

MANAGEMENT OF RADIOACTIVE MIXED WASTES IN COMMERCIAL LOW-LEVEL WASTES*

C. R. Kempf, D. R. MacKenzie, P. L. Piciulo,
B. S. Bowerman and B. Siskind

Department of Nuclear Energy
Brookhaven National Laboratory
Upton, New York 11973

ABSTRACT

Potential mixed wastes in commercial low-level wastes have been identified and management options applicable to these wastes have been evaluated. Both the identification and management evaluation have necessarily been based on review of NRC and EPA regulations and recommendations. The underlying intent of both agencies is protection of man and/or environment, but differences may occur in the means by which intent is achieved. Apparent discrepancies, data gaps and unresolved issues that have surfaced during the course of this work are discussed.

INTRODUCTION

The potential for dual regulation of some low-level radioactive wastes (LLW) by both the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA) has been recognized as a consequence of the radioactive and chemically hazardous characteristics of these wastes (hereafter referred to as "mixed wastes"). Federal law has historically lacked clear language regarding these wastes and, most recently, the 1985 amendments to the Low-Level Waste Policy Act were passed without clarification of the mixed waste issue. Brookhaven National Laboratory (BNL), under the auspices of the NRC, has carried out a three-part study^{1,2,3} aimed at addressing the identification and management of mixed wastes. The results of the first two parts of this work establish the potential existence, estimated quantities, characteristics, and current management practices for mixed wastes in commercial LLW. The last part identifies and evaluates management options for the three generic mixed waste categories found as a result of the earlier efforts. These options have been evaluated for their potential to address both NRC and EPA concerns and they include regulatory or administrative actions as well as treatment or handling methods. For each of the wastes, the treatment or handling option evaluation has included an assessment of testing appropriate to determine the effect of the option on both the radiological and potential chemical hazards present.

The BNL study has necessarily included a review of EPA regulations pertaining to hazardous wastes. In the attempt to address both NRC and EPA concerns, BNL has recognized similarities and differences in intent and respective strategies to accomplish intent for the two agencies. This paper presents an outline of the pertinent NRC and EPA similarities and differences, gives a review of the findings of the BNL study, and attempts to present an overview of potential inconsistencies and unresolved issues that have surfaced during the course of this work.

REGULATORY BACKGROUND

The ultimate goal of waste handling and disposal regulations of both the NRC and the EPA is the minimization of contact of waste materials with man and/or the environment such that protection of human health and the environment is ensured. The hazard posed by low-level radioactive wastes is due to nuclear phenomena and is, thus, independent of chemical state. The radiological hazard has a definite half-life which is a function of the particular radionuclide(s) involved. The hazard posed by chemically hazardous non-radiological wastes, on the other hand, may be due to the properties of an element (e.g., arsenic, lead or chromium), or it may be intimately linked to the chemically bound state. The hazards associated with these two (non-radiological) types of material can not be said to have a definite or easily predictable half-life and, certainly for the elemental hazardous materials, the chemical hazard is expected to be at least as long-lived as the radiological hazard for a radionuclide.

The NRC, as a successor agency to the Atomic Energy Commission, has historically been responsible for regulation of radioactive wastes, while, in a much shorter time frame, the EPA has been concerned with regulation of chemical wastes. It is only fairly recently (and certainly as a consequence of increased awareness of potential health and environmental effects) that the significance of the mixed wastes issue has been recognized. Concurrently, the question of their proper management and the appropriate designation of responsibility to one or both agencies has arisen.

This discussion of the regulatory differences and similarities between NRC and EPA will highlight the majority of references pertinent to mixed waste, to be followed by the summary of results from BNL studies. From this overview, the apparent inconsistencies and unresolved issues may be more clearly understood.

NRC Regulations

The NRC regulations pertaining to low-level waste disposal are codified in 10 CFR Part 61.⁴ The logic structure of these regulations was largely based on the principle of groundwater protection for as long

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as the waste poses a radiation hazard, effected through waste form stabilization to limit trench subsidence, and trench capping, resulting in minimal contact of wastes with water. In addition to the regulations themselves, NRC has issued a technical position on waste forms and high integrity containers (HICs)⁽⁵⁾ which recommends methods and tests to help generators produce waste packages which will meet technical requirements.

NRC's emphasis is on the elements of the trench -- trench stability is expected to be achieved in large measure by stability of the waste, in order to minimize trench slumping and consequent contact of the waste with surface water. Thus, Class B and C waste, segregated from Class A waste, is required to be stabilized through the use of stable waste forms or placement in HICs. All LLW must be packaged in containers. The NRC requirements for containers are minimal (e.g., cardboard and fiberboard boxes are not allowed) since, in general, the waste form and not the container is considered the principal barrier to release of radioactivity. High integrity containers for Class B and C wastes, however, must meet stringent requirements in that they are expected to have a design lifetime of 300 to 500 years. NRC forbids disposal of liquid waste. Incidental amounts of liquid accompanying solid waste up to 1% of the volume of the solid may be accepted. Section 61.56(a)(2) of 10 CFR Part 61 requires that liquid waste must be either solidified or packaged in sufficient absorbent material to absorb twice the volume of the liquid.

NRC encourages storage for decay of short-lived isotopes, since fully decayed material does not require disposal at a burial site. Also, extended storage of LLW for 5 to 15 years may soon be necessary because of unavailability of burial space. Additionally, as a general rule and even more importantly now, NRC advocates waste volume reduction.

At the disposal site, shipments of LLW must be checked to see that their packages match the information given in the manifests, as outlined in 10 CFR Section 20.311.⁴ However, no examination of package contents or analysis of the waste is required. This is, at least in part, because such inspection would result in radiation exposure of operating personnel. Routine safety inspection for problems such as leaking containers is a condition of licensing by the states and periodic inspections for free liquid in containers are carried out case-by-case. NRC's regulations have thus been directed toward the waste as-shipped; in this manner the efforts of the waste generators in properly packaging LLW for disposal are expected to complement the performance of the disposal site.

Lohaus and Johnson have pointed out⁶ that NRC recognized in 1977 the need to evaluate the chemical hazard in LLW, and initiated studies in this area. When 10 CFR Part 61 was issued in December 1982, it contained a section requiring special treatment of chemically and biologically hazardous waste. Section 61.56(a)(8) states that:

"Waste containing hazardous, biological, pathogenic or infectious material must be treated to reduce to the maximum extent practicable the potential hazard from the nonradiological materials."

This is one of the minimum requirements given in Section 61.56(a) for all classes of radioactive waste and is intended, among other things, to facilitate

handling and provide protection of health and safety of personnel at the disposal site.

The states which license the three operating LLW burial sites have amplified and extended this section of the rule as it concerns hazardous chemicals. In general, the disposal sites presently are not permitted to receive waste containing both radioactive material and toxic and hazardous chemicals until an independent evaluation of the relative radiologic and chemical hazards has been performed. If the chemical hazard is assessed as exceeding the radiologic, specific state approval is required, and records of the hazard evaluation must be kept for inspection by the state.

EPA Regulations

The EPA, under authority of the Resource Conservation and Recovery Act (RCRA), has promulgated regulations governing hazardous waste disposal in 40 CFR Parts 260 through 270.⁷ Part 261, which covers identification and listing of hazardous wastes, and Part 264, which gives the requirements for operation of hazardous waste treatment, storage and disposal facilities (TSDFs), are particularly pertinent to mixed wastes. In addition to these regulations governing chemically hazardous waste, EPA expects to have a draft version of standards for low-level radioactive waste available early in 1986, with a final version a year later.⁸

The approach of EPA to management of hazardous waste differs from that of NRC with respect to LLW. This is evident from their respective choices of the time at which material becomes waste for regulatory purposes -- broadly speaking, in EPA's consideration this is when it is generated; whereas for NRC it is at the time of shipment (i.e., after treatment and packaging).

The four main elements of EPA's action plan have been stated as⁹ :

- Reduce the amount of hazardous waste produced to the extent possible. This can be accomplished, for example, through substitution of materials.
- Recycle or reclaim materials whenever possible. Besides actual reuse of materials, this includes burning of certain hazardous wastes as fuel.
- Wastes that cannot be recycled should be treated. Treatment methods are physical, chemical and biological. They may eliminate the need for disposal (e.g., incineration to the required degree of destruction of the hazardous material), or reduce the amount requiring disposal. In any case the hazard should be reduced by treatment.
- Disposal is to be considered as a last resort. This can be in landfills, burial sites, or deep injection wells. It has been made clear that Congress wants treatment of hazardous materials prior to disposal in order to reduce risk from unforeseen processes which might occur after disposal.

Several options are open for handling chemically hazardous wastes. In essence, EPA does not require, but would recommend, treatment of hazardous waste before disposal.⁹ EPA limits un-permitted storage of hazardous waste to three months.

The greatest volume of hazardous waste is liquid and most of this is disposed of by deep-well injection.⁹ Under the 1984 amendments to RCRA, bulk (i.e., non-containerized) hazardous liquids can no longer be accepted for disposal in landfills. EPA still allows land disposal of liquids in containers or liquids that have been treated, e.g., by absorption or solidification, but further restrictions on disposal of liquids are possible in the revised regulations expected in the near future. Disposal of hazardous waste in liquid form by the EPA "lab pack" method is, however, acceptable. This method involves placing small waste containers in an overpack container filled with absorbent, and is described in 40 CFR Section 264.316.

There are no EPA requirements or performance standards specified in 40 CFR Part 264 regarding containers used for disposal, since hazardous waste does not have to be containerized.

A generator of a listed hazardous waste has the option of petitioning to have it delisted, while LLW generators have no such option. Delisting of hazardous waste is a complicated process and essentially requires demonstrating that the waste as generated is non-hazardous.

The EPA landfill operation is subject to very definite requirements, such as use of a double plastic liner for the whole hazardous waste trench or pit, pumping out of all collected leachate from the liners during the operating period of the landfill, etc. After the operating period, the trench or pit is capped to help prevent access of surface water to the contents. EPA's emphasis thus appears to be on performance of the trench as a whole.

Under Section 264.13 of 40 CFR Part 264, EPA requires that operators of facilities such as landfills must inspect each hazardous waste shipment received to determine whether it matches the identity of the waste specified in the accompanying manifest. This inspection includes analysis, if necessary for such determination.

Emphasis is placed by EPA on identification of hazardous wastes. This identification is the responsibility of the generator, and 40 CFR Part 261 subparts C and D are most important to generators for determining whether their wastes are hazardous. Subpart C defines general characteristics which, if exhibited by a waste material, cause the classification of that material as hazardous. Representative sampling of wastes is discussed in Appendix I to Part 261.

There are four hazardous waste characteristics defined at present:

1. ignitability
2. corrosivity
3. reactivity
4. extraction procedure (EP) toxicity

The specific waste properties are given in detail, as well as recommended tests for determining these characteristics, in 40 CFR Sections 261.21 to 261.24. Subpart D contains lists of specific waste streams which are considered hazardous.

DETERMINATION OF HAZARD - SAMPLING AND TESTING

The significance of the hazardous waste identification procedures (for chemically hazardous wastes) results largely from the fact that once a waste is

identified as hazardous, its fate is determined (subject to applicable regulations in 40 CFR Parts 262-271). The methods by which wastes are sampled and tested thus becomes quite important and, given that the development of EPA's identification and testing guidance has historically been based on nonradioactive materials, any consideration of their potential application to LLW must address the question of appropriateness, representativeness, and radiation safety. As has been found during the course of BNL's studies, direct application of EPA's identification procedures to LLW has not been feasible, thus, as is discussed later in the section on BNL findings, potential mixed wastes have been identified. An overview of the EPA identification scheme and its differences from and similarities to NRC guidance is helpful in understanding the results of the BNL work.

In the following discussion, a comparison is given of the EPA and NRC approaches to sampling and to the first three of the Subpart C characteristics. There is no close NRC analog to the fourth hazardous characteristic, EP toxicity, since, historically, NRC and its predecessors have been concerned with leaching from wastes of radionuclides rather than of hazardous chemical constituents.

Sampling

EPA emphasizes obtaining representative waste test samples since such tests decide the question of hazardous nature, and hence, subsequent regulation. NRC focuses on radiological monitoring of: (1) effluent waste streams prior to their release as gases or liquids to the environment, and (2) solid wastes for radiological safety purposes and to determine their classification under 10 CFR Section 61.55. Sampling of LLW material is also recommended as part of solidification process control. In order to determine whether a given LLW type is hazardous according to EPA regulations, more (or different) sampling than that which has been customary for LLW generators may be needed.

The diversity of wastes, containers, and storage facilities has precluded EPA's giving detailed consideration to any specific sampling plan, but generic sampling strategies for wastes have been identified in EPA documents, for example, in the Test Methods Document.¹⁰ In particular, equipment and procedures for the sampling of wastes in drums and storage tanks, both of which are frequently used for LLW, have been considered.

LLW stabilized in cement or bitumen, or general laboratory trash may not be amenable to the sampling methods identified by the EPA. For stabilized wastes, sample sections or cores may be taken from a batch. Laboratory trash samples may be limited to grab sampling at a frequency dependent on the variation in the quantitative values for the hazardous characteristics.

In summary, given the wide variety in physical types and packages for LLW, the method of sampling to obtain 40 CFR Part 261 Subpart C test material may have to be developed on a case-by-case basis for LLW. In any event, the radiation safety of workers must be taken into consideration as well as the possibility that additional sampling (and/or testing) may result in increased waste volumes generated.

Ignitability

According to the NRC's 10 CFR Section 61.56(a) and (b), LLW must not be pyrophoric. The definition of "pyrophoric" used in 10 CFR Part 61 overlaps the

definition of "ignitable" used by EPA in 40 CFR Section 261.21. Ignitable compressed gases as described in 40 CFR 261.21 are prohibited in LLW by the NRC's limit of 1.5 atmospheres for LLW in gaseous form. The one type of ignitable waste which is not covered explicitly in the NRC regulations is liquid ignitable waste as defined in 40 CFR Section 261.21, i.e., a liquid (other than certain aqueous alcohol solutions) with a flash point under 140°C. Some liquids may be ignitable without being pyrophoric.

EPA has specified testing for the ignitability of liquid wastes, but states that no test methods are available which could accurately identify the small class of ignitable solids at which its regulation is directed. Generators of thermally unstable solids are likely to be aware that their wastes exhibit this property. It should be noted, however, that tests for the flash and fire points of solid materials do exist, e.g., ASTM E502-74, "Standard Test Method for Flash Point of Chemicals by Closed-Cup Methods." ¹¹

Corrosivity

According to 10 CFR Section 61.56(a)(3), "solid waste containing liquid shall contain as little free-standing and non-corrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1% of the volume." There are further restrictions on free liquid for LLW processed to a stable waste form, i.e., it must comprise no more than 0.5% of the waste by volume and it must be non-corrosive. In the Technical Position on Waste Form ⁵ corrosivity of wastes toward the structural material(s) of a high-integrity container are considered, i.e., "The high integrity container design should consider the corrosive and chemical effects of both the waste contents and the disposal trench environment. Corrosion and chemical tests should be performed to confirm the suitability of the proposed container materials to meet the design lifetime goal."

EPA defines corrosivity for waste in terms of an aqueous pH range of <2 or >12.5 , or the capability as a liquid of corroding steel at a rate >6.35 mm/year under specified conditions.

Parameters such as pH or corrosion rates are not explicitly given by the NRC, although in the TP on Waste Form ⁵ a pH of 4 to 11 is specified for the free liquid up to 0.5% by volume permitted in processed (i.e., solidified) Class B and C waste. However, the relevance, if any, of the EPA definitions of corrosivity to situations such as wastes in polyethylene high-integrity containers is unclear. Also, the corrosivity of solids is not addressed by the EPA. Work on the corrosion of container materials (mild steel) embedded in solidified waste (urea-formaldehyde and cement) has been carried out ¹² under the auspices of the NRC; this showed that the urea-formaldehyde binder material is corrosive towards mild steel. The potential corrosivity of wastes stabilized in urea-formaldehyde was not addressed by the EPA in its discussion of this binder material in its "Guide to the Disposal of Chemically Stabilized and Solidified Wastes." ¹³

Reactivity

According to 10 CFR Section 61.56 [a] [4] and [5], LLW must not be explosive or reactive. These waste characteristics overlap extensively the EPA's definition of reactive waste in 40 CFR Section 261.23. According to EPA, suitable test methods for reactivity are unavailable, but most generators of reactive waste are aware that their wastes exhibit

this property and thus require special handling. It would be expected that generators of potentially reactive LLW would also be aware of this characteristic in their wastes.

EP Toxicity

According to 40 CFR Section 261.24, a solid waste exhibits the characteristic of extraction procedure (EP) toxicity if, using a specified extraction (leaching) procedure or approved equivalent methods, the extract (leachate) from a representative sample of the waste contains, above specified concentration levels, any of a list of contaminants.

The EPA extraction procedure (EP) was devised to address contamination of groundwater through the leaching of contaminants from waste disposed of by land burial. This is considered a major pathway for toxic waste constituents to migrate to the environment. The test was developed to simulate the physical and chemical processes which could occur given a conservative mismanagement scenario of co-disposal of toxic wastes in an actively decomposing municipal landfill overlying a groundwater aquifer. An acidic leachant typically occurs in such landfills, and attenuation in concentration is expected between leachate generation and reception or exposure points.

The EP toxicity test procedure specifies a pH of 5.0 (+ 0.2) for the leaching medium (acetic acid), and tabulated concentration values for contaminants represent a dilution factor of 100 from the maximum contaminant levels allowed by the National Interim Primary Drinking Water Standards for eight inorganic contaminants [40 CFR Section 141.11(8)] and for four chlorinated hydrocarbon pesticides and two chlorophenoxy herbicides [40 CFR Sections 141.12(a) and (b)]. Toxic contaminants other than those in Table 1 of 40 CFR 261.24 were not included because no chronic exposure threshold levels relating to drinking water consumption had been established at the time of regulation preparation. ⁷ However, as a result of the 1984 Amendments to RCRA, the EPA plans to extend the list of contaminants to include additional metal and organic constituents. Their identities and threshold values are not available at present. An expanded toxicity leaching procedure, the toxicity characteristic leaching procedure (TCLP), has been recently published as an appendix to proposed EPA regulations. ¹⁴

The applicability of the EPA mismanagement scenario to LLW sites is questionable. Data on the composition of trench leachates from at least four commercial LLW disposal sites have been reported which indicate that the composition of LLW site trench water would be significantly different from the EP toxicity leachate. Reported pH ranges for trench leachates were: Barnwell, 5.8 to 7.6 ¹⁵; Sheffield, 5.0 to 6.8 ¹⁶; West Valley, 6.5 to 9.4 ¹⁶; and Maxey Flats, 5.1 to 12.1 ¹⁷ and 2.0 to 12.4 ¹⁶ (for the latter most were in the pH range of 6.0 to 8.5). The concentrations of dissolved organic carbon measured in the trench leachates were lower than the concentration of acetic acid in the EP toxicity leachate. Also, the trench leachates contained other ions (e.g., Na⁺, Ca⁺⁺, Mg⁺⁺, Cl⁻, CO₃⁼). Of the sites discussed, only that at Barnwell, South Carolina, continues to accept radioactive waste, and steps are taken in the site operation to minimize the contact of water with the waste. On the other hand, the LLW sites at Beatty, Nevada, and Richland, Washington, which are also currently operating, are located in arid regions of the U.S. and are not likely to have significant accumulations of trench leachates.

Further consideration seems warranted to determine an appropriate leachate for evaluating the EP toxicity of LLW.

BNL STUDIES

The results of the BNL generator survey and potential mixed waste management options study are briefly described here, with emphasis on the significance of these findings in light of the existing regulatory framework just discussed. Details of the BNL work may be found in References 1, 2 and 3 and also in the papers by B. S. Bowerman et al., "Identification of Radioactive Mixed Wastes in Commercial Low-Level Wastes" and C. R. Kempf et al., "Management Options for Radioactive Mixed Wastes in Commercial Low-Level Waste - Technical Considerations," both being presented at Waste Management '86.

Identification of Potential Mixed Wastes

BNL's literature and document review and survey of LLW generators focused on establishing the types and volumes of mixed wastes shipped to commercial LLW sites for disposal. The literature and disposal site record review identified two waste categories as potentially hazardous under the EPA 40 CFR Part 261 Subpart C characteristics.⁷ These were lead metal and organic solvents used in liquid scintillation media. No LLW types were identified which directly corresponded to the hazardous waste from specific sources listed in Subpart D. Lead was considered potentially EP toxic. Organic solvents were identified as potentially hazardous due to ignitability and also to the presence of spent solvents from non-specific sources.

The lack of consistent quantitative data on potential mixed wastes was apparent from the literature review, and a survey was conducted in order to fill this gap. The survey was directed at those LLW generators identified in the early phases of BNL's studies, as well as at larger generators whose names were provided by NRC. The survey questionnaire was designed to obtain information on any potential mixed wastes and, based on findings of earlier work, also on the presence and concentrations of various hazardous constituents such as phenols, hydrazine, cyanide, and chromates. Questionnaires were sent to 239 reactor and non-reactor generators of LLW. Of these, 97 responses were received, representing 22,000 m³, or approximately 30% by volume of all LLW sent to commercial disposal sites in 1984.²

Table I summarizes the categories of potential mixed wastes identified from the survey results. The classification of oil- and solvent-containing LLW as potential mixed wastes is applicable to the wastes as-generated. A further classification as EP toxic under new EPA TCLP guidance may be pertinent as well. The solvent-containing wastes include scintillation counting fluids, lab solvents, and cleaning and degreasing solvents and sludges. The two categories of lead and chromium wastes are considered potential mixed wastes based on EP toxicity. The applicability of the EP toxicity test for evaluating lead metal as hazardous in a LLW disposal site may be open to question.

The chromium-containing wastes considered most likely to be EP toxic were process wastes (ion-exchange resins and evaporator concentrates) from light water reactors which use chromates as corrosion inhibitors. A follow-up telephone survey indicated that chromate use was more widespread than reported in the initial results. However, in all cases, chromates

were used in normally nonradioactive systems. Plant management practices are directed at keeping these systems isolated and preventing the release of chromate-containing liquids to radwaste cleanup systems. Thus, the potential for LWR process wastes to contain chromates is lower than originally assumed in the survey analysis.

Overview of Possible Management Options for Mixed Wastes

A number of management options may be applicable to mixed wastes. They involve either (1) rendering the waste of clear concern to only one agency, NRC or EPA, and not both, or (2) processing the waste so that both the radiological and chemical hazards will have an acceptably low probability of causing harm to man or the environment. Rendering the waste of clear concern to only NRC may be accomplished by:

- delisting or exemption by EPA of the chemically hazardous component;
- preclusion of mixed waste status by substitution of a non-hazardous chemical in the process or application giving rise to the original waste;
- destruction of the chemically hazardous component; or
- separation of the chemically hazardous component from the radioactive component.

Alternatively, mixed waste may become a concern exclusively to EPA if it is found that the radioactive content is at a level or concentration low enough to allow NRC regulatory action defining it as de minimis, or below regulatory concern.

Regulatory Actions

Delisting a waste essentially requires demonstration that the waste is not hazardous as generated, as opposed to after treatment. Certain wastes are excluded by EPA from being listed as hazardous wastes even though they contain listed hazardous constituents (given in Appendix VIII of 40 CFR Part 261). For example, fly ash, bottom ash, and slag from burning of fossil fuel, are excluded. The basis for their exclusion is the demonstration to EPA's satisfaction that their hazardous heavy metal constituents are not released at a rate high enough that the waste could fail the EP toxicity test. Such an exclusion might be feasible for treated wastes from power plants at which chromates are used as a corrosion inhibitor.

Scintillation fluid wastes containing sufficiently low levels of C-14 and/or H-3 are classified by NRC as de minimis and are therefore not LLW. Since they are not LLW, they can be handled by such methods as incineration at an EPA-permitted treatment, storage, and disposal facility (TSDF). Extension of this classification to scintillation fluids or other wastes containing similarly low levels of other isotopes would permit their handling in a like manner.

Treatment or Processing Methods

The treatment methods described in detail in Reference 3 are listed in Table II, and the degree of their applicability to liquid organics and lead wastes is indicated. Chromium has not been included in the table because it has not been found to be a generic mixed waste.

TABLE I
LLW Identified as Potential Mixed Wastes

Waste Category	Tentative Hazard Classification	Percentage of Survey Total Volume ^a	Source ^b
oil-containing wastes	listed (F030) ^c	4.2	R, I
solvent-containing wastes (scintillation fluids, lab solvents, cleaning and degreasing solvents and sludges)	listed (F001 to F005) or ignitable (D001)	2.3	M, A, I, R
lead-containing wastes (shielding, containers)	EP toxic (D008)	<0.1	M, A, I, R
chromium-containing wastes (LWR process wastes, system decontamination wastes)	EP toxic (D007)	0.6 ^d	R

^aCalculated using as-shipped volumes, which, depending on the waste category, may include absorbents, solidification agents, compactible or non-compactible trash or other packaging materials.

^bBy facility type, I = industrial, R = reactor, M = medical, A = academic.

^cProposed rule. See Reference 18.

^dVolume refers to light water reactor process wastes only.

TABLE II

Degree of Applicability of Treatment Methods to Identified Potential Mixed Wastes^a

Treatment Method	Waste Type	
	Liquid Organic	Lead Metal
Destruction		
Incineration	A	C
Wet Air Oxidation	C	C
Acid Digestion	B	C
Immobilization		
Sorption	A	C
Solidification	B	C
Containment in a High Integrity Container (HIC)	C ^b	A
Glass Furnace ^c	A	C
Recovery/Reclamation	A	A
Segregation	A	A

^aRefer to the key system below for the meaning of letter designations:

A - Applicable

B - Feasible but limited applicability due to expense or required development

C - Not generally suitable

^bCould be contained in a High Integrity Containers when sorbed or solidified.

^cCombines destruction and immobilization in a single step.

It should be noted that the destructive methods give rise to residues, which may require treatment for disposal. In the case of liquid organic wastes for which destructive methods eliminate the chemical hazard, the residue will not be a mixed waste, but simply LLW. If an organic mixed waste's original radioactivity consisted only of C-14 and/or H-3, its destruction residue will not be hazardous at all. Destructive methods are in general applicable only to organic materials.

Of the immobilization methods, sorption can be used only for organic liquid wastes. Solidification, though feasible for organic liquid wastes, may require additional development work and generally increases the volume for disposal rather than providing volume reduction. From the technical viewpoint, a particularly attractive option is the glass furnace process which combines destruction with incorporation of the residue into a high quality waste form in a single step.

Oil Wastes

EPA published a proposed rule listing used oil as a hazardous waste on November 29, 1985.¹⁹ When this rule becomes final, radioactively contaminated oil wastes may be considered a mixed waste. As a result, BNL is conducting a study to characterize oil wastes present in LLW, particularly identities and concentrations of radionuclides present. In addition, options for the treatment of used oils will be identified and evaluated. These options will include incineration and immobilization. One regulatory alternative to be considered is the development of BRC standards for used oils. The applicability of EPA standards regarding the burning of waste fuel and used oil fuels in boilers and industrial furnaces may also have to be assessed.

Metallic lead was identified as a specific material disposed of as or with low-level wastes that is potentially hazardous under 40 CFR Part 261, since it has been found to exhibit the hazardous waste characteristic of EP toxicity.²⁰ In order to assess the potential mixed waste hazard posed by lead metal, BNL is presently evaluating for the NRC the interactions between metallic lead and other waste package components and between metallic lead and the disposal environment. Some of BNL's preliminary findings are presented here.

It has already been mentioned that the EP toxicity and TCLP test protocols¹⁴ were devised by the EPA to assess the potential for the leaching of certain specified contaminants from potentially hazardous waste disposed of in an actively decomposing municipal landfill and their subsequent transport to an underlying aquifer. For the purpose of assessing the potential mixed waste hazard posed by metallic lead, BNL finds that the leaching conditions specified in the EP toxicity test and the TCLP may not be generally representative of the environment of the buried waste at shallow land burial disposal facilities. For humid area sites, the pH of the trench waters is usually above 5 (generally tending to neutral or slightly alkaline). The pH values specified in the EP toxicity and TCLP test protocols are, respectively, 5.0 and, depending on the alkalinity of the waste, 2.88 or 4.93. In addition, the ability of dissolved organic carbon species (resulting from biodegradation of naturally occurring organic matter such as leaf litter or of biodegradable waste in the same or neighboring trenches) to complex with aqueous lead has not been quantified and thus it cannot be compared with the ability of the acetic acid or acetate buffer solutions specified in the leaching test protocols to dissolve and complex with lead. Because of the episodic nature of the precipitation at an arid area site, accumulations of water in the trenches at such a site generally do not occur and wet-dry cycling may need to be incorporated into a leaching test to render it representative of burial conditions at such a site.

The assessment of the mixed waste hazard posed by metallic lead may have to be done on a site-specific basis for each shallow land burial disposal site. A conservative mismanagement scenario for toxic waste may be justified for EPA's evaluation of the potential for groundwater contamination by lead metal buried at the large number of municipal landfills and at the smaller but still relatively large number of hazardous waste disposal facilities because of the sheer magnitude of the problem in developing a site-specific leaching test for each disposal facility. There are likely to be far fewer LLW disposal facilities, however, and at present, LLW must go to a licensed LLW site. Initially, only one LLW disposal facility per state compact (or state, if it is not a member of a compact) would be expected. It would be much more feasible to tailor the parameters of a test protocol such as the TCLP to match those of a particular proposed or existing LLW disposal site for each of the relatively few sites. Perhaps a site-specific tailored test protocol could make use of soil and groundwater samples from the site in order to avoid the difficulty of simulating the array of naturally-occurring organic complexing agents. To some extent, such an approach is the laboratory analog of the National Bureau of Standards field tests of corrosion of buried metals described by Romanoff.²¹ Similar site specific considerations may be applicable to other potential mixed wastes.

The regulatory differences between NRC and EPA pertaining to LLW and hazardous waste disposal, respectively, begin with the waste designation point. For the NRC, the source and presence of radioactivity in the waste automatically make it LLW. For EPA, waste identification procedures must be applied to the material as generated at the time the decision to discard has been made. NRC has thus promulgated regulations directed toward disposal site and as-shipped waste package performance. EPA regulates both treatment or processing, and disposal of waste once it has been identified as hazardous.

The time frame for NRC Class B and C package designs is 300 to 500 years. EPA specifies a 30-year monitored double-lined trench design; subsequent efforts to limit water infiltration are required but the projected fate of these wastes beyond the monitored period is not clear. LLW liquids must be solidified or absorbed in twice the necessary absorbent while EPA allows disposal of hazardous liquids (most are disposed of by deep-well injection) except by landfill at which the "lab-pack" absorbed liquid method (specific absorbent volumes not given) is accepted. Related to this, EPA does not require containerization, while NRC container requirements range from minimum (Class A) to rather extensive for HICs (Class B and C). Storage for decay to reduce the radiological hazard is allowed by NRC (the effectiveness of this is, of course, a function of the particular radionuclides involved) while storage of EPA hazardous wastes for longer than three months may only occur at permitted facilities. At-disposal-site inspections for waste package correspondence with the manifest is required by NRC but waste content inspection and, if necessary, analysis, is mandated by EPA. In the former case, there is concern about worker exposure to radiation hazard. NRC minimum requirements that non-radiological hazards of LLW be reduced to the maximum extent possible are present in 10 CFR Part 61. Until now, EPA has not specifically been concerned with LLW, while the states have required a determination that radiological hazard in waste exceeds the non-radiological hazard. Such a determination would require use of a generally accepted ranking scheme.

Mechanisms by which regulatory authority is removed for wastes include the de minimis designation by NRC, and at present, delisting or exclusion by EPA (the establishment by EPA of the "below regulatory concern" designation is expected in the near future). For the potential mixed waste identified as a result of the BNL studies,^{1,2} there is no single universal management option feasible. Each of the waste types, however, may, in some cases, be candidates for exclusion or de minimis designation. Organic liquids may be treated with any of several destruction techniques, thereby eliminating the chemical hazard. They can also be immobilized or, depending on the type and level of radiological or chemical hazard present, they might be designated de minimis or below regulatory concern (BRC). Waste oils have recently been proposed as a hazardous waste and these are presently undergoing further study at BNL but, their classification as organic should make feasible at least some of the management options found applicable to organic liquids³. The burning of waste oil as fuel and the setting of de minimis or BRC levels are being investigated.

For lead wastes, substitution is not feasible and destruction is impossible. Containment in a HIC is a viable management option as is immobilization of

decontamination residues. However, the designation of lead as a hazardous waste is based on application of a specific test method. Since lead is only open to non-destructive processing (whether it is in LLW or not), it should be shown on a broad basis that any test method for determining hazard is appropriate regardless of the management approach decided upon.

BNL work on chromium-containing wastes indicates these are not a generic potential mixed waste. They may be effectively subjected to solidification or containment in a HIC and substitution should be possible as well.

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