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TO RETRIEVE OR NOT TO RETRIEVE: THESE ARE THE ISSUES

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TO RETRIEVE OR NOT TO RETRIEVE?
THIS IS THE QUESTION.

There are many factors that must be evaluated when determining whether a buried mixed waste site should be retrieved and subsequently stored, treated, and/or disposed of, or if some other action is more appropriate.

The criteria developed for the evaluation of remedial actions at mixed waste sites under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulation EPA (1), provide an excellent methodology for deciding upon a preferred action - even if the site is not under CERCLA regulation. Each topic for evaluation in the criteria is not mutually exclusive, and many tradeoffs must be reviewed. The criteria have been broken down into a number of categories: overall protection of human health and the environment; compliance with Applicable or Relevant and Appropriate Requirements (ARARs); long-term effectiveness and permanence; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; cost; state acceptance; and community acceptance. These categories are shown below in more detail.

Overall Protection of Human Health and the Environment

- How the technology provides human health and environmental protection.

Compliance with ARARs:

- Compliance with chemical-specific ARARs
- Compliance with Action-Specific ARARs
- Compliance with Location-Specific ARARs
- Compliance with other criteria, advisories, and guidance

Long-term Effectiveness:

- Magnitude of residual risk
- Adequacy and reliability of controls

Reduction of Toxicity, Mobility, and Volume

- Treatment process used and materials treated
- Amount of hazardous materials destroyed or treated
- Degree of expected reductions in toxicity, mobility, and volume
- Degree to which treatment is irreversible
- Type and quantity of residuals remaining after treatment

Short-term Effectiveness:

- Protection of community during remedial actions
- Protection of workers during remedial actions
- Environmental impacts
- Time until remedial action objectives are achieved

Implementability:

- Ability to construct and operate the technology
- Reliability of the technology
- Ease of undertaking additional remedial actions, if necessary
- Ability to monitor effectiveness of remedy
- Ability to obtain approvals from other agencies
- Coordination with other agencies
- Availability and capacity of off-site treatment, storage, and disposal services
- Availability of necessary equipment and specialists
- Availability of prospective technologies

Cost:

- Capital costs
- Operating and Maintenance costs

Figure 1 shows a high level process flow for determining a preferred action. Before any decisions can be made concerning retrieving the waste and treating it later or choosing a different alternative, the site must be characterized using geophysical, radiological, and chemical sensors (as appropriate) to identify the level of contamination, expected objects, geometric boundaries, and depth of the contaminated waste. Crane-deployed sensors, remotely operated vehicles, traditional characterization methods, or other characterization equipment is required to perform this task. Different characterization options will require different levels of rigor with respect to the type and amount of data to be collected. The expected levels of contamination, other hazards of the particular site, and historical records also drive the rigor required.

Once the data is gathered, a Hazards Analysis must be performed to understand the risks of the site to workers, the public, and the environment. The Hazard Analysis is critical in helping personnel understand the associated issues so that an effective evaluation can take place.

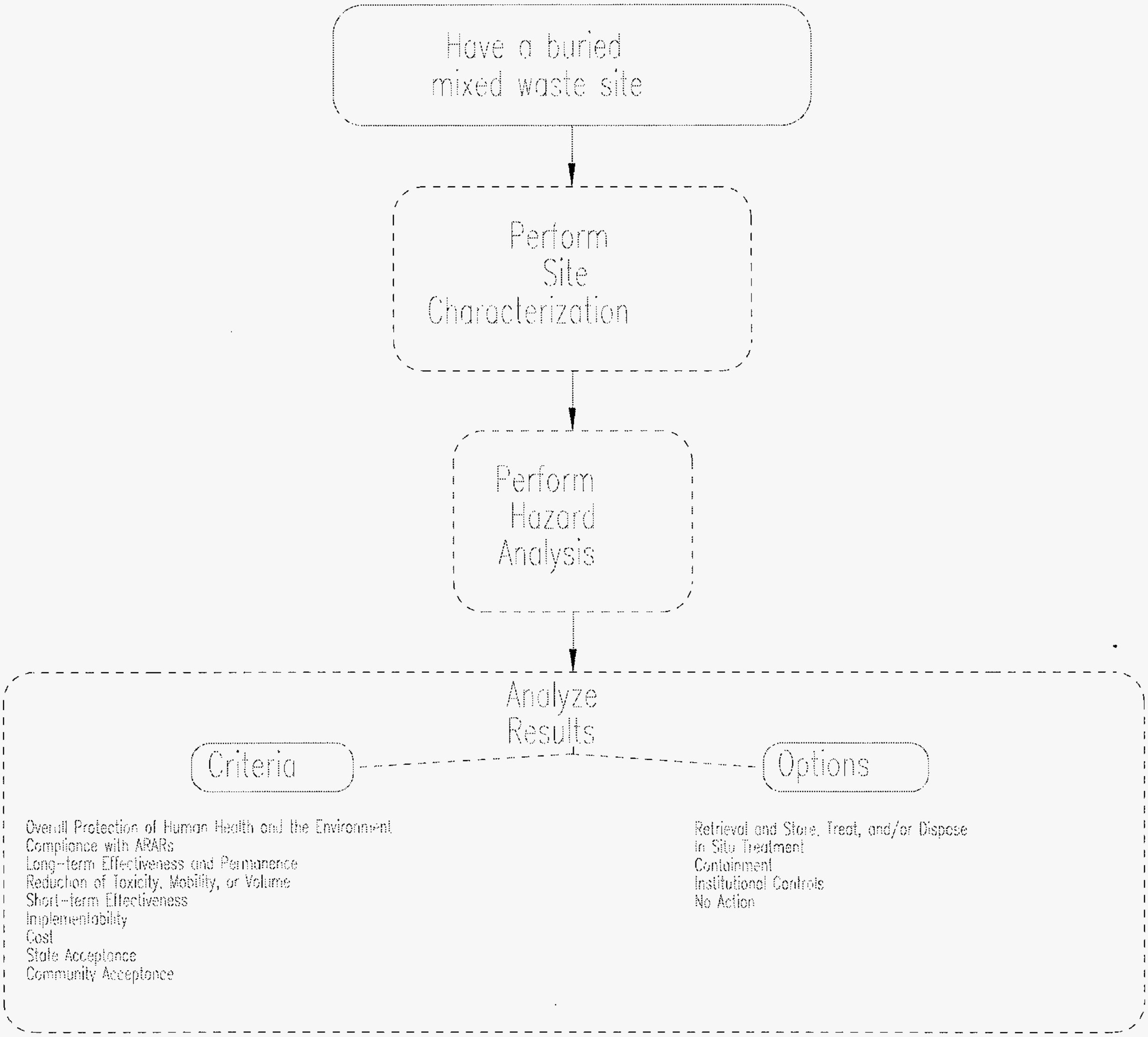

Figure 1. Process Flow for Determining Preferred Option

Typically, alternatives are formed and evaluated. Some of these options can be screened based on Stakeholder (regulatory and community) issues. In addition, the future use designation of the land can screen out some options. However, there are always tradeoffs that should be considered.

The intent of this paper is not to focus on a particular site, but to provide information that is useful for many problem holders to better understand the issues associated with buried mixed waste retrieval. Ultimately, these issues affect the final decision of whether or not retrieval is a feasible alternative.

Contaminated buried mixed waste sites in the United States of America can have other alternatives open to them, including: no action, provide institutional controls, contain the waste, or encapsulate the waste in situ. These alternatives also have many issues associated with them. Personnel at the sites are required to prove that the waste will be secure for the entire life of the contaminant of concern, until the exposure levels of the substance fall within acceptable limits. This could mean that the site must protect the environment from the waste for as little as a few years up to thousands of years, depending on the type and amount of waste present at the waste site. The future use designation of the site, and other issues, can also drive the feasibility of these other options. However, this paper concentrates on those issues specific to a retrieval option.

IS IT MORE NOBLE TO RETRIEVE?

Assuming that the retrieve and treat, store, and/or dispose scenario is of interest as a preferred alternative, there are issues that affect it's feasibility. The decision really boils down to: *Can it be done?* and *Is it worth it?*. The issues discussed below are more unique to a retrieval option than to no action, institutional controls, containment, or in situ treatment.

CAN IT BE DONE?

There are several issues that must be considered when implementing a retrieval action. Factors that affect the implementability of a retrieve and treat, store, and/or dispose scenario include: contaminant of concern (COC); site location and access; the depth, size, and weight of objects in the waste matrix; contamination control; decontamination issues; transport; mobilization and demobilization; and final disposition of waste.

Once the decision to retrieve the waste has been determined, the method of retrieval must be considered - manually or remotely. The methods used will be determined by general regulatory concerns and the concept of keeping the exposure of personnel As Low As Reasonably Achievable (ALARA). If the contaminant of concern poses a low risk to personnel, the public, and the environment, less stringent controls are required, and manual retrieval is probably the best way to go. Manual retrieval can be accomplished more quickly and inexpensively than remote retrieval. If manually retrieving the waste does not provide adequate personnel safety, remote operations will have to be conducted Hyde et al. (2). As remote operations are more likely to be used in sites with higher risks to personnel, the public, and the environment, the following discussion will focus on those issues associated with remote operations.

Confinement Enclosure

Alpha contamination is probably the most difficult contaminant of concern to deal with in a retrieval situation. If alpha contamination is one of the constituents in the mixed waste matrix, either a confinement enclosure with negative pressure or a double confinement is needed during the retrieval activities. In both cases, air lock doors with good seals should be provided to bring equipment in and out of the confinement enclosure without risking exposure to personnel or allowing releases to the environment. Radiological and chemical monitors should be incorporated into the ventilation exhaust downstream from high efficiency particulate air filters (HEPAs) to ensure air emissions are below regulatory limits.

Contamination Control

Once equipment is contaminated with alpha particulates, it is very difficult to decontaminate, thus an aggressive contamination control strategy should be undertaken to keep any equipment in the confinement enclosure or double confinement as clean as possible. This may include in situ soil stabilization to control the contamination at its source by encapsulating the soil in a grout or polymer, electrostatic curtains or electrostatic plastic to shield the equipment, soil fixants and dust suppressants, water misters, et cetera. The confinement enclosure/double confinement could also contain some form of polyethylene liner, which could be removed and disposed of as waste should it become contaminated. This liner would minimize the potential need to dispose of the confinement enclosure as waste.

Retrieval Equipment

Several options exist with respect to the remotely operated retrieval equipment. Parameters that must be considered when choosing retrieval equipment include the depth, size, and weight of the buried objects; access to the excavation site; mobilization and demobilization issues; and transportation of the equipment. Heavy, large objects can be lifted out of an excavation site with either a large excavator or crane. Excavators are preferred in most retrieval actions because they do not require rails or tracks to operate as do cranes. Cranes, however, do offer an advantage for "surgical" retrieval because they can be position controlled and are easier to operate.

In sites with limited space or access, consideration should be given to vertical excavation, using subsurface barrier walls created by jet-grouting cement or polymer into the soil surrounding the pit. The barrier walls could then be sprayed with soil stabilizers to keep the surface from eroding or breaking up during retrieval. These walls not only minimize the size of the excavation pit, but also allow the use of smaller excavators, as vertical excavation precludes the need to reach over a sloped area to gather waste. In addition, excavators are more readily transported from site to site, thus making mobilization, demobilization and transportation of the equipment easier and less expensive. If an excavator is used, however, care must be taken in choosing an excavator capable of lifting heavy objects out of the excavation pit at the required depth from all of the different boom positions. This will be site dependent.

Waste Transfer

Equipment may be necessary to transport the retrieved waste from the excavator or crane to the waste segregation equipment. This waste transfer system could consist of a remotely operated forklift, an overhead trolley and crane system, a conveyor, or other more conventional transportation system. Transfer systems that reduce dust generation and are easily decontaminated should be used.

Remote Vision

In conjunction with the equipment used for the actual removal of waste from the site, consideration must be given to the remote vision system and how it will effect operations. Cameras being used in alpha contaminated areas should be sealed to protect them from any airborne particulates, be operable in the radiation fields expected at the site, be capable of self-defogging and cleaning, and be compatible with the control system on the retrieval equipment. Care should also be taken in the placement of the cameras to avoid any voids in coverage, or areas that will not be visible by the cameras due to shadowing created by other equipment. A combination of stereoscopic and two dimensional camera systems is currently the most widely used form of remote vision and has been shown to be quite adequate in remote operations. The addition of the stereoscopic cameras can reduce the time required for many tasks by more than 50 percent.

Waste Minimization

Once the waste has been retrieved from the site, the next question is "What does one do with it?". If the waste has been determined to be treatable, it can be packaged in standard waste packages, decontaminated sufficiently for transport, and sent to a treatment facility. If the waste will be stored or disposed of, consideration should be given to waste volume minimization prior to packaging, as the volume of waste to be packaged and stored directly determines cost. Any time the waste volume can be minimized, it should. Waste volume minimization could be accomplished by waste sorting, compaction, or sizing.

The sorting of waste could be done according to radioactivity level, contaminant of concern, or physical size. Only waste determined to be a risk to personnel, the public, or the environment would be packaged and treated, stored, or disposed of, thus reducing the waste volume that must be dealt with. It should be noted that if in situ stabilization is chosen as a form of contamination control, care must be given in choosing a stabilization media as it could affect the ability to separate the waste later. For example, cement is commonly used to encapsulate the waste. Once encapsulated, however, it is not easily separated from the waste and thus becomes an integral part of the waste matrix. Wax based media, on the other hand, could be removed easily from the waste matrix simply by heating the waste at low temperatures.

Waste compactors are available in many different sizes with very high compression forces. Several of the commercially available compactors are available with negative pressure compaction chambers for use in mixed waste environments and can be operated remotely. The waste is compacted into a variety of standard waste packages, including different sized boxes, 55-gallon drums, and 83-gallon drums. By compacting and packaging the waste with one piece of equipment, the decontamination required later is also minimized.

Sizing the waste can be accomplished by using shredders, saws of different types, cryogenic fracturing, abrasive cutters, lasers, water jets, cryogenic cutting, shears, and pipe or wire cutters, just to name a few. The sizing methods chosen for a particular site will depend on the types of expected buried objects and the contaminant of concern. In alpha contaminated waste matrices, only those sizing techniques which control the spread of contamination should be used. Methods involving the addition of secondary waste (i.e. water jets) should be avoided, as this would create more waste volume.

Once the waste is packaged and sent on its way, the retrieval equipment will either be decontaminated or sized/compacted and disposed as waste. The more preferred option would be, of course, to decontaminate the equipment. Decontamination can be broken down into two basic categories: mechanical and chemical decontamination.

Mechanical Decontamination

Mechanical decontamination refers to those methods which physically dislodge the contamination from the surface by wiping or scrubbing, media blasting, grinding, et cetera. In cases where the contamination level does not pose a significant risk to personnel, wiping/scrubbing is a simple, yet effective, means of decontamination. This method can be used if the contamination is loose and not fixed to the surface. If the contamination is fixed to the surface, more aggressive means of cleaning should be used. In decontaminating alpha contaminated equipment, any type of blasting operation (carbon dioxide pellets, water jets, air jets, etc.) should be avoided, as blasting tends to knock the contaminants loose from the surface, and in so doing, spreads the contamination throughout the area. Contamination spread during blasting operations can be minimized, however, if done in an environmentally controlled decontamination chamber. In some cases, depending on the surface material, contaminants can be driven further into the surface by blasting methods.

Chemical Decontamination

Chemical decontamination refers to those methods using chemical agents to loosen or solubilize the surface contamination. The piece of equipment to be cleaned is either dipped in a vat containing the chemical agents, or the chemicals are sprayed on the surface in liquid, foam, gel, or paste form. The equipment is then rinsed or brushed off. If chemical decontamination methods are used, any rinse agents, chemicals, or the like will have to be contained. The chemicals must then be either disposed as low-level mixed waste, treated, or stored.

Explosives and Pyrophorics

Explosives and pyrophorics encompass another contaminant of concern which may require special consideration when deciding whether or not to retrieve the waste. This type of waste includes pressurized vessels and drums, unexploded ordinances, flammable materials, et cetera. Issues associated with contamination control would not be as big a risk driver as in alpha contaminated sites, but some type of dust control should be employed as a means to save wear and tear on equipment and to reduce clean up later. In situ stabilization would also have to be looked at in great detail to determine if, when injecting the grout or polymer, fires and explosions could be initiated.

All of the equipment used in explosive and pyrophoric retrieval should be explosion proof, unless the loss of said equipment would not create a risk to personnel, the public, or the environment and is financially acceptable. Any equipment coming in contact with the explosive or pyrophoric contaminant should be designed such that sparks are not created during operations, as this could cause ignition. In addition, all equipment that may become hot during operations (i.e. internal combustion engines) should be provided with a means of cooling to prevent the starting of fires and explosions. A fire protection system should be in place whenever dealing with explosives, including, but not limited to, sprinkler systems, fire hoses, and fire extinguishers. Also, a means of diffusing, deactivating, or venting pressurized vessels, explosives, et cetera, should be made available on the site to stabilize the waste prior to removal from the area.

IS IT WORTH IT?

Is it worth it to retrieve and treat, store, and/or dispose of the waste? What are the risks? What are the costs?

RISK?

When retrieving hazardous or radioactive mixed buried waste, certain tradeoffs need to be considered and evaluated. One tradeoff that is often part of the decision for deciding whether to retrieve waste is risk.

In order to evaluate risk as a tradeoff, it must be understood what "risk" really means. The definition in the *American Heritage Dictionary* is "the possibility of suffering harm or loss; danger or a factor, element, or course involving uncertain danger; hazard." Risk is frequently expressed as a function of the probability that a certain event will occur and the resulting consequence of that event:

Risk = Probability X Consequence

Risk is managed through lowering the probability of an event occurring, reducing the consequence of that event, or minimizing both the probability and the consequence.

For hazardous waste retrieval there are multiple factors that make up risk. These factors influence either the probability of an event occurring or the resulting consequence for a given remediation scenario. Each site requires a separate analysis to determine the risk posed by the situation. The consequence of an event can include harm to the workers or nearby public, harm to the environment, or a full or partial loss of equipment, operating systems, and monitoring systems.

The hazardous waste worker is at various levels of risk during all phases of remediation: construction, operations, maintenance, and surveillance. The hazards the workers are exposed to vary widely. They include standard construction hazards (cranes, electrical, etc.), industrial hazards (heavy equipment operation, maintenance, etc.), and hazards that result from the unique characteristics of a hazardous waste site. These unique hazards could include high radiation fields, exposure to toxic substances (heavy metals, radionuclides, organics, asbestos, etc.), explosion, rupture of pressurized containers, and fire.

The probability of occurrence for specific events that result in harm to workers, within standard industrial and construction practices, is fairly well understood. However, the uncertainty that exists at a buried, mixed waste site may force the risk manager to assume a probability of occurrence of 1 in the Risk = Probability X Consequence equation. This drives the effort to mitigate the consequences such that an acceptable level of risk is attained. Completely remote operations may be necessary to reduce the risk to manageable levels.

Many factors affect the risk to the remediation worker, including radioactivity level, radiation fields, exposure pathway, time of exposure, potential for explosion or fire, contaminants of concern adequacy of administrative controls, human reliability, equipment design, operation complexity and time, and adequacy of protection systems.

The level of radioactivity, pathway, and hazards are examples of factors that compose risk. The level of radioactivity refers to the radioactivity levels (assumed to be heterogeneous) for alpha, beta, and gamma in the buried mixed waste. The intensity of the radiation field is driven by the alpha, beta, and gamma fields that may be encountered within the buried mixed waste. High gamma fields may require either heavy shielding to lower the consequence to a manageable level, or the removal of the worker from the exposure pathway through use of remote operations. The exposure pathway factor refers to the various pathways that both hazardous and radioactive wastes may harm personnel and the environment. Pathways may include skin irritants, ingestion, and inhalation. The time of exposure to radiation fields, toxic substances, or other potential hazards is a critical factor in evaluating risk. The time of exposure is dependent on the nature of the operations, the specific manual tasks that have to be performed (e.g. maintenance, surveillance), and the magnitude of the retrieval operation.

The factor associated with explosion and fire potential is one that carries great uncertainty within the buried waste environment. Knowledge of the buried waste contents and characterization of the site before and during retrieval operations will weigh into the determination of the risk associated with these events.

Hazards refer to the physical hazards that may be involved in retrieving buried mixed waste. For example, there are inherent dangers of working around heavy equipment.

BREAKING THE PIGGY BANK

In concert with risk, cost will be a major factor in determining whether or not a retrieval action will be performed. In assessing these costs, the life cycle of the project must be considered. The obvious costs to take into account include the capital costs for acquiring the equipment, the operating costs for performing the retrieval operation, and the maintenance costs expected during the operation.

There are many other issues that affect the cost of a retrieval scenario as well. In some cases, due to Stakeholder or other pressures, retrieval may be the only option available, despite costs. Note that capital, maintenance, and operating costs are excluded from this paper due to the fact that each site possesses different requirements and may not require all of the equipment or techniques discussed, and that numerous suppliers have varying costs. Rather, the intent of this discussion is to focus on the issues that can greatly affect the overall cost of a retrieval scenario for buried mixed waste.

For the retrieve and treat, store and/or dispose option, the following activities can affect cost:

- Site Characterization
- Overburden Removal
- Removal (Characterization, Retrieval, Contamination Control, etc.)
- Packaging (Sizing, Sorting, etc.)
- Transport
- Processing
    - Storage
    - Treatment

  - Physical (Sorting, Shredding, Compacting, etc.)
  - Chemical
  - Thermal
- Disposal

Beyond these costs, many indirect costs will also be affected. If additional technology development activities are required, the associated costs must be included in the life-cycle costs. Decontamination and disposal costs for the equipment may also change due to different design considerations for the options.

Capital costs

Capital costs consist of direct and indirect costs. Direct costs include construction costs (materials, labor, and equipment to prepare for use), equipment costs, land and site development costs, buildings and services costs, relocation expenses, and disposal costs. Indirect capital costs include engineering expenses, license or permit costs, startup and shakedown costs, and contingency allowances.

Land and site development costs may be required for the operation of retrieval actions. Buildings and services refer to the additional costs that may be required as a result of using retrieval, storage, treatment, and disposal technologies. Relocation expenses refer to the costs for temporary or permanent accommodations for affected nearby residents. This cost would depend on the site that was being remediated and would not be affected by the equipment itself. Disposal costs include the costs for transporting and disposing of the waste material. This cost is also site specific. Secondary wastes should also be included.

Indirect capital costs for engineering expenses would include demonstration support, program management, performance of the tests, quality assurance, safety, and shipping expenses. Licenses and permits would be obtained based on the particular site being remediated. Startup and shakedown costs are the estimated costs to ensure the systems are operational and functional. Contingency refers to money to cover costs resulting from unforeseen circumstances such as adverse weather, waste variability not anticipated, equipment repair, explosion, fire, et cetera.

Operating and Maintenance costs

Operating and maintenance costs are incurred after construction costs and are necessary to ensure the continued effectiveness of a remedial action. The following are considered operating and maintenance costs: operating labor costs; maintenance materials and labor costs; auxiliary materials and energy; disposal of residues; purchased services; administrative costs; insurance; taxes; licensing costs; maintenance reserve and contingency funds; rehabilitation costs; and costs of periodic site reviews.

Summary of Cost Issues

The overall cost evaluation for a retrieve and treat, store, and/or dispose option is very dependent on the contaminants of concern. As discussed previously, alpha contamination drives the contamination control requirements, thus adding cost. This is especially true when a confinement or containment enclosure is required. Other cost drivers for retrieval are the remote versus manual excavation equipment.

However, the real cost driver is going to be which treatment(s) will be required for the contaminants of concern. In a recent cost estimate for buried waste removal at the Idaho National Engineering and Environmental Laboratory (INEEL), approximately 80 percent of the removal costs were attributed to treatment. If the treatment equipment can be used for multiple remediations, these costs should be dispersed throughout the alternative evaluations.

REFERENCES

1 EPA (United States Environmental Protection Agency). Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA - Interim Final. Washington, DC: Office of Emergency and Remedial Response - U.S. Environmental Protection Agency; 1988.

2 Hyde, R. A.; Nickelson, D. F.; Griebenow, B. E. Tradeoffs of Risk and Cost for the Remote Retrieval of Buried Waste. 16th Annual U.S. DOE Low-Level Radioactive Waste Management Conference. National Low-Level Waste Management Program, Idaho National Engineering Laboratory. P.O. Box 1625 Idaho Falls, ID 83415 (208) 526-6927. 1994.

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