applicable to risk assessment parameters	Applicable to volume reduction
Groundwater free from Contamination		
<ul style="list-style-type: none"> Thorium, Radium, and Uranium contaminants have high density and are concentrated in the smaller soil particle size fractions (generally larger than 10 micron size) 		
---	Application to inhalation, ingestion, and soil to air resuspension	Applicable to soil wash of coarse particles from fines and concentration of contaminants
<ul style="list-style-type: none"> 65% of Maywood soil & 50% of Wayne soil less than 5 pCi/g 	---	Applicable to volume reduction remedial design

Montclair and Glen Ridge, New Jersey
Radium Contaminated NPL Sites.

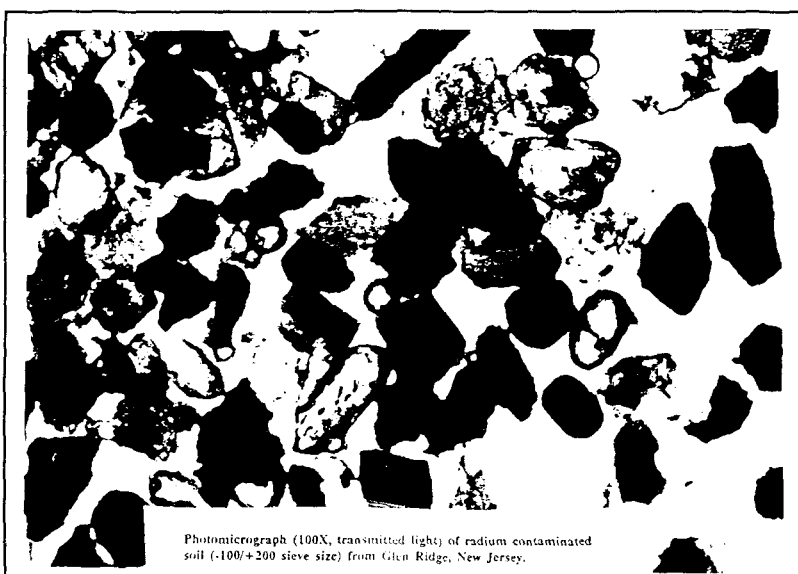
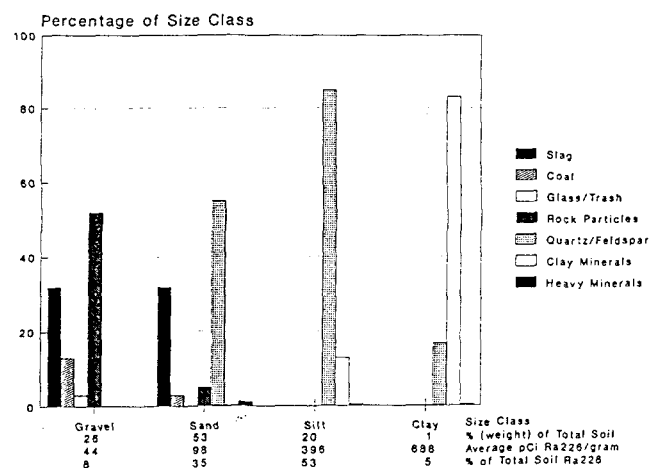


Sieve No.	Size (mm)	Soil Size	Sizing Method	Separation Method	Analytical Methods
4	25.00 12.50 4.75	Gravel	Gilson Mechanical Screener		Gamma Spectroscopy Alpha Spectroscopy Magnetic Properties
10 16 30 60 100 140 200	2.00 1.18 .30 .25 .15 .105 .075	Sand	Brinkman Vibrator Screener	Bromofom and Tetrabromoethane Sink Float Method (heavy mineral concentration)	Gamma Spectroscopy Alpha Spectroscopy Petrographic Microscopy Chemistry Magnetic Properties
270 400	.050 .039 .015 .005 .002	Silt	Sedimentation	Heavy Liquid Linear Density Method (high activity separation)	Gamma Spectroscopy Alpha Spectroscopy X-Ray Diffraction Scanning/Transmission Electron Microscope w/X-Ray Analyzer
	.0005 -.0005	Clay	Centrifugation		

Laboratory Methods for Characterization of Radium Contaminated Soils



Mineral and Material Composition of Montclair Soil

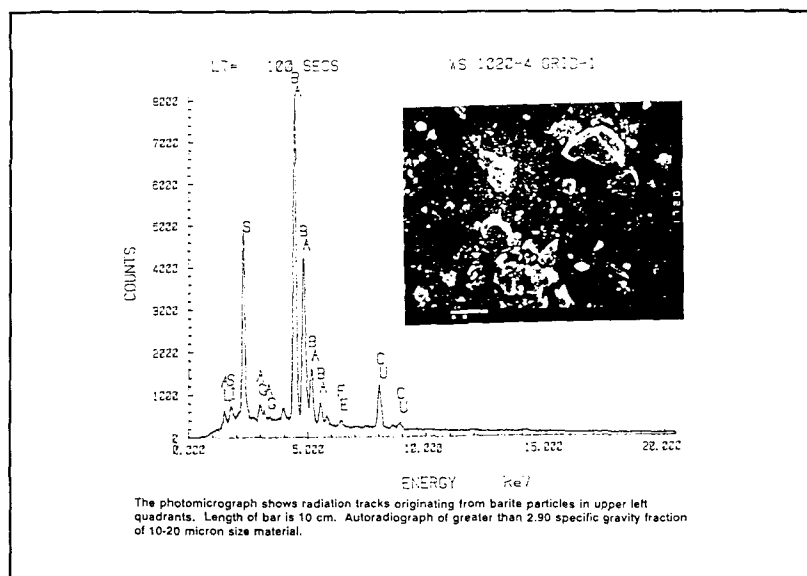


Photomicrograph (100X, transmitted light) of radium contaminated soil (-100/+200 sieve size) from Glen Ridge, New Jersey.

MINERAL COMPOSITION AND RADIUM 226 ACTIVITY OF SILT-SIZE (-45 MICRON +2 MICRON) SOIL FROM GLEN RIDGE SITE. ANALYSIS BY PNL.

Wt%	DENSITY	% FRACTION	Ra-226 ACTIVITY	Ra-226 CONTENT	% Ra	MINERAL COMPOSITION ^{1,2}
GLEN RIDGE 20-45 MICRON SIZE						
7.2	Light 2.10 - 2.35	29.32	2,670 pCi/g	766 pCi	30.84	Major: AS, O Minor: M1, K, M, F
	Medium 2.35 - 2.71	48.26	1,400 pCi/g	676 pCi	27.30	Major: Q, L, K, F, C, M Minor: AS, B, H
	Heavy > 2.71	22.52	4,590 pCi/g	1,034 pCi	41.76	Major: B, H, M, O Minor: K, M1, F, C
GLEN RIDGE 10-20 MICRON SIZE						
11.7	Light 2.10 - 2.25	32.30	1,640 pCi/g	530 pCi	25.21	Major: AS, O, M1 Minor: K, H
	Medium 2.25 - 2.71	55.89	1,040 pCi/g	579 pCi	27.55	Major: Q, M1, K, F, C Minor: M, B, H, AS
	Heavy > 2.71	12.01	8,270 pCi/g	993 pCi	47.24	Major: B, H, M Minor: Q, M1, K, F, C
GLEN RIDGE 2-10 MICRON SIZE						
3.6	Light 2.10 - 2.27	31.68	2,010 pCi/g	637 pCi	25.82	Major: AS, O Minor: M1, K, M, H
	Medium 2.27 - 2.62	45.01	1,450 pCi/g	653 pCi	26.47	Major: AS, O, K, M1 F, M, C Minor: H, B
	Heavy > 2.62	23.31	5,050 pCi/g	1,370 pCi	47.71	Major: B, H, M Minor: Q, M1, F, C

Notes: 1. Mineral composition based on x-ray diffraction (XRD) analysis linear density gradient bands and x-ray fluorescence (XRF) analysis of amorphous materials.
2. Amorphous Silica = AS; Quartz = Q; Mica/illite = M1; Kaolinite = K; Feldspar = F; Mullite = M; Barite (Radium-bearing) = B; Cristobalite = C; Humate = H.



TYPES OF RADIUM CONTAMINANTS AT MONTCLAIR SITE

15% Natural Uranium Minerals - Carnotite, Uraninite, and minor others in medium sand to coarse silt size

85% Anthropogenic Radium Materials

50 Radiobarite - medium sand to fine silt size

23 Amorphous Silica - silt to clay size

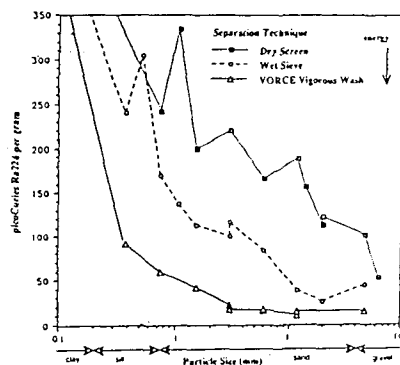
2 Uraninite in Coal Ash - all sizes

4 Furnace Fired Slag/Cinders - gravel and coarse sand

6 Adsorbed on Illite and other materials - silt to fine clay size

Result: Vigorous water wash/wet sieving laboratory scale tests reduced 30-40% of Montclair and Glen Ridge soil to a target level of 12 - 15 pCi/g (Ra-226). The wash water can be recycled.

Activity Versus Grain Size



Summary Soil Characterization Protocol Additions to RI/FS Process

- Identifies the physical form and mineral/material composition of radioactive contaminants and activity levels on the various size fractions.
- Data applicable to prediction of retention or transport of contaminant and impact on groundwater.
- Provides explicit site specific data to key parameters in risk assessment evaluations.
- Provides data to evaluate feasibility of Volume Reduction technologies.

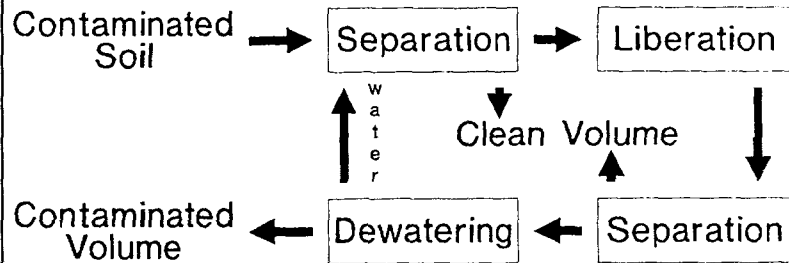
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VORCE (Volume Reduction/Chemical Extraction) PROGRAM

**Mr. Mike Eagle
U.S. Environmental Protection Agency
Washington, D.C.**

The EPA Office of Radiation Programs (ORP) developed the VORCE (Volume Reduction/Chemical Extraction) Program to conduct treatability studies for the volume reduction of Superfund soils contaminated with radionuclides. The VORCE Program has developed a laboratory screening process (including an innovative soil characterization protocol), a bench-scale testing process, and a pilot plant. The pilot soil washer is currently being tested to reduce the volume of radioactive soils at two Superfund sites in New Jersey (Montclair and Glen Ridge). The pilot plant completed the first round of testing with soil from the sites. The result was a 30% volume reduction of 9 picoCurie per gram soil, with the clean portion at 6 picoCurie per gram. The pilot plant also achieved a steady-state operation for 4 hours at the rate of almost 2 tons per hour. Presently, the plant is being optimized in preparation for the second round of testing.

GENERAL FLOW DIAGRAM



TIER 2, BENCH-SCALE TESTING

◆ Particle Liberation Unit Operations

- detach clean particles from contaminated particles
- washing
- scrubbing
- attrition
- crushing and grinding

◆ Particle Separation Unit Operations

- divide mixture of soil particles into two or more volumes
- sieving
- wet classification
- density separation
- magnetic separation
- flotation

◆ Dewatering

- remove water from contaminated fraction of soil (fines)
- centrifugation (future)
- gravity sedimentation
- evaporation (future)

VORCE PROGRAM FOUR TIERS OF TREATABILITY STUDY

◆ Soil Characterization

- Designed to quickly and inexpensively determine if volume reduction is feasible.

◆ Bench-scale Testing

- Designed to verify whether a volume reduction technology can meet the performance goals for the site.

◆ Process Development Unit (PDU)

- Developed to demonstrate volume reduction on-site at a small-scale (150 lbs/hr).

◆ Pilot Plant

- Designed to provide detailed cost, design, and performance data.

TABLE PARTICLE LIBERATION TECHNIQUES

Technique	Washing	Scrubbing	Attrition	Crushing	Surface De-Bonding
Basic Principles	water action	particle/particle action	vigorous particle/particle action	size reduction	surfactant action
General Equipment	trommel, washer, screw classifier	trommel, screw classifier	trommel, mill		trommel, mill
Lab Test Equipment	stirring units, trommel, elutriation column	trommel	trommel		trommel

TABLE 2: PARTICLE SEPARATION TECHNIQUES

Technique	Sizing	Settling Velocity	Specific Gravity	Magnetic Properties	Flotation
Also Called	screening	classification	gravity separation	magnetic	flotation
Basic Principle	various diameter openings	faster vs. slower settling grains	differences in density, size, shape, and weight of grains	magnetic susceptibility	suspend fines by air agitation, add promoter/collector agents, skim oil froth
Major Advantage	inexpensive	continuous processing, long history, reliable, inexpensive	economical, simple to implement, long history	simple to implement	very effective for some grain sizes
Major Disadvantage	screens can plug, fine screens are fragile, dry screens produce dust	difficulty with clayey, sandy, and humus soils	ineffective for fines	high operating costs	contaminant must be small fraction of total volume
General Equipment	screens, sieves	mechanical, non-mechanical, hydraulic classifiers	jigs, shaking tables, troughs, sluices	magnetic separators	flotation machines
Lab Test Equipment	vacuum sieve/screen, trommel screen	elutriation columns	jig, shaking table	lab magnets	

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TREATMENT OF RADIOACTIVE COMPOUNDS IN WATER

Mr. Thomas J. Sorg
U.S. Environmental Protection Agency
Cincinnati, Ohio

Currently, the EPA has maximum contaminant levels (MCLs) for only two specific radionuclides in drinking water, radium-226 and radium-228. On July 18, 1991, the Agency proposed revisions to the radionuclides in drinking water regulations to change the MCLs for radium and to add MCLs for uranium and radon-222. All of these radionuclides occur naturally and are frequently found in drinking water sources, primarily groundwaters.

Although limits have not been established for other specific radioactive elements in drinking water, the Agency has limits for a variety of other natural and man-made radionuclides under a group heading listed as gross alpha emitters and beta and photon emitters. Included under the category of alpha emitters, in addition to radium-226, uranium and radon are isotopes of bismuth, polonium, thorium, and plutonium, most of which are naturally occurring. Under the proposed revised regulations, the gross alpha in drinking water cannot exceed 15 pCi/L, excluding the contribution of radium-226, uranium, and radon-222.

- The MCL for gross beta and photon emitters is 4 mrem ede/yr (excluding the contribution of radium-228). The regulation states that gross beta emitters in drinking water cannot produce a radiation dose of more than 4 mrem per year to the total body or to an individual internal organ. The majority of beta emitters are man-made radioactive elements and include tritium and isotopes of carbon, cobalt, strontium, cesium, barium, and iodine. These radionuclides are not normally found in natural drinking water sources.

By law, the EPA must list the Best Available Technology (BAT) for each MCL established. Both current and proposed BAT for radium-226 and radium-228 are ion exchange, lime softening, and reverse osmosis. The BAT proposed for uranium is coagulation/filtration, ion exchange, lime softening, and reverse osmosis. Although granular activated carbon (GAC) has been shown to remove significant amounts of radon-222, only aeration has been proposed for BAT. GAC was not listed because of the "long empty bed contact time" which was considered to be impractical for large water utilities. However, GAC has been demonstrated to be effective for application on small systems and, therefore, would be practical for site contamination problems.

Because the MCL's for alpha and beta emitters apply to groups of radioactive contaminants, selecting one technology for all is not easily done. For alpha emitters, reverse osmosis was proposed for BAT because it provides the highest removal efficiencies for the most common alpha emitters. For beta emitters, ion exchange (cation and anion exchange) and reverse osmosis were proposed for BAT. The selection of cation exchange, anion exchange, or mixed bed treatment depends on the specific contaminants found in the contaminated water. Cation exchange has been found to be effective for isotopes of barium, cadmium, cesium, lanthanum, and strontium. Anion exchange resins have inhibited high removal for niobium, tungsten, zirconium, and yttrium. If the contaminated water contains both cations and anions, mixed bed treatment or reverse osmosis would be required.

DRINKING WATER REGULATIONS

(RADIONUCLIDES)

**MAXIMUM CONTAMINANT LEVEL GOAL
(MCLG)**

**"0" CONCENTRATION FOR ALL
RADIONUCLIDES**

**DRINKING WATER REGULATIONS
(RADIONUCLIDES)
CURRENT AND PROPOSED MCL'S**

Radionuclide	Current Limit	Proposed Limit (July 1991)
--------------	---------------	-------------------------------

Combined Ra-226 and Ra-228	5 pCi/L	--
Ra-226	--	20 pCi/L
Ra-228	--	20 pCi/L
Rn-222	--	300 pCi/L
U (Total)	--	20 pCi/L (30 µg/L)

**DRINKING WATER REGULATIONS
(RADIONUCLIDES)
CURRENT AND PROPOSED MCL'S**

Radionuclide	Current	Proposed (July, 1991)
Gross Alpha	15 pCi/L (including Ra-226, but not Rn nor U)	15 pCi/L (excluding Ra-226, U, and Rn-222)
Beta particle and photon emitters (man-made radio- nuclides)	4 m rem/year (dose to body or any internal organ)	4 m rem/year (does to body or any internal organ)

RADIONUCLIDES

CHEMICAL FORM IN WATER

Radium	Cation - Ra^{+2}
Rn (Gas)	Gas - Rn^0
Uranium	<p>pH ≤ 2.5 Cation - UO_2^+</p> <p>pH 2.5-7 Neutral - $UO_2(CO_3)^0$</p> <p>pH 7-10 Anion - $UO_2(CO_3)_2^{-2}$</p> <p>- $UO_2(CO_3)_3^{-4}$</p>

RADIONUCLIDES

ALPHA EMITTERS

BETA & PROTON EMITTERS

Bismuth
 Polonium
 Thorium
Plutonium
 Radium-226
 Uranium
 Radon

Tritium
 Carbon
 Cobalt
 Strontium
 Cesium
 Barium
Iodine
 Radium-228

BEST AVAILABLE TECHNOLOGY SDWA

Radionuclide(s)	BAT
Ra-226/Ra-228	Cation Exchange Lime Softening Reverse Osmosis
Rn-222	Aeration
U	Coagulation/Filtration Ion Exchange (Anion/Cation) Lime Softening Reverse Osmosis
Alpha emitters	Reverse Osmosis
Beta and photon emitters	Ion Exchange Reverse Osmosis

REMOVALS - PERCENT

Contami- nant	Ion Exchange	Lime Softening	Coagulation Filtration	Reverse Osmosis	Aeration
Radium	65-97	75-95	--	87-98	--
Uranium	65-99	85-99	80-95	98-99	--
Radon	--	--	--	--	up to 99
Beta Emitters					
Cs-137	95-99	--	90-99	--	--
I -131	--	--	90-99	--	--
Sr- 89	95-99	--	90-99	--	--

TREATMENT SELECTION CRITERIA

- ~ PERCENT REMOVAL REQUIREMENTS
- ~ COST OF TREATMENT
- ~ TYPE, QUANTITY, AND COST OF DISPOSAL OF WASTE PRODUCTS

POLYMER SOLIDIFICATION OF LOW-LEVEL RADIOACTIVE, HAZARDOUS, AND MIXED WASTE

**Mr. Paul D. Kalb
Brookhaven National Laboratory
Upton, New York**

The Department of Energy (DOE) has generated large volumes of low-level radioactive (LLW), hazardous, and mixed waste as a result of its research and defense activities over the last 50 years. These include a broad range of waste types (such as evaporator concentrate salts, sludges, dry solids, incinerator ash, and ion exchange resins) encompassing diverse chemical and physical properties. The most common practice at DOE and commercial facilities is to solidify waste using hydraulic cement such as portland cement. Cement solidification processes are limited, however, because cement hardens by means of a chemical hydration reaction that is susceptible to interference with the waste. These interactions can limit the types and amount of waste that can be solidified and can lead to waste form degradation under anticipated disposal conditions.

BNL has developed two thermoplastic processes for improved solidification of radioactive, hazardous, and mixed wastes. Both the polyethylene and modified sulfur cement encapsulation processes result in durable waste forms that meet current Nuclear Regulatory Commission and Environmental Protection Agency regulatory criteria and provide significant improvements over conventional solidification systems. For example, the polyethylene process can encapsulate up to 70 wt% mixed waste nitrate salt, compared with a maximum of about 20 wt% for the best hydraulic cement formulation. Modified sulfur cement waste forms containing as much as 43 wt% mixed waste incinerator fly ash have been formulated, whereas the maximum quantity of this waste in hydraulic cement is 16 wt%. Data for waste form testing are presented including compressive strength, water immersion testing, freeze-thaw cycling, radioactive and hazardous constituent leachability, biodegradation, and radiation stability. These data indicate that waste form performance far exceeds minimum regulatory standards. Both processes have completed bench-scale development. Production-scale feasibility has been established for the polyethylene process using process equipment with a maximum output of 900 kg/hr (2000 lb/hr). A full-scale technology demonstration is planned in which surrogate wastes similar to actual waste in chemical and physical composition will be processed under plant conditions.

*Polymer Solidification
of Low-Level Radioactive, Hazardous,
and Mixed Wastes*

Paul D. Kalb

*Presented at the EPA/DOE
Technology Transfer Seminar Series
on Radioactive Site Remediation*

*Waste Management Research & Development Group
Radiological Sciences Division
Department of Nuclear Energy
Brookhaven National Laboratory*

Overview

- ☛ *Introduction*
- ☛ *Background*
- ☛ *Polyethylene Encapsulation Process*
- ☛ *Modified Sulfur Cement Encapsulation Process*
- ☛ *Summary/Conclusions*

Program Support

*In FY 1992, the DOE Office of Technology Development
(DOE OTD) is supporting three programs in this area:*

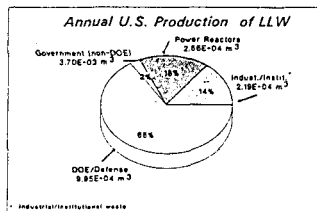
- ☛ *Polymer Solidification*
 - *Technology Demonstration and Transfer*
 - *Coordination of national efforts to develop polymer solidification technology*
- ☛ *Polymer Solidification Support for Rocky Flats Plant*
- ☛ *Polyethylene Encapsulation of Single Shell Tank Low-Level Wastes (at Westinghouse Hanford)*

Background

☛ DOE is a major generator of hazardous and mixed wastes

☛ Many are "problem wastes":
- difficult to solidify
- poor quality waste forms

☛ BNL is investigating new and innovative techniques for improved encapsulation of mixed wastes



Objectives

To develop materials and processes that:

- ☛ have potential to encapsulate problem mixed wastes
- ☛ minimize potential for release of toxic materials
- ☛ comply with applicable regulatory requirements
- ☛ result in durable waste forms
- ☛ are simple to operate, easy to maintain and economical

MATERIALS USED AT BNL FOR THE IMMOBILIZATION OF RADIOACTIVE AND MIXED WASTE STREAMS

CEMENTS

Portland
Masonry cement
Cement-sodium silicate
Pozzolanic
High alumina
Portland blast furnace slag
Latex modified cement
Polymer modified gypsum
Polymer-impregnated concrete

THERMOPLASTIC

Bitumen
Polystyrene
Polymethylmethacrylates
Polyethylene
Sulfur cement

THERMOSETTING

Vinyl-ester styrene
Polyester styrene
Water extendable polyester
Epoxy resins

BNL EXPERIENCE WITH ENCAPSULATION/SOLIDIFICATION OF RADIOACTIVE AND MIXED WASTE STREAMS

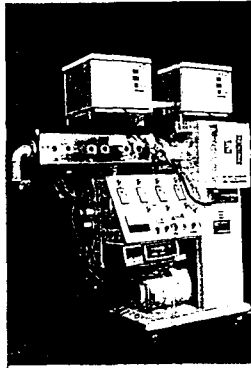
Aqueous and Dried Nitrate Salt Waste
 Chrome Sludge from Y-12
 Incinerator Ash
 Vacuum Pump Oils
 Mixed Organic Solvents
 Sodium Sulfate Evaporator Concentrates
 Boric Acid Evaporator Concentrates
 Mixed Bed Spent Ion-exchange Resins
 Mixed Waste Contaminated Soils
 Aqueous Tritiated Waste

Polyethylene Encapsulation Process Technology Description

- ☛ *Encapsulation of LLW, hazardous, and mixed wastes in polyethylene, an inert thermoplastic material.*
- ☛ *Contaminants are immobilized in stable, monolithic solid waste forms with high solidification efficiencies and excellent performance in disposal environment*
- ☛ *Application of single-screw technology*
- ☛ *Developed at BNL using bench-scale extruder (16 kg/hr); Feasibility demonstrated at production-scale (900 kg/hr)*
- ☛ *Technology Demonstration at BNL planned*

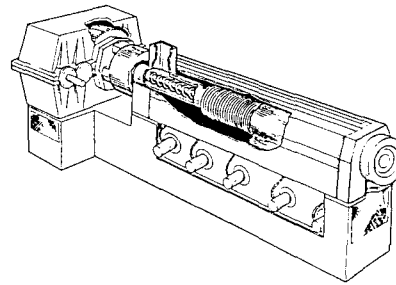
Comparison of Polyethylene and Cement for Waste Encapsulation

Polyethylene	Cement
<i>Solidification assured</i>	<i>Chemical hydration reaction required</i>
<i>Compatible with wide range of waste types</i>	<i>Chemical interactions can limit waste compatibility</i>
<i>High solidification efficiency (more waste/drum)</i>	<i>Solidification efficiency poor (less waste/drum)</i>
<i>Lower product density (reduced shipping & disposal costs)</i>	<i>Higher product density (increased shipping & disposal costs)</i>

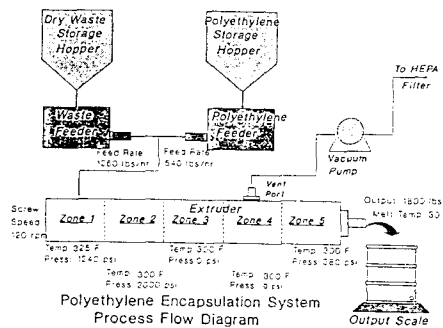


Bench-scale polyethylene extruder

Polyethylene Encapsulation Process Technology Demonstration



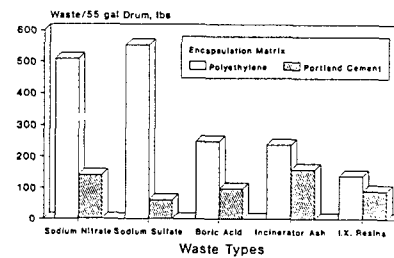
Production-scale (114 mm) extruder with output capacity of 900 kg/hr will be used to demonstrate processing of surrogate nitrate waste at BNL



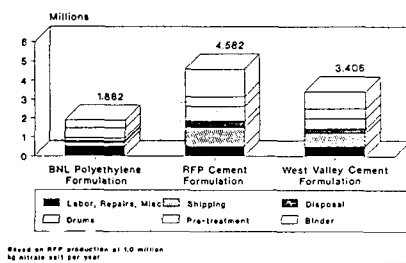


Pilot-scale polyethylene waste form produced during scale-up feasibility test containing 60 wt% sodium nitrate

Polyethylene vs. Portland Cement Maximum Waste/Drum



Economic Analysis for Rocky Flats Plant Nitrate Salt Encapsulation



Waste Form Performance Testing

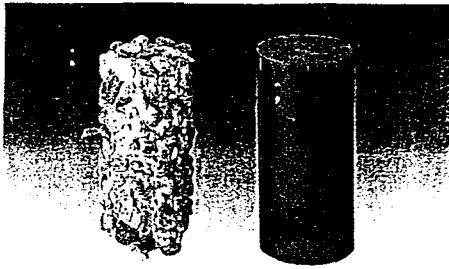
<i>NRC Test Criteria</i>	<i>Test Method</i>
<i>Compressive Strength</i>	<i>ASTM D-695, C-39</i>
<i>Water Immersion</i>	<i>90 day</i>
<i>Thermal Cycling</i>	<i>ASTM B-553</i>
<i>Radionuclide Leachability</i>	<i>ANS 16.1</i>
<i>Biodegradation</i>	<i>ASTM G-21, G-22</i>
<i>Radiation Stability</i>	<i>10⁵ rad</i>
<i>EPA Test Criteria</i>	<i>Test Method</i>
<i>Toxic Leachability</i>	<i>Toxicity Characteristic Leaching Procedure (TCLP)</i>
<i>DOT Test Criteria</i>	<i>Test Method</i>
<i>Oxidizers</i>	<i>Solid Oxidizer Test</i>

Modified Sulfur Cement

- ☛ Thermoplastic material developed by U.S. Bureau of Mines to utilize by-product sulfur (> 5 million tons/year)
- ☛ Commercially manufactured and available under license from USBM (\$0.17/lb)
- ☛ Stable, resistant to extremely harsh environments, forms strong, durable waste forms

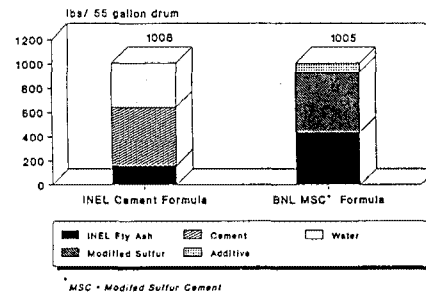
Advantages Over Hydraulic Cement

- ☛ Chemical reaction not required for set
- ☛ Full strength attained within hours rather than weeks
- ☛ Greater compressive and tensile strengths are possible
- ☛ Resistant to attack by most corrosive acids and salts



Portland cement concrete Sulphur concrete

Comparison of INEL and BNL Formulations for Encapsulation of INEL Fly Ash



Summary /Conclusions

- ☛ Polyethylene and Modified Sulfur Cement have successfully completed bench-scale development and will be demonstrated at full-scale
- ☛ Compared with conventional hydraulic cement, these thermoplastic binders provide:
 - improved compatibility with wide range of wastes,
 - improved waste loadings (more waste/drum) that result in lower overall costs,
 - improved waste form performance.

IN SITU VITRIFICATION OF SOILS CONTAMINATED WITH RADIOACTIVE AND MIXED WASTES

**Mr. James L. Buelt and Mr. Leo Thompson
Battelle, Pacific Northwest Laboratory
Richland, Washington**

In Site Vitrification (ISV) is a patented thermal treatment process for the in-place destruction and immobilization of contaminants in soil. ISV melts contaminated soil by introducing an electrical current among four graphite electrodes, achieving temperatures of about 1600 degrees centigrade. The molten soil zone grows outward and downward during processing, and consolidates soil and compressible materials into a voidless mass. Organic materials are destroyed and/or removed by the process. Most of the radionuclides and heavy metals are retained within the molten soil which, when allowed to cool, forms a relatively nonleachable glass and crystalline material similar to obsidian or basalt. Organic and particulate contaminants that are evolved with the gaseous effluents are captured in a hood overlying the site and directed to an off gas system for treatment. The subsidence region that forms from the consolidation of soil particles and compressible wastes in the soil is backfilled with clean fill after processing.

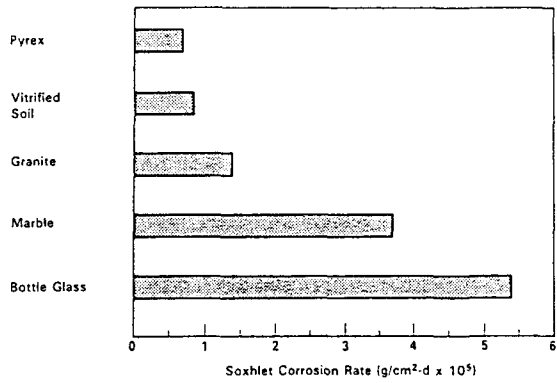
ISV, which was conceived in 1980 and patented in 1983, has been tested and demonstrated under a variety of conditions for several types of contaminants. It has been demonstrated at two past practice units at the Department of Energy's (DOE's) Hanford, Washington reservation. It has also been tested on a variety of soils from around the country, including tests at the Idaho National Engineering Laboratory (INEL) and Oak Ridge National Laboratory (ORNL). Radionuclide, heavy metal, and organic contaminants (including PCBs) have been successfully vitrified or destroyed in these tests and demonstrations. As a result of this testing and demonstration program, established capabilities and limitations of the ISV technology have been identified, along with technical and regulatory issues that need to be resolved for successful implementation of the technology at DOE sites. The ISV Integrated Program was created by DOE's Office of Technology Development to help resolve these issues and promote deployment of the technology in the field.

The near term priority issues directed for resolution include the following:

- Develop methods that accurately predict, measure, and achieve significantly greater melt depth and control of the melt shape. Presently, the ISV process has been demonstrated to a depth of 5 m. Significantly greater depths (i.e., up to 10 m) are needed for broad implementation.
- Improve the understanding of and empirically verify volatile organic contaminant (VOC) behavior. Implementation of ISV would be enhanced if the behavior of VOCs, such as carbon tetrachloride or trichloroethylene that may coexist with other contaminants at some sites, were better defined.
- Determine the potential for transient gas release events while vitrifying relatively low permeability soils. Operating limits are being better defined to ensure containment and treatment of off gases during processing.
- Resolve secondary waste generation and handling concerns as they relate to the volatilization of ^{137}Cs from contaminated soils with unusually high Cs concentrations (multiple curies per setting). Cesium recycle or volatility suppression techniques will be developed.

ISV Glass Durability

Soxhlet Leach Rate $< 1 \times 10^{-5} \text{ g/cm}^2/\text{day}$

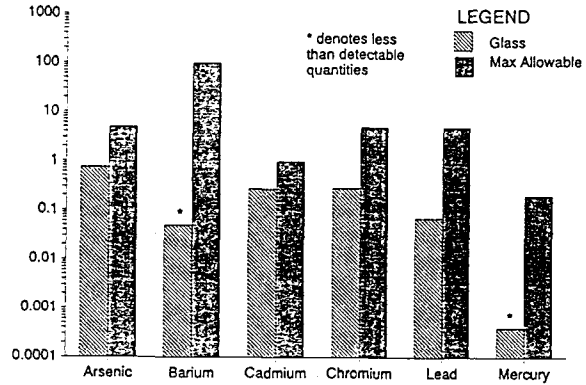


MCC-1 Test
Weathering
Fracture

$< 2 \times 10^{-7} \text{ g Pu/cm}^2/\text{day}$
 $< 1 \text{ mm}/10,000 \text{ years}$
Conchoidal

TCLP RESULTS OF VITRIFIED PRODUCT

Concentration, mg/L



Strength Comparison

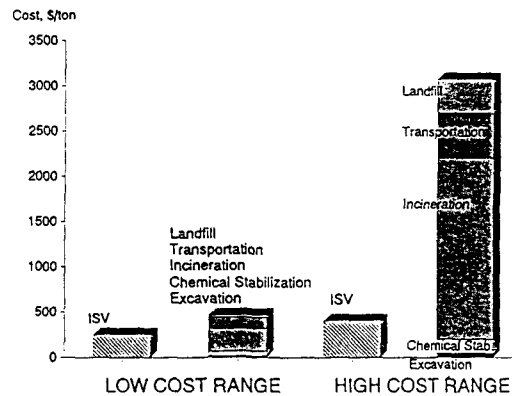
	Concrete	Vitrified Soil
Compressive Strength (psi)	3,000 to 8,000	35,000 to 45,000
Splitting Tensile Strength (psi)	400 to 600	4,000 to 8,000

RESIDUAL WASTE FORM QUALITIES

- No organics present
- Incorporated/immobilized inorganics
- Excellent mechanical properties
- Unaffected by weathering (freeze/thaw, wet/dry)
- Superior resistance to chemical leaching
- Acceptable biotoxicity

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Laboratory

ISV COST COMPARISONS WITH ALTERNATIVES



CURRENT ISV APPLICABILITY

- Soil Properties
 - All Textures - Sand, Silt, and Clay; Sludge; and Sediment (Low permeability soils, $<10^{-3}$ cm/s, require special monitoring or testing)
 - Broad Chemical Compositions (with a minimum of 1.4 wt% of Na or K and 30 wt% silica)
 - Depths up to 5 meters
 - Varying Moisture Content up to 50 wt% (exclusive of permeable aquifers)

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CURRENT ISV APPLICABILITY

- Contaminants
 - Transuranics (up to established criticality limits of ~30 kg Pu per setting)
 - Fission Products (up to 1000 Ci of Cs per setting)
 - Inorganic Chemicals (volatiles, such as chlorides and sulfates, removed and treated in off gas)
 - Organic Contaminants and Materials up to 7 wt% (limited field experience)

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CURRENT ISV APPLICABILITY (continued)

- Soil Inclusions
 - Metals up to 25 wt% (with Electrode Feeding)
 - Concrete, Rubble, Rock, and Debris up to 50 wt% (Mixed with Soil)
 - Solid Combustibles up to 7 wt% (Limited Field Experience)
 - Not Ready for Sealed Containers

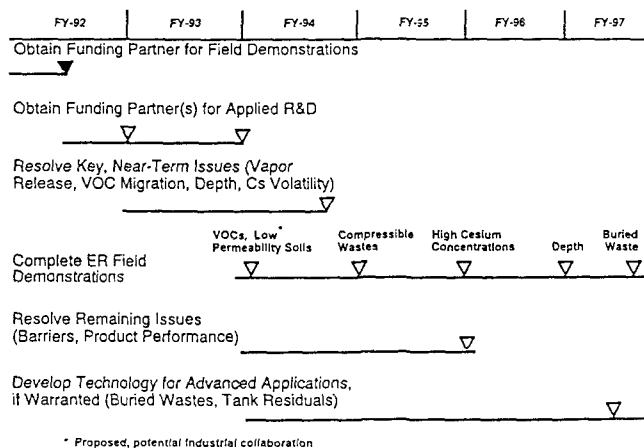
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NEAR TERM PRIORITIES

- Increase Achievable Depth from ~5 m to Greater Than 10 m.
- Develop Cesium Recycle/Suppression Techniques
- Improve Understanding of VOC Behavior
- Better Define Operational Constraints in Low Permeability Soils
- Develop Technique for Subsurface Vitrified Barriers

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IN SITU VITRIFICATION INTEGRATED PROGRAM SCHEDULE



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DECONTAMINATION OF CONTAMINATED BUILDINGS

Mr. Jerry M. Hyde
U.S. Department of Energy
Washington, D.C.

The decontamination of contaminated buildings may pose risks to both human and environmental health. The objectives of decontamination activities are: to minimize the potential contamination to workers, the general public, and the environment; to generate the least amount of secondary waste possible; and to maximize the quantity of building materials that can be recycled after they are decontaminated.

The deactivation and decommissioning of a building is the construction process in reverse. The systems and components that are installed last in the construction process (ventilation systems, insulation, and electrical wiring) are the first items to be decontaminated. The process of selecting methods for these activities should be driven by the recycle and the disposal decisions.

The activities to deactivate and decommission a building can be divided into seven categories:

- characterization
- decontamination
- dismantlement
- material disposition
- robotics/automation/artificial intelligence
- regulatory compliance
- planning

Today, each site has its own list of accepted methods for these activities.

Characterization of contaminated buildings begins with the identification and mapping of the contaminants present within the building.

Decontamination activities reduce radiation levels or remove radioactive contamination in or on structures, equipment, and materials. The primary emphasis of decontamination today is pollution prevention.

Dismantlement of contaminated buildings attempts to contain the contamination, and at the same time, protect the workers.

Material disposition activities address the issues of release criteria for the reuse of construction materials and the waste form criteria for storage and disposal.

All the other groups are supported by **robotics, automation, and artificial intelligence** activities. The objective here is to protect the workers.

Regulatory compliance activities attempt to establish standards for Below Regulatory Concern for waste disposal and De Minimus for material release.

Recently, a group of experts met to identify the technology needs within the seven categories. Based on these needs, technology development activities have been identified.

Using these methods in the future, the decontamination of a contaminated building will be safer, faster, and less costly, and will produce less secondary waste than the accepted group of activities selected today.

Decontamination Methods for Contaminated Buildings

Jerry Hyde
U.S. Department of Energy
Office of Environmental Restoration
and Waste Management

General Approach

- Building selected for decommissioning
- What it means to decontaminate a building
- How we would decontaminate a building with today's methodology
 - By activity area
 - Total package
- Needs identified during decontamination and decommissioning workshop
- How we would decontaminate a building in the future
 - By activity area
 - Total package

What It Means To Decontaminate A Building

- Decontamination and Decommissioning activity areas
 - Characterization
 - Type of contaminants
 - Levels of contaminants
 - Decontamination
 - Surface contamination
 - Bulk contamination
 - Dismantlement
 - Green field condition
 - Material deposition
 - Recycle and reuse (De Minimus standards)
 - Disposal (Below Regulatory Concern standards)
 - Regulatory compliance
 - Robotics, automation, and artificial intelligence

Characterization of Buildings, Equipment, and Waste

- Chemical analysis techniques
- Instrumentation
 - Field instruments
 - Laboratory instruments
 - Monitors and sensors

Decontamination of Buildings, Equipment, and Waste

- In Situ Decontamination
- Methodologies for metal bulk and surfaces
- Methodologies for surface layer removal
- Reagent recycle technology
- Secondary waste minimization

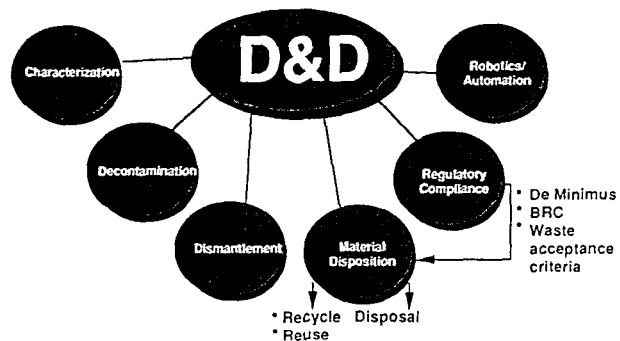
Dismantlement of Buildings and Equipment

- *Contamination containment*
- Special problems associated with high radiation areas
- Worker protection

Material Disposition

- Recycle and release for reuse of valuable materials
- Storage
- Waste disposal

Recycle Projects Support Decontamination and Decommissioning



Regulatory Compliance

- Below Regulatory Concern and De Minimus levels for release
- Cost
- End point scenarios
- Environmental statutory requirements
- Mixed wastes
- Public perception
- Risk assessment

Robotics, Automation, and Artificial Intelligence

- Characterization
- Decontamination
- Dismantlement
- Materials information management
- Packaging

Available Characterization Methods

- Field deployable monitors
 - Alpha, Beta, Gamma counters
 - Infrared analyzers
 - Photoionization and ionization flame detectors
 - Measurements include radiation levels, total organic exposure
- Laboratory analysis
 - Gamma spectroscopy
 - Inductively coupled mass spectroscopy
 - X-ray fluorescence
 - Samples include bulk materials, surface swipes, air filters, traps

Available Decontamination Methods

- Manual methods
 - Scraping, scrubbing, wiping
- Abrasive methods
 - High pressure water/steam
 - Grit blasting
- Chemical methods
 - Foams, gels, pastes
 - Hard chemical (greater than 5 percent) solutions
- Electrochemical methods
 - Electrorefining

Available Dismantlement Methods

- Concrete demolition
 - Headache ball
 - Jack hammers
- Metal/pipe cutting
 - Abrasive cut off saws
 - Plasma torches
- Asbestos removal
 - Automatic cutters and knives
 - Wetting agents
- Worker protection
 - Area radiation monitors
 - Robotics equipment

Available Material Disposition Methods

- Treatment
- Packaging
- Storage
- Disposal
 - Burial
- Recycle versus disposal costs
- Treatment for purposes of volume reduction

Existing Methodology for Decontaminating Buildings

- Field deployable instruments to measure radiation level and total organic exposure
- Samples sent to mobile and permanent laboratories
- High pressure water for concrete surfaces
- Headache ball for walls and ceilings
- Jack hammers for floors
- Abrasive saws for metal/pipe cutting
- Package all wastes and transport for burial

Identified Characterization Needs

- Instrumentation to determine nature, concentration, and extent of contamination before, during, and after decontamination
 - Techniques that are certifiable by regulatory agencies for release of facilities, recycle and reuse of materials, and evaluation of exposure to the public and the environment
- Benefits
 - Reduce worker exposure to radiation and hazardous materials
 - Minimize time lost waiting on analysis
 - Better definition of public and environmental exposure
 - Support to De Minimus and Below Regulatory Concern standards

Identified Decontamination Needs

- Technology to remove radioactive and hazardous substances from concrete surfaces and metal equipment and structures
 - Decontaminate surfaces, equipment, and structures sufficiently to permit release, reuse, recycle, or disposal as Below Regulatory Concern
- Benefits
 - More material can be recycled and reused
 - Reduce radioactive and hazardous waste disposal requirements

Identified Dismantlement Needs

- Choice of technology may be highly site and application specific, is influenced by the types and levels of contamination present, and by the facility size and configuration
 - Will only be feasible through the use of robotics and automation
 - Some available technologies generate large quantities of mixed waste
- Benefits
 - Produces a larger fraction of materials which are recyclable
 - Improves worker protection systems

Identified Material Disposition Needs

- Activities needed to recycle valuable materials and to dispose of materials which cannot be reused cost effectively utilizing methods that protect human health and the environment
 - Need treatment methodologies to support material disposition
- Benefits
 - Establish reasonable health based standards for recycle of materials (De Minimus) and disposal (Below Regulatory Concern) of slightly contaminated materials
 - Cost recovery through the recycle of materials

Characterization Development Activities

- Integrated analysis system for real time analysis of organic and mercury compounds
- Passive monitors for measuring surface alpha contamination
- Portable real time polychlorinated biphenyl sensors
- Surface characterization technologies for monitoring metal and concrete

Decontamination Development Activities

- Concrete decontamination by electro-osmosis
- Electropolishing of irregular shapes
- Gas phase decontamination
- High speed cryogenic pellet decontamination
- In Situ cleaning of pipes and drains
- Laser decontamination with recycle of metals
- Liquid phase decontamination
- Microwave concrete decontamination system

Dismantlement Development Activities

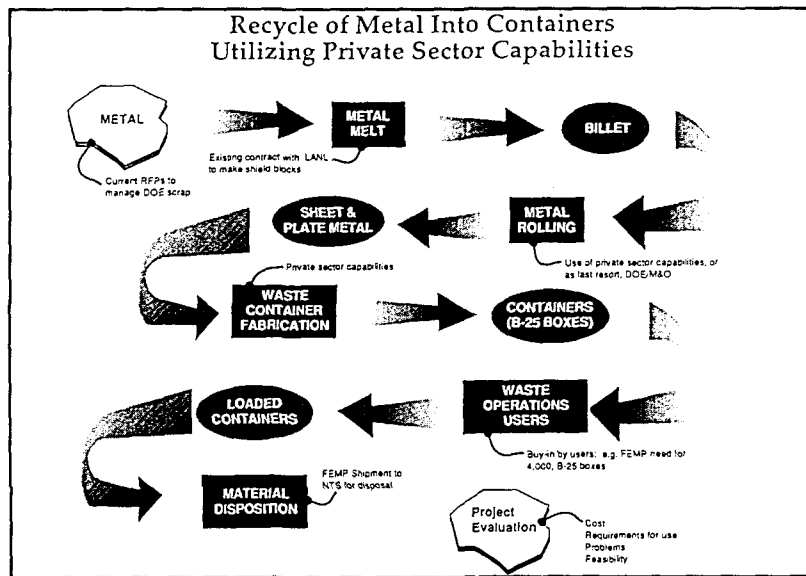
- Cutting and breaking of concrete structures
- High velocity pellet cutting
- Improved portable modular shielding systems

Material Disposition Development Activities

- De Minimus limits and Below Regulatory Concern standards
- System method analysis of decontamination and decommissioning options
- Treatment and recycle of cleaning waters for water and steam decontamination systems

Future Methodology for Decontaminating Buildings

- Real time monitoring of process
- Real time field analysis of all samples
- Microwave scabbling for concrete surfaces
- Laser melting for metal surfaces
- High velocity pellet cutting for walls, ceilings, and floors
- On site concrete rubble recycling
- Package all homogeneous waste and transport for burial



Summary

- Developing technologies to permit the decontamination and decommissioning of excess Department of Energy facilities while minimizing waste generation and exposure of workers, the public, and the environment to hazardous and radioactive materials
- Improved technology must be developed in a timely manner
 - Fernald Plant 7 is scheduled to begin decontamination in 1993
 - Oak Ridge gaseous diffusion plant is scheduled to begin decontamination in 2003
- Technologies will emphasize recycle and reuse of as much material as practical

INCINERATION OF RADIOACTIVE WASTE

**Dr. H.W. "Bud" Arrowsmith
Scientific Ecology Group, Inc.
Oak Ridge, Tennessee**

The incineration of low level radioactive waste in the United States is now making a major contribution to the effort of reducing waste volumes requiring burial and is also improving waste forms. This contribution is primarily being made by the world's largest radioactive waste incinerator, which is housed and operated at the Scientific Ecology Group (SEG) facilities in Oak Ridge, Tennessee. The SEG incinerator is an automated, controlled air incinerator capable of burning waste consisting of 70% plastic, with smaller amounts of paper, cloth, rubber, wood, sludges, and ion exchange resin, at the rate of 1000 pounds per hour. Volume reductions of at least 100:1 are regularly obtained when burning these mixtures. The incinerator was built in Denmark by Envikraft, the off gas system was built in Holland by American Air Filter, and the system was integrated by SEG.

The SEG incinerator consists of a primary chamber, a secondary chamber, and a third burning chamber. Waste charges, averaging two hundred fifty pounds, are charged into the primary chamber through a vertical airlock system every fifteen minutes. The charged waste falls onto a burning pile in the primary chamber, which is operating at an average temperature of 1000 degrees centigrade. Most of the waste is converted by pyrolysis into burnable gases which are then transported to the secondary chamber for burning. In the secondary chamber, excess oxygen is added and the gases are burned at a temperature ranging from 1000-1200 degrees centigrade. After burning, the gases are transported to the third chamber where they are reburned at temperatures ranging from 1000-1300 degrees centigrade. The transit time required for gases to travel through the primary chamber and exit the third chamber is 2 seconds.

Waste from the incinerator includes bottom ash, fly ash, scrubber salt, and boiler ash. Bottom ash is removed from the incinerator using augers, and is then collected at 50 degrees centigrade 12 hours from the time the original waste entered the incinerator. Baghouse dust is collected and treated to reduce the leachability of the heavy metals, which are volatilized in the primary chamber. Scrubber salts are concentrated from the scrubber liquor and dried. The bottom ash, treated fly ash, and dried scrubber salts are all disposed of as radioactive waste.

The incinerator off gas system consists of a boiler to reduce gas temperatures, a baghouse to remove a high percentage of the particulate entrained in the gas stream, a 3 stage filter, including a HEPA filter, a quench tower, and a packed tower scrubber. This off gas system is very efficient in removing the non volatile radioactive nuclides and it efficiently removes the acid gases from the incinerator exhaust. In 1991, the SEG incinerator burned 5.3 million pounds of low level radioactive waste and produced an estimated dose of only 0.027 mr/year to the nearest resident, compared to natural background radiation levels of approximately 150 mr/year.

BENEFITS OF INCINERATION

- * REDUCED WASTE VOLUME REQUIRING BURIAL
- * IMPROVES THE WASTE FORM
- * REDUCES BURIAL GROUND SUBSIDENCE

RADIOACTIVE WASTE MATERIALS THAT ARE INCINERATED

- | | |
|----------------------|----------------|
| * PAPER | * PLASTIC |
| * WOOD | * CLOTH |
| * RUBBER | * CANVAS |
| * FIBERGLASS | * CHARCOAL |
| * ION EXCHANGE RESIN | * SLUDGES |
| * ANIMAL CARCASS | * OILS |
| * OILS | * HEPA FILTERS |

INCINERABLE WASTE PROCESSING

- * RECEIPT
- * WASTE TRACKING IDENTIFICATION
- * SORTING
- * PACKAGING
- * INCINERATION
- * PACKAGE ASH FOR BURIAL

INCINERATOR WASTES

<u>WASTE TYPE</u>	<u>HAZARDOUS CATEGORY</u>
* BOTTOM ASH	SOMETIMES CHARACTERISTIC
* BOILER ASH	ALWAYS CHARACTERISTIC
* FLY ASH	ALWAYS CHARACTERISTIC
* SCRUBBER SALT	NON HAZARDOUS

REDUNDANT INCINERATOR FEATURES

- * DRAFT FANS
- * AIR SUPPLY FANS
- * GAS MONITORS
- * OPACITY DETECTORS
- * HEPA FILTERS
- * NEGATIVE AIR PRESSURE CONTROLLERS
- * EMERGENCY POWER

WASTE CHARGING PERMISSIVES

- * TIME FROM LAST CHARGING
- * OPACITY AFTER BOILER
- * PRIMARY CHAMBER AND SECONDARY CHAMBER
- * WASTE LEVEL IN PRIMARY CHAMBER
- * OXYGEN CONTENT AFTER THIRD CHAMBER\

BENEFICIAL USE OF WASTE ENERGY

- * OPERATE EVAPORATOR FOR SCRUBBER LIQUOR
- * REHEAT STACK GASES
- * PROVIDE ENERGY FOR RESIN DRYING
- * HEAT BUILDINGS

IN SITU STABILIZATION/SOLIDIFICATION WITH CEMENT-BASED GROUTS

**Mr. T. Michael Gilliam
Oak Ridge National Laboratory
Oak Ridge, Tennessee**

The cement-based grout stabilization/solidification (CGSS) systems currently in use are actually derived from work begun in the 1950s with low-level radioactive waste (LLW). CGSS systems have become the most widely used hosts for the immobilization of LLW streams because (1) the cost of the materials is low; (2) the processes are run at low temperature, use standard "off-the-shelf" equipment, and are adaptable to a wide variety of disposal scenarios; (3) the resulting waste forms can be highly resistant to chemical, biological, thermal, and radiation degradation; and (4) high waste loadings are achieved with a minimum waste-volume increase when the waste-host formulas are tailored to the specific waste streams. The positive characteristics of the CGSS products that made them acceptable for disposal of LLW have also proved desirable for disposal of some hazardous wastes. Indeed, the Environmental Protection Agency (EPA) has specified CGSS as the Best Demonstrated Available Technology (BDAT) for selected hazardous wastes (e.g., F006 and K046) or for residuals from other BDATs (e.g., K001 and K022).

In general, the CGSS systems are batch processes where the waste is removed, the materials is processed through the CGSS system, and the product is either placed where the original waste was located or elsewhere. However, in situ (i.e., in place) grouting, involves solidification/stabilization (S/S) or the waste without removal and processing through the CGSS system. There are two general types of in situ S/S processes: (1) those in which the reagents are mixed with the waste using a rotary device such as an auger and (2) those that involve the physical encapsulation of the waste by pressure injecting the reagents into the accessible void spaces around the waste. The EPA has performed several evaluations of this technology under the auspices of its Superfund Innovative Technology Evaluation (SITE) program.

Both batch and in situ processes require laboratory-scale "treatability studies" to establish the matrix design (i.e., the composition of the mix of reagents to be used). These studies must not only address compliance with required performance objectives, such as concentration of the leachate from the Toxicity Characteristic Leaching Procedure (TCLP), but must also determine compatibility with both process and site-specific constraints. This compatibility assessment may require the determination of characteristics such as density, particle size, settling rate, rate of set, compressive strength, viscosity, and bulking factor. In general, these characteristics determine the limitations of a specific in situ process, and the site characteristics and specific performance objectives determine the applicability of the in situ S/S option.

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ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

Dr. Rashalee Levine
Office of Technology Development
U.S. Department of Energy
Washington, D.C.

Bioremediation and biotreatment are key technology components of the mission of the Office of Technology Development (OTD). OTD's overall mission is to: (1) rapidly develop, demonstrate, and transfer needed technology to Defense Programs and the Office of Environmental Restoration and Waste Management (EM); (2) minimize waste generation; and (3) obtain faster, better, cheaper, and safer cleanup and disposal of waste.

The Bioremediation Program of OTD supports DOE's needs for environmental restoration and in-situ cleanup. OTD conducts applied research in the areas of soil/groundwater and waste minimization/processing on the hazardous and mixed (hazardous plus radioactive) wastes generated by DOE over the past half-century. Biotechnology, as part of an interdisciplinary approach to waste stabilization and waste reduction, could have less environmental impact than other methods and could be applied at less cost. Wastes amenable to bioremediation include radioactive materials, heavy metals, organic materials, and other wastes such as nitrates.

In situ Remediation: This sub-program is focused on bioremediation at the contaminated site. Successful *in situ* bioremediation would eliminate the need for soil removal, transportation, off-site treatment, and possible generation of secondary contamination. Projects underway include biosorption of uranium tailings from leachate and groundwater, vapor-phase bioreactors for *in situ* removal of vaporizable organic compounds from vacuum-generated waste streams in contaminated soils, and modeling of subsurface fate and transport of heavy metals and radionuclides during *in situ* bioremediation and nutrient injection.

Biotechnology for Characterization and Post-closure Monitoring: This sub-program is focused on the use of non-invasive real-time biosensors and monitoring systems to identify and track hazardous contaminants. Studies are underway to determine whether microbial and plant systems could be used for bioremediation of contaminated soils with resulting improvement in underground water quality.

Waste Minimization/Waste Processing: This sub-program is focused on reduction of hazardous and mixed waste in on-going DOE industrial processes. An example of this program is a process developed for the biological removal of nitrate from low level rad waste process streams which may be successfully adapted to high level rad waste streams, thus significantly reducing the quantity of waste generated.

DOE sites have many environmental restoration and waste management issues that can be addressed by environmental biotechnology. Five high-priority areas were selected to address DOE's most pressing needs. These areas are consistent and complementary to those identified in EPA's biotechnology plan and integrate with existing DOE integrated programs and demonstrations.

Technologies will be developed for use in full-scale field operations at DOE sites in the short term (less than 5 years). A strategic objective attainable within a 5-year period was developed for each of the five areas.

The five priority areas and the strategic objective of each are:

1. Hydrocarbons: Provide mature technologies for bioremediation of petroleum hydrocarbons in soils (*in situ* and ex situ) within 3 years;
2. Chlorinated solvents: Demonstrate at several sites the use of environmental biotechnology to clean up groundwater and soils contaminated with chlorinated solvents within 5 years;
3. Heavy metals/radionuclides: Perform pilot-scale demonstration of cost-effective concentration/separation for several metals or radionuclides from water within 3 years;

Demonstrate *in situ* techniques in field plots for metals/radionuclides mobilization or immobilization of priority metals within 5 years;

4. Mixed Waste: Provide a full-scale demonstration of biological denitrification of mixed waste within 4 years;
5. Characterization Assessment: Develop and transfer several characterization and assessment technologies to EM within 5 years.

The current climate is good for development and acceptance of environmental biotechnology, whether it is for *in situ* bioremediation, ex situ bioremediation when uniquely required, or biocharacterization to demonstrate efficacy of cleanup or control *in situ* activities. What is needed is conduct of controlled efforts that develop the data demonstrating the utility of these techniques at field scale, real world sites.

REMOVAL OF CONTAMINANTS FROM SOILS BY ELECTROKINETICS

Dr. Yalcin B. Acar
Louisiana State University
Baton Rouge, Louisiana

Bench-scale studies conducted at Louisiana State University and other institutions demonstrate that ionic species of heavy metals, selected organic contaminants (phenol, BTEX compounds below solubility, and trichloroethylene), and radionuclides (uranyl and thorium ions) can be removed efficiently from fine-grained deposits by application of electrical currents in the order of 25 to 1000 $\mu\text{A}/\text{cm}^2$ across electrodes inserted in a soil mass. A pore fluid is also supplied at the electrodes during the process. This technique, electrokinetic soil processing, results in generation of an acid front at the anode and a base front at the cathode by the electrolysis reactions. The acid front flushes across the soil mass by diffusion, migration, and advection due to electro-osmosis. The advance of the acid front coupled with the chemical, hydraulic, and electrical potential differences generated across the soil mass results in contaminant desorption, transport, collection, and removal. Different types of conditioning fluids may be used at the electrodes to enhance removal.

The objective of this presentation is to provide the fundamentals of the electrokinetic remediation process. The efficiency of the technique in soil remediation, energy requirements, and guidelines for its implementation are discussed. Outlines of the ongoing large-scale laboratory study and the pilot-scale field study are also presented. The advantages, shortcomings, and the complicating features of the technique are reviewed and the implications of the results of the bench-scale, large-scale, and field-scale studies on field implementation of the electrokinetic remediation process are provided.

REMOVAL OF CONTAMINANTS FROM SOILS BY ELECTROKINETICS

Yalcin B. Acar
Louisiana State University

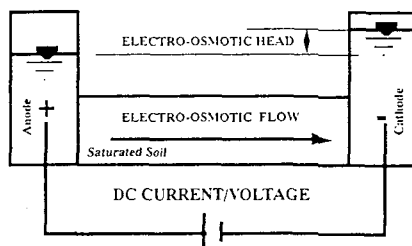
CONTENT

- ELECTROKINETIC PHENOMENA IN SOILS
 - POTENTIAL USE
- FUNDAMENTALS OF EK REMEDIATION
 - BENCH-SCALE STUDIES
- PILOT LARGE-SCALE / FIELD STUDIES
 - SUMMARY

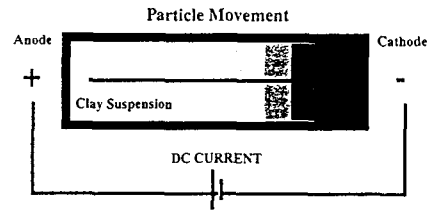
ELECTROKINETIC PHENOMENA IN SOILS

- ELECTROOSMOSIS
- ELECTROPHORESIS
- SEDIMENTATION POTENTIAL
- MIGRATION POTENTIAL

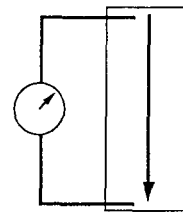
ELECTRO-OSMOSIS



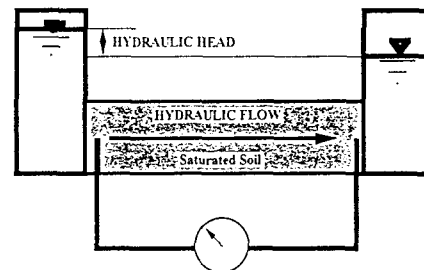
ELECTRO-PHORESIS



SEDIMENTATION POTENTIAL

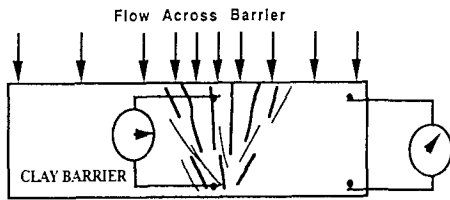


MIGRATION POTENTIAL

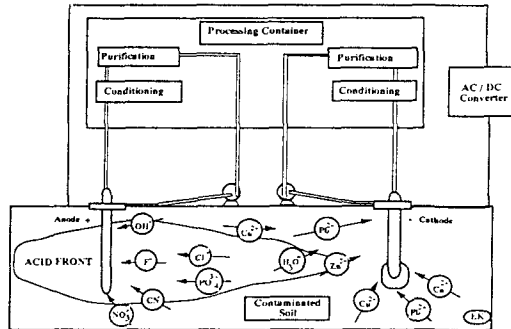
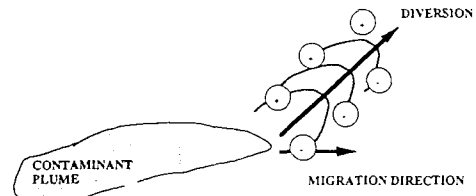


POTENTIAL USE OF ELECTROKINETIC PHENOMENA IN REMEDIATION

LEAK DETECTION IN CONTAINMENT BARRIERS



PLUME DIVERSION SCHEMES



$$Q_h = k_h i_h A$$

Q_h = Flow under Hydraulic Gradients
(cm³/s)

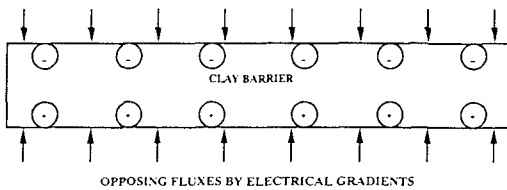
k_h = Hydraulic Conductivity
(cm/s)

i_h = Hydraulic Gradient

A = Area (cm²)

FLOW BARRIERS IN CLAY LINERS

TRANSPORT OF CONTAMINANTS
BY HYDRAULIC AND CHEMICAL POTENTIAL GRADIENTS



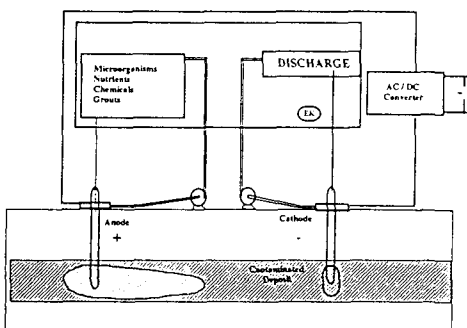
$$Q_e = k_e i_e A$$

Q_e = Flow under Electrical Gradients
(cm³/s)

k_e = Electroosmotic Coefficient of Permeability
(cm/s)/(V/cm)

i_e = Electrical Gradient (Volt/cm)

A = Area (cm²)



$$\frac{Q_e}{Q_h} = \frac{k_e i_e}{k_h i_h}$$

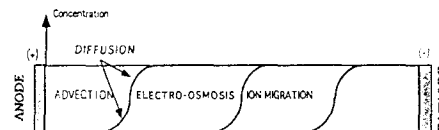
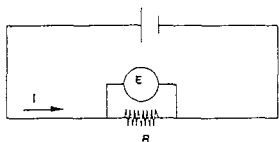
FROM FINE SANDS TO CLAYS

$k_h = 10^{-3}$ to 10^{-10} cm/sec

$k_e = 10^{-4}$ to 10^{-6} (cm/s)/(V/cm)

$$Q = k_i A = k_e E A / L = k_e (RA/L) I = (k_e / \sigma) I$$

$$k_i = k_e / \sigma$$

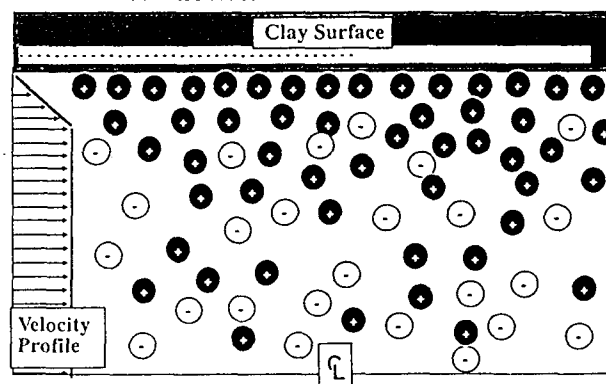


$$k_i = 0 \text{ to } 1.5 \text{ gallons/ A-h}$$

Maximum Values

- Low Activity Clays
- High Water Contents
- Low Electrolyte Concentrations
- Initial Stages of the Process

ADVECTION BY ELECTRO-OSMOSIS

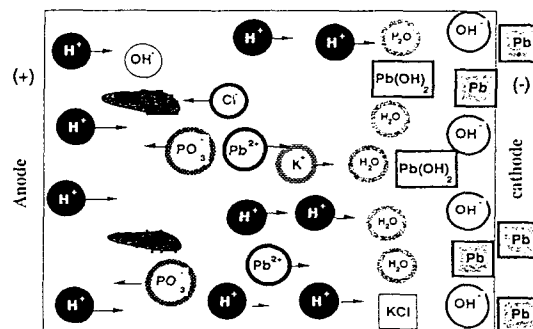


ENERGY EXPENDITURE

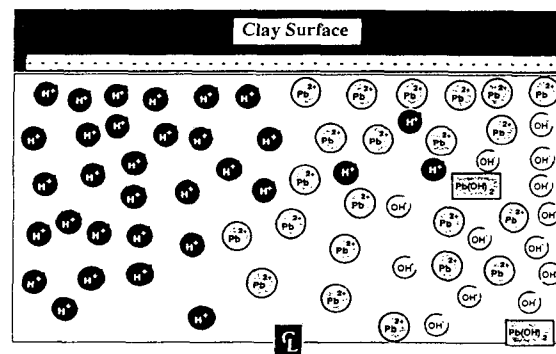
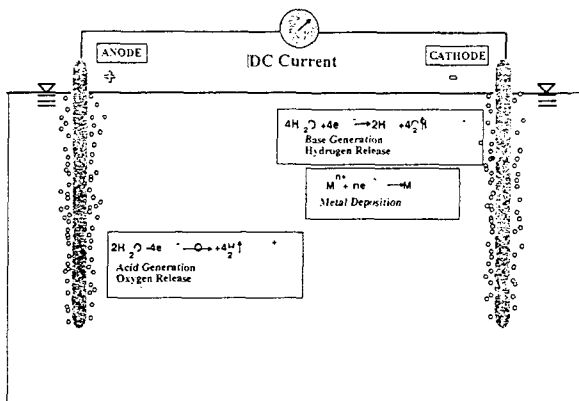
$$P = \frac{dE}{dt} = \frac{I^2 R}{A L} = \frac{I V}{A L} = \frac{I}{A} i_e$$

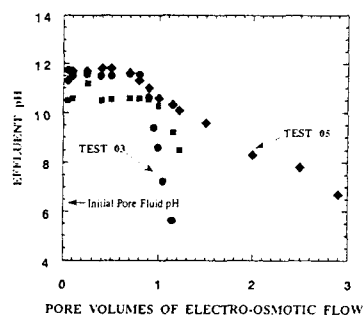
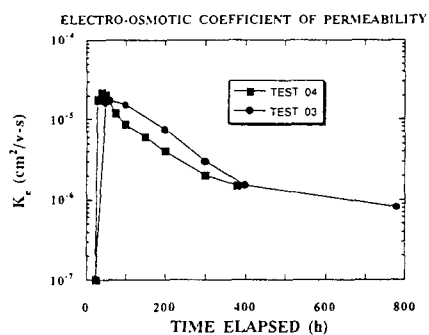
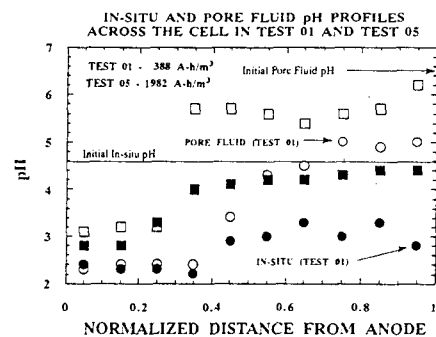
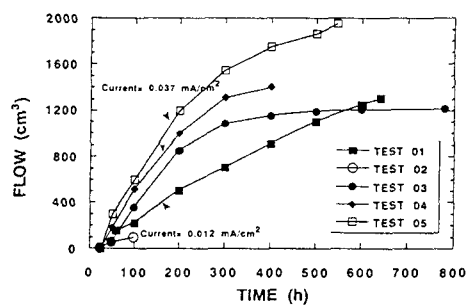
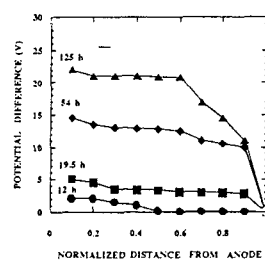
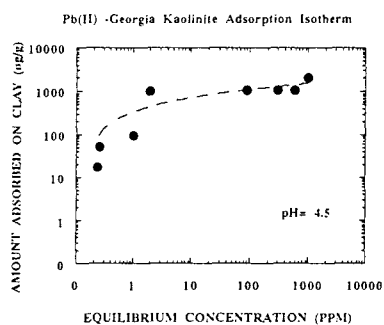
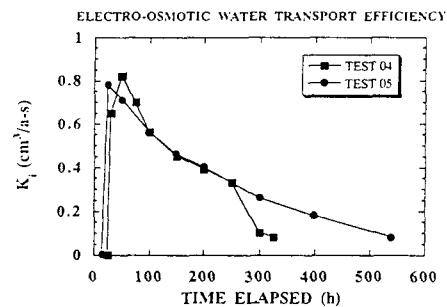
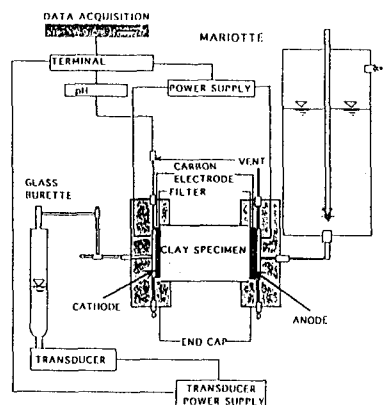
P = Power/unit volume
I = Current (constant)
R = Resistance

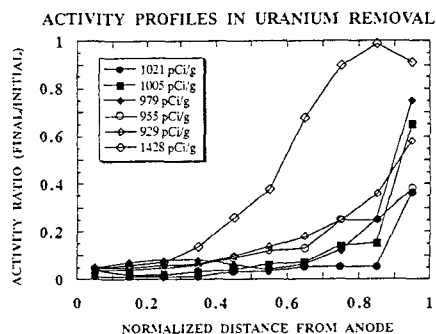
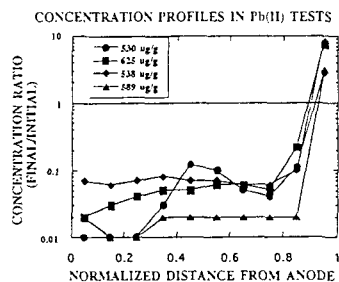
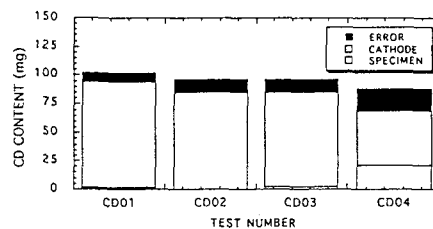
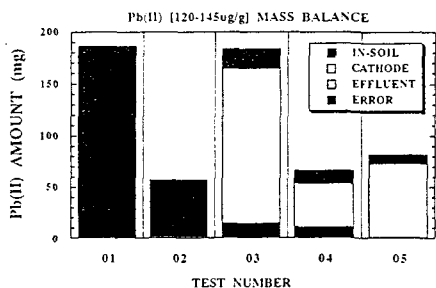
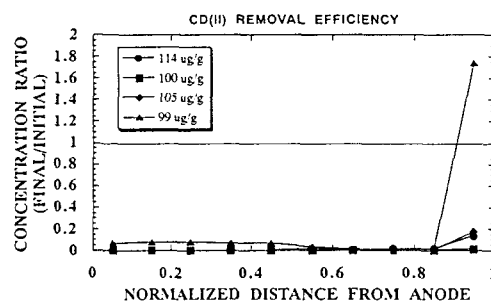
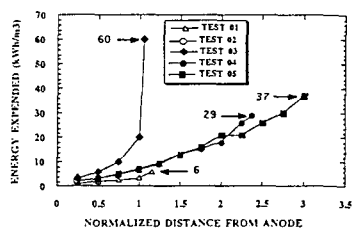
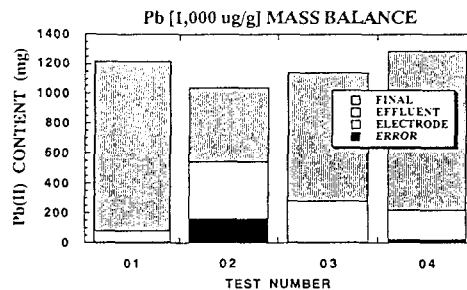
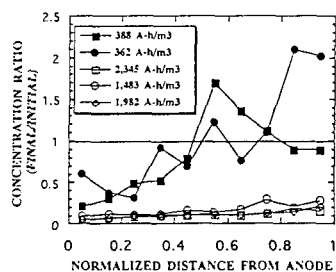
A = Area
L = Length
i_e = Electrical Gradient

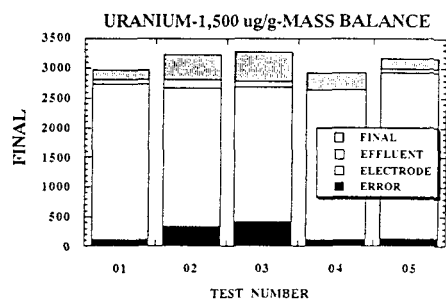
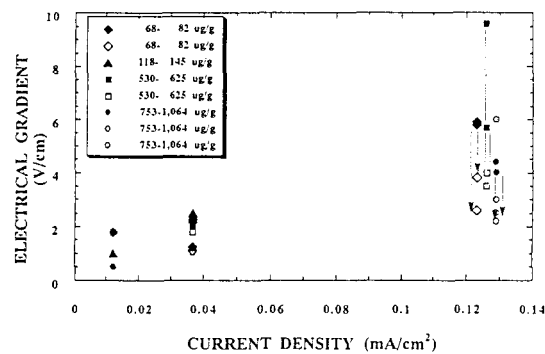
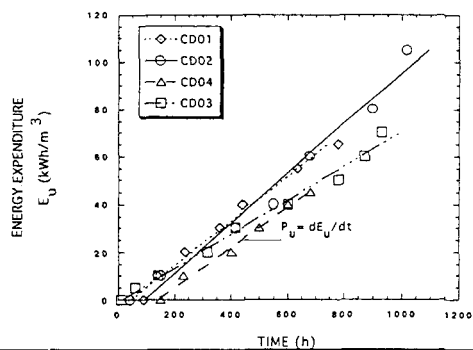


ELECTRODE REACTIONS









RESEARCH AND DEVELOPMENT

BASIC RESEARCH

CONDITIONING FLUIDS
SURFACE CHEMISTRY
ELECTRODE TYPES

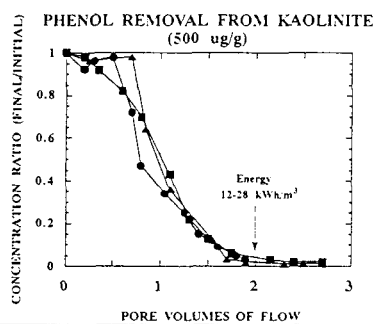
LARGE-SCALE MODEL (LSU)

THEORETICAL MODEL (LSU)

DESIGN / ANALYSIS SCHEMES (EK)

IMPLEMENTATION GUIDELINES (EK)

CONSTRUCTION PROCEDURES (EK)



PILOT-SCALE TESTS

ELECTROKINETICS / LSU (USA)

Pb(II) 4,000-36,000 ug/g

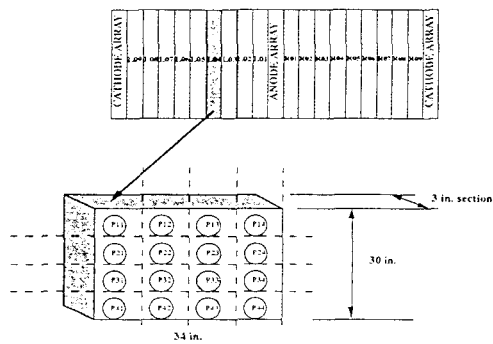
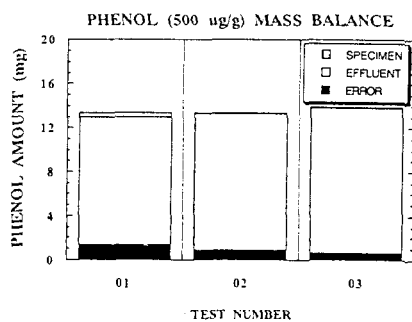
GEOKINETICS (NETHERLANDS)

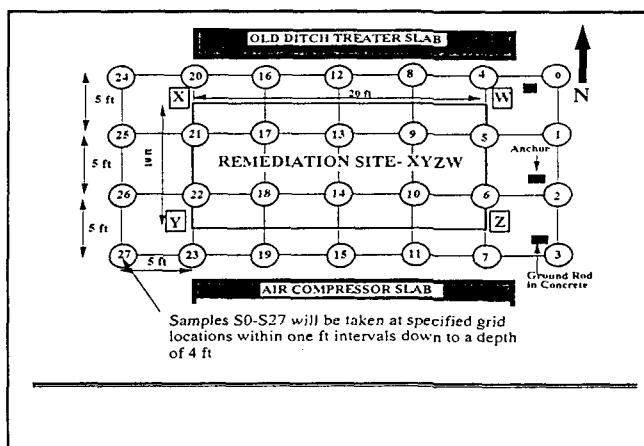
Zn 5,120 ug/g

As 385 ug/g

Pb 500 ug/g

Cu 1,150 ug/g





SUMMARY (continued)

CURRENT/VOLTAGE LEVELS

BENCH-SCALE TESTS

- 10 $\mu\text{A}/\text{cm}^2$ to 1000 $\mu\text{A}/\text{cm}^2$
- 1 to 2 V/cm
- Preferable (< 50 $\mu\text{A}/\text{cm}^2$)

PILOT-SCALE TESTS

- up to 4 mA/cm² or
- up to 2 V/cm

SUMMARY

- BENCH-SCALE AND LIMITED PILOT-SCALE TESTS DEMONSTRATE THAT ELECTROKINETIC SOIL PROCESSING IS A FEASIBLE AND EFFICIENT TECHNOLOGY IN REMEDIATION OF (FINE-GRAINED) SOILS FROM INORGANIC, SELECT RADIONUCLIDES AND SOME ORGANIC CONTAMINANTS

SUMMARY (continued)

ELECTRODE DETAILS / LAYOUT

TYPE

- ANODE INERT
- CATHODE OTHER
- SHEETS / RODS OR COATED

DISTANCE

- UP TO 4 m (6 m?)

LAYOUT

- 1-D CONDITIONS PREFERRED

SUMMARY (continued)

- THE PROCESS REMOVES CONTAMINANTS FROM SOILS BY ELECTRO-OSMOTIC ADVECTION AND ELECTRICAL MIGRATION COUPLED WITH THE DESORPTION GENERATED BY THE ADVANCING ACID FRONT AND/OR ANY CONDITIONING FLUIDS INTRODUCED AT THE ELECTRODES UNDER AN ELECTRICAL POTENTIAL DIFFERENCE

SUMMARY (continued)

ENERGY EXPENDITURE

BENCH-SCALE TESTS

18-100 kW-h/m³

PILOT-SCALE TESTS

100 - 400 kW-h/m³

SUMMARY (continued)

TYPE OF CONTAMINANTS

INORGANIC IONIC SPECIES

As, Cd, Cr, Cu, Pb, U, Zn
Th & Ra (Precipitation)

ORGANIC CONTAMINANTS

• Phenol, BTEX Compounds (Below Solubility Limits)
O-Nitrophenol

• Hexachloroburadienne (failed at 1,000 ppm)
(Micellar removal is investigated)

TREATMENT, COMPACTION, AND DISPOSAL OF RESIDUAL RADIOACTIVE WASTE

**Mr. Walter M. Hipsher
Scientific Ecology Group, Inc.
Oak Ridge, Tennessee**

The remediation of a facility or site that has radioactive contaminants will result in the generation of secondary radioactive waste, such as anticontamination clothing, and radioactive waste that is to be removed from the site. These materials need to be processed to reduce disposal costs, to meet disposal site acceptance criteria, or to meet NRC waste form stabilization requirements. Treatments applied by industry to prepare these materials for either release or disposal are broken down into three categories and discussed in this presentation.

The first category is that of decontamination of materials either to reduce the activity for unrestricted release or to reduce the radiation levels of the materials for future handling and storage. Techniques to accomplish this task include manual cleaning, chemical cleaning, abrasive cleaning, pressurized water, and various combinations of these techniques. Any of these techniques could be used for removal of contaminants that result in the unrestricted release of the materials.

The second category is that of treatment to reduce the volume and/or cost for disposal of the materials. The primary technique utilized is to volume reduce the materials by compaction. Recently, incineration has become the primary choice for combustible materials as it reduces both weight and volume. Other volume reduction techniques such as the removal of liquids by suction dewatering and/or drying are used for specialized waste forms such as dirt, resins, and some sludge.

The third category is the processing of materials to assure that the waste form meets specific NRC and/or disposal site acceptance criteria. The process may involve some of the techniques previously discussed that are used as pretreatment steps and the addition of techniques to assure that specific waste form criteria are achieved. Ashes may be solidified or compacted to meet the receipt requirements that they be non-dispersible in air. Higher activity sludge, liquids, soils, and resins may be placed in specialized disposal containers or solidified with specialized stabilization agents. Characteristic mixed wastes may be solidified to remove the hazardous waste characteristic so that the material may be disposed of as radioactive.

RADIOACTIVE SITE REMEDIATION TREATMENT, COMPACTION, DISPOSAL

I. TYPICAL DRY ACTIVE WASTE (DAW)

- SOIL
- ANTI-C's
- RESIN
- BUILDING RUBBLE

II. COMPACTION

- PREPACKAGED DRUMS/BINS
- BULK MATERIALS
- LIMITATIONS

RADIOACTIVE SITE REMEDIATION TREATMENT, COMPACTION, DISPOSAL

III. INCINERATION

- WEIGHT REDUCTION
- VOLUME REDUCTION
- RESIN
- COMBUSTIBLES
- LIMITATIONS

RADIOACTIVE SITE REMEDIATION TREATMENT, COMPACTION, DISPOSAL

IV. RADIOLOGICAL DECONTAMINATION

- METALS
- LIQUIDS
- SOILS
- LIMITATIONS

RADIOACTIVE SITE REMEDIATION TREATMENT, COMPACTION, DISPOSAL

V. DISPOSAL

- BEATTY, NV
- RICHLAND, WA
- BARNWELL, SC
- DOE
- NARM

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati, OH 45268

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