INNOVATIVE TECHNOLOGY
Summary Report

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Lead TechXtract Chemical Decontamination

Efficient Separations and Processing Crosscutting Program and Deactivation and Decommissioning Focus Area

Prepared for
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Innovative Technology
Summary Report

Lead TechXtract Chemical Decontamination

OST Reference #1450

Efficient Separations and Processing
Crosscutting Program and
Deactivation and Decommissioning
Focus Area

Demonstrated at
Hanford Site
Richland, Washington

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Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

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SECTION 1

SUMMARY

The TechXtract® technology is a decontamination system using ultrasonics and chemical baths to remove fixed and smearable contaminants from metals. The DOE has successfully demonstrated the technology for lead bricks, commonly used at nuclear facilities, so they can be released for recycling. The process, entirely housed in a portable trailer, moves the objects to be decontaminated along a hoist and rail system to apply and then remove several chemical solutions in sequence. No hazardous constituents are in the solutions, except for the extracted contaminants. The technology is an attractive alternative to the baseline treatment for contaminated lead bricks, which is to encapsulate and bury them as mixed waste in an approved landfill, at significant costs, and with a waste of potentially reusable resources. The improved technology, mobilized from New Jersey to Washington State and with 5 hours of production per day, costs $2.12/kg ($0.96/lb) less salvage value, versus baseline costs of $0.38/kg ($0.17/lb) for encapsulation and burial at the Hanford Site landfill. The improved technology should be especially considered where disposal costs are higher than at the Hanford Site.

• Technology Summary

The Hanford Site C Reactor Technology Demonstration Group decontaminated lead bricks using the TechXtract® chemical process. The demonstration indicated that the technology could reduce radioactivity to below surface "free release" requirements. Out of 80 bricks (1 ton) decontaminated, 78 bricks were releasable, with activity levels that were equal to background levels or non-detectable.

"TechXtract" Deconned Lead

Active Environmental Technologies of Mt. Holly, New Jersey, operated the TechXtract® technology at the C Reactor on the Hanford Site in Richland, Washington. This was the first production-scale demonstration of the technology on lead bricks. Previously, the process had been tested on lead only in a laboratory by EET Corporation, now a subsidiary of Active Environmental Technologies.

The decontamination process applies and then removes several chemicals in sequence. The chemicals are scrubbed into the contaminated surfaces with ultrasonics for a specified time; then rinsed and removed with vacuum. The decontamination stations inside the trailer consist of three heated, ultrasonic baths, two rinse stations with vacuum drying, and a final vacuum drying station. The system is housed in a trailer with an overhead rail and hoist for handling bricks in batches of four.

Problem Addressed

The U.S. Department of Energy (DOE) is in the process of decontaminating and decommissioning many of its nuclear facilities throughout the country. Typically, the facilities undergoing D&D are contaminated, either chemically, radiologically, or both. In its D&D work, the DOE may benefit from processes that can remove contaminants from lead bricks. The methods must be easy and economical to operate, and safe for workers. The alternative disposition is to encapsulate contaminated lead bricks and bury them in a landfill as a mixed waste. Successful decontamination allows the lead to be recycled as a valuable resource, instead of adding to disposal costs and the volume of wastes.

Features and Configuration

The TechXtract® chemical formulas incorporate dissolution, oxidation, reduction, hydrolysis, wetting, complexation, microencapsulation, and flotation chemistry principles. The chemistry further compensates for situations in which the contamination is a mixture of pure elements, oxides, and related compounds with varying solubility indices. The spent chemical solutions do not contain any hazardous constituents (except for extracted contaminants) and have been disposed of by incineration, solidification (and land disposal), and discharge to liquid effluent treatment systems.

In most projects, three chemical formulas are used in sequence. Chemicals can be applied in low volumes as a spray or dip to minimize consumption and secondary waste volume. The chemicals are scrubbed into the contaminated surfaces with ultrasonics for a defined time, and then rinsed and removed with vacuum.

Potential Markets/Applicability

The lead TechXtract® chemical decontamination system would be useful at DOE, U.S. Environmental Protection Agency (EPA), or U.S. Nuclear Regulatory Commission (NRC) sites in which contamination must be removed from metallic surfaces as part of the waste minimization, landfill volume reduction, and material recycling processes. The technology could be economical at facilities where the traditional encapsulation of contaminated lead and subsequent burial would be costly. This technology can be used to decontaminate lead bricks and sheets, as well as objects made of other metals, including tools, fittings, and valves.

Advantages of the Improved Technology

The following tabulation summarizes the advantages and disadvantages of the improved technology against the baseline method of encapsulating and landfill disposal:

Category	Comments
Cost	For the 1956 bricks in the C Reactor inventory, decontamination would cost $49,000 less salvage value, versus $8,770 for encapsulation and disposal in a Hanford Site landfill, where disposal costs are $60/ton
Performance	Produces a recyclable resource at a rate of 220 bricks per 5-hr day, versus the baseline rate of approximately 1,000 bricks per day
Ease of Use	Decon is comparable to the encapsulation step in the baseline
Secondary Waste Generation	About 0.2 m^3 (7 ft^3), or one 55-gal drum, of wastes are produced to decontaminate 1956 bricks, versus 21 m^3 (736 ft^3), or 5500 gal, for the baseline technology, including the grout volume needed for encapsulation
ALARA/Safety	Comparable, except the baseline does not need precautions for organic vapors

Using the TechXtract® service for onsite decontamination of lead bricks achieved the following:

- Production rate of more than 200 bricks per day, versus a performance objective of 100 per day
- Decontamination factors ranging up to over 182
- Decontamination performed in a safe workplace environment with good ALARA practices
- Secondary waste production of only 0.038 L (0.01 gal) per brick, equivalent to approximately 2.7 kg (6 lb) per ton of lead processed. The liquid waste can be solidified with cement, which would double the waste volume

- The cleaned lead can be recycled and has a salvage value
- The improved technology meets ALARA considerations and work safety concerns can be suitably addressed
- The improved technology can be applied to decontaminating other metals and tools.

Operator Concerns

The demonstration showed that the basic concept and the design of the trailer were sound in that the demonstration's production and decontamination goals were exceeded. Continuous monitoring of the workplace during the demonstration also showed that the process was generally safe from a worker exposure perspective, although organic vapors are generated. ALARA considerations were also met, because the process does not use aggressive surface ablation techniques.

Skills/Training

Training required for field workers is minimal. However, an experienced chemist must be on-call.

• Demonstration Summary

The lead TechXtract® chemical decontamination was demonstrated by the C Reactor Technology Demonstration Group during May 1998.

Demonstration Site Description

The bricks at the C Reactor site were used as shielding in the late 1970s. Since then, the bricks have been wrapped in high-density polyethylene (HDPE) and stored on wooden pallets in a secure area at the C Reactor compound. All of the bricks surveyed for the demonstration had a significant amount of surface oxidation as a result of their long storage. The decontamination was carried out in a vendor-furnished trailer brought to the C Reactor yard and parked near the pallets.

Regulatory Issues

There are no special regulatory or permit requirements associated with implementation of this technology. Normal worker safety practices should be applied when using this tool in accordance with applicable regulations, particularly, 10 *Code of Federal Regulation* (CFR), Parts 20 and 835, and proposed Part 834, for protection of workers and the environment from radiological contaminants; and 29 CFR Occupational Safety and Health Administration (OSHA) worker requirements.

Technology Availability

The TechXtract® chemical decontamination technology is available from Active Environmental Technologies, Inc., of Mt. Holly, New Jersey.

Technology Limitations/Needs for Future Development

Refinements that could be made to either the mechanical or chemical features of the system include:

- Add a HEPA-filtered ventilation system to allow more highly contaminated bricks to be processed
- Automate the manual hoist system

- Explore shorter dwell times and/or eliminating one dipping step to increase production
- Adapt the brick holders to process other metal items, such as tools
- Enlarge the batch size to increase throughput and reduce costs.

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Other

All published Innovative Technology Summary Reports are available at http://em-50.em.doe.gov. The Technology Management System, also available through the EM50 Web site, provides information about OST programs, technologies, and problems. The OST Reference Number for Lead TechXtract Chemical Decontamination is 1450.

SECTION 2

TECHNOLOGY DESCRIPTION

• Overall Process Definition

The TechXtract® technology is a sequential chemical extraction process for the removal of radionuclides, PCBs, and other hazardous organic and inorganic substances from materials such as lead, concrete, construction bricks, and steel. The technology uses chemical formulations and engineered applications to penetrate the materials and remove the contaminants from below the surface. The chemistry is based on hypotheses regarding contaminant migration and removal. For example, contaminants migrate into the pores and microscopic voids of a material, even for seemingly non-porous media. The mobility of the contaminants, time, and electrostatic forces often drive these contaminants deeper in the substrate. Furthermore, the contaminants tend to become chemically or electrostatically bonded to the substrate. In many cases, the time between the contamination event and decontamination efforts allows the contaminant migration pathways to become partially closed.

The chemical extraction is designed to:

- Reopen the pores and capillary pathways to the maximum possible extent
- Penetrate into the pores as deeply as possible
- Break the physical and chemical bonds that may be holding the contaminants in place
- Bind or sequester the contaminants in the chemical solutions to prevent recontamination.

The chemical solutions address each of these complex needs, using components that incorporate dissolution, oxidation, reduction, hydrolysis, wetting, complexation, microencapsulation, and flotation chemistry principles. The solution also compensates for situations in which the contamination is a mixture of pure elements, oxides, and related compounds with varying solubility indices. The spent chemical solutions do not contain any hazardous constituents (except for the extracted contaminants) and have been disposed of by incineration, solidification (and land disposal), and discharge to liquid effluent treatment systems.

The process is a sequence for applying and removing each of the chemicals. In most projects, three chemical formulas are used. Chemicals can be applied in low volumes as a spray or dip to minimize the amount used and the volume of waste produced. The chemicals are scrubbed into the contaminated surfaces with ultrasonics for a defined time, and then rinsed and removed with vacuum. The application and removal of all three solutions is one cycle of the process. Sampling and/or radiation surveys can be performed at the end of any step in the cycle, and they will often show reductions of 90% or more per step.

Figure 1. Decontamination trailer and pre-survey tent.

Figure 2. Light-rail hoist.

• System Operation

The system was specified to decontaminate lead bricks at a minimum rate of 100 bricks per day. A 4.9-m x 2.4-m (16-ft x 8-ft) trailer contains the material handling, decontamination, and waste handling systems. All interior vertical and horizontal surfaces are covered with welded, seamless, 4-mil high-density polyethylene (HDPE) for easy decontamination. The trailer also protects the workers and equipment from weather and provides secondary containment for the TechXtract® baths. The normal work crew for the unit is two persons, a technician and supervisor. The trailer's power requirement is for 120 v, 60 Hz, 45 amps, which can be provided externally or with an onboard generator. All bricks were 5 cm x 10 cm x 20 cm (2 in. x 4 in. x 8 in.) and were limited to beta-gamma activity levels of less than 800,000 dpm/100 cm^2.

Material Handling System: The bricks are decontaminated in batches of four. The individual bricks are placed into baskets constructed from non-reactive materials. Batches are staged at the open end of the trailer where the baskets are loaded and then lifted by means of a light-rail hoist. The hoist's I-beam and manual hoist construction has a lift capacity of 91 kg (200 lb). The I-beam rail runs in a circuit along the ceiling of the trailer and outside for loading and unloading baskets.

Decontamination Systems: The decontamination stations inside the trailer consist of three heated ultrasonic baths, two rinse stations with vacuum drying, and a final vacuum drying station. The ultrasonic baths are electronically heated, thermostatically controlled, and measure 51 cm x 29 cm x 28 cm (20 in. x 11.5 in. x 11 in.). TechXtract® solutions are the ultrasonic cleaning medium. The first two baths contain surface preparation formulations designated “Pro” and “Clean” that are blends of acids and other agents that clean dirt, oil, grease, and other interfering substances from the surface. The third bath is an extraction blend designated “XT” containing organic compounds, including chelating agents, and other compounds, designed to interact with contaminants at the molecular level. The batch dwell time is a maximum of 15 minutes per station, with the capability to run simultaneous batches, giving a minimum production capacity of 16 bricks per hour. The decontamination steps progress as a series of dipping operations. The actual dwell time was 7 minutes per bath for 13 batches and 5 minutes per bath for 7 batches. All but two bricks were free released after decontamination. With the shorter dwell time, the initial batch takes 30 minutes, and then sequential batches exit the process every 5 minutes. Bath temperatures were approximately 60EC (140EF).

Waste Liquids System: Waste contaminated liquids are removed using two vacuum systems with HEPA filters on the exhaust side. Wastes are captured in the vacuum drum body and later transferred to a disposal drum. Optionally, stabilization agents added to the liquids in the drum form a solid waste product.

SECTION 3

PERFORMANCE

• Demonstration Plan

Site Description

The demonstration was conducted at the DOE's Hanford Site by Bechtel Hanford, Inc. (BHI), the DOE's Environmental Restoration Contractor responsible for the D&D program at Hanford. The purpose of the Large Scale Demonstration and Deployment Project (LSDDP) is to demonstrate innovative or improved, commercially available and recently developed technologies during DOE D&D operations. In the case of the C Reactor, the cost and performance of innovative technologies are comprehensively assessed while placing the reactor block into an interim storage mode for up to 75 years, or until the final disposal of the reactor's core is completed. The C Reactor ISS objectives include: reduce or limit future decommissioning costs, minimize releases to the environment, and reduce the frequency of inspections and potential risk to workers.

The DOE is in the process of decontaminating and decommissioning many of its nuclear facilities throughout the country. Facilities have to be dismantled and demolition waste must be sized into manageable pieces for handling and disposal. Typically, the facilities undergoing D&D are contaminated, either chemically, radiologically, or both. In its cleanup of the Department's former weapons complex, the DOE may realize benefits by employing technologies capable of decontaminating lead bricks so that they can be recycled. The lead TechXtract® chemical decontamination system satisfies this need and is an attractive alternative to traditional technologies, such as encapsulation and landfill burial.

The lead bricks that were decontaminated are 5 cm x 10 cm x 20 cm (2 in. x 4 in. x 8 in.). Lead bricks are commonly used as shielding material at almost every nuclear facility in the world. The bricks at the C Reactor were last used in that role in the late 1970's. Since then, the bricks have been wrapped in HDPE and stored on wooden pallets in a secure area at the C Reactor compound. All of the bricks surveyed for the demonstration had a significant amount of surface oxidation as a result of their long storage. The decontamination was carried out in a vendor-furnished trailer brought to the C Reactor yard and parked near the pallets. Health physics concerns limited the beta/gamma activity level of candidate bricks to 800,000 dpm /100 cm^2. This level was set at the discretion of the site's radiological control technicians (RCT) because the trailer was not equipped with mechanical ventilation. However, the entire rear of the trailer was open so that a buildup of airborne radionuclides was unlikely. No buildup was observed during the demonstration. None of the bricks tested had painted surfaces.

Performance Objectives

Objectives of the demonstration included the following desired capabilities and design features for the system:

- Have a production rate of at least 100 bricks per day or up to 9.1 m^2 (100 ft^2) of lead sheets per day
- Result in a very high percentage of bricks or sheets that meet surface release criteria
- Stabilize any liquid chemical waste to meet waste disposal regulations for landfills
- Be easy and economical to operate
- Able to operate in ambient temperatures from 3EC to 40EC (37EF to 104EF)
- Use conventional equipment in a portable enclosure
- Be safe for workers.

Demonstration Chronology

<u>IMPROVED TECHNOLOGY</u>
On day one of the demonstration (May 8, 1998), the first batch of four bricks was surveyed and processed using a 7-minute dwell time. The total time for the initial batch to move into and out of the trailer was 50 minutes. The time difference between total dwell time of 35 minutes and the total time through the trailer is accounted for in

handling time. For this initial batch, only one technician, who handled all operations, was in personal protective equipment (PPE). The hoist and rail system worked well, and there was no physical exertion on the part of the technician. As each dwell was completed, the bricks were moved to the next station. The batch sequence was TechXtract® Pro, then TechXtract® Clean, rinse and vacuum, TechXtract® XT, rinse and vacuum. All but two of the bricks that were decontaminated showed no final activity above background.

On day two of the demonstration (May 12, 1998) the bricks were pre-surveyed. At the end of the workday, 76 more bricks were ready for processing and placed on a pallet at the open end of the trailer. On day three (May 13, 1998), two technicians took up stations in the trailer. The first six batches (24 bricks) were decontaminated with 7-minute cycles. All of those bricks showed no activity above background after processing. A decision was made to reduce the dwell time to 5 minutes per bath. The remaining batches were all processed with the shorter dwell time. Six bricks had to be run through the process twice. Two of the six failed bricks showed higher levels of contamination after multiple cycles, and were put aside. The remaining bricks were all processed to background or non-detect levels.

A total of 76 bricks were processed on day three in 3.5 hours using both 7-minute and 5-minute batch dwell times. The shorter bath dwell time did not appear to affect decontamination efficiency. Using the 5-minute dwell time as a base, a production rate equivalent to 220 bricks per 5-hr day was achieved with a pass rate of over 97%. All of the bricks that passed were below background activity. This was more than double the target rate, with a maximum final decontamination factor of more than 182.

The initial trial plan called for variations in temperature, dwell time, and the elimination of one of the first two ultrasound baths. Time constraints in the demonstration execution, brought on by the length of time required to complete pre-surveys, prevented thorough examination of all those parameters. The dwell time was reduced, but only by one step, before the supply of pre-surveyed bricks was exhausted.

Three potential sources of liquid secondary waste exist in the treatment scheme: the first vacuum station, which has a mixture of rinse water, “Pro” and “Clean” TechXtract® solutions; the second vacuum station, which has a mixture of rinse water and the “XT” solution; and the solutions that remain in the ultrasonic baths at the conclusion of the demonstration. There was not a large enough inventory of pre-surveyed contaminated bricks available to exhaust the original 57 L (15 gal) total of TechXtract® solutions in the ultrasonic baths. Therefore, the secondary waste volume produced is estimated as follows: A total of 13.2 L (3.5 gal) of secondary waste was produced with the throughput of 80 bricks. Standard operating procedure would be to recycle this material back into sonication baths 2 and 3, as appropriate for the origin of the waste, until indicator pH end points had been reached. The solution strength left in the baths, as indicated by the solutions’ pH, was sufficient to process at least 78 more bricks. At that end point, 10% of the solution would need to be refreshed. It is therefore estimated that 5.7 L (1.5 gal) of secondary waste would be produced per 156 lead bricks, or 0.038 L (0.01 gal) per 11.8-kg (26-lb) brick. This is equivalent to approximately 2.7 kg (6 lb) of liquid waste per ton of lead.

The chemical character of the secondary waste stream was not determined. The liquid waste that was produced was stabilized into a solid form that was compatible with the Hanford Site Environmental Restoration Disposal Facility (ERDF) acceptance criteria. The TechXtract® solutions themselves are not hazardous; the used solutions contain contaminants that may be hazardous. The protocol used for the demonstration was not aggressive enough to put elemental lead into solution. The waste solidification process almost doubled the waste volume.

<u>BASELINE TECHNOLOGY</u>

The baseline is the encapsulation of the bricks and disposal at the ERDF. The encapsulation process includes procurement of liners (casks), setting the casks in the ERDF, placement of earth shoring around the casks, loading the lead debris using a crane and rigging, pumping grout into the liner, and sealing the lid to the liner. The grout to be used for the void space filler must have a compression strength of at least 31.65 kg/cm^2 (450 lb/in.^{2}) in 28 days, when tested in accordance with ASTM D4832. The lid would be secured using a continuous bead of bonding material and the placement of screws every 15 cm (6 in.) around the lid.

Backfilling and compacting around the filled casks would be the final step for disposal of the lead. Encapsulation is an approved treatment method for contaminated lead debris per 40 CFR 268.45, *Treatment Standards.*

• Technology Demonstration Results

Key Demonstration Results

Successes

The TechXtract® lead decontamination technology was successfully demonstrated at the C Reactor with the following results:

- Production rates of more than 200 bricks per day
- Decontamination factors ranging up to over 182
- Decontamination was performed in a safe work place environment employing ALARA practices
- Secondary waste production of only 0.038 L (0.01 gal) per brick or 2.7 kg (6 lb) per ton of lead processed.

Shortfalls

Six bricks (7.5% of the 80 bricks processed) did not meet release criteria after one time through the process. Of these, four bricks met release criteria after a second time through, and two bricks increased in surface contamination levels. It is believed that for these two bricks, the process was bringing contaminants to the surface from deeper in the substrate, and that decontamination would succeed if enough passes through the process were made.

Meeting Performance Objectives

The objectives listed in the Demonstration Overview section were met, except no lead sheets were processed because pre-surveys could not be scheduled.

• Comparison of Improved Technology to Baseline

The C Reactor has approximately 1956 lead bricks that require chemical decontamination. Based on the data obtained in this demonstration, Table 2 compares this planned decontamination with the alternative of encapsulating and disposal of 1956 bricks at the ERDF.

Table 2. Comparison of improved and baseline parameters

Activity or Feature	Improved TechXtract®	Baseline [a] Encapsulation and Landfill
Setup	2 hr to connect power to trailer and fill warm baths	Much more time [b]
Production Rate	220 bricks per 5-hr day	Approximately 1,000 bricks per day
Safety	Need precautions against radioactivity, lead, and organic vapors	Same, except no organic vapor concerns
Ease of operation	Same	Same
Waste generation	Minimal waste (0.2 m^3, or one 55-gal drum)	Maximum waste - approximately 100 times as much[c]
Utility requirements	Minimal--heating and ventilation	None

Training	Minimal for decontamination operators, but an experienced chemist must be available	Minimal

TABLE 2 NOTES:

a. The encapsulation step in the baseline method has similar parameters to the improved technology
b. Encapsulation setup includes shoring around casks
c. The baseline method not only has all the lead brick volume, but also includes grout and casks, making the total volume 21 m^3 (736 ft^3), equivalent to 21,000 L (5,550 gal)

Surface release criteria meet DOE Order 5400.5 as shown in Table 3.

Table 3. DOE surface release criteria

Activity	Removable (dpm/100 cm^2)	Total (Fixed and Removable, dpm/100 cm^2)
Alpha	20	100
Beta/Gamma	1,000	5,000

The bricks were surveyed using smear samples to detect removable contamination, with minimum detectable activities of 20 dpm/100 cm^2 for alpha and 1000 dpm/100 cm^2 for beta/gamma. Surveys for total (removable plus fixed) contamination were done with an Eberline 380 probe and Eberline 600 meter, with minimum detectable activities of 100 dpm/100 cm^2 for alpha and 1000 dpm/100 cm^2 (background) for beta/gamma. The results of the surveys and corresponding decontamination factors (DFs) are given in Table 4.

As reflected in the table, initial total alpha activities and beta/gamma activities were recorded for at least one brick out of each batch of four except for batches 6, 7, and 8. Initial smearable activities were recorded for at least one brick out of each batch for 5 batches.

Table 4. Lead brick decontamination survey results for a single cycle

Batch #	Brick # for Batch	Initial Smearable (dpm/100 cm^2)		Initial Total (dpm/100 cm^2)		Final Smearable[a] (dpm/100 cm^2)		Final Total[b] (dpm/100 cm^2)		Smear Final DF	Total Final DF
		a	ß-?	a	ß-?	a	ß-?	a	ß-?		
1	1	44.6	<1k	350	35k	ND	ND	ND	ND	>2.2	>35
	2	<100	1k -21k	<100 - 300	8.4k - 182k	ND	ND	ND	ND		>182
	3					ND	ND	ND	ND		
	4					ND	ND	ND	ND		
2	5	<20	<1k	150	154k	ND	ND	ND	ND		>154
	6					ND	ND	ND	ND		
	7					ND	ND	ND	ND		
	8					ND	ND	ND	ND		
3	9	40	<1k	600	14k	ND	ND	ND	ND	>2	>14
	10					ND	ND	ND	ND		
	11					ND	ND	ND	ND		
	12					ND	ND	ND	ND		
4	13	22	<1k	700	70k	ND	ND	ND	ND	>0.1	>70
	14					ND	ND	ND	ND		
	15					ND	ND	ND	ND		
	16					ND	ND	ND	ND		
5	17	<20	<1k	600	40.6k	ND	ND	ND	ND		>40.6
	18					ND	ND	ND	ND		

Table 4. Lead brick decontamination survey results for a single cycle

Batch #	Brick # for Batch	Initial Smearable (dpm/100 cm²)		Initial Total (dpm/100 cm²)		Final Smearable[a] (dpm/100 cm²)		Final Total[b] (dpm/100 cm²)		Smear Final DF	Total Final DF
		a	ß-?	a	ß-?	a	ß-?	a	ß-?		
	19					ND	ND	ND	ND		
	20					ND	ND	ND	ND		
6	21					ND	ND	ND	ND		
	22					ND	ND	ND	ND		
	23					ND	ND	ND	ND		
	24					ND	ND	ND	ND		
7	25					ND	ND	ND	ND		
	26					ND	ND	ND	ND		
	27					ND	ND	ND	ND		
	28					ND	ND	ND	ND		
8	29					ND	ND	ND	ND		
	30					ND	ND	ND	ND		
	31					ND	ND	ND	ND		
	32					ND	ND	ND	ND		
9	33	<20	<1k	<100	7k	ND	ND	ND	ND		>7
	34					ND	ND	ND	ND		
	35					ND	ND	ND	ND		
	36					ND	ND	ND	ND		
10	37			<100	10.5k	ND	ND	ND	ND		>10.5
	38					ND	ND	ND	ND		
	39					ND	ND	ND	ND		
	40					ND	ND	ND	ND		
11	41			<100	7k	ND	ND	ND	ND		>7
	42					ND	ND	ND	ND		
	43					ND	ND	ND	ND		
	44					ND	ND	ND	ND		
12	45			<100	7k	ND	ND	ND	1500[c]		4.7
	46					ND	2500	ND	6375[d]		
	47					ND	ND	ND	5500[c]		
	48					ND	ND	ND	2500[c]		
13	49			<100	7k	ND	ND	ND	ND		>7
	50					ND	ND	ND	ND		
	51					ND	ND	ND	ND		
	52					ND	ND	ND	ND		
14	53			<100	6.3k	ND	ND	ND	ND		>6.3
	54					ND	ND	ND	ND		
	55					ND	ND	ND	ND		
	56					ND	ND	ND	ND		
15	57			<100	9.1k	ND	ND	ND	ND		>9.1
	58					ND	ND	ND	ND		
	59					ND	ND	ND	ND		
	60					ND	ND	ND	ND		
16	61			<100	8.4k	ND	ND	ND	ND		>8.4
	62					ND	ND	ND	ND		
	63					ND	ND	ND	ND		
	64					ND	ND	ND	ND		

Table 4. Lead brick decontamination survey results for a single cycle

Batch #	Brick # for Batch	Initial Smearable (dpm/100 cm^2)		Initial Total (dpm/100 cm^2)		Final Smearable[a] (dpm/100 cm^2)		Final Total[b] (dpm/100 cm^2)		Smear Final DF	Total Final DF
		a	ß-?	a	ß-?	a	ß-?	a	ß-?		
17	65			<100	70k	ND	ND	ND	12k[e]		5.8
	66					ND	ND	ND	4500[c]		>4.5
	67					ND	ND	ND	ND		
	68					ND	ND	ND	ND		
18	69			150	42k	ND	ND	ND	ND		>42
	70					ND	ND	ND	ND		
	71					ND	ND	ND	ND		
	72					ND	ND	ND	ND		
19	73			<100	28k	ND	ND	ND	ND		>28
	74					ND	ND	ND	ND		
	75					ND	ND	ND	ND		
	76					ND	ND	ND	ND		
20	77			<100	3.5k	ND	ND	ND	ND		>3.5
	78					ND	ND	ND	ND		

k = 000; ND = non-detect; DF = decontamination factor
[a] "Removable" detection limits: a <20 dpm/100 cm^2; ß-? < 1,000 dpm/100 cm^2.
[b] "Total" detection limits: a <100 dpm/100 cm^2 ;ß-?< 1,000 dpm/100 cm^2, background
[c] Second decontamination produced ND results
[d] Third decontamination resulted in 28,000 dpm/100 cm^2; ß-? total
[e] Third decontamination resulted in 6,300 dpm/100 cm^2; ß-? total

Skills/Training

Minimal skills are required to operate the decontamination equipment. However, a chemist experienced in liquid extraction of radioisotopes must be available, whether onsite or on-call offsite, to advise on proportioning the chemical solutions. D&D Workers and radiation control technicians should be trained in Lead Hazards and Awareness, Rad Worker, 40-Hour OSHA, and Bioassay Lead Blood Level Baseline, and be in a respiratory protection program.

Operational Concerns

C The selection of chemicals, operating temperatures, and bath dwell times should be optimized, depending on the substrate being cleaned, what isotopes are being extracted, their concentrations, and their depth below the surface.

C The technology is applicable to lead that has become contaminated from the outside, and not to activated lead or lead that has been remelted after becoming contaminated. Consequently, the history and use of the lead must be determined.

C Cleaned bricks that fail to meet release criteria should be either rerun through the process, disposed of as mixed waste, or decontaminated by a different process.

C To ensure that the decontamination was totally effective, smear samples should be taken from cleaned bricks at least several days after cleaning, when a lead oxide film has formed. This is because after some time the oxide can cause non-fixed contamination to form from beneath the surface.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

• Technology Applicability

The TechXtract® chemical lead decontamination system would be useful at DOE, EPA, or NRC sites in which contamination must be removed from lead surfaces as part of waste minimization, landfill volume reduction, and material recycling processes. The technology could be used economically at facilities where the traditional encapsulation of contaminated lead and subsequent burial would be costly. This technology can be used to decontaminate lead bricks and sheets, as well as objects made of other metals, including tools, fittings, and valves.

• Competing Technologies

A patented process developed by Non Destructive Cleaning Inc. (Walpole, MA) uses small, solid carbon dioxide (CO_2) particles propelled by dry compressed air. The CO_2 particles shatter upon impact with the surface of the material and flash into dry CO_2 gas. The surface is cleaned by the rapidly expanding CO_2 gas lifting and flushing the foreign materials out. Demonstrations at the Hanford Site are summarized below:

- **B-Plant Demonstration -** Successes at the B-Plant from a 3-month demonstration of the CO_2 pellet decontamination technology included the free release of materials and equipment accumulated over 10 years. The efforts resulted in the elimination of hundreds of cubic meters of radioactive waste as well as the decontamination of tons of contaminated lead shielding, allowing the lead to be recycled. Items free released included assorted hand tools, electric drills, cage-type blower wheels, shafts and bearings, shelving, door stop carriers, fan blades, and metal collars.

- **222-S Process and Analytical Laboratories Demonstration -** The demonstration activities at the 222-S laboratories resulted in more than 76.4 m^3 (2700 ft^3) of material decontaminated during the CO_2 blasting process. Most of the material was free released. Where free release was not achieved, two other actions were attained: (1) reducing dose rates (ALARA); and (2) reducing burial costs by converting high-level waste to low-level waste. In addition, a number of chemical sampling hoods were decontaminated for reuse or resale using the CO_2 process. HEPA filter housings and a variety of ducts were also cleaned to determine the CO_2 decontamination efficiency. Select results are summarized as follows with activities reported as “smearable” and “fixed,” dpm/100 cm^2:

  A. Lead bricks with initial smearable at 10k, fixed at 10k-200k, after 90 minutes cleaning time free released at <1k.

  B. Lead bricks with initial smearable at 1k, fixed at 10k-200k, after 10 minutes final smearable at <1k, final fixed at 10k-200k.

ATG Inc., of Richland, Washington, also has a chemical decontamination system using solutions marketed by CORPEX Technologies Inc. (Research Triangle Park, NC) that can decontaminate lead. ATG would handle the bricks at C Reactor as follows:

- Transport the bricks to their facility for decontamination

- Decontaminate the bricks using a cleaning mixture with chelating agents to achieve free release limits

- Survey the bricks to ensure that the free release limits have been successfully met, with 200% surveys on all surfaces to ensure full compliance
- Sell the decontaminated bricks to a commercial buyer for salvage value
- Package any secondary waste and lead that cannot be decontaminated into a form that meets Hanford Site requirements for land disposal.

ATG's price for these services is $1.81/kg ($0.82/lb) based upon a minimum of 1,900 bricks at approximately 11.8 kg (26 lb) per brick. Rather than return the clean lead to BHI, ATG would sell and retain the salvage value for the lead. ATG would survey the bricks, and a salvage value of $0.24/kg ($0.11/lb) for cleaned lead is built into their price.

Patents/Commercialization/Sponsors

Active Environmental Technologies has taken over EET, Inc., which developed the TechXtract® process, partially under the sponsorship of DOE. The DOE commissioned EET to study the ultrasonic-assisted chemical cleaning process and that was completed in July 1997. Active Environmental Technologies owns the patents.

SECTION 5

COST

• Introduction/Methodology

This section provides a cost analysis that compares the costs for the improved and baseline technologies used to disposition lead bricks at the Hanford C Reactor. This analysis determined that improved Scenario A (includes pre-survey of bricks) is 582% more expensive than the baseline and that improved Scenario B (no pre-survey) is 597% more expensive for the conditions and quantities of this demonstration. The improved is more expensive because of the site mobilization cost and the daily cost of the vendor decontamination trailer.

The cost analysis assumes rental of the main equipment for the improved technology (one vendor personnel oversight only) and site labor. The cost estimate is based on decontaminating 1,956 bricks (an extrapolation, based on the actual demonstrated) under two different scenarios compared to the baseline costs for simple disposal of the same quantity of lead bricks. Improved Scenario A incorporates a 100% radiological pre-survey and sort with a 100% post-decon survey while Improved Scenario B uses no pre-survey and sort with a 20% post-decon survey. Scenario A has a lower unit cost than Scenario B because the demonstration indicated that approximately half the used bricks stored at C Reactor can be released without cleaning if the bricks are pre-surveyed. The improved and baseline costs use a site-specific production time available of five hours per eight-hour shift. When using this information for another site, the basis of production and non-production time must be adjusted. The cost effectiveness analysis includes the improved technology equipment, site mobilization, decontamination, demobilization, and secondary waste disposal activities. Each brick weighs 11.8 kg and is 5 cm x 10 cm x 20 cm (2 in. x 4 in. x 8 in.) in size. The baseline disposition of lead bricks at the Hanford Site is to encapsulate the bricks with grout in a cask at $.22/kg ($0.10/lb) followed by disposal as low-level mixed waste at the site Environment Restoration Disposal Facility (ERDF) at $60 per ton of material including lead, grout and the cask, an additional $0.15/kg ($0.07/lb).

• Cost Analysis

The Lead Brick Decontamination technology uses commercially fabricated equipment that is transported to site in a single mobile trailer. The vendor Active Environmental charges $3,500 to deliver one person and the trailer to the Hanford Site in Washington State and return it to New Jersey. This equipment is outfitted with government-owned HEPA vacuum/filtration systems after arrival. The vendor charges $2,700 per eight-hour day including chemicals plus vendor technician living expenses. The costs for equipment rental and purchase and rates for vendor personnel are summarized below.

Description	Hourly Rate	Purchase Price	Maintenance Cost	Technician Living Expense
Decon Trailer	$192	$52,000	$3,000 for 3-year life	
Vendor Technician	$59			$80 per diem

Observed unit costs and production rates for principal components of the demonstrations for both the improved and baseline technologies are presented in this tabulation:

Table 5. Summary of production rates and unit costs

Cost Element	Improved A		Baseline	
	Production Rate	Unit Cost	Production Rate	Unit Cost
Operation	17.9 bricks/hr (including 2 min bricks for pre-survey)	$2.12/kg ($0.96/lb) less salvage value	194 bricks/hr	$0.36/kg ($0.165/lb)
Cost Element	Improved B		Baseline	
	Production Rate	Unit Cost	Production Rate	Unit Cost
Operation	44 bricks/hr	$2.18/kg ($0.99/lb) less salvage value	194 bricks/hr	$0.36/kg ($0.165/lb)

The unit costs and production rates shown for non-productive portions of the work are considered site specific and equal across all scenarios. The intention of this table is to show unit costs at their elemental level that are free of site-specific factors (such as work culture or work environment influences on productivity loss factors). Consequently, the unit costs shown in the above table are the same unit costs for the corresponding line item in Table B-1.A, Table B-1.B, and Table B-2 of Appendix B. Table B-1.A is a summary of the improved decon technology employing a pre-survey of all lead bricks, Table B-1.B uses the same technology without the pre-survey, and Table B-2, the baseline scenario, is provided for comparison of the improved technology to encapsulation/disposal costs.

There are some features of the demonstration that are unique to the Hanford Site and also unique to this demonstration that affect cost. Consequently, specific conditions at other sites will result in different costs. The following site-specific conditions for this demonstration are judged to be the principle factors affecting costs:

- 1956 lead bricks, size 5 cm x 10 cm x 16 cm (2 in. x 4 in. x 8 in.), beta/gamma activity levels less than 800,000 dpm / 100 sq. centimeters
- Compare decon of lead bricks to meet “free release” criteria vs. encapsulation/disposal
- Lead brick pre-survey is approximately 2 minutes per brick
- 50% of bricks pre-surveyed will be free released without subsequent decon
- Lead brick decon is approximately 44 bricks/hr (1.36 minutes per brick based on 300 minutes for 220 bricks) with a failure rate of 6 bricks for every 220 or 2.7%
- Lead brick encapsulation/disposal averages 194 bricks/hr (0.31 minutes per brick) for the baseline alternative.

• Cost Conclusions

The mobilization, decontamination, disposal, and demobilization costs are analyzed for the improved and baseline technologies in this comparison. Since the level of contamination encountered in all three scenarios is the same, the three scenarios for comparison are pre-survey and decon, no pre-survey and decon, and the baseline technology with encapsulation plus disposal. Refer to Appendix B of this report for detailed cost tables for the improved and baseline cost. The costs for the improved and the baseline technologies are summarized in Figure 3. Also, in Figure 4 the three scenarios’ (A, B, & Baseline) costs are shown as a function of the number of bricks.

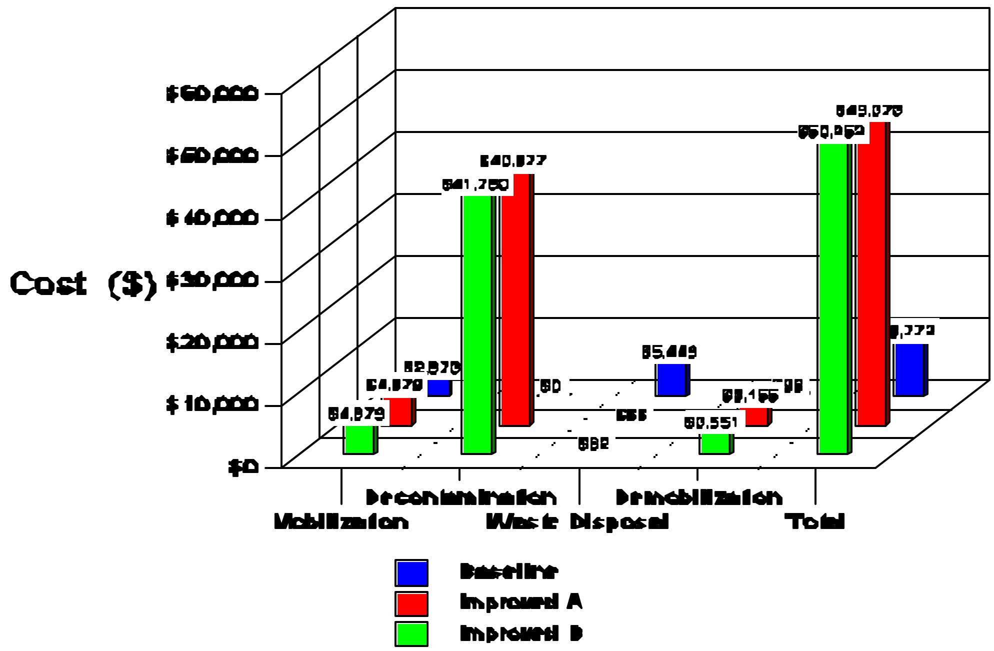

Figure 3. Cost summary.

Figure 4 below shows the dollar relation to the number of bricks for the improved technology scenarios and the baseline disposal scenario.

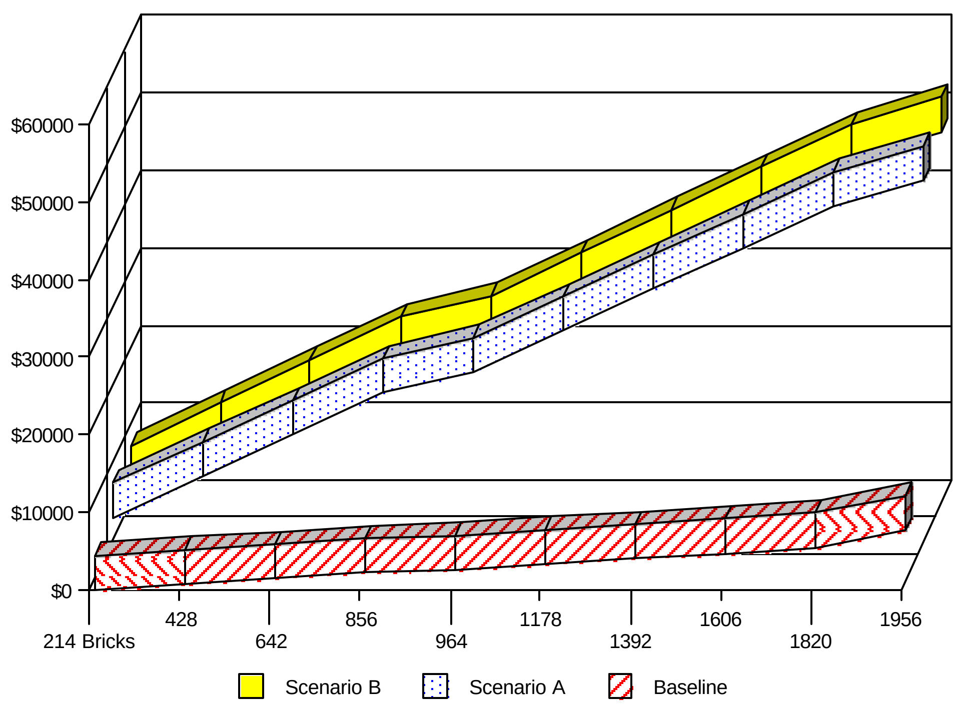

Figure 4. Cost as a function of job size.

Cost Summary

The major cost drivers for the improved technology are the mobilization/demobilization and rental cost of the mobile decon trailer and vendor-supplied technician. The baseline scenario encapsulates and disposes of the contaminated lead bricks. Where continued use of this type of improved decon system would be beneficial, one must consider purchase of the equipment for long-term cost savings. Another consideration is space availability in the disposal facility in the future. Also, for applications away from a readily available disposal facility such as the ERDF, the transportation costs for disposal must be evaluated. Break-even could be realized for other sites with approximately $600/ton versus $60/ton (ERDF) for transport/disposal costs.

The improved technology reduces the disposal volume to a mere 2.7 kg (6 lb) of secondary waste per ton of decontaminated lead. The lead can be recycled and has a salvage value. Also, the improved technology was shown to meet ALARA considerations, worker safety concerns, and could be viable for decon of larger volumes of metals and tool items as would be encountered on a long-term D&D project.

Purchase break-even is 7,450 lead bricks @ 26 lb/brick (194,000 lb of lead). This cost includes vendor technician for onsite oversight for the first 3,000 lead bricks processed for training, process optimization, and troubleshooting.

SECTION 6

REGULATORY/POLICY ISSUES

• Regulatory Considerations

- No special regulatory permits are required for operation of the TechXtract® system. At the Hanford Site, the system meets air quality permit conditions by incorporating HEPA filtration for exhausts from the vacuum stations.
- The system can be used in daily operation under the requirements of 10 CFR Parts 20 and 835, and proposed Part 834 for protection of workers and environment from radiological contaminants; 29 CFR, OSHA worker requirements.
- Although the demonstration took place at a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site, no CERCLA requirements apply to the technology demonstrated.

• Safety, Risk, Benefits, and Community Reaction

Worker Safety

- Normal radiation protection worker safety procedures used at the facility apply. Where there is potential exposure to organic vapors generated from heated chemical baths, use of an air purifying respirator (APR) with a charcoal cartridge may be needed. The acid strength of solutions is not high enough to pose a hazard.
- In order to avoid spreading contamination, the operator must ensure that the HEPA filters are operating normally.
- National Electric Code requirements should be met for the electric system.

Community Safety

- It is not anticipated that implementation of the TechXtract® technology would present any adverse impacts to community safety if cleaned materials are properly surveyed for release.

• Environmental Impact

- It is not anticipated that implementation of the TechXtract® technology would present any adverse impacts to the environment if cleaned materials are properly surveyed for release.

• Socioeconomic Impacts, and Community Perception

- No socioeconomic impacts are expected in association with the use of this technology.

SECTION 7

LESSONS LEARNED

• Implementation

No special implementation concerns apply to TechXtract® technology. Ordinary electrical power supply voltage and circuitry are used for heating chemical solutions and for exhausting air from the vacuum drying stations.

• Technology Limitations/Needs for Future Development

Currently, there is no need to modify the system demonstrated at the Hanford Site C Reactor. However, refinements that could be made to either the mechanical or chemical features of the system include:

- Add a HEPA-filtered ventilation system to allow more highly contaminated bricks to be processed
- Automate the manual hoist system
- Explore shorter dwell times and/or eliminate one dipping step to increase throughput
- Adapt the brick holders to process other metal items such as tools
- Enlarge the batch size to increase throughput and reduce costs.

• Technology Selection Considerations

- The technology is suitable for DOE nuclear facility D&D sites or commercial nuclear power sites where lead bricks or other metal objects must be decontaminated to facilitate release.

- The technology should be especially considered where costs for disposal of low-level mixed waste are more expensive than at the Hanford Site.

APPENDIX A

REFERENCES

10 CFR Part 835, "Standards for Protection Against Radiation, " *Code of Federal Regulations,* as amended.

Proposed 10 CFR Part 834, "Environmental Radiation Protection," *Code of Federal Regulations,* as proposed.

10 CFR Part 20, "Occupational Radiation Protection," *Code of Federal Regulations,* as amended.

29 CFR Part 1910, "Occupational Safety and Health Standards," *Code of Federal Regulations,* as amended.

29 CFR Part 1926, "Safety and Health Regulations for Construction," *Code of Federal Regulations,* as amended.

40 CFR Part 268.451, "Treatment Standards."

Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary, 1996, Headquarters United States Army Corps of Engineers, 20 Massachusetts Avenue, N.W., Washington, D.C., 20314-1000.

Means Construction Equipment Cost Data, R.S. Means Co., Kingston, Massachusetts 1997.

Office of Management and Budget (OMB) Circular No. A-94 for Cost Effectiveness Analysis

USACE, 1996, *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS), U.S. Army Corps of Engineers, Washington, D.C.

APPENDIX B

COST COMPARISON

• Technology Cost Comparison

The cost effectiveness analysis computes the cost for the lead brick decontamination job by using hourly rates for equipment and labor.

The selected basic activities being analyzed come from the Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS), USACE, 1996. The HTRW RA WBS, developed by an interagency group, used in this analysis to provide consistency with the established national standards.

Some costs are omitted from this analysis so that it is easier to understand and to facilitate comparison with costs for the individual site. The overhead and general and administrative (G&A) mark up costs for the site contractor managing the demonstration are omitted from this analysis. Overhead and G&A rates for each DOE site vary in magnitude and in the way they are applied. Decision makers seeking site-specific costs can apply their site's rates to this analysis without having to first back-out the rates used at the Hanford Site.

The following assumptions were used as the basis of the improved cost analysis:

- Oversight engineering, quality assurance, and administrative costs for the demonstration are not included. These are normally covered by another cost element, generally as an undistributed cost.
- The equipment hourly rates for the site owned equipment that may be used in support of the improved equipment (for example the site owned truck that transports the rented improved equipment from the warehouse receiving to the C Reactor) uses standard equipment rates established at Hanford.
- The equipment hourly rate for the Active Environmental decon trailer and vendor supplied technician are based on a rental rate and operation cost from the vendor for the improved technology (hourly rate used in the analysis based on daily rate of $2700/8 hours).
- The standard labor rates established by the Hanford Site for estimating D&D work are used in this analysis for the portions of the work performed by local crafts.
- The analysis uses an eight-hour work day with an effective five hours of production time day net due to site culture and constraints, including don/doff PPE, surveying personnel exiting from the work zone, and documenting results of surveying bricks.

MOBILIZATION (WBS 331.01)

Move Decon Trailer to Work Area: The vendor charges a flat rate to bring one vendor person and the trailer with chemicals to the Hanford site and return it to New Jersey. Also, there is a per diem living expense charge for the vendor-supplied person. Observed time for vendor set up of the trailer and warming of the chemical baths was used for the improved technology cost analysis.

Setup of Rad Zone Tape Barricades and Signs: An estimate of time required for two D&D workers and two RCTs to set up the rad zone tape barricades and signs is used for the both the improved and the baseline technologies and considered to be an equal amount of time and effort.

Install Temporary Power Supply to Trailer: Observed time required for two electricians to connect a temporary power supply from a portable generator to the vendor decon trailer is used for the improved technology.

Move/Setup for Disposal at Environmental Restoration Disposal Facility (ERDF): This activity applies only to the baseline and is based on information from an onsite disposal subcontractor given to the C Reactor technical engineer.

Install Temporary HEPA Vacuum/Filtration Systems: In both of the improved scenarios(pre-survey **A** and non pre-survey **B**), HEPA vacuum/filtration systems must be installed for the vacuum drying stations prior to the start of work.

DECONTAMINATION (WBS 331.17)

Safety Meeting: The costs for the improved technology are assumed to be similar to the duration for the baseline.

Don and Doff PPE: This cost item includes time for each worker to fully suit-up in personal protective equipment/clothing (PPE) as well as material costs for the PPE, and includes removal of the PPE. The time spent donning and doffing each day is based on observed times for previous projects (long-term and large-scale jobs). Material costs for daily PPE for one D&D worker at the Hanford Site are shown in the table below:

Equipment	Cost Each Time Used ($)	No. Used Per Day	Cost Per Day ($)
Air Purifying Respirator (PAPR)	71.06	1 ea	71.06
Face Shield	1.28	1 ea	1.28
Booties	0.62	2 pr	1.24
Coverall	5.00	2 ea	10.00
Double Coverall (5% of the time)			0.56
Hood	2.00	2 ea	4.00
Gloves (inner)	0.14	2 pr	.28
Gloves (outer)	1.30	2 pr	2.60
Gloves (liner)	0.29	2 pr	.58
Rubber Overshoe	1.38	2 pr	2.76
Total			**94.36**

Notes: Based on a PAPR price of $603 each, assuming 50 uses, requiring four cartridges per day at a cost of $14 each, and maintenance and inspection costs of $150 over the life of the PAPR (50 uses). Based on a face shield price of $64 each and assuming 50 uses, one RCT is assumed to remain out side the contaminated area and does not suit up.

Sort and Pre-survey Lead Bricks and Post-survey 100%: For **Scenario A** of the demonstration of the improved technology (the actual procedure used), two RCTs and one D&D worker performed the pre-surveying at an average rate of two minutes/brick. The pre-surveying was done before the vendor's person and trailer arrived onsite. About half of the bricks pre-surveyed needed cleaning and about half were releasable without cleaning and have salvage value (salvage value will not be considered for the purpose of this cost comparison since the baseline scenario is for 100% disposal). For each of the 214 bricks that were successfully cleaned, another 220 releasable bricks found in the pre-survey could be added to the clean pile. This production rate or success factor is based on observation during the demonstration. To derive the total weight for the dollars per pound ($/lb) for Scenario A use (214 + 220) x 26 lb/day = 11,284 lb/day. RCT time is needed for an RCT to analyze swipe samples; this is done right at C Reactor. During the days of decon production for Scenario A, 1½ RCTs are required and need time each day for paperwork, which will require one RCT to work an hour of overtime each day during the production phase of this scenario.

No Sort and No Pre-survey and Post-survey 20%: For **Scenario B** of the improved technology, the net production rate is 214 bricks per day (the rate achieved during the demonstration, but without the benefit of the additional clean 220 bricks obtained during the pre-survey). To derive the total weight for the dollars per pound ($/lb) conversion for this scenario use 214 x 26 lb/day = 5,564 lb/day. The paperwork requirements of the RCTs is estimated at 20% of Scenario A so there would be no overtime required for Scenario B.

Decon of Lead Bricks: Both Scenario A and Scenario B of the improved technology demonstrated are the same for the performance of the actual decon activities. With the trailer set up and the chemical baths warmed, 4 bricks (a batch) were placed into a semi-basket suspended from a chain hoist on a monorail that runs the circuit of the processing area in the trailer and outside for loading and unloading baskets. Each batch was dipped for 5 minutes (this was proven to be an adequate amount of time) in each of two baths in series and then lowered into a vacuum drying sink. Next the batch was dipped for 5 minutes into the third solution bath and then lowered into the second vacuum drying sink. Finally the batch was manually pulled out of the semi-basket and each of the 4 bricks was hand vacuumed individually. It took 30 minutes for the full production run of the first batch with subsequent batches rolling out every five minutes thereafter. The decon time per brick, based on the five hours (300 minutes) actual working time in an eight hour shift, is computed as 300 min/220 bricks = 1.36 min/brick. The failure rate was determined in the demonstration to be 2.7%. The result is a net of 214 successfully decontaminated lead bricks in five hours of production time.

Disposal of Lead Bricks at the ERDF: The baseline scenario is for encapsulation followed by 100% disposal and estimates are based on information from an onsite disposal subcontractor given to the C Reactor technical engineer and site-established cost standards. See Waste Disposal (WBS 331.18) below.

Non-Productive Time: The non-productive time used in this cost analysis for both the improved and the baseline technologies is based on the use of 5 hours of production time as a standard for all scenarios. An average loss per 8 hour day of 3 hours is used to account for unexpected issues with the work, waiting on RCT support, including don/doff PPE, surveying personnel exiting form the work zone, and documenting results of surveying bricks, and for expected production time loss for safety meetings.

Wrap PAPRs: The average time observed in the baseline for wrapping powered air-purifying respirators (PAPRs) was assumed for both the improved and the baseline technologies.

DEMOBILIZATION (WBS 331.21)

Disassemble & Decontaminate Equipment: The durations observed for the improved scenario will be used for the improved estimate. One vendor person, one D&D worker and 1¼ RCTs must add reagents to solidify the spent chemical solutions and wipe down the inside of the trailer. Also, two RCTs must survey/release the trailer and do the associated paper work while the vendor person is on standby and charging for the time. The baseline scenario durations will be considered equal since approximately the same amount of paper work must be filled out and cleanup of work areas and equipment must be performed.

WASTE DISPOSAL (WBS 331.18)

Disposal of PPE, Plastic, Sheeting, and Sleeving: The observed quantity and duration for the baseline is assumed for the improved technology.

Disposal of Secondary Waste Produced: The secondary waste produced from the cleaning chemicals has been determined to be 6 pounds per ton processed. This is from the addition of reagents to the cleaning chemicals to solidify them. The weight would be equal to 6 lb x 25.43 tons or 152.58 pounds. Once solidified, this would be disposed of at the ERDF at the $60/ton Hanford Site rate.

Disposal of Lead Bricks: The baseline scenario is for 100% disposal and estimates are based on information form an onsite disposal subcontractor given to the C Reactor technical engineer and site established cost standards. The 1,956 lead bricks would be encapsulated and disposed of at the ERDF with no salvage value. This scenario requires purchase of a liner (cask), shoring of the cask, loading of the bricks into the cask, encapsulation of the bricks in the cask with grout, and disposal. The costs are $60/ton for disposal at the ERDF, and apply to the total weight of the lead, grout and liner. The total lead brick weight is calculated as: 0.037 cf per brick (2-in x 4-in x 8-in) x 708 lb/cf x 1956 bricks = 51,257 lb. Liner consists of a cask with the dimensions 23-ft x 8-ft x 4-ft of 300 mil HDPE. This results in 15.4 cf of HDPE. At a density of 74.88 lb/cf, the weight of HDPE is 1,153 lb. The grout fills the voids in the HDPE lined cell. If the cell volume is 23-ft x 8-ft x 4-ft = 736 cf, and the volume of the bricks is 72.4 cf (2-in x 4-in x 8-in x 1956 bricks) then there are 664 cf of grout. Assuming a typical weight of grout of 100 lb/cf, the total grout weight is 66,356 lb. Total weight for lead, liner and grout is 118,766 lb (59.4 tons). The cost for hauling and burial at $60/ton is (59.4 ton x $60/ton) 51,257 lb of lead, or $0.07/lb of lead.

The details of the cost analysis for the two improved options and the baseline are summarized in Tables B-1.A, B-1.B and B-2.

Table B-1.A. Cost summary - improved technology A

Work Breakdown Structure (WBS)	Unit	Unit Cost $	Qty	Total Cost $	Computation of Unit Cost: Prod Rate	Duration (hr)	Labor & Equipment Rates: Labor Items	$/hr	Equipment Items	$/hr	Other Costs and Comments
MOBILIZATION (WBS 331.01)		**Subtotal**		**$ 4,878.95**							
Move Decon Trailer to/from Work Area (round trip)	LS	$ 3,500.00	1.00	$ 3,500.00					DCT		Vendor LS
Install Temp Power to Trailer	LS	$ 439.54	1.00	$ 439.54		1.00	2 ES	$ 92.04	DCT	$ 347.50	
Install Temp HEPA Systems	LS	$ 428.97	1.00	$ 428.97		1.00	1RCT+1DD	$ 81.47	DCT	$ 347.50	
Setup Rad Zone	LS	$ 510.44	1.00	$ 510.44		1.00	2RCT+2DD	$ 162.94	DCT	$ 347.50	
DECONTAMINATION (WBS 331.17)		**Subtotal**		$ 40,876.92							
Safety/Pre-job Meetings	Hours				included	in	non-production	time			
Don & Doff PPE (13 days pre-survey) (5 days decon work)	Person Day Person Day	$ 94.36 $ 94.36	39.00 20.00	$ 3,680.04 $ 1,887.20			2RCT+1DD 2DD+1V+1RCT		PPE		PPE $94.36/ person/day
Non-Production Pre-survey Non-Production Decon	Day Day	$ 392.91 $1,457.07	13 5	$5,107.83 $ 7285.35		3 3	2RCT+1DD 2DD+1½ RCT	$130.97 138.19	DCT	$ 347.50	Trailer on standby
Sort and Pre-survey (5 hrs per day)	Hours	$ 130.97	65.20	$ 8,539.24		65.20	2RCT+1DD	$ 130.97			Survey 2 min/brick
Decon of Lead Bricks (5 hrs per day of production)	Hours	$ 485.69	21.85	$ 10,612.65		21.85	2DD+1½ RCT	time	DCT	$ 347.50	Decon 1.36 min./brick
RCT Overtime Required per Day (During decon only)	Day	$ 74.25	5.00	$ 371.25		1.00	1 ½ RCT	$ 74.25			1 hour/day of O/T
HEPA Filters for Vendor Trailer	LS	$ 3,393.36	1.00	$ 3,393.36		72.00			HEPA	$ 47.13	3 @ $15.71/hr
DEMOBILIZATION (WBS 331.21)		**Subtotal**		$ 3,551.40							
Disassemble & Decon Equip: Add reagent/wipe down trailer	Hour	$ 93.85	4.00	$ 375.40		4.00	1DD+1 1/4 RCT	$ 93.85	DCT	$ 347.50	
Vendor assist add reagent/wipe down trailer	Hour	$ 347.50	4.00	$ 1,390.00		4.00	1V				
Survey/release trailer & paper work	Hour	$ 99.00	4.00	$ 396.00		4.00	2RCT	$ 99.00			
Vendor standby for 4 Hours awaiting release	Hour	$ 347.50	4.00	$ 1,390.00		4.00	1V		DCT	$347.50	
WASTE DISPOSAL (WBS 331.18)		**Subtotal**		**$ 61.52**							
Disposal of PPE, Plastic, Sheeting	LS	$ 56.72	1.00	$ 56.72		0.50	2DD+.24 RCT	$ 75.74			Disposal fee $60/ton included
Disposal of Secondary Waste	Ton	$ 60.00	0.08	$ 4.80							6 lb/ton x 25.43 tons =153 lb
TOTAL				$ 49,373.59	$ .96 per	lb.	to decon				

Table B-1.B. Cost summary - improved technology B

Work Breakdown Structure (WBS)	Unit	Unit Cost $	Quantity	Total Cost $	Computation of Unit Cost: Prod Rate	Duration (hr)	Labor & Equipment Rates: Labor Items	$/hr	Equipment Items	$/hr	Other Costs and Comments
MOBILIZATION (WBS 331.01) Subtotal				**$ 4,878.95**							
Move Decon Trailer to/from Work Area (round trip)	LS	$3,500.00	1.00	$ 3,500.00							Vendor LS
Install Temp Power to Trailer	LS	$ 439.54	1.00	$ 439.54		1.00	2ES	$ 92.04	DCT	$ 347.50	
Install Temp HEPA Systems	LS	$ 428.97	1.00	$ 428.97		1.00	1RCT+1DD	$ 81.47	DCT	$ 347.50	
Setup Rad Zone	LS	$ 510.44	1.00	$ 510.44		1.00	2RCT+2DD	$ 162.94	DCT	$ 347.50	
DECONTAMINATION (WBS 331.17) Subtotal				**$ 41,760.00**							
Safety/Pre-job Meetings	Hours			Included in	non-prod	time					
Don & Doff PPE (decon 9 days) (hours accounted for in non-production time below)	Per-son Day	$ 94.36	36.00	$ 3,396.96			2DD+1V+1RCT	part of nonprod time	PPE		PPE cost is $94.36/person/day
Non-Production Time (3 hrs x 9 days)	Hours	$ 485.69	27	$ 13,113.63		27	2DD+1½ RCT	$ 138.19	DCT	$ 347.50	
Decon of Lead Bricks (5 hrs per day)	Hours	$ 485.69	45	$ 21,856.05		45	2DD+1½ RCT	$ 138.19	DCT	$ 347.50	1.36 min/brick
HEPA Filters for Vendor Trailer	Hours	$ 47.13	72.00	$ 3,393.36		72.00			HEPA	$ 47.13	3 each @ $15.71/hr
DEMOBILIZATION (WBS 331.21) Subtotal				**$ 3,551.40**							
Disassemble & Decon Equip: Add reagent/wipedown trailer	Hours	$ 93.85	4.00	$ 375.40		4.00	1DD+1 1/4 RCT	$ 93.85			
Vendor assist add reagent / wipe down trailer	Hours	$347.50	4.00	$ 1,390.00		4.00	1V		DCT	$347.50	
Survey/release trailer & paper work	Hours	$ 99.00	4.00	$ 396.00		4.00	2 RCT	$ 99.00			
Vendor standby for 4 Hrs awaiting release	Hours	$347.50	4.00	$ 1,390.00		4.00	1V		DCT	$347.50	
WASTE DISPOSAL (WBS 331.18) Subtotal				$ 61.52							
Disposal of PPE, Plastic, Sheeting	Hours	$ 113.44	.50	$ 56.72		0.50	2DD+1RCT	$ 113.44			
Disposal cost of Secondary Waste	Ton	$ 60.00	0.08	$ 4.80							6# X 25.43 tons = 152.58
TOTAL				$ 50,251.87	$ .99 per	lb	to decon				
Crew Item	**Rate $/hr**	**Abbrevi-ation**	**Crew Item**		**Rate $/hr**	**Abbrevi-ation**	**Crew Item**	**Rate $/hr**	**Abbrevi-ation**	**Crew Item**	**Rate $/hr** / **Abbrevi-ation**

Table B-2. Cost summary - baseline disposal technology

Work Breakdown Structure (WBS)	Unit	Unit Cost $	Qty	Total Cost $	Computation of Unit Cost Prod Rate	Duration (hr)	Labor & Equipment Rates Labor Items	$/hr	Equipment Items	$/hr	Other Costs and Comments
MOBILIZATION (WBS 331.01) Subtotal				**$ 2,873.48**							
Purchase Liner (cask) & Ship to Site	LS	$ 1,950.00	1.00	$ 1,950.00					LSA/Liner		$1200 cost + $750 shipping
Roadway Shoring: Move shoring material to area	Hours	$110.50	1.00	$ 110.50		1.00	1OP+1TM	$ 75.03	LD+TK	$ 35.47	
Perform shoring of roadway	Hours	$ 205.37	2.00	$ 410.74		2.00	1OP+1TM+1SL+1L	$165.88	LD+WT	$ 39.49	
Setup Rad Zone at C Reactor and ERDF	Hours	$ 162.94	2.00	$ 325.88		1.00	2RCT+2DD	$ 162.94			
Setup for Disposal at ERDF: Place liner in ERDF	Hours	$ 152.72	.50	$ 76.36		0.50	1OP+1TM	$ 75.03	CR+TK	$ 77.69	
DECONTAMINATE (WBS 331.17) Subtotal				**$ 0.00**							
n/a											
DEMOBILIZATION (WBS 331.21) Subtotal				**$ 95.57**							
Survey/Decon of Equipment	Hours	$ 191.13	.50	$ 95.57		0.50	2DD+1RCT	$ 113.44	CR+TK	$ 77.69	
WASTE DISPOSAL (WBS 331.18) Subtotal					**$**	**5, 802.84**					
PPE & PAPRs Required in Rad Zones (2 days)	PPE	$ 94.36	10.00	$ 943.60			1RCT+2DD+1SL+1OP		PPE/PAPR		PPE cost is $94.36/person/day
Waste Disposal Fee	Ton	$ 60.00	59.4	$ 3,562.97							Transport & burial $60/ton
Load Lead Bricks into Liner	Hours	$ 211.72	2.00	$ 423.44		2.00	2DD+1OP+1SL+1RCT	$ 211.72			
Grout Lead Bricks in Liner to Fill Voids	LS	$ 564.23	1.00	$ 564.23		1.00	1DD+1OP+1TM	$ 107.00	PT+ 20 cu Grout	$ 457.23	Grout is $22.50 cubic yd. Pump is 2.49, Truck is 4.74
Seal Lid on Liner	Hours	$ 123.54	2.00	$ 247.08		2.00	2DD+1SL	$ 123.54			Encapsulation not included
Haul Lead Bricks to ERDF	Ton	$ 60.00	25.43								Included in Waste Disposal Fee
Disposal of PPE, Plastic, Sheeting	Hours	$ 113.44	.50	$ 61.52		0.50	2DD+1RCT	$ 113.44			Transport & burial $60/ton
TOTAL				$ 8,771.89	$ .17	per	lb for encapsulation and disposal				
Crew Item	**Rate $/hr**	**Abbrevi-ation**	**Crew Item**		**Rate $/hr**	**Abbreviation**	**Crew Item**	**Rate $/hr**	**Abbreviation**	**Crew Item**	**Rate $/hr** / **Abbrevi-ation**

APPENDIX C

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Description
ALARA	as low as reasonably achievable
APR	air purifying respirator
ASTM	American Society for Testing of Materials
BHI	Bechtel Hanford, Inc.
cf	cubic feet
CFR	*Code of Federal Regulations*
D&D	decontamination and decommissioning
DF	decontamination factor
DOE	U.S. Department of Energy
DOE-RL	DOE-Richland Operations Office (WA)
ERDF	Environmental Restoration Disposal Facility (landfill)
FETC	Federal Energy Technology Center
HDPE	high-density polyethylene
HEPA	high-efficiency particulate air (filtration)
ISS	interim safe storage
LSDDP	Large-Scale Demonstration and Deployment Project
PCB	polychlorinated biphenyl
PPE	personal protective equipment
RCT	radiological control technician
USACE	U.S. Army Corps of Engineers
WBS	work breakdown structure