OPTIONS FOR TREATMENT, STORAGE, AND/OR DISPOSAL OF RADIOACTIVE MIXED WASTE AT THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT

A study is being performed at the Department of Energy's Idaho National Engineering Laboratory (INEL) to determine the most feasible options for the management of INEL radioactive mixed waste and to develop a program plan for implementing the selected options.

Radioactive mixed waste generated at the INEL by Department of Energy (DOE) facilities must be managed in accordance with DOE Order 5480.2 and the Memorandum of Understanding between the Environmental Protection Agency Administrator and the Secretary of Energy. These requirements specify that facilities which generate, treat, store, and/or dispose radioactive mixed waste comply with regulations issued under the Resource Conservation and Recovery Act for hazardous waste. Currently, there are no suitable INEL facilities for the treatment, storage, and/or disposal of radioactive mixed waste.

This paper will discuss the type and volume of radioactive mixed waste generated at the INEL; selection criteria used to determine the most viable option (i.e., technical, economic, and regulatory constraints); and available options for treatment, storage, and/or disposal.

BACKGROUND

Prior to February 22, 1984, compliance with the Resource, Conservation, and Recovery Act (RCRA) regulations at the INEL was governed by Department of Energy (DOE) Order 5480.2, "Hazardous and Radioactive Mixed Waste Management." This order was predicated upon the preemption of RCRA by the Atomic Energy Act of 1954. The DOE was not disputing the applicability of RCRA to federal facilities. Instead, it was invoking a section in RCRA (42 USC 6905) which said in a pertinent part that

> nothing in this chapter shall be construed to apply to ... any activity or substance which is subject to the .... Atomic Energy Act of 1954 [42 USCA ¶ 2011 et seq.] except to the extent that such application (or regulation) is not inconsistent with the requirements of such Acts.

It was the position of the DOE that RCRA was indeed inconsistent with the provisions of the Atomic Energy Act. This position of the DOE was contrary to that of the Environmental Protection Agency (EPA), and the resulting DOE-EPA conflict led to a compromise position represented by the "Memorandum of Understanding (MOU) Between the U.S. Department of Energy and the U.S. Environmental Protection Agency for Hazardous Waste and Radioactive Mixed Waste Management."

This agreement, signed February 22, 1984, stated that DOE facilities must operate in compliance with a waste management program that is comparable to the design and performance criteria, other technical requirements, and recordkeeping and reporting requirements of EPA's RCRA regulations. By the terms of the MOU, these requirements would apply to both hazardous and mixed waste streams. Important, however, is the fact that the MOU did not subject the DOE to RCRA permitting procedures.

On April 13, 1984, the MOU was in large part struck down by the decision of the United States District Court for the Eastern District of Tennessee, Northern Division in the case of the Legal Environmental Assistance Foundation, Inc., and Natural Resources Defense Council, Inc. v. Donald Hodel, Secretary, United States Department of Energy, et al. The Court held that Atomic Energy Act facilities are subject to the provisions of RCRA except as to nuclear waste and radioactive materials. Thus, the MOU was rendered inapplicable to the extent that it covered hazardous waste.

In the absence, then, of the MOU, and in light of the Court's decision, EG&G Idaho, Inc., as prime operating contractor for the INEL, is proceeding to implement a program for complying with RCRA-mandated regulations for both hazardous and radioactive mixed waste. Radioactive mixed waste is defined as radioactive waste that also meets the definition of a hazardous waste under 40 CFR Part 261. Currently, all hazardous waste generated at the INEL is transported offsite to a RCRA-permitted treatment, storage, and/or disposal (T/S/D) facility in full compliance with EPA regulations. However, there are no RCRA-permitted facilities on or off the INEL for radioactive mixed waste. In the past, radioactive mixed waste was managed under DOE Order 5820.2 as radioactive waste. Currently, radioactive mixed waste generated at the INEL is being stored onsite until alternative options for managing these wastes in accordance with EPA requirements for hazardous waste and DOE requirements for radioactive waste can be examined and implemented.

The purpose of this paper is to describe the current status of efforts to thoroughly characterize INEL-generated radioactive mixed waste, identify treatment and disposal alternatives, and implement a program to manage these wastes.

IDENTIFIED RADIOACTIVE MIXED WASTE STREAMS

The first step toward developing and implementing an effective radioactive mixed waste program is the identification of INEL-generated radioactive mixed waste streams. These streams are produced at the INEL during the course of the research and development activities conducted for the federal government, including nuclear reactor safety evaluation.

Table I lists the currently identified INEL streams, along with the possible T/S/D options that need to be considered. The list represents an alteration to previous reports, since many of the streams were eliminated by altering process chemistry or employing elementary neutralization steps. However, the list is by no means complete, and an ongoing effort is needed to further identify and characterize the radioactive mixed wastes generated at the INEL. Besides identifying any additional streams, work needs to be done on further characterizing those currently identified, especially in the area of radiological composition.

The wastes given in Table I are generated during the nuclear research and development activities taking place at the INEL - either directly, or indirectly from the handling or processing of radioactive material. For example, streams 8, 11, and 19 (shield tank water, mercury contaminated piping, and contaminated lead) are the result of employing shielding for the reduction of radiation exposure levels. Others, such as streams 2, 5, and 10, are produced by the laboratory work required to support the nuclear programs and include scintillation counting and analytical samples. Silver zeolite is used to remove airborne radionuclides from the hot cells. The pond sediments, streams 6 and 7, are likely candidates for the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) program and are included here to indicate their possible disposition in the T/S/D facility. Most of the remaining streams are generated during the handling or processing of radioactively contaminated material, e.g., incinerator ash, spent acidic solutions and filters from electropolishing operations, and filters and still bottoms from decontamination units.

Lead, largely in the form of sheeting, bricks, and shot, is used at the INEL for shielding purposes. It is declared waste when it has become contaminated to the point of contributing to a high background radiation level, or the facility in which it was used is being decontaminated and decommissioned. Preliminary studies have indicated that lead bricks exhibit the characteristic of EP toxicity and, therefore, may be radioactive mixed waste. Other lead wastes such as lead aprons, gloves, wipes which have been used to obtain radioactive smears of lead, and lead turnings have not been tested yet, but are also suspect of exhibiting the characteristics of EP toxicity.

EXISTING TREATMENT FACILITIES

At this time, there are no EPA-permitted INEL facilities for the treatment, storage, and/or disposal of radioactive mixed waste. However, several treatment facilities, described in detail below, are currently processing radioactive non-hazardous wastes that could, with the necessary modifications, be utilized to treat radioactive mixed wastes. The incorporation of these existing facilities in a T/S/D program will be assessed, along with the development of additional processes and offsite treatment, to eventually determine the most viable option(s) for the treatment, storage, and/or disposal of radioactive mixed wastes generated at the INEL.

Waste Experimental Reduction Facility

EG&G Idaho, Inc., has established the Waste Experimental Reduction Facility (WERF) at the INEL as a facility for the development of low-level beta/gamma waste management processes, specifically volume reduction techniques. At present, only solid waste with less than 10 mrem/hr at contact is collected for processing; however, as processing and material handling technologies are developed, waste with higher radiation levels may be collected and processed. The level of transuranic (TRU) contamination is limited to less than 0.1 nanocurie per gram.

The purpose of the facility is to develop high-throughput (several hundred tons per year) waste processing technology utilizing full-scale processes and equipment. Capabilities are being developed in the following four areas:

1. Size-reduction of contaminated metal using various torches and saws.

2. Metal decontamination employing either, or both, a freon degreaser and an electropolisher. The freon cleaner is a commercially available unit that is a closed-cycle system using recyclable cleaning solvent. It is a dual-mode cleaning device that incorporates both pressurized solvent spray cleaning (100-1000 psi) and vapor degreasing to remove grease, dirt, and/or smearable contamination. The electropolisher can be used to provide further decontamination, if necessary. The electropolishing unit consists of a 6 x 3 x 3-ft phosphoric acid bath, equipped with a recirculating pump and filters, and a water rinse tank of similar size. After the metal to be processed has been placed in the acid tank and connected electrically, power is provided at about 150 amps per square foot of surface to be cleaned.

3. The melting of low-density (due to voids) scrap metal into compact, high-density ingots in two coreless electric induction furnaces with capacities of 1500 and 1000 lb. The charge material is normally preheated prior to contact with the molten metal bath. Once the charge is brought to temperature and melted, slag coagulating agents are added to

TABLE 1

Identified INEL Radioactive Mixed Waste Streams and Possible Treatment, Storage, and/or Disposal Options

Stream Number	Name or Description of Waste	Chemical and Radiological Composition	Quantity Generated or Stored	Treatment, Storage or Disposal Option(s)	Hazardous Waste Code
RMW-01	Degreasing solutions	30% lubricants, 70% trichloroethane; <10 mrem/hr (non-TRU)	250 gal/yr (anticipated)	Incineration	F001
RMW-02	Scintillation fluids	Toluene, xylene; low-level radioactivity	25 gal, stored	Incineration	F003, F005
RMW-03	PCB-contaminated oil	PCB's, oil; 90 mrem/hr	2 55-gal drums, stored	Incineration Incineration at LANL	TSCA regulated
RMW-04	Paint and rags	Lead-based paint, solvent on rags; low-level radioactivity	2 drums, stored	Incineration/solidification Solidification	D008, D001
RMW-05	Miscellaneous lab wastes	Organics, heavy metals; variable radioactivity	10 gal/yr	Incineration/solidification	D004, D011
RMW-06	Pond sediments	17.5-ppm As, 8200-ppm Cr, 54-ppm Hg, 56-ppm PCBs, 20-ppm CN	45.7 x 76.2 x 4.6-m pond	Incineration/solidification Solidification In-place stabilization Washing/solidification	D004, D007, D009, TSCA regulated, P020
RMW-07	Pond sediments	5.3-ppm Cr, 13-ppm Pb	800,000 ft^3 pond	Solidification In-place stabilization Washing/solidification No treatment	D007, D008
RMW-08	Shield tank water	2500 ppm Cr; low-level radioactivity	18,000 gal (generated one time in Dec. 1985)	Evaporation/solidification Reduction/precipitation/ solidification Ion exchange/solidification Reverse osmosis/solidification	D007
RMW-09	Incinerator ash	Variable-Cd, Cr, Pb; low-level radioactivity	100-200 drums/yr	Solidification	D004-D011
RMW-10	Miscellaneous lab wastes	Trace metals, acids; variable radioactivity	120 gal/yr	Neutralization/solidification Evaporation/solidification	D002, D004-D011
RMW-11	Mercury-contaminated piping	SS and carbon steel, mercury; low-level radioactivity	420 lb steel stored	Freon decontamination Vaporization of mercury/solidification Metal smelting/solidification	D009
RMW-12	Mercury	Mercury; Cs-137, 2 mrem/hr	1 L	Solidification	D009
RMW-13	Silver zeolite	Silver, zeolite; variable radioactivity	6300 lb in place; (T/S/D required only when efficiency gets too low)	Silver extraction via smelting/ slag burial Zeolite regeneration	D011
RMW-14	Freon decontamination still bottoms	Freon, metals; intermediate-level radioactivity	Undetermined	Incineration/solidification	F002
RMW-15	Freon degreasing still bottoms	Freon, grease; intermediate-level radioactivity	Undetermined	Incineration/solidification	F001
RMW-16	Disposable filters from freon units	Freon, metals, grease; intermediate-level radioactivity	Undetermined	Incineration/solidification	F001, F002
RMW-17	Acid solution from electropolisher	Phosphoric acid, metals; intermediate-level radioactivity	15-20 drums/yr (anticipated)	Neutralization/solidification Evaporation/solidification	D002, D004-D011
RMW-18	Filters from electropolisher	Phosphoric acid, metals; intermediate-level radioactivity	Undetermined (anticipated)	Neutralization/solidification	D002, D004-D011
RMW-19	Lead	Lead bricks, shot, and sheeting	400,000 lb/yr	Electropolishing/recycle lead Freon decontamination/recycle lead Smelting/slag solidification	D008

congeal any slag present and to maximize the radionuclide partitioning between the melt and the slag. After the slag has been removed and power to the furnace turned off, the furnace is hydraulically tilted to pour its contents into prepositioned molds.

4. Incineration of combustible low-level radioactive waste in a dual-chambered (325 ft^3 per chamber), controlled-air incinerator that is designed to handle up to 400 lb/hr of 12,000 Btu/lb waste. Fuel oil-fired burners provide the heat for the oxygen deficient partial combustion in the lower chamber at 650-980°C and the complete combustion of the resulting volatile gases with excess air in the upper chamber. Off-gas residence times in excess of 2 s in the upper chamber are obtained for a 400 lb/hr feed rate and a 1150°C exhaust temperature. The ash leaving the lower chamber is cooled and deposited into 55-gal drums.

It is estimated that these four processes can reduce the total contaminated metallic waste volume generated at the INEL by 80-90% and the combustible waste volume by about 95%. Such reductions could result in halving the total volume of solid, radioactive waste being generated, thereby doubling the remaining useful life of the INEL radioactive waste disposal site.

Idaho Chemical Processing Plant

The Idaho Chemical Processing Plant (ICPP), operated by Westinghouse Idaho Nuclear Company (WINCO) at the INEL, is designed to reprocess nuclear fuels to recover fissile material from test reactor fuels on a plant scale. The significant quantities of radioactive liquid wastes generated during reprocessing have made it necessary to develop the capabilities to treat them. The ICPP processes that could, if warranted, be adapted to handle radioactive mixed waste are the Process Equipment Waste (PEW) evaporator and the New Waste Calcining Facility (NWCF).

The PEW evaporator is currently used to separate the intermediate-level aqueous wastes, generated at ICPP and other INEL facilities, into a concentrate and a low-level waste fraction. There are two steam-heated thermosyphon evaporators operated on a semi-continuous basis with a feedrate of 5-10 gal per minute. The feed is shut off when the solution in the evaporator approaches saturation. The concentrated evaporator bottoms are then transferred to an interim storage area and eventually solidified in the calciner Low-level condensed overheads can be sent through the PEW ion exchange system to further reduce the radionuclide concentration before being discharged into the nonhazardous percolation pond.

The NWCF is designed to solidify the radioactive liquid wastes generated at the ICPP, which include aqueous raffinate from first-cycle extraction, concentrated aqueous raffinates from subsequent extraction cycles, and wastes of similar radioactivity levels such as the PEW evaporator bottoms. The NWCF replaced the Waste Calcining Facility (WCF) in 1982. The WCF operated for 18 years as a production-scale radioactive waste solidification facility, employing fluidized bed calcination at a temperature of 500°C to convert 15,000 m^3 of liquid wastes to 2200 m^3 of calcined solids (1). Fluidized-bed calcination involves evaporating the water, providing sufficient heat for chemical decomposition reactions, and drying the residual solids. The NWCF process system is very similar to the WCF system. The fluidized-bed is heated to 500°C by in-bed combustion of kerosene and oxygen. However, the new calciner is larger, to handle a higher throughput, and is made of more corrosion-resistant materials. The calcine is pneumatically transferred to underground storage bins where it can be retrieved at a later date, for final long-term disposal.

Process Experimental Pilot Plant

The primary objective of the Process Experimental Pilot Plant (PREPP), being developed by EG&G Idaho, Inc., is to demonstrate the viability of full-scale methods for processing transuranic (TRU) waste into a form acceptable for disposal at the Waste Isolation Pilot Plant (WIPP). PREPP will operate as an experimental pilot plant. The facility construction is expected to be completed in late 1985 and will handle an average input of fifteen 55-gal drums per shift. The drums are fed into a low-speed shredder that will shred the containers and contents into a nominal size of 3 x 1 x 6-in. Shredded waste will then be fed to a propane-fired rotary kiln incinerator at a rate of 7 tons per day. The kiln is 24.5 ft long, 8 ft in diameter, and equipped with a liquid waste injection nozzle. Inside the kiln, waste will be subjected to temperatures of 815-980°C for about 90 minutes to ensure complete waste combustion. Gases passing to the secondary combustion chamber are heated to 1090-1260°C with 3% excess oxygen for a minimum of 2 s. The remains from incineration will be cooled and fed into a trommel separator, which will divide the waste into coarse and fine ash. The fine ash is mixed with sand, cement, sludge from the off-gas system, and water to form a wet grout that is combined with the coarse ash in a lined, final-product drum.

T/S/D OPTIONS

Currently, no radioactive waste facilities meet RCRA requirements for hazardous waste management. Consequently, there are no suitable facilities for the T/S/D of radioactive mixed waste, and all such waste generated at the INEL must be stored temporarily until a course of action is determined. The options being examined for the management of INEL's radioactive mixed waste can be grouped into the following three categories: (a) offsite T/S/D, (b) utilization of existing facilities, with or without modifications, and (c) construction of new facilities.

Land disposal of radioactive mixed waste was not considered as an option in this study because RCRA regulations appear to be moving away from land disposal. Therefore, the approach considered was to treat radioactive mixed waste, either by destruction or immobilization, so that it is no longer a hazardous waste and then dispose of the remaining waste as a radioactive waste.

Offsite T/S/D

The only offsite T/S/D option currently being considered is the incineration of PCB-contaminated oil at the Los Alamos National Laboratory (LANL). LANL is licensed to burn alpha-, and PCB-contaminated oil.

Utilization of Existing Facilities

Several existing facilities at the INEL could, if warranted, be adapted to handle radioactive mixed waste. The facilities at WERF (incineration, metal decontamination, and smelting) are especially well-suited for incorporation into a radioactive mixed waste T/S/D program. Many of the combustible waste streams in Table I could be eliminated of in the WERF incinerator. Furthermore, the incineration capability could be greatly increased by modifying the existing facility. For example, the installation of a liquid feed system would make it possible to handle many of the liquid mixed wastes. The high-halogen wastes (stream 1 in Table I) may require further modifications, since the present system is susceptible to damage via corrosion. One possibility is the addition of an auxiliary halogenated liquid burner, equipped with a wet scrubber, that can be attached to the WERF off-gas system. Combustible waste not suitable for treatment at WERF, due to high levels of TRU contamination, may be more aptly processed by the PREPP incinerator.

The contaminated lead would also be a good candidate for treatment at the WERF facility. The feasibility of surface decontamination via high-pressure freon washing and/or electropolishing could be evaluated with minimal modifications to the existing facility. Alternatively, lead melting/refining could be examined as a means of decontamination by melting the lead in a WERF induction furnace and employing the same protective equipment currently used to treat contaminated steel.

Assuming that the EPA will require the same permitting documentation of DOE as it would a commercial facility, these existing facilities must be included in the permit application. Also, any modifications to the facilities required to satisfy both radioactive and hazardous regulations must be covered when applying for a permit.

Construction of New Facilities

If it is decided that EG&G should develop a T/S/D program for radioactive mixed waste, it would probably require the construction of new facilities to complement existing facilities such as WERF. Examination of the waste streams and treatment options given in Table I indicates that a solidification facility would be a prime candidate. Solidification would be a viable treatment option for the incinerator ash, if deemed necessary, and many of the liquid wastes that contain toxic metals. Another possibility is an evaporator to concentrate the liquid wastes prior to solidification. Also, an integral and necessary part of any onsite T/S/D facility would likely be a storage facility, where radioactive mixed waste could be stored while awaiting treatment and/or disposal. The building of any, or all, of these new facilities would, of course, have to be included in the permit application.

CRITERIA FOR ASSESSING TREATMENT OPTIONS

To determine the best processing options, a study will be performed to assess commercially available treatment systems that are applicable to INEL-generated radioactive mixed waste. The evaluation will be accomplished using a set of criteria that was selected to comprise the elements of a successful radioactive mixed waste processing system. The major performance criteria are as follows:

1. End product quality
2. Flexibility
3. Cost
4. Demonstrated technology
5. Health and safety.

Other less important factors include system reliability, maintainability, operability, level of feed pretreatment required, and resource use.

These criteria are similar to those used in an earlier figure-of-merit analysis of low-level radioactive treatment systems (2), but the relative importance of the criteria will be markedly different in the current study. In the previous investigation on low-level radioactive processing options, for example, end product quality was one of the least important criteria. However, for radioactive mixed waste, end product quality is the single most important factor in technology assessment. This is due to the added restraints placed on the final product when treating radioactive waste that is also classified as hazardous. The increased hazard potential is also responsible for placing greater emphasis on the health and safety aspect.

The five major criteria are discussed in more detail in the following sections and are futher divided into subcriteria where necessary.

End Product Quality

This criterion is a measure reflecting the intrinsic ability of the final product waste form to meet or exceed state and federal low-level radioactive and hazardous waste regulations, as appropriate. For example, in the case of incineration, the required destruction efficiency for the hazardous components must be achieved and the ash converted to a form suitable for disposal. The final waste form should no longer exhibit any of the characteristics of a hazardous waste. As a result, a major factor in the evaluation of this criterion is the leachability of the waste form.

Flexibility

Flexibility is a measure of the ability to process a wide range of "as received" wastes at variable rates. Due to the variety of INEL-generated mixed waste streams, those treatment systems that possess a greater amount of flexibility will be valued more highly. Subcriteria include:

1. Number of waste streams that can be processed
2. Ability to treat low-level and/or hazardous wastes, if deemed necessary
3. Large acceptable range in feed composition
4. Large acceptable range in feed rate.

Cost

The comparisons will include the minimum necessary expenditures, from design to final closure, required by each system to satisfy the processing objectives. Those systems that utilize existing facilities will be valued more highly. Subcriteria include:

1. Capital cost, including design and construction or modifications to an existing facility
2. Permitting costs
3. Start-up costs
4. Operating cost, including manpower
5. Final closure, including decontamination and decommissioning cost.

Demonstrated Technology

All processing systems are evaluated on the basis of the current and anticipated state of the art for similar units with adequate processing capacity and with adequate materials of construction. A system with more successful operating experience is valued more highly. Subcriteria include:

1. Actual operating experience in an existing INEL facility
2. Actual hazardous waste experience
3. Actual radioactive waste experience
4. Nonradioactive, nonhazardous experience.

Health and Safety

Health and safety is a measure of the ease of protecting operating personnel, the public, plant equipment, structures, and the environment from hazardous or damaging events. The less the potential for such events and the easier to mitigate them, the higher is the value of the system. Subcriteria include:

1. Ease of minimizing toxic chemicals exposure and radiation exposure, either through inherent system capability or by system design.

2. Minimal industrial hazards and ease of protecting against physical hazards and explosions.

3. Ease of designing for spill and contamination control.

EVALUATION OF OPTIONS

This paper has focused on the identification of possible treatment systems for the various waste streams and the criteria needed to assess these systems. The next step will be to apply the criteria to evaluate the processing options that are applicable to INEL-generated radioactive mixed waste. Both the construction of new facilities and the modification (if necessary) of existing facilities will be considered when assessing the treatment systems. Weighting factors will be assigned to the criteria to place more emphasis on the major criteria. The comparative examination that results will reveal the relative merits and ranking of each treatment system. Once the preferred systems are identified, the additional storage or processing capabilities required to supplement existing treatments can be determined. The resulting T/S/D facility is expected to be able to handle all INEL-generated radioactive mixed waste in an effective and economic manner. An additional factor that may warrant consideration is the applicability of the T/S/D facility to the processing of radioactive mixed wastes generated at other DOE sites.

CONCLUSIONS

The currently identified radioactive mixed waste streams generated at the INEL have been compiled, along with possible treatment options. Since there are no suitable facilities in existence for the treatment, storage, and/or disposal of these wastes, offsite management is not presently a viable option. Therefore, the only alternative is to develop and implement a T/S/D program at the INEL to handle the radioactive mixed waste onsite.

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