Land Disposal Restrictions Treatment Standards: Compliance Strategies for Four Types of Mixed Wastes[1]

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ABSTRACT

This paper describes the unique challenges involved in achieving compliance with the Resource Conservation and Recovery Act (Public Law 94-580) Land Disposal Restrictions (LDR) treatment standards for four types of mixed wastes generated throughout the U.S. Department of Energy (DOE) complex: (1) radioactively contaminated lead acid batteries; (2) radioactively contaminated cadmium-, mercury-, and silver-containing batteries; (3) mercury-bearing mixed wastes; and (4) radioactive lead solids. For each of these mixed waste types, the paper identifies the strategy pursued by DOE's Office of Pollution Prevention and Resource Conservation Policy and Guidance (EH-43) in coordination with other DOE elements and the U.S. Environmental Protection Agency (EPA) to meet the compliance challenge. Specifically, a regulatory interpretation was obtained from EPA agreeing that the LDR treatment standard for wastes in the D008 "Radioactive Lead Solids" subcategory applies to radioactively contaminated lead acid batteries. For cadmium-, mercury-, and silver-containing batteries, generically applicable treatability variances were obtained from EPA approving macroencapsulation as the alternative LDR treatment standard for all three battery types. Joint DOE/EPA technology demonstrations were pursued for mercury-bearing mixed wastes in an effort to justify revising the LDR treatment standards, which focus on thermal recovery of mercury for reuse. Because the demonstrations failed to produce enough supporting data for a rulemaking, however, EPA has recommended site-specific treatability variances for particular mercury-bearing mixed waste streams. Finally, DOE has filed an application for a determination of equivalent treatment requesting approval of container-based macroencapsulation technologies as an alternative LDR treatment standard for radioactive lead solids. Information is provided concerning the length of time required to implement each of these strategies, and suggestions for obtaining variances from the LDR treatment standards at the site-specific level are also discussed.

[1] The Argonne National Laboratory (ANL) work regarding this paper was supported by the U.S. Department of Energy, Assistant Secretary for Environment, Safety and Health, under contract W-31-109-Eng-38.

INTRODUCTION

When a waste generated at a site in the United States is classified as hazardous under the Resource Conservation and Recovery Act (RCRA), land disposal of that waste is prohibited unless it has been treated to meet treatment standards established by the U.S. Environmental Protection Agency (EPA) under the RCRA Land Disposal Restrictions (LDR) program. Mixed wastes (i.e., wastes that contain a hazardous waste component regulated under RCRA and a radioactive waste component subject to the Atomic Energy Act of 1954 [Public Law 83-703]) that are destined for disposal are no exception. Like other hazardous wastes, they must be treated to meet LDR treatment standards before disposal. Where no LDR treatment standard is specified for a mixed waste, the treatment standard for the non-radioactive, hazardous component of the mixed waste applies.

LDR treatment standards are identified in Title 40 of the *Code of Federal Regulations* (CFR), Section 268.40 (40 CFR 268.40). Each prohibited waste is linked to its LDR treatment standard by means of a hazardous waste code and a "waste description and treatment/regulatory subcategory." In general, this system allows waste managers responsible for treatment and disposal of hazardous or mixed wastes to easily determine the LDR treatment standard applicable to a waste stream and to identify an approach for achieving compliance. Yet, some mixed wastes present unique challenges for complying with LDR treatment standards, most of which were established on the basis of treatability studies conducted using non-radioactive hazardous wastes. Treatment of mixed wastes using methods that have proven successful for non-radioactive hazardous wastes may not always be effective, practicable, or possible because of the radioactive character of the mixed wastes. Furthermore, even if a treatment method that accounts for the radioactive character of a particular mixed waste has been specified as its LDR treatment standard, sometimes new treatment methods have become available that would reduce exposure of workers to radiation while being more cost effective and equally protective against contaminant releases.

This paper describes the unique challenges involved in achieving compliance with the LDR treatment standards for four types of mixed wastes generated throughout the U.S. Department of Energy (DOE) complex: (1) radioactively contaminated lead acid batteries; (2) radioactively contaminated cadmium-, mercury-, and silver-containing batteries; (3) mercury-bearing mixed wastes; and (4) radioactive lead solids. For each of these mixed waste types, the paper identifies strategies pursued by DOE's Office of Pollution Prevention and Resource Conservation Policy and Guidance (EH-43), in coordination with other DOE elements and EPA, to meet the compliance challenge. The regulatory issues driving each strategy are explained and EPA's collaboration and reactions are reported, along with the status or outcome. Information is provided concerning the length of time required to implement each strategy and the benefits derived by DOE mixed waste generators. Strategies for achieving LDR compliance at the site-specific level are also discussed.

RADIOACTIVELY CONTAMINATED LEAD ACID BATTERIES

DOE handles radioactive materials at many of its facilities, which are located in several states. Some handling activities involve equipment powered by lead acid batteries. As a result, such batteries are exposed to radioactive materials and are considered radioactively contaminated. When this occurs, the options for managing affected batteries after removal from service become limited. Unless a demonstration can be made that the batteries are not contaminated,[2] they must be managed as mixed waste, because they exhibit the RCRA toxicity characteristic (TC) for lead and they also have a radioactive component.

The RCRA LDR treatment standards contain three subcategories applicable to wastes that exhibit the TC for lead: (1) the D008 general subcategory, (2) the D008 "Lead Acid Batteries" subcategory, and (3) the D008 "Radioactive Lead Solids" subcategory. According to the waste descriptions associated with these subcategories in 40 CFR 268.40, the LDR treatment standard for either the "Lead Acid Batteries" subcategory or the "Radioactive Lead Solids" subcategory could apply to drained, radioactively contaminated lead acid batteries. However, before 2001, waste regulators and DOE waste management personnel commonly assumed the applicable subcategory to be the D008 "Lead Acid Batteries" subcategory.

The LDR treatment standard for wastes in the D008 "Lead Acid Batteries" subcategory is RLEAD, which is described in 40 CFR 268.42, Table 1 as "thermal recovery of lead in secondary lead smelters." This standard is problematic for drained, radioactive lead acid batteries because uses for the radioactively contaminated lead recovered from RLEAD treatment of such waste are extremely limited. Furthermore, in 2001, no capacity existed for thermal recovery of radioactively contaminated lead in secondary lead smelters.[3] As a result, the DOE sites listed in Table I were, at that time, storing lead acid batteries that contained measurable radioactivity and could not be decontaminated because compliant LDR treatment was not available. In addition to the sites listed in Table I, DOE's West Valley Demonstration Project site (West Valley, New York), which was not storing radioactively contaminated lead acid batteries at that time, projected future generation of approximately 0.14 cubic meters.

Table I. DOE Sites Storing Radioactively Contaminated Lead Acid Batteries in 2001

DOE SITE	AMOUNT OF RADIOACTIVELY CONTAMINATED LEAD ACID BATTERIES
Portsmouth, Ohio	Approximately 9.5 cubic meters
Brookhaven, New York	0.9 cubic meters
Hanford, Washington	A few drums at most
Savannah River, South Carolina	Approximately 1.2 cubic meters

[2] Demonstration that a radioactively contaminated battery contains no measurable radioactivity may not be possible if the contamination consists of either fixed surface contamination or residual radioactive material that has become embedded in cracks, surface roughness, or other types of damage to the casing. For fixed surface contamination, the demonstration is not possible if removal of the contamination to non-measurable levels is not practicable. For embedded contamination, the demonstration is not possible if contaminated surfaces cannot be accessed by using a monitoring device capable of showing that contamination is at non-measurable levels.

[3] In October 2000, GTS-Duratek, Inc. successfully demonstrated a process at DOE's Oak Ridge site for reusing potentially contaminated lead as a component in shielded storage containers for radioactive wastes. This internal DOE recycling project, which was coordinated through the Department's National Center of Excellence for Metals Recycling (managed by DOE's Oak Ridge Operations Office), was consistent with the DOE-wide Lead Reuse Policy issued by the Secretary of Energy on January 19, 2001. However, the project was not configured to accept radioactive lead acid batteries.

Clearly, a viable means of complying with LDR treatment standards for drained, radioactively contaminated lead acid batteries was needed. Accordingly, DOE’s Transuranic (TRU) and Mixed Waste Focus Area (TMFA)[4] and EH-43 approached EPA in May 2001 with a request for a regulatory interpretation to clarify that, instead of thermal recovery, the LDR treatment standard for this waste stream should be macroencapsulation, which is the designated LDR treatment standard for the D008, “Radioactive Lead Solids” subcategory [1]. In support of the request, DOE explained that existing regulatory provisions do not appear to preclude drained, radioactively contaminated lead acid batteries from being categorized as D008 “Radioactive Lead Solids.” Furthermore, 40 CFR 268.40 describes the wastes in this subcategory as being “all forms of lead shielding and *other elemental forms of lead*” (emphasis added), which seems to include drained, radioactively contaminated lead acid batteries. DOE also referenced the preamble to the proposed rule establishing LDR treatment standards for wastes in the D008 “Radioactive Lead Solids” subcategory, in which EPA noted that macroencapsulation (rather than thermal recovery) is an appropriate treatment standard for such wastes because: “Any lead recovery would be radioactive, and thus unusable. If the radioactive lead was smelted along with normal lead, the entire mass recovered would be unusable” [2].

On August 9, 2001, less than 3 months after DOE’s request was filed, EPA responded in a letter agreeing that the appropriate treatment standard for drained, radioactively contaminated lead acid batteries is macroencapsulation [3]. Subsequently, on September 20, 2001, the Utah Department of Environmental Quality (DEQ) approved the macroencapsulation of drained, radioactively contaminated lead acid batteries at Envirocare of Utah, Inc. [4]. These actions by EPA and the Utah DEQ have helped to significantly clarify a disposal path for drained, radioactively contaminated lead acid batteries.

RADIOACTIVELY CONTAMINATED CADMIUM-, MERCURY-, AND SILVER-CONTAINING BATTERIES

Batteries containing toxic metals are used in a variety of ways across the DOE complex. For example, nickel-cadmium (NiCd) rechargeable batteries are commonly found in cellular and cordless telephones, two-way radios, video cameras, portable power tools, laptop computers, and radiological monitoring equipment. Mercury-containing batteries have been widely used in watches, calculators, and cameras. Silver-containing batteries may be found in watches, cameras, paging devices, and calculators. At the end of their service life, these battery types exhibit the TC for one or more toxic metals. Hence, if they were used in a radioactively contaminated area, they are mixed waste, unless — through decontamination and/or radiological surveys — they can be cleared for management as non-radiological hazardous waste. Sometimes, because of cracks, fissures, holes or uneven surfaces in the battery casings, a reasonable assurance that the batteries are free of radioactive contamination cannot be achieved. In other cases, radioactive contamination is found that cannot be easily removed. In either case, there are always some batteries that are classified as radioactively contaminated.

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[4] DOE launched the TMFA in July 1995 (it was then called the Mixed Waste Focus Area or MWFA) to coordinate the development of technologies to characterize, treat, and dispose of mixed low-level and mixed TRU wastes in accordance with federal and state environmental regulations. TMFA funding was discontinued after the mission of the Science and Technology Program within DOE’s Office of Environmental Management was refocused in 2002.

In 2001, DOE’s TMFA and EH-43 obtained input from individual facilities across the DOE complex to determine whether radioactively contaminated cadmium-, mercury-, and silver-containing batteries were being generated and stored. Estimates from the sites indicated that a total of 2,653 kg of radioactively contaminated cadmium-containing batteries and 247 kg of radioactively contaminated mercury-containing batteries were in storage. At that time, projected generation rates for these battery types were 23 kg/yr and 4 kg/yr, respectively. No radioactively contaminated silver-containing waste batteries were reported to be in storage at the DOE sites, but waste management personnel at the sites could not rule out the possibility that a small number had been commingled with the other waste batteries during accumulation.

While these results showed that radioactively contaminated mercury-, cadmium-, and silver-containing waste batteries were not a large-volume waste stream at DOE facilities, the results also showed that lack of treatment and disposal capacity for such wastes was a widespread problem in 2002. For mercury- and cadmium-containing batteries, the problem had developed because the LDR treatment standards applicable at that time were based on metals recovery, and neither DOE nor EPA was aware of any metals recovery facility with the capability to recycle radioactively contaminated mercury or cadmium wastes. Furthermore, even if it were possible to thermally recover the metals from radioactively contaminated batteries, the recovered metals would themselves be radioactive, and DOE could not identify a viable use for such metals.

In the case of radioactively contaminated silver-containing batteries that exhibit the TC for silver, the LDR treatment standard consisted of concentration limits (for silver and any underlying hazardous constituents), which had to be met in the leachate generated when the treated batteries were tested using the toxicity characteristic leaching procedure (TCLP). Although the standard was achievable, either manual sorting of the waste battery inventory would have been necessary to locate any commingled silver-containing batteries requiring treatment, or the entire inventory would have had to be treated in order to ensure treatment of an extremely small number (if any) of silver-containing batteries. Both scenarios would have exposed workers to additional radiation.

On the basis of these facts, DOE concluded that the existing LDR treatment standards were technically inappropriate for radioactively contaminated cadmium-, mercury-, and silver-containing waste batteries. Accordingly, DOE’s TMFA, in cooperation with EH-43, prepared a petition requesting that EPA approve generically applicable LDR treatability variances, under 40 CFR 268.44(a), for these waste batteries. DOE filed the petition in June 2002.

Generically applicable LDR treatability variances are available when the same types of wastes are generated at multiple sites, and either:

(1) It is not physically possible to treat the wastes to the level specified in the existing LDR treatment standard or by the method specified in the existing standard; or

(2) It is inappropriate to require the wastes to be treated to the level specified in the existing LDR treatment standard or by the method specified in the existing standard, even though such treatment is technically possible.

Unlike a site-specific LDR treatability variance, a generically applicable treatability variance must be proposed and finalized as an EPA regulation under the procedure established in 40 CFR 260.20. This means that EPA must publish a *Federal Register* notice announcing its intention to issue a generically applicable treatability variance and provide an opportunity for public review and comment. If an interested member of the public requests it or EPA judges that it would be helpful to the decision-making process, EPA may, at its discretion, hold an informal public hearing.

Just 5 months after DOE filed the variance request, EPA issued a direct final rule granting generically applicable (national) treatability variances from the LDR treatment standards for radioactively contaminated cadmium-, mercury-, and silver-containing waste batteries [5]. Because no adverse comments were received, EPA's direct final rule took effect immediately at the end of the public comment period.

The national treatability variances, which are now available to all generators of waste batteries, designate three new treatment subcategories in the table of Treatment Standards for Hazardous Wastes (40 CFR 268.40), as follows:

- D006, Radioactively Contaminated Cadmium-Containing Batteries,
- D009, Radioactively Contaminated Mercury-Containing Batteries, and
- D011, Radioactively Contaminated Silver-Containing Batteries.

The specified LDR treatment standard for each of the three treatment subcategories is "macroencapsulation in accordance with 40 CFR 268.45," which is the macroencapsulation option provided in the alternative LDR treatment standards for hazardous debris. In other words, the direct final rule established the following new LDR treatment standard for radioactively contaminated cadmium-, mercury-, and silver-containing batteries (derived from 40 CFR 268.45, Table 1, Item C.1):

> Application of surface coating materials such as polymeric organics (e.g., resins and plastics) or use of a jacket of inert inorganic materials to substantially reduce surface exposure to potential leaching media. Encapsulating material must completely encapsulate the batteries and be resistant to degradation by the batteries and their contaminants and by materials with which it may come into contact after placement (leachate, other waste, microbes).

EPA's action allows DOE site operators and other generators to proceed with arrangements for macroencapsulation and final disposition of cadmium-, mercury-, and silver-containing batteries in appropriately permitted facilities located in authorized states that have adopted the direct final rule.

MERCURY-BEARING MIXED WASTES

Radioactively contaminated elemental mercury wastes have been generated over the years at many DOE sites, especially the Oak Ridge Reservation in Tennessee, Lawrence Livermore National Laboratory in California, Los Alamos National Laboratory in New Mexico, and the former Argonne National Laboratory-West in Idaho. Another mercury-bearing waste stream of much smaller volume generated at several DOE sites consists of mercury in oil. In addition, during the 1990s, remedial activities at DOE sites where mercury had been used over the years began to generate large volumes of radioactively contaminated mercury-bearing sludges, soils, and debris. The mercury concentrations in the non-debris solids generated during remedial activities are often greater than or equal to 260 mg/kg, although a considerable amount of this type of waste also contains mercury at concentrations below 260 mg/kg. Wastes consisting of mercury in oil also exhibit concentrations of mercury both less and greater than 260 mg/kg. All of these wastes are classified as hazardous wastes under RCRA either because they exhibit the TC for mercury (EPA waste code D009) or because the elemental mercury they contain is a discarded chemical product, which is a listed hazardous waste (EPA waste code U151).

When discarded, each DOE-generated mercury-bearing waste stream mentioned above must be treated prior to disposal to meet the applicable LDR treatment standard. Table II lists the LDR treatment standards for hazardous waste code subcategories applicable to pertinent mercury-bearing wastes.

Table II. LDR Treatment Standards Applicable to Mercury-Bearing Wastes in Pertinent Subcategories

WASTE CODE	PERTINENT MERCURY SUBCATEGORY DESCRIPTION	LDR TREATMENT STANDARD
D009	High-Mercury Organic Subcategory (i.e., the waste exhibits the TC for mercury, has total mercury content greater than or equal to 260 mg/kg, contains organics, and is not an incinerator residue)	Incineration (IMERC); or Roasting or Retorting (RMERC)
D009 U151	High-Mercury Inorganic Subcategory (i.e., the waste has total mercury content greater than or equal to 260 mg/kg, contains no organics, and may be the residue of IMERC or RMERC treatment)	RMERC
D009 U151	Low-Mercury Subcategory (i.e., the waste has total mercury content less than 260 mg/kg and is the residue of RMERC).	0.20 mg/L Toxicity Characteristic Leaching Procedure (TCLP) and, for D009, meet the Universal Treatment Standards (UTS) in 40 CFR 268.48 for any underlying hazardous constituents (UHCs)
D009 U151	Low-Mercury Subcategory (i.e., the waste has total mercury content less than 260 mg/kg and is not the residue of RMERC).	0.025 mg/L and, for D009, meet the UTS for any UHCs
D009	Hydraulic Oils Contaminated with Mercury Radioactive Materials Subcategory	IMERC
D009 U151	Elemental Mercury Contaminated with Radioactive Materials (non-wastewaters only)	Amalgamation (AMLGM)

Source: 40 CFR 268.40, Table of Treatment Standards for Hazardous Wastes

In 1996, DOE’s TMFA identified the need for improved technologies to treat mercury-bearing mixed wastes to meet applicable LDR treatment standards. Of particular concern was the emphasis in the existing LDR treatment standards on thermal recovery of mercury for reuse, which had proven problematic for mixed wastes because of their radioactive content. Accordingly, over the next several years, DOE, in conjunction with EPA, conducted three technology demonstration campaigns with the goal of identifying suitable technologies and conditions to support direct disposal of residues from the treatment of mercury-bearing mixed wastes. These technology demonstration campaigns addressed amalgamation of radioactively contaminated elemental mercury wastes, stabilization of radioactively contaminated low-mercury wastes (i.e., wastes containing mercury at concentrations below 260 mg/kg), and stabilization of radioactively contaminated high-mercury wastes (i.e., wastes containing mercury at concentrations greater than or equal to 260 mg/kg).

As the DOE/EPA joint technology demonstrations proceeded, EPA was also conducting other studies and gathering information on the broader issue of mercury’s interaction with the environment. Through such efforts, EPA had confirmed that mercury and its compounds are mobile in the environment and that multiple pathways exist for human exposure. Some evidence suggested that, because mercury is a persistent, bioaccumulative, and toxic (PBT) substance, small releases may contribute to the build up of mercury in the environment — especially the aquatic environment — over time, which may increase the potential for environmental and human health impacts. Consequently, EPA began to consider whether the LDR mercury treatment standards, which were designed to encourage thermal recovery for reuse, should be changed. Specifically, EPA was contemplating putting stronger emphasis on non-thermal recycling and treatment of residual mercury-bearing waste using methods that would further reduce air emissions, the mobility of mercury species at the time of disposal, and the potential for future biological or chemical conversion to other mobile and bioaccumulative species of mercury.

On May 28, 1999, EPA published an advance notice of proposed rulemaking (ANPRM) requesting comments and data to assist the Agency in evaluating potential alternatives for revising the LDR treatment standards applicable to mercury-bearing wastes [6]. Specifically, EPA sought input regarding alternatives to the existing LDR program requirement that high-mercury hazardous wastes be treated using thermal processes to recover elemental mercury followed by land disposal of any treatment residues that pass a leaching standard (i.e., 0.2 mg/L as measured by the TCLP for residues from roasting or retorting and 0.025 mg/L TCLP for residues of incineration). In October 1999, EH-43 filed a DOE consolidated comment package in response to the ANPRM [7]. The DOE consolidated comments generally advocated that EPA expand the LDR treatment standards applicable to high-mercury subcategory wastes to allow both mercury removal/recovery (using either thermal or non-thermal processes) and direct disposal options, particularly for mercury-bearing radioactive mixed wastes.

On January 29, 2003, EPA published a Notice of Data Availability (NODA) regarding supplemental treatability studies conducted on characteristic hazardous wastes containing mercury concentrations greater than or equal to 260 mg/kg and discarded elemental mercury wastes (i.e., RCRA hazardous waste codes D009 high-mercury subcategories and U151 high-mercury subcategory) [8]. The NODA explained that the supplemental treatability studies were initiated in cooperation with DOE because earlier joint EPA/DOE studies did not address the treatability of these waste types and information received in response to the 1999 ANPRM had not been adequate to support a proposal for changes to any of the mercury LDR treatment standards. The NODA reported the results of the supplemental studies and announced that, on the basis of all available information, EPA had concluded that stabilization/solidification technologies are potentially subject to pH-dependent attack by leachates. Furthermore, none of the technologies had been demonstrated to immobilize high-mercury waste adequately to justify changing the existing LDR treatment standards. However, the NODA acknowledged that there may be case-specific circumstances in which the existing LDR treatment standards listed in Table II are not appropriate for certain high-mercury wastes, on the basis of the particular type of waste and the expected conditions under which direct disposal of treatment residues from an alternative treatment method would occur. Therefore, the NODA encourages generators in such circumstances to file a petition for a site-specific treatability variance pursuant to 40 CFR 268.44(h)(2).

While EPA's NODA does not provide the relief that DOE would have preferred for mercury-bearing mixed wastes, DOE facilities with problem mercury-bearing mixed wastes now have the opportunity to pursue site-specific treatability variances.

RADIOACTIVE LEAD SOLIDS

Lead is used in the DOE complex principally for radiation shielding in buildings and equipment. Over the years, large quantities of lead have become contaminated with radionuclides. As equipment and buildings are removed from service, radioactively contaminated lead has been and continues to be generated in considerable quantities and in a variety of forms. Consistent with the Department's Lead Reuse Policy [9], DOE site operators — in conjunction with the DOE National Center of Excellence for Metals Recycle (Oak Ridge, Tennessee) — attempt to identify operations in which radioactively contaminated lead and lead products can be reused as an initial step in managing these inventories. However, some radioactively contaminated lead-containing materials that are not reusable or recyclable still must be treated to meet LDR treatment standards in order to support land disposal. Among these radioactive lead-containing materials are elemental lead in the form of sheets, lead-lined blankets and gloves, bricks, shot, wire, and other shielding, which are classified in the D008 Radioactive Lead Solids Subcategory for purposes of the LDR program.

On the basis of input from individual facilities, EH-43 — in cooperation with the TMFA — has estimated that approximately 2.5 million kilograms of lead-containing waste materials classified in the D008 Radioactive Lead Solids Subcategory are in storage across the DOE complex. Greater than 50 % of this existing inventory was commingled at the point of generation with mixed waste debris. The commingling occurred either because (1) at the time of generation, there was no regulatory driver for segregating radioactive lead solids from the debris, or (2) the radioactive lead solids were so intimately attached to equipment and structures, which qualify as debris when discarded, that separating them would have been extremely difficult and hazardous to workers. Because much of the existing inventory of commingled D008 radioactive lead solids and debris is already containerized, separation of the lead solids at this point would involve manual repackaging, which would create the potential for added worker radiation exposure.

Through 2006, DOE facilities estimate a cumulative generation rate for lead-containing waste materials classified in the D008 Radioactive Lead Solids Subcategory of approximately 192,995 kg/yr.

Under the existing LDR treatment standards, D008 radioactive lead solids wastes must be treated by using the specified method of treatment referred to as "MACRO." The "MACRO" treatment method consists of "macroencapsulation with surface coating materials such as polymeric organics (e.g., resins and plastics) or with a jacket of inert inorganic materials to substantially reduce surface exposure to potential leaching media" (40 CFR 268.42). Also, 40 CFR 268.42, Table 1 restricts the MACRO treatment method to technologies that do not employ a tank or container (as defined in 40 CFR 260.10). In comparison, the LDR treatment standards allow hazardous and mixed waste debris that are not classified as D008 radioactive lead solids to be treated by using a specified method of treatment referred to as "macroencapsulation." The hazardous debris "macroencapsulation" treatment method has essentially the same definition as the "MACRO" treatment method, except that hazardous debris "macroencapsulation" is not restricted with respect to the use of tanks and containers (40 CFR 268.45, Table 1, item C.1).

When EPA enacted the LDR treatment standards for hazardous debris 2 years after establishing the treatment standards for D008 radioactive lead solids, the Agency explained that it viewed the constraint on using tanks and containers in macroencapsulation technologies as being overly restrictive [10]. Furthermore, EPA later indicated that its formulation of the hazardous debris "macroencapsulation" treatment method was intended to increase treatment flexibility [11, 12].

DOE has been working for a number of years with several vendors to demonstrate to regulatory agencies that macroencapsulation technologies that incorporate certain containers are capable of meeting the performance requirements in the LDR treatment standards applicable to land disposal of hazardous and mixed waste debris. Through these efforts, significant advances have been made in container-based debris macroencapsulation technologies. In 2001, EH-43 — in cooperation with the TMFA — initiated discussions with EPA about the possibility of establishing the equivalency of the "MACRO" method of treatment and the hazardous debris "macroencapsulation" method of treatment so that both methods could be applied to meet the LDR treatment standards for D008 radioactive lead solids. Pursuant to 40 CFR 268.42(b), EH-43 submitted an application to EPA for such a determination of equivalent treatment (DET) and approval of an alternative treatment method in July 2004 [13].

The application for approval of an alternative treatment method provides detailed information demonstrating that the hazardous debris "macroencapsulation" method of treatment, as defined in 40 CFR 268.45, Table 1, item C.1, achieves a measure of performance equivalent to that achieved by the "MACRO" treatment method for D008 radioactive lead solids. The application also presents information illustrating the level of performance achieved by an example non-container macroencapsulation technology already used to implement the "MACRO" treatment method (i.e., low-density polyethylene [LDPE] extrusion). This information is compared with similar information about each of several example container-based macroencapsulation technologies already used to implement the hazardous debris "macroencapsulation" treatment method (i.e., high-density polyethylene [HDPE] tubes [such as extruded pipes] and HDPE molded shapes [such as cylindrical or rectangular boxes]).

According to its most recent Semi-Annual Regulatory Agenda [14], EPA anticipates taking action in the form of a NODA to announce issuance of a national DET for D008 radioactive lead solids for which DOE has treatment responsibility. Issuance of the NODA is currently scheduled for approximately March 2006. In the Semi-Annual Regulatory Agenda, EPA states its belief that HDPE containers can be constructed to provide a resistant barrier to degradation resulting from contact with wastes and other materials in the disposal environment. EPA also expresses the opinion that the DET will promote more efficient cleanup of contaminated DOE sites by (1) removing the regulatory distinction between radioactive lead solids and other forms of hazardous debris, (2) reducing worker radiation exposures, and (3) promoting further advances in new disposal technologies.

Issues that contributed to EPA's lengthy review of the application for a DET are listed below.

- The nature of the EPA action to be taken (DET vs. generically applicable LDR treatability variance).
- The role of states and EPA regions in implementation of the DET.

STRATEGIES FOR SITE-SPECIFIC LDR COMPLIANCE

There are three ways to comply with LDR treatment standards:

- Qualify for a regulatory exemption,
- Treat the hazardous waste to meet applicable LDR treatment standards, and
- Obtain a variance.

Fig. 1 illustrates the process for selecting among these compliance options. This section focuses on the processes for obtaining treatability variances and DETs.

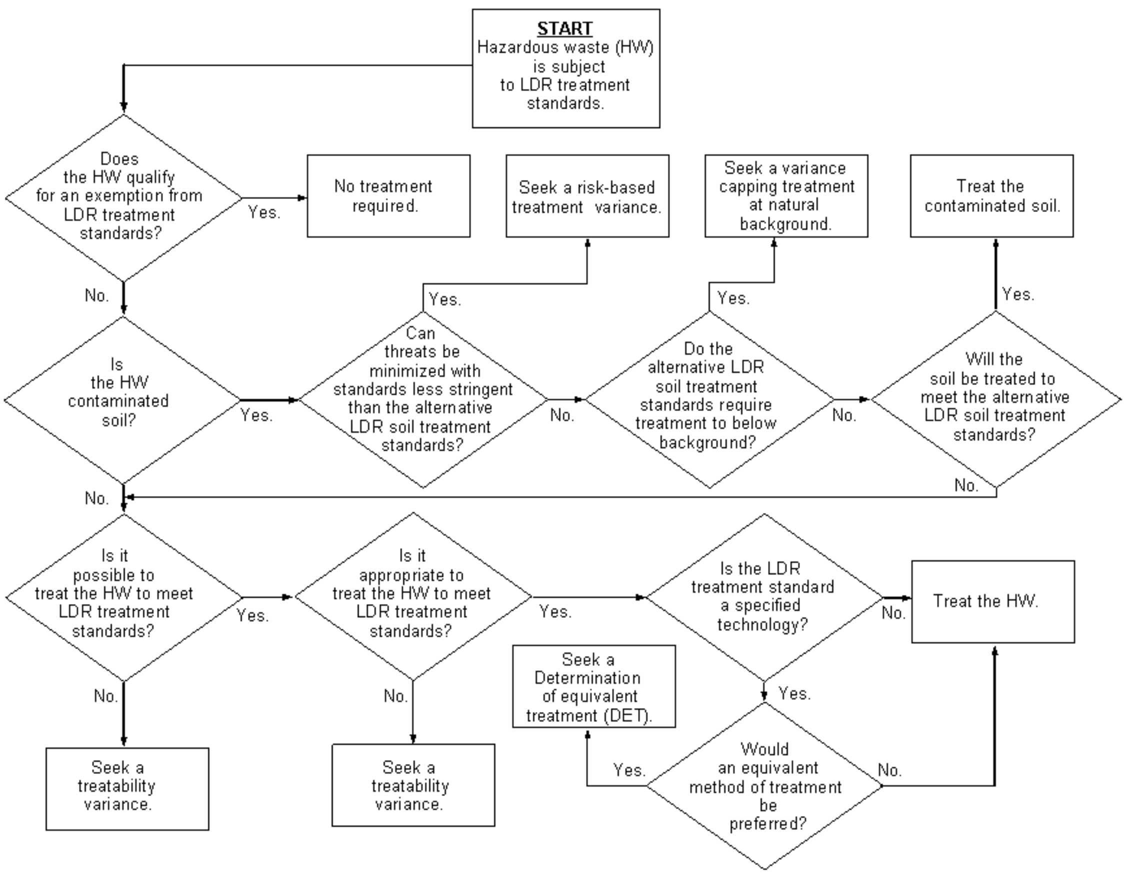

Fig. 1. Process for selecting an LDR compliance option

When EPA decided in 1989 to implement the RCRA LDR program by means of technology-based treatment standards, the Agency recognized that there could be wastes for which treatment standards expressed as concentration limits would be either not achievable or not appropriate. EPA also recognized that there could be wastes for which treatment standards expressed as a specified method of treatment would be inappropriate or for which the same performance level would be achievable by using a different method of treatment. Accordingly, in addition to adopting exemptions from and alternatives to the generally applicable LDR treatment standards for wastes EPA developed criteria and procedures for obtaining variances from otherwise applicable LDR treatment standards on a case-specific basis.

The radioactively contaminated cadmium-, mercury-, and silver-containing batteries discussed in this paper are examples of wastes that EPA has determined are eligible for a generically applicable treatability variance under 40 CFR 268.44(a). The mercury-bearing mixed wastes are examples of wastes that EPA has stated may be appropriate for site-specific treatability variances under 40 CFR 268.44(h)(2). The D008 radioactive lead solids generated by DOE facilities are examples of wastes for which EPA is planning to issue a DET under 40 CFR 268.42(b). Additional information about the criteria and procedures for obtaining site-specific treatability variances and DETs is provided below.

Criteria and Procedures for Obtaining Site-Specific Treatability Variances

Site-specific treatability variances are available when (1) a hazardous waste cannot be treated to meet the applicable LDR treatment standard (i.e., such treatment is not physically possible), or (2) treating the waste to meet the applicable standards would be inappropriate (i.e., treatment is physically possible and technically feasible, but it is unsuitable, impractical, or could result in a net environmental detriment or discourage aggressive remediation). Evaluation criteria are the same for both generically applicable and site-specific treatability variances, but a generically applicable treatability variance must be proposed and finalized as an EPA regulation, whereas a site-specific treatability variance may be processed by the EPA region or an authorized state agency without following rule-making procedures. For this reason, EPA does not authorize states to grant generically applicable treatability variances.

To grant a site-specific variance on the basis that it is not possible to treat a waste either to the levels or by the methods established in the LDR treatment standards, the regulatory agency must find that the physical or chemical properties of the waste differ significantly from those of the wastes analyzed during development of the existing LDR treatment standards. To make this finding, the regulatory agency will first evaluate the design and operation of the technologies used in attempts to treat the waste. If treatment was attempted using one or more properly designed and operated best demonstrated available treatment (BDAT) technologies, but treatment was unsuccessful, the regulatory agency may infer that something about the waste is making it more difficult to treat than the wastes used in developing the existing LDR treatment standards. In that case, the regulatory agency will evaluate the waste to determine whether the waste matrix and/or physical parameters differ significantly from those of the waste analyzed during development of the existing LDR treatment standards. If they do differ, the treatability variance may be granted.

To grant a site-specific variance on the basis that it would be inappropriate to require the waste to be treated either to meet the hazardous constituent concentration levels or by using the treatment method specified in the existing, applicable LDR treatment standards, the regulatory agency must make one of the following findings:

- Treatment to the specified level or by the specified method is technically inappropriate; or
- For remediation waste only, treatment to the specified level or by the specified method is environmentally inappropriate because it would likely discourage aggressive remediation.

A treatability variance, whether based on physical impossibility or inappropriateness of the treatment standards or methods, is obtained by filing a petition with the appropriate EPA region or authorized state. The required contents for a site-specific treatability variance petition are summarized in Table III, which appears after the subsection on DETs. The regulatory agency will make the petition available for public review and comment. The vehicle for soliciting public input will be determined on the basis of state requirements or on a case-specific basis if no state requirements have been announced.

Criteria and Procedures for Obtaining DETs

If the LDR treatment standards require that a specified method be used to treat a waste, the generator or treatment facility may achieve compliance by either treating the waste using the specified treatment method or seeking a determination that an alternative treatment method could achieve an equivalent level of performance. Although the alternative treatment method established by such a DET is typically both waste-and site-specific, the decision to issue a DET may require examination of national concerns (e.g., whether the existing LDR treatment standard should be modified through a rulemaking procedure). For this reason, EPA does not authorize states to implement 40 CFR 268.42(b), and DETs must be issued or denied by EPA Headquarters.

To issue a DET, EPA must determine that the proposed alternative treatment is protective of human health and the environment and will achieve a level of performance at least equivalent to that of the method specified in the existing LDR treatment standards. The proposed alternative treatment may take any of the forms listed below.

- A different specified method of treatment
- Specified concentration levels for surrogate or indicator constituents, the measurement of which will guarantee that hazardous constituents of concern have been treated to levels at least equivalent to the level achieved by the treatment method specified in the existing LDR treatment standard
- Specified concentration levels for hazardous constituents of concern that are newly measurable by using a new analytical method

The regulations in effect since the inception of the LDR program do not require EPA to solicit public participation as part of its DET application review process. For this reason, during most of the early history of the LDR program, EPA did not publish public notices or seek comments before issuing DETs. However, in 1999, in order to encourage maximum public involvement in its decision-making process, EPA began voluntarily publishing notices in the *Federal Register* of its intent to issue or deny DET petitions. Table III summarizes the required contents of a DET petition as well as the required contents for a site-specific treatability variance petition.

Table III. Summary of Information to be Provided in Petitions for Site-Specific Treatability Variances and DETs

INFORMATION TO BE PROVIDED	DET	SITE-SPECIFIC TREATABILITY VARIANCE
Petitioner and Facility Information (petitioner's name and address, generating facility's name and address, generating facility's EPA identification number, plant contact's name and telephone number)	X	X
Statement of Interest in the Proposed Action (type of variance requested, applicable waste codes, LDR treatment standards from which variance is requested, reasons and rationale for requesting a variance)	X	X
Description of the Waste Generation Process	X	X
Description of the Waste (physical and chemical properties of the waste for which the existing LDR treatment standards were developed, physical and chemical properties of the waste that will be treated under the variance, estimated quantities of untreated waste to be treated under the variance)	X	X
Description of Treatment Systems (treatment system necessary under existing LDR treatment standard, treatment system to be used under proposed alternative treatment standard, physical and chemical properties of treatment residues for existing and proposed treatment systems)	X	X
Engineering Evaluation (demonstration that existing LDR treatment standards are not achievable, demonstration that existing LDR treatment standards are not appropriate)		X
Proposed Alternative LDR Treatment Standard (specification of the alternative method of treatment, indicator/surrogate concentration levels, hazardous constituent concentration levels, and/or other requirements, if any, comprising the proposed alternative LDR treatment standard)	X	X
Sampling and Testing Data (dates of sampling and testing, operating conditions at time of sampling, methodologies and equipment used to obtain representative samples, description of sample handling and preparation techniques, description of tests performed, description of quality assurance/quality control [QA/QC] measures for waste sampling and testing)	X	X
Certification that Petition Contents are True, Accurate, and Complete		X
Potential Under the Variance for Adverse Environmental Impacts to Media Other than Land	X	
Conditions to be Placed on the Proposed Alternative Treatment System	X	
Demonstration that Compliance with the Alternative LDR Treatment Standard will Minimize Threats to Human Health and the Environment		X

CONCLUSION

EH-43 and the TMFA, with the support of DOE field elements, were successful in obtaining EPA approval of a regulatory interpretation and national treatability variances for radioactive lead acid battery wastes and mixed waste batteries, respectively. Additionally, at DOE's request, EPA has announced its intention to issue a DET that will allow the use of certain container-based macroencapsulation technologies as alternative treatment methods for D008 radioactive lead solids. These successes suggest EPA's willingness to work with DOE to identify and implement appropriate alternative LDR treatment standards for challenging mixed wastes. Furthermore, although EPA is unable, at this time, to justify modifying any of the LDR treatment standards for mercury-bearing mixed wastes, DOE's collaboration with the Agency on treatability studies for such mixed wastes has fostered a respectful relationship that should support obtaining site-specific variances in the future. DOE waste managers are encouraged to consult with appropriate regulatory agencies and, when suitable, to develop quality petitions for site-specific treatability variances and DETs so that challenging mixed wastes can proceed to compliant LDR treatment and final disposition.

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