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Guidelines for Mixed Waste Minimization

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February 1992

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Prepared for the
U.S. Department of Energy
Office of Environmental Restoration and Waste Management
Under DOE Idaho Field Office
Contract No. DE-AC07-76ID01570

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EXECUTIVE SUMMARY

Currently, there is no commercial mixed waste disposal available in the United States. Storage and treatment for commercial mixed waste is limited. Host States and compact region officials are encouraging their mixed waste generators to minimize their mixed wastes because of management limitations. This document provides a guide to mixed waste minimization.

The overall objective of a waste minimization program is to implement waste practices that achieve a realistic reduction in the total generation of wastes. The success of any waste reduction program depends on the support of management--both financially and structurally. However, without the entire organization's cooperation and commitment to waste minimization, the program will not be successful. Management and employee commitment will require training and awareness, awards and recognition, and information exchange.

Other key phases to a successful minimization program are

- Problem definition--Identify waste generation problems
- Process definition--Conceptualize techniques for minimizing wastes
  - Substituting process inputs
  - Modifying or redesigning end products
  - Reformulating or redesigning production process
  - Changing material usage, handling and storage practices
  - Using onsite or offsite recycling technologies
  - Eliminating contact of hazardous and radioactive streams
- Process development--Once waste sources have been identified and waste minimization options have been conceptualized, evaluate and implement options into the minimization process
- Document and communicate results--Report lessons learned and successful results to public groups through reports, presentations, and newspaper articles.

These waste minimization activities can help reduce operating, storage, and disposal costs and increase efficiency in an operation.

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ACRONYMS

AEA	Atomic Energy Act
AEC	Atomic Energy Commission
CFA	Code of Federal Regulations
DOE	Department of Energy
EPA	Environmental Protection Agency
HLW	high level waste
HPLC	high pressure liquid chromatography
HSWA	Hazardous and Solid Waste Amendment
INEL	Idaho National Engineering Laboratory
LLW	low-level radioactive waste
LLRWPA	Low-Level Radioactive Waste Policy Amendments Act
LSC	liquid scintillation counting
NARM	naturally occurring and accelerator-produced radioactive material
NORM	naturally occurring radioactive materials
NRC	Nuclear Regulatory Commission
PAH	polyaromatic hydrocarbons
PRP	potentially responsible party
QA	quality assurance
RCRA	Resource Conservation and Recovery Act
SWDA	Solid Waste Disposal Act
TCLP	Toxicity Characteristic Leaching Procedure
TRU	transuranic
TSCA	Toxic Substances Control Act
UV	ultraviolet

Guidelines for Mixed Waste Minimization

1. INTRODUCTION

This document discusses the subject of mixed wastes and serves as a guide to minimize mixed waste generation. Section 1 contains the definition of mixed wastes and an overview of the regulations that govern the storage, treatment, and disposal of mixed wastes. Sections 2-8 address the topic of mixed waste minimization in both philosophy and practice. Appendix A provides a guide for determining mixed wastes. Appendix B contains forms for voluntarily assessing the status of a waste minimization program. Appendix C contains U.S. Environmental Protection Agency (EPA) cost information forms that can be used as an aid for determining the economic impact of waste minimization. Appendix D is a survey of technologies for treating mixed wastes. Waste treatment is the processing of a waste after it has been generated and before it is disposed. Treating waste is not waste minimization but is included in this document because several States have mixed waste in storage that will require treatment. It is recognized that many generators of mixed wastes have developed a waste minimization program, but this document may help to further that program. Although this document will be a useful guide, it is not a substitute for consulting with the applicable Federal and State laws and regulations.

1.1 Definition of Mixed Wastes

Mixed low-level radioactive waste (Mixed LLW) as defined by the EPA and the U.S. Nuclear Regulatory Commission (NRC) is

Waste that satisfies the definition of low-level radioactive waste (LLW) in the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPA) and contains hazardous waste that either (1) is listed as a hazardous waste in Subpart D of 40 Code of Federal Regulations (CFR) Part 261 or (2) causes the LLW to exhibit any of the hazardous waste characteristics identified in Subpart C of 40 CFR Part 261. (See Appendix A Attachment in this document.)

Prior to the July 3, 1986, EPA notice, mixed waste was handled only as radioactive waste.

Many activities produce mixed waste including biological and genetic research, commercial nuclear power plant operation, and medical diagnostics. Examples of mixed waste streams include

- Polychlorinated biphenyls-bearing solvents, lead-based paints, lead-acid batteries, lead shielding, and spent Freon that have become radiologically contaminated
- Radioactive solutions used in biological research (i.e., to extract radiolabeled deoxyribonucleic acid) that contain mixtures of chloroform and phenols
- Scintillation fluids containing radioactive solvents from medical diagnostics [see 10 CFR 306 (a) for possible exemptions pertaining to scintillation fluids].

Much of the research in medicine and physiology and many medical diagnostic techniques could not be performed without the use of radiolabeled compounds that produce mixed wastes. Eliminating mixed waste production altogether would necessitate eliminating some beneficial production as well.

More detailed information on determining mixed waste is provided in Appendix A.

1.2 Regulatory Responsibilities Pertaining to Mixed Wastes

This section presents an overview of regulatory responsibilities for low-level mixed waste. Appendix A provides 40 CFR 261.20, Subparts C and D.

1.2.1 Low-Level Radioactive Waste Regulatory Responsibility

The regulatory framework that governs the treatment, storage, and disposal of mixed waste can be confusing. This confusion results from how regulations governing mixed waste evolved into their present form. An explanation of the origin of these regulations and who enforces them follows.

The Atomic Energy Act of 1954 (AEA), as amended, brought into effect the first regulations governing the commercial management of most of the radioactive materials used in the private sector. The AEA established the Atomic Energy Commission (AEC) to perform licensing and regulatory functions over the commercial and government sectors. The Energy Reorganization Act of 1974 (42 USC 5811 et seq.), as amended, delegated most of these regulatory and licensing duties to the U.S. Department of Energy (DOE) for the government sector and the NRC for the commercial sector.

The amendments of the AEA allow for some of the regulatory powers of the NRC to be relinquished to the States. This relinquishment must be by formal agreement, and these States must maintain regulations and programs that are compatible with those of the NRC. Not all States have become "Agreement States," and not all Agreement States have been granted the

same regulatory authority. Table 1 provides a list of Agreement States. (The agreement status of States is subject to change. The present status of a State should be verified to ensure proper compliance.)

With the enactment of the LLRWPA (42 USC 2021b et seq.), States were given the responsibility of providing for disposal of all commercially generated LLW within their borders. States could carry out this responsibility on their own or with other States.

1.2.2 Hazardous Waste Regulatory Responsibility

Resource Conservation and Recovery Act (RCRA) was enacted as an amendment to the Solid Waste Disposal Act (SWDA). The purpose of RCRA is to regulate the storage, treatment, and disposal of hazardous wastes. The EPA develops and enforces regulations under the RCRA statute. The EPA can delegate some of their regulatory duties to the States similar to the manner in which the NRC delegates some authority to the Agreement States. In order to become "States of Final Authority," the State must maintain a program that is at least as stringent as that of the EPA.

One of the most important environmental legislative actions with regard to hazardous waste minimization was the Hazardous and Solid Waste Amendments (HSWA) to RCRA in 1984, which the EPA incorporated into the existing hazardous waste regulations on July 15, 1985 (50 FR 28702). In these amendments, Congress stated:

The Congress hereby declares that it is to be a national policy of the United States that, where feasible, the generation of hazardous waste is to be reduced or eliminated as expeditiously as possible. Waste nonetheless should be treated, stored, or disposed of so as to minimize the present and future threat to human health and the environment.

The impact of the HSWA is that every generator of hazardous waste must establish a waste minimization program. The HSWA does not provide guidance on how a generator is to manage a waste minimization program or even what actions constitute waste minimization.

1.2.3 Mixed Waste Regulatory Responsibility

Until the early 1980s, wastes that met the definition of LLW, even if the waste contained a hazardous component, were almost always managed as LLW. This probably resulted from the assumption that the radioactive risk of the waste outweighed the risk from the hazardous components; strong acids or bases were exceptions to this rule. Furthermore,

Table 1. Agreement States as of September 1991.^a

Alabama	Kentucky	North Dakota
Arizona	Louisiana	Oregon
Arkansas	Maryland	Rhode Island
California	Mississippi	South Carolina
Colorado	Nebraska	Tennessee
Florida	Nevada	Texas
Georgia	New Hampshire	Utah
Illinois	New Mexico	Washington
Iowa	New York	
Kansas	North Carolina	

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a. Current as of October 1, 1991.

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most isolation procedures for radioactive material would simultaneously isolate the hazardous materials.

Throughout the 1980s, EPA's authority over the management of mixed wastes increased. In 1987, the EPA and NRC coissued *Guidance on the Definition and Identification of Commercial Mixed Low-Level Radioactive and Hazardous Waste and Answers to Anticipated Questions* (1987).

1.3 Storage, Treatment, and Disposal Problems Related to Mixed Waste

The dual regulatory responsibility governing treatment, storage, and disposal of mixed wastes has contributed to a shortage of storage, treatment, and disposal options for mixed waste. For a facility to accept mixed waste for storage, treatment, or disposal, that facility must be licensed under the AEA (either by an Agreement State, or by the NRC if in a nonagreement State) for the disposal of LLW and must also be permitted under RCRA (by either the EPA or by a State of final authority) for treatment or disposal of hazardous waste.

The LLRWPA of 1980 encouraged States to form interstate compacts to develop new disposal facilities for LLW. Compact regions are groups of States that have agreed to codevelop disposal capabilities, usually with one State agreeing to host the facility. As a result, there are now nine compacts that comprise 40 States. The remaining 10 States are responsible for developing their own disposal capabilities. These same compacts and the unaffiliated States and territories are also responsible for developing their own low-level mixed LLW disposal sites.

2. MIXED WASTE MINIMIZATION

Several features determine the success of a mixed waste minimization program. Listed below are development and implementation phases of successful waste minimization programs, and Sections 3 through 8 provide detailed descriptions of these phases. A waste minimization methodology provided in Section 3 shows the individual phases and their interaction.

- **Management commitment at all levels**
  - Employee training to recognize waste minimization opportunities
  - Tracking waste generation (both hazardous and radioactive components of waste stream)
  - Assigning cost of waste management to the individual process
- **Problem definition**
  - Identifying waste sources
  - Collecting and reviewing data
- **Process definition**
  - Conceptualizing waste minimization options
  - Preparing alternatives
- **Process development**
  - Performing general screening and evaluation of options
  - Performing detailed evaluation of options
  - Modifying criteria
- **Designing and implementing management plans**
- **Documenting and communicating lessons learned and successful results.**

Taking into account the varied sources of mixed wastes, not all waste minimization programs will use all of these features.

3. MANAGEMENT COMMITMENT

Management commitment helps to ensure that all levels of personnel understand the need to adopt a new way of looking at waste generation. Minimizing waste inherently means considering changes in the way a business operates in order to affect the overall material balance of the facility, even if the facility seems to be operating "satisfactorily" at the time. However, when a business minimizes its wastes, it may improve the conversion of raw materials into finished products, transform waste into useful by-products that can be recycled, and realize a cost savings in waste management activities.

Management commitment is as important to a successful waste minimization program as it is to other organizational commitment to waste minimization goals and successful safety, quality, energy reduction, or cost-savings programs. Successful programs require two forms of management commitment: (a) written directives stating program objectives and (b) allocation of resources to achieve waste minimization objectives.

Directives from management should include

- A written mission statement signed by senior level personnel.
- Measurable goals (such as 50% reduction in the first 2 years and a 20% reduction in the following 3 years).
- Incentives to ensure the goals are achieved to the highest degree possible. Several types of incentives can be used. Employee awards such as dinners, cash, and prizes or similar awards for the departments or units that meet or exceed their goals are examples of positive program awards. Other incentives include reassigning the cost of the waste production, storage, treatment, and disposal to the individual generator such that it impacts their "bottom line."
- Periodic reporting to management of progress toward goals.

To achieve the waste minimization program's objectives, resources must be allocated to

- Provide experienced staff to define tasks, assign priorities, participate in committee meetings, evaluate progress, and report back to management.
- Provide capital to implement changes that will minimize wastes within the framework of profitability objectives. It may be necessary to waive the normal return on investment criteria to justify additional capital for waste minimization because it is more regulatory driven than profit driven. It is important to note that some of the early efforts at waste minimization were not initiated to minimize waste in the current regulatory parlance. Many early waste minimization efforts were really efforts to increase productivity because materials that were produced as waste cannot be sold as product. Raw material, energy, and capital were used

to make the waste rather than product. By increasing the product yield and recovery, and thereby minimizing waste, more profit is realized; raw materials, energy, and capital are used to produce product, not waste. In many cases, the value of the additional product or reduced raw material and energy use was greater than the cost for waste disposal.

- Implement an internal publicity campaign that educates all employees and emphasizes the reasons for waste minimization. Detail the cost savings, productivity increases, and reduced liability for the waste produced.

For waste minimization, enthusiastic endorsement by management is required to help people overcome the opinion that no further improvements can be made to "mature" processes. Although resistance to considering process changes may be encountered, it usually dissipates when the benefits are recognized.

3.1 Training Employees

A comprehensive training program is essential to help educate those involved in implementing a waste minimization program. A training program should meet the letter, intent, and spirit of the minimization program. The training should help make employees aware of the role of minimization to the company, what the individual role of each employee should be, the financial and environmental impacts waste has, and empower employees to seek ways to eliminate or minimize waste by taking advantage of opportunities present in their own jobs.

It is important to provide training that is directly and immediately applicable to employees in varying positions. Waste minimization goals, objectives, and accomplishments might be incorporated into annual job performance evaluations for managers and employees to help encourage waste minimization efforts.

3.2 Tracking Waste Generation

Once management has provided directives and resources for the waste minimization program and training has been implemented, it is important to develop a method for measuring progress toward achieving those goals. Management should implement a tracking system to provide data needed to assign (and if necessary reassign) priorities that maximize the program's effectiveness. This tracking system will also allow the generator to provide documentation about the waste minimization program as required by the various State and Federal agencies.

The most effective systems measure and report quantities of waste by its chemical and physical characteristics, radiological isotope and activity, and waste stream generation process. When a waste is generated by more than one process or source, the tracking system should be able to distinguish between the quantities of waste from each.

Businesses often try to estimate the quantities of waste generated by using purchasing records or by applying unit ratios to production data. However, more accurate and meaningful tracking data are generated most often by directly measuring the quantities of waste. Manufacturing processes have two kinds of output that can change when production conditions change. These two outputs are the products and the waste. Quality assurance (QA) programs usually measure the quality and quantity of products to verify that the manufacturing process performed as expected. These methods of measurement can also be applied to the production of waste. Measuring the quantities and composition of waste (in effect, "QAing" the waste) yields more accurate data than do estimates.

Direct, routine measurement of the quantities and composition of waste provides an added benefit for waste minimization programs. Variations in process operating conditions often change the quantity or composition of the waste more dramatically than the quantity or quality of the products. Routinely monitoring the quantities and composition of the waste provides real-time data that often identify process problems before the quantity or quality of the products are changed enough to be noticed; therefore, waste is minimized by more quickly identifying process problems (unwanted or unexpected changes in process conditions such as temperature or feed-rate variations).

3.3 Assigning Cost of Waste Management to the Individual Process

One effective way to involve front-line supervision in a waste minimization program is to assign the cost for managing a waste to the individual production unit that generates the waste. This strategy can have two benefits.

First, information about the economic impact of the generation of waste is provided directly to the people who have the most influence on those costs. Often, waste management costs are collected on a plant-wide or division-wide basis and then allocated along with the other general and administrative costs to individual processes as one overhead cost. When waste management costs are diluted in the plant overhead, the front-line supervisors often feel that minimizing waste has little impact on the financial performance of their individual processes. However, when the cost of waste management is assigned as line items to financial statements of the individual processes, supervisors can directly monitor the economic impact of generating waste just as they monitor costs for labor, maintenance, raw materials, and other items. Generating the waste also requires raw materials, energy, labor, and capital. If the raw

materials, energy, labor, and capital for producing and collecting the waste can also be added to the generator's cost ledger, the incentive to reduce the waste can be more powerful. This approach to accounting for the costs of waste management informs the people who make daily decisions concerning waste generation of the costs of these decisions. This often has the net effect of convincing supervisors and operators of the merits of waste minimization because the results of their work can be seen directly.

Second, assigning waste management costs to individual production units identifies those processes that generate a larger quantity of waste than other processes. When waste management costs are not assigned to individual production units, these large-volume processes are often not identified. Frequently, 80% of the waste is attributable to only 20% of the processes. When this 80:20 rule applies, priorities can be assigned to focus waste minimization efforts on the limited number of waste sources that generate the majority of waste and the associated waste management costs.

Assigning costs of waste management to individual production units usually involves a simple adjustment in the accounting procedures. Although resistance to changing the accounting procedures is occasionally encountered, it easily can be overcome. The accounting change can simply mimic the same procedures that allocate the cost for raw materials to the departments that consume them.

4. PROBLEM DEFINITION

Wastes cannot be minimized until the problems associated with the waste generation are identified and the solutions to these problems are defined, developed, and implemented. These three elements (define, develop, and implement) of successful waste minimization programs create an atmosphere for examining current ways of generating wastes and then managing them. Successful waste minimization programs have shown that

- All waste-producing processes can be represented by a generic flow diagram as shown in Figure 1.
- Process waste generation can be reduced or eliminated.
- Discarded materials can be generically categorized as by-products, raw materials (or impurities in the raw materials), process solvents, or catalysts.
- Identifying the true source of a specific discharge helps to categorize the type of source control approach that should be evaluated.

Figure 2 presents a waste minimization methodology, which shows the identification, conceptualization, and implementation phases.

Waste minimization involves the logic of going through a process backwards, that is, from the end of the pipe back into the process steps that lead to the final discharge stream. The contributing steps to the waste must be known before the minimization method can be defined. The problem definition activity also identifies data gaps and helps set priorities for filling those data gaps. This section discusses the first phase, problem definition.

4.1 Identifying Waste Sources

The first step in problem definition is identifying the waste source before trying to conceptualize, develop, and implement solutions. The most effective problem definition activities seek to place the true sources of the waste into one of the following categories relating waste generation to the way the process is (a) engineered, (b) operated, (c) maintained, or to (d) process dynamics/chemistry. Appendix A provides generator information to determine if mixed waste is being generated, and the waste assessment form described in Section 4.2.1 will help categorize the waste source.

Categorizing the waste source is important because it identifies the category of the solutions that should be evaluated, streamlines the waste minimization activities, and limits the number of alternatives to only those solutions addressing that category. For example, depleted uranium may be used as a catalyst in the process of producing acrylonitrile. The waste from this process will include acrylonitrile contaminated uranium. Since acrylonitrile is a listed waste

Figure 1. Generic process flow diagram from a waste perspective.

Figure 2. Waste minimization methodology.

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(U009) and uranium is radioactive, this creates a mixed waste stream. Iron bismuth can be substituted as the catalyst in this process, thus eliminating the mixed waste stream. The iron bismuth contaminated with acrylonitrile may still be RCRA regulated waste, or may be recycled. However, as long as depleted uranium is used as a catalyst, that specific mixed waste will be produced in some quantity regardless of how many engineering, operating, or maintenance changes are contemplated. The only way to minimize mixed waste generation is to consider changes to the process chemistry that allows the substitution of a catalyst that does not contain depleted uranium.

4.2 Collecting and Reviewing Data

The second step in problem definition is collecting and reviewing all available data pertaining to the waste generation and treatment. These data can include process chemistry, flow sheets, and material balances pinpointing known waste sources. Compilation and review of these waste characterization data summarize all that is known about the "what, how much, how, why, and when" for the waste generation. Problem definition differs from a traditional waste characterization in that waste characterization only answers "what and how much."

Frequently, the available data are not sufficient to completely answer the questions of "what, how much, how, why, and when" wastes are generated. For example, known losses of a process solvent may account for only half the losses indicated by inventory records. In those situations, an in-depth review of all waste sources within a process provides valuable information pertaining to the generation of wastes. This activity includes sampling and analysis of individual process waste streams and observing the process to provide insight into the true sources of the waste, i.e., whether they are related to the process chemistry or how the equipment used to carry out the chemistry is designed, operated, or maintained.

Identifying the true waste source is more than a simple waste characterization that only defines "how much and what" wastes are generated. Successful problem definition also determines "how, why, and when" wastes are generated. Answering these three additional questions is critical to determining the true waste source. Also, problem definition and collection and review of all pertinent data are not linear steps. These steps should be used interactively to ensure thorough study of the waste generation process under review.

An example of the benefits of determining "how, why, and when" wastes are generated is when calculated losses of solvents from known discharges do not completely account for known consumption based on inventory and purchasing records. When the process is observed and reviewed from the specific viewpoint of discharges, the location and nature of previously unidentified losses can be determined. Identifying the waste source (i.e., location and nature of the losses) makes the solution development and implementation more straightforward.

The output of problem definition is a summary of the economic and environmental impacts of the waste generation process being reviewed. This summary provides the basis for later waste minimization prioritizing activities so that the most significant problems are addressed first.

4.2.1 Waste Minimization Assessment Form

A waste minimization assessment form allows the generator to quickly determine the sources of the subject waste. A sample form is included in Appendix B. The first part of the assessment form requests basic generator information and descriptions of the major process at the location being assessed. A description of any existing waste minimization programs is requested to help evaluate the existing program. In addition, raw materials (including catalysts and solvents) are identified along with the quantities used and are evaluated and prioritized by their contribution to waste management impacts as part of the evaluation's economic analysis.

The second part of the assessment details each waste stream. The quantity and source of the stream is identified. The source may be defined as a process or several pieces of equipment, not just the equipment from which the stream is discharged. For example, in the distillation of a product with an impurity, the source of the impurity may not be the distillation column from which it is discharged. It could be either a chemical processing unit upstream of the distillation column or a part of the raw material feed. It is important to identify the true source of the waste in order to apply effective waste minimization techniques.

The third part of the assessment investigates the waste source. As discussed previously, all waste sources fall into one of the following categories: (a) engineering design, (b) operations, (c) maintenance, or (d) process chemistry. By categorizing the waste source, potential minimization options can be quickly identified.

After the waste source is categorized, it then can be placed into one or more of the following classifications:

- Raw materials that passed through the process unreacted
(Incomplete conversion of propylene to acrylonitrile)
- Product that was not recovered
(Acrylonitrile that is lost in the catalyst purge stream)

- Impurities in the raw material
(Small amounts of propane or butane in the propylene feed stream that must be disposed of, invariably with some product carryover)
- Catalysts or solvents that are not recycled
(The depleted uranium in the catalyst purge stream that is not recovered)
- Useful by-products that are not recovered
(Acetonitrile is also produced in the process in low yields and is not recovered)
- Nonuseful by-products that are made in the process and do not have any current use. (Various nitration products that have no current use are produced in the process and must be disposed.)

For example, one method of producing acrylonitrile is by the reaction of propylene and air over a catalyst containing depleted uranium. Many by-products and other nitration materials are produced. The catalyst must also be periodically replaced. The process produces a number of mixed waste streams.

Classification of the wastes in this manner provides a unique perspective. Suppose a waste generated from a distillation that is fed from a chemical reaction processing unit (reactor) contains a large amount of unreacted raw material and nonuseful by-products, and the assessment has indicated that the process chemistry or operations produce the waste. The clear indication is that the waste minimization program for this waste should focus on the process chemistry and operation of the reactor. In addition to disposal and treatment costs, this represents increased raw material use and product losses. If the process chemistry or operations could be modified so that the waste is reduced or eliminated, then the generation of waste would be minimized and a cost savings could be realized. Placing the components of each waste into one of the six classifications is a key step in clarifying the method, costs, and benefits of waste minimization.

The assessment forms request additional information including current treatment parameters and costs, permit requirements, and other regulatory data. This information is needed to ensure that waste minimization proposals that may result from the assessment do not adversely affect those current treatment systems within regulatory guidelines. Figure 2 shows a generic process flow from a waste perspective and prompts the assessor for the required information.

Waste characterization (the determination of chemical components, physical form, hazardous characteristics, and concentration) is only part of an effective waste minimization assessment. The characterization survey, which is usually conducted separately or as a part of an assessment, only identifies the waste composition and characteristics and does not identify

the source and cause of the waste in the same manner as the waste minimization assessment. Waste characterizations, by definition, only identify what is produced, whereas the waste minimization assessment looks for causes and possible solutions to minimize the production of the waste as its primary goal. Properly done, however, the waste characterization study can be a valuable part of a waste minimization assessment and subsequent waste minimization programs.

4.2.2 Waste Minimization Audits

To collect the data required for the problem definition, someone knowledgeable of the process must perform an audit. The output of the audit allows for the evaluation of waste generation from a cost standpoint and provides for an analysis of the waste minimization needs. The audit identifies the impact of waste generation and analyzes the economic potential for minimization. It is also very effective in evaluating existing waste minimization programs by providing an independent review or supplementing them by providing useful input.

5. PROCESS DEFINITION

Process definition includes those activities that conceptualize options for minimizing wastes. Most companies already have approaches for changing their production facilities to increase capacity, convert raw materials, improve quality, or reduce energy consumption. These same approaches can be used for conceptualizing waste minimization options and possible alternatives because all of these activities involve chemical engineering applications. In successful waste minimization programs, innovative solutions depend on

- Accurate problem definition
- Effectively determining options that addresses the waste problem.

Appendix B provides guidance on technologies for treating mixed waste, and Appendix C contains forms that were developed for evaluating the cost of waste minimization options. During the process definition phase, there should be no attempts to evaluate the options. The purpose of the process definition phase is to generate as many options from as many technology categories as possible. If evaluations are attempted at this time, the process will get bogged down, and some options will be overlooked.

Process waste generation is not necessarily inevitable. A brainstorming session can be very effective in conceptualizing a creative, yet simple, approach to minimizing waste. The key is to avoid the tendency to believe that no further improvements can be made to a mature process.

5.1 Conceptualizing Mixed Waste Minimization Options

After the waste generation problems and waste sources are identified, the next step is determining possible waste minimization options. Potential waste minimization options can be identified by onsite engineers and operators, corporate engineering staff, literature searches, trade associations, government environmental agencies, university research laboratories, equipment vendors, or consultants.

Waste minimization options usually fall into the following categories:

- Improvements requiring only equipment repairs or changes in operating procedures that become obvious after the specific waste source of discharge has been identified. Examples include repairing leaking pump seals or moving hazardous materials out of radioactive areas to prevent their contamination.

- Simple improvements in operating procedures that require some form of simple testing. Two examples are kettle washes as the makeup water for the next batch, or minor modification of a recipe to reduce the amount of excess raw material.
- Process changes requiring significant development work and/or capital expenditures. Providing additional capacity for chemical reaction, distillation, extraction, or stripping is an example. Another example is recovery of lost product that may require extensive testing to verify proper separation from unwanted by-products.
- Addition of an extra system to reduce the discharge of a specific component at the source. Separation and recovery of a valuable material or oxidation of a troublesome component are two examples.

To further breakdown waste minimization options, use these seven technology classifications:

- Substitute process inputs
- Modify or redesign end products
- Reformulate or redesign production processes
- Change material usage, handling, or storage practices
- Use closed-loop reclamation, reuse, or recycling
- Use onsite or offsite recycling technologies
- Eliminate contact of hazardous and radioactive streams.

5.1.1 Substitute Process Inputs

The substitution of nonhazardous, less-hazardous, nonradioactive, or less-radioactive inputs into the process stream can reduce the volume or hazard (including chemical hazard or radiological hazard) of the waste produced.

When examining a process to determine the applicability of substitution, the first questions that must be answered are

1. What inputs produced each hazardous or radioactive component of each mixed waste stream?
2. What was the purpose of introducing the input that produced the mixed waste into the component?

3. What can be substituted that will acceptably perform the intended function of the original input while at the same time reduce the volume or hazard of the waste stream?

Examples of successful substitutions to reduce the generation of mixed wastes include

- Substituting a nonhazardous solvent in place of a hazardous solvent in scintillation vials
- Substituting nonhazardous degreasing agents, such as aqueous degreasers with ultrasonic cleaning, in place of hazardous solvents for degreasing radioactive components.

5.1.2 Modify or Redesign End Products

Modifying or redesigning the end product of a process often reduces the volume or hazard (including chemical hazard or radiological hazard) of the waste resulting from the manufacture or use of the end product. Applicability of the technology options in this category can be judged by determining the function of the end product and the mixed waste produced by either the production or use of the end product. Then it must be determined if the intended function of the original end product can be accomplished by a new product that either minimizes or eliminates the volume or hazard of mixed wastes generated.

Examples of successful end product modification or redesign include

- Substituting short-lived radionuclides (I-125, P-32, S-35) in place of long-lived radionuclides (C-14 and tritium) for radiolabeling.
- Using nonsolvent-based paints in areas that could be radioactively contaminated.
- Replacing the thorium alloy light bulb filament with a nonradioactive alloy to eliminate the use of a radioactive material and subsequent potential for mixed waste.

5.1.3 Reformulate or Redesign Production Processes

Reformulating or redesigning the production process, technologies, or equipment may result in the reduction of volume or hazard (either chemical or radiological) of the waste stream. The questions to ask when determining if a process modification is required are

1. What step of the process actually produces the mixed waste?

2. What is the purpose of the step that produces the mixed waste?
3. Are there modifications that can be made to the process or alternative process that will acceptably perform the objective of the original process step while at the same time reducing the volume or hazard of the waste stream?

Mixed waste generation from decommissioning a facility can be minimized if, during the design phase, proper care is taken to ensure that materials and equipment that are likely to become radioactively contaminated do not contain any components that will be considered hazardous when it is time to dispose of them.

Examples of reformulating or redesigning a process include

- Reformulating a process by changing from uranium/antimony catalyst to an iron/bismuth catalyst for the production of acrylonitrile
- Redesigning a process by changing from solvent stripping of paint and coatings from contaminated surfaces to "sand blasting" the paints and coatings off using pelletized dry ice (frozen carbon dioxide)
- Redesigning a parts cleaning process by incorporating ultrasonic cleaning instead of cleaning the parts with methylchloroform or by using pelletized dry ice for decontamination
- Replacing molten salt or lead baths with induction heating for heat treating uranium billets
- Using small bore tubing on high pressure liquid chromatography (HPLC) to reduce the amounts of solvents required to perform analytical procedures
- Substituting steel or other nonhazardous shielding in place of lead.

5.1.4 Change Material Usage, Handling, and Storage Practices

Often a mixed waste is produced as a result of how a chemical is used, handled, or stored. The questions to ask when determining waste minimization options in the category are

1. Does any of the mixed waste result from how a material is used, handled, or stored?
2. What is the objective of the usage, handling, or storage practice that generates the mixed waste?

3. How can I change the usage, handling, or storage to acceptably meet the objective identified in question two while at the same time reducing or eliminating the hazard or volume of the waste stream?

An example of changing material usage, handling, and storage practices is to reduce or eliminate the quantities of RCRA chemicals stored in radiologically contaminated areas.

5.1.5 Use Closed-Loop Reclamation, Reuse, or Recycling

Closed-loop reclamation, reuse, or recycling uses all or a portion of a waste stream as part of the feedstream for the production process. To determine the suitability of using closed-loop reclamation, reuse, or recycling, all of the components of the waste stream must be known, and it must be determined if any of these components can be used as a feedstock for the process. Some of these components are suitable as feedstocks; then it must be determined if the other components in the waste stream will have unacceptable effects on the process, and if so, what technologies or process changes can be used to negate these unacceptable effects.

An example of closed-loop reclamation, reuse, or recycling options includes distilling spent solvents and reusing the recovered solvent. The resulting distillation bottoms can be thermally treated to remove the oils and solvents and then disposed of as a mixed waste.

5.1.6 Use Onsite or Offsite Recycling Technologies

The difference between this recycle technology category and the closed-loop reclamation, reuse, and recycling technologies discussed above is that the recyclable waste from this technology category is used as a raw material in a process other than the one that produced the waste in the first place. This recycling process can either be onsite or offsite. As in the previous technology classification, all of the components of the waste stream must be known. The next step is to determine if there are any components from the stream that can be used as feedstock to another process either onsite or offsite. If it is determined that there is one (or more) component suitable for feedstock, then it must be determined if there is a component(s) in the waste stream that will cause unacceptable effects on the process, and if so, what technologies or process changes can be used to negate these unacceptable effects.

Some examples of successful onsite or offsite recycling options include

- Lead shielding management and decontaminating lead shielding forms instead of discarding as waste

- The spent solvent example in Section 5.1.5 would apply to this technology if the recovered solvent is used in a process other than the process that produced the waste.

5.1.7 Eliminate Contact of Hazardous and Radioactive Streams

This technology is unique to mixed waste minimization since the objective can be accomplished by simply preventing the hazardous and radiological components of the waste from ever being mixed. While the technology options in this classification still allow for the generation of a hazardous and a radiological waste stream, the objective of mixed waste minimization is achieved because neither stream meets the definition of mixed waste. To determine the feasibility of using options from this technology category, the present process must be examined to determine if there is any mixing of hazardous and radioactive waste streams. If mixing of streams is indicated, the next step is to determine if the streams can be separated without any unacceptable effects on the process.

Examples of successfully eliminating contact with hazardous and radioactive streams include

- Using segregated areas for hazardous and radioactive waste to avoid cross-contamination.
- Sorting hazardous and radioactive waste materials into designated bins at the point where they are first generated.
- Removing the catalyst purge stream of acrylonitrile (see Section 4.2.1) producer to eliminate the production of a mixed waste pond.
- Providing separate wastewater treatment processing units for treating LLW and RCRA streams to eliminate the potential for mixing and creating a mixed waste stream.

5.2 Preparing Alternatives

As part of process definition, alternatives are prepared to determine the best solution for the identified waste problem. The alternatives involve developing capital and operating cost estimates based on preliminary process design using site-specific parameters such as

- Feed composition
- Flow rate
- Desired effluent criteria
- Availability and cost for utilities
- Treatment period

- Assumed values for key design parameters
- Fate of by-products.

Overall costs, including operating cost, labor, and capital-related charges, are prepared for several possible solution technologies and are compared to determine the best alternative for solving the problem.

6. PROCESS DEVELOPMENT

After all the waste minimization options and alternatives have been determined, move into the process development phase. Process development consists of three steps, screening evaluation, detailed evaluation, and modifying criteria.

6.1 Screening Evaluation

The options conceptualized in the process definition phase are screened to determine those options that should be evaluated in more detail. Options that are impractical, excessively cost prohibitive, or otherwise unwarranted for further detailed evaluation are dropped in the screening. The options that make it through the screening will go on to be evaluated in the detailed evaluation. Obviously, any option that is certain to minimize the generation of mixed wastes can be implemented without going through detailed evaluation.

6.2 Detailed Evaluation

The second step of process development is the detailed evaluation. In this step, each option is evaluated from both technical and economical perspectives. As with the options generation process, it is important to involve representatives from all the groups that could be affected by the selection. As a minimum, personnel from operations, engineering, and maintenance should be involved in this evaluation.

6.2.1 Technical Evaluation

The technical evaluation determines if the option is applicable to the process. Questions that should be answered in this phase are

- Will the cost of the minimization effort be greater than the cost of a compliant treatment, storage, and disposal program for the mixed waste stream?
- Will the option actually reduce mixed waste generation?
- Will safety be impaired?
- Can full product quality be maintained?
- How compatible is the option with the present system?
- What are the key design parameters?

- What will be the impacts to the operations staff?
- What will be the impacts to the maintenance staff?
- How much production will be lost implementing the option?
- Will other problems be created by implementing the option?

Some of these questions may require bench-scale testing to answer, and others may be answered by visiting facilities where the same or similar solutions have already been implemented. Equipment vendors also may be a good source of information for answers to some of the questions.

6.2.2 Economic Evaluation

After the technical evaluation is complete, those options that have not been eliminated should undergo an economic evaluation. The economic evaluation should consider the short-term and long-term costs of implementing the option and should compare these to the long-term savings associated with implementing the option. Appendix C contains EPA forms that may help in performing an economic evaluation.

The short-term costs will include the capital costs of implementing the option such as purchase cost of new equipment, new utilities connections, site preparations, procurement, engineering, permitting, and training. The cost of lost production that is incurred during the process modification is another short-term cost.

Long-term cost of an option includes any increase in labor costs as a result of any increased operator or maintenance requirements and costs from increased utilities if required. For options that require only administrative or procedural changes, the long-term costs may be insignificant.

Long-term cost savings associated with incorporating an option include some easily measured savings on the following: raw material costs, disposal costs, permitting costs, storage costs, shipping costs, and any utilities or labor costs. Other cost savings include the reduced cost of bonding and insurance that may be realized if the generation of mixed waste is reduced. There are also some cost savings that are not as easy to measure, such as the reduced liability if a mixed waste disposal facility, which received a waste from a Potentially Responsible Party (PRP), should require remediation.

Mixed waste minimization is not only an economic issue; preserving the environment should go beyond meeting the regulatory requirements at the lowest possible cost. Protecting the health of employees and the public is good for business.

6.3 Modifying Criteria

Other modifying criteria to be considered when assessing each option are the reduced risk to employees, the public, and the environment from the minimization of mixed waste generation. Also, if employees from all levels are involved in the waste minimization effort from the start and are knowledgeable about the technical and economic evaluation decisions, they are more likely to accept and support the chosen options. Similarly, with good public relations, a well-run and ongoing waste minimization program can improve the community acceptance of the company.

Another consideration is that the ethical problem of the impact of the waste minimization effort may be worse than if no waste minimization were done at all. For example, if an effort to reduce mixed wastes required a reduction in medical diagnostic tests, would there be an unacceptable increase in deaths as a result?

7. DESIGN AND IMPLEMENTATION

Implementation of the selected options begins with preparing waste management plans to develop priorities, budgets, and schedules based on results of the previous steps. After these plans have been reviewed and approved, implementation can proceed through

- Process design
- Budget for any process modification
- Permitting
- Construction
- Startup
- Documentation.

Allocation of funds for implementing waste minimization projects is an area where the commitment of management is crucial. This commitment is demonstrated by the guidelines regarding return on investment generated by savings associated with the waste minimization process. Sometimes a waste minimization process does not generate enough savings to satisfy the profitability index used for other projects. Successful waste minimization programs usually relax the profitability guidelines for the waste minimization process by including more subtle, but important, sources of cost savings such as reduced future liability for disposing of smaller amounts of mixed waste and minimizing employee and public exposure to hazardous materials and wastes.

8. DOCUMENT AND COMMUNICATE RESULTS

Employees should be encouraged to make regular reports on waste minimization progress. These reports should be communicated to management and other company employees. These reports should document successful minimization results. Details of waste minimization successes also should be reported to local civic groups, educational institutions, environmental organizations, trade associations, and similar public groups in the form of public meetings presentations, newspaper articles, and other technology transfer activities. A speaker's bureau may provide a positive avenue to educate the public about waste minimization efforts.

A minimization newsletter to all employees could recognize individual accomplishments, waste minimization goal achievements, and chart total company and industry progress. A section of the newsletter might focus on lessons learned including problems encountered and problem resolution. Direct exchanges of process technology between facilities should also be encouraged.

Quarterly and annual reports could disperse waste minimization information and technology transfer. Generator meetings would provide a direct medium for waste minimization technology exchange. Discussions on minimization methods in use, future minimization technologies, and individual employee contributions could provide a free flow of information among generators. Employee accomplishments might be recognized during performance appraisals, award ceremonies, or company staff meetings.

9. SUMMARY

The objectives of the *Guidelines for Mixed Waste Minimization* are to provide an introduction to mixed waste and a guide to minimizing mixed waste generation.

This document meets these objectives by defining mixed waste (Appendix A) and outlining several key elements that should be included in a mixed waste minimization program. Management and employee commitment are essential to initiating a mixed waste minimization program. However, there are other critical steps in the process that should be analyzed.

The problem definition step defines waste generation problems before trying to develop and implement solutions. Problem definition also includes collecting and reviewing all available data.

Another step in a waste minimization program evaluates the techniques for minimizing wastes and implements the appropriate mixed waste minimization technology options. Specific options are presented in the document along with definitions and examples. Equipment repairs or changes in operating procedures may not require a great amount of analysis but may minimize mixed waste generation. However, more ambitious undertakings, such as process changes, may require a technical and economic evaluation. After implementing appropriate mixed waste minimization options, documenting and communicating successful results can be helpful in identifying more mixed waste minimization processes and also recognizing the achievements of those who have participated.

Regulations relating to mixed waste are included in the appendices. An example of a waste minimization assessment form, EPA cost information form, and the related mixed waste treatment technologies are included. Treatment technologies are provided because some generators are storing mixed waste and need information on treatment to help manage their stored mixed waste.

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Appendix A

Determining Mixed Wastes

APPENDIX A

DETERMINING MIXED WASTES

This appendix provides generator information to determine if mixed waste is generated. An overview of hazardous waste characterization is followed by an overview of radioactive and mixed waste characterization. Decision trees are provided to assist the generator in characterizing waste. The regulations should be consulted anytime there are questions concerning characterization of a waste stream.

1. Hazardous Waste Overview

The EPA adopted lengthy and complex regulations that define what constitutes a hazardous waste and how such wastes must be managed and disposed. Solid wastes, liquids, and sludges that are generated, stored, or disposed are regulated as a hazardous waste if they meet certain basic definitions and/or exhibit defined characteristics. This appendix addresses wastes that are classified by EPA regulations as hazardous.

The first step in determining if a waste is hazardous, is to determine if the subject material is a regulated solid waste. This determination is made by applying the definition of regulated waste from 40 CFR 257.2 and 40 CFR 261.2.

Following this solid waste determination, it is the generator's responsibility to determine if the waste is hazardous under Federal and State regulations. Under both sets of regulations, a waste is considered to be hazardous if

- The waste is specifically listed or defined in the regulation, 40 CFR 261, Subpart D (referred to as a "listed waste"), or
- The waste exhibits specific physical and/or chemical characteristics described in the regulation, 40 CFR 261, Subpart C (referred to as a "characteristic waste").

All hazardous wastes are defined in 40 CFR 261 Subpart D and are assigned alphanumeric identification consisting of an alphabetic letter followed by three numbers. The "listed wastes" are known as P, U, K, or F wastes while "characteristic wastes" are known as D wastes. These waste types are briefly defined by the following.

- Listed F Wastes - A waste that is a spent solvent or certain specified electroplating or metal heating process wastes. F wastes are listed in Appendix A Attachment of this report.
- Listed P and U Wastes - Any off-specification commercial chemical products or manufacturing chemical intermediates that are discarded or intended to be discarded. This includes any residue or contaminated soil, water, or other debris resulting from the cleanup of a spill of the above. P and U wastes are listed in the Appendix A Attachment of this report.

Example: Listed P wastes are discarded commercial chemical products, off-specification species container residues, and spill residues thereof such as a chlorinated hydrocarbon. If this chlorinated hydrocarbon is used in the decontamination of radioactively contaminated equipment at a nuclear power plant, the resulting fluid would be a mixed waste.

Listed U wastes are commercial chemical products, manufacturing chemical intermediates, or off-specification toxic chemical products.

- Listed K Wastes - A waste that is not a F, P, or U waste and meets any of the descriptions/definitions assigned to the K hazardous waste numbers. A K waste must come or result from the specific source and process described. K wastes are also listed in the Appendix A Attachment of this report.
- Characteristic D Wastes - A waste that is not a P, U, F, or K waste and exhibits any one or more of the characteristics identified in Table D-1. The waste must exhibit one or more of the following:

Table 1. D Waste characteristics.

<u>Characteristic</u>	<u>Parameter</u>	<u>Federal</u>
Ignitability	Flash point	<140°F
Corrosivity	pH	<2,>12,5
Reactivity	Numerous	See 40 CFR Part 261 Subpart C
Toxicity	Numerous	See 40 CFR Part 261 Subpart C

Hazardous waste from specific sources are listed K wastes. An example of a commercially produced mixed waste is the bottom stream from the wastewater stripper in the production of acrylonitrile where the catalyst used is depleted uranium, which is slightly radioactive.

Hazardous wastes from nonspecific sources, such as liquid scintillation counting (LSC) fluid, are listed F wastes. This waste results in a mixed waste because of the low-level radioactivity picked up by the LSC fluid.

It is important to note that these lists could change; therefore, the Federal Register should be reviewed for updated listings.

2. Hazardous Waste Characterization

The process of characterizing a waste as hazardous under RCRA should always contain and follow the same series of questions. This will allow consistency in arriving at the same conclusions with any waste in question. Figure 1 presents a series of questions that, when properly answered, will determine if a waste is hazardous under Resource Conservation and Recovery Act (RCRA). As much information as possible should be obtained on the waste in question before answering any of the questions in Figure 1.

Logic Pathway Instructions

- The decision blocks are numbered for instructional purposes only and do not represent the order of flow. However, the process should always start with Block No. 1.
- Block No. 1 must be answered from historical data/knowledge. If the container has never been opened, or appears to be a pure substance that has been discarded, a determination will have to be made whether the container could be discarded commercial chemical products, off-specification chemicals, container residues, or spill residues of discarded chemicals. Analysis would be needed for P and U listed wastes. In cases of an unmarked drum or container, which has been opened and has no label, other analyses may be needed. A determination would have to be made whether the container holds spent solvents or wastes having hazardous characteristics (ignitability, corrosivity, reactivity, or leachable regulated toxic metals.) Process knowledge would

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Figure 1. Logic pathway for hazardous waste determination.

be used to determine if the waste was generated through any of the K listed generation activities.

- If Block No. 1 is answered "yes," chances are you will have a match with an F, P, or U listed waste(s). If historical data show the container to be a mixture of two or more P or U wastes, then the waste is identified by the corresponding multiple numbers. Proportions do not affect the listings.
- To understand the above, one must understand the mixture rule. Simply put, even the most minute drop of a listed waste (P, U, F, or K) in any container makes the entire contents a listed hazardous waste. The intent of this rule is to prevent any dilutions as means of avoiding regulation.
- Block No. 4, as with Block No. 1, requires historical information to be answered. Typically, analytical data will be of no use unless historical information points to two or three possible K listings for which chemical or physical analysis will narrow the material to one listing.
- If Block No. 4 simply cannot be answered (this should be rare), then follow the "no" arrow to Block No. 6.
- As with Block Nos. 1 and 4, historical information can aid with Block No. 6 in determining if the waste is a listed F waste. However, unlike Block Nos. 1 and 4, physical and chemical data can go a long way in defining if the waste in question is an F listed waste. This is because, in general, F listed wastes are more dependent on the chemical components than their actual origin.
- Answering Block No. 8 is almost completely dependent on analytical data. This is because, as their name states, wastes are characteristically hazardous purely because of their physical and chemical characteristics. Origin of the waste has no bearing on D waste classifications.
- It is possible for Block Nos. 1, 4, and 6 to be answered both "yes" and "no" simultaneously. This could occur when the container of waste in question contains a mixture of wastes from several sources.

The following is an example of how the logic pathway determination functions (see Figure 1):

You have a bulk 2,000 gal. tank three-quarters filled with a liquid. The tank is located at a closed metal finishing and fabrication facility. The tank is marked 1,1,1-trichlorethane. The foreman who worked at the facility has been contacted to help you identify materials/wastes left behind.

The foreman notes that the bulk tank was for receiving virgin 1,1,1-trichlorethane, which was used as a degreasing agent in various fabrication and metal cutting operations. However, at plant shutdown, solvent (spent and unspent) from all the work stations was collected and poured back into the tank, which was half full of pure solvent at the time. In addition, he believes the cutting oils (used and unused) were dumped into the tank.

Logic Pathway Analysis

Block No. 1 - Yes, because 1,1,1-trichlorethane is now off-specification since it is contaminated with other materials.

Block No. 2 - No, because 1,1,1-trichlorethane is not a P or U listed waste.

Block No. 4 - No, because the 1,1,1-trichlorethane does not come from any specific sources in the K listings.

Block No. 6 - Yes, because spent 1,1,1-trichlorethane is an F002 listed waste.

Block No. 11 - Yes, because there are waste cutting oils in the tank.

Block No. 8 - Yes, because you performed toxicity characteristic leaching procedure (TCLP) (Federal) on a sample and found levels of chromium that exceed 5.0 mg/L; therefore, you have a D007 waste.

Results of logic pathway - You have two hazardous wastes mixed together: F002 and D007.

**Appendix A Attachment
(40 CFR 261.20
Subparts C and D)**

(1) It exhibits any of the characteristics of hazardous waste identified in Subpart C.

(2) It has been found to be fatal to humans in low doses or, in the absence of data on human toxicity, it has been shown in studies to have an oral LD 50 toxicity (rat) of less than 50 milligrams per kilogram, an inhalation LC 50 toxicity (rat) of less than 2 milligrams per liter, or a dermal LD 50 toxicity (rabbit) of less than 200 milligrams per kilogram or is otherwise capable of causing or significantly contributing to an increase in serious irreversible, or incapacitating reversible, illness. (Waste listed in accordance with these criteria will be designated Acute Hazardous Waste.)

(3) It contains any of the toxic constituents listed in Appendix VIII and, after considering the following factors, the Administrator concludes that the waste is capable of posing a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of, or otherwise managed:

(i) The nature of the toxicity presented by the constituent.

(ii) The concentration of the constituent in the waste.

(iii) The potential of the constituent or any toxic degradation product of the constituent to migrate from the waste into the environment under the types of improper management considered in paragraph (a)(3)(vii) of this section.

(iv) The persistence of the constituent or any toxic degradation product of the constituent.

(v) The potential for the constituent or any toxic degradation product of the constituent to degrade into non-harmful constituents and the rate of degradation.

(vi) The degree to which the constituent or any degradation product of the constituent bioaccumulates in ecosystems.

(vii) The plausible types of improper management to which the waste could be subjected.

(viii) The quantities of the waste generated at individual generation sites or on a regional or national basis.

(ix) The nature and severity of the human health and environmental damage that has occurred as a result of the improper management of wastes containing the constituent.

(x) Action taken by other governmental agencies or regulatory programs based on the health or environmental hazard posed by the waste or waste constituent.

(xi) Such other factors as may be appropriate.

Substances will be listed on Appendix VIII only if they have been shown in scientific studies to have toxic, carcinogenic, mutagenic or teratogenic effects on humans or other life forms.

(Wastes listed in accordance with these criteria will be designated Toxic wastes.)

(b) The Administrator may list classes or types of solid waste as hazardous waste if he has reason to believe that individual wastes, within the class or type of waste, typically or frequently are hazardous under the definition of hazardous waste found in section 1004(5) of the Act.

(c) The Administrator will use the criteria for listing specified in this section to establish the exclusion limits referred to in § 261.5(c).

[45 FR 33119, May 19, 1980, as amended at 55 FR 18726, May 4, 1990]

Subpart C—Characteristics of Hazardous Waste

§ 261.20 General.

(a) A solid waste, as defined in § 261.2, which is not excluded from regulation as a hazardous waste under § 261.4(b), is a hazardous waste if it exhibits any of the characteristics identified in this subpart.

(Comment: § 262.11 of this chapter sets forth the generator's responsibility to determine whether his waste exhibits one or more of the characteristics identified in this subpart.)

(b) A hazardous waste which is identified by a characteristic in this subpart is assigned every EPA Hazardous Waste Number that is applicable as set forth in this subpart. This number must be in complying with the notification requirements of section 3010 of

the Act and all applicable recordkeeping and reporting requirements under parts 262 through 265, 268, and 270 of this chapter.

(c) For purposes of this subpart, the Administrator will consider a sample obtained using any of the applicable sampling methods specified in Appendix I to be a representative sample within the meaning of Part 260 of this chapter.

[Comment: Since the Appendix I sampling methods are not being formally adopted by the Administrator, a person who desires to employ an alternative sampling method is not required to demonstrate the equivalency of his method under the procedures set forth in §§ 260.20 and 260.21.]

[45 FR 33119, May 19, 1980, as amended at 51 FR 40636, Nov. 7, 1986; 55 FR 22684, June 1, 1990]

§ 261.21 Characteristic of ignitability.

(a) A solid waste exhibits the characteristic of ignitability if a representative sample of the waste has any of the following properties:

(1) It is a liquid, other than an aqueous solution containing less than 24 percent alcohol by volume and has flash point less than 60°C (140°F), as determined by a Pensky-Martens Closed Cup Tester, using the test method specified in ASTM Standard D-93-79 or D-93-80 (incorporated by reference, see § 260.11), or a Setaflash Closed Cup Tester, using the test method specified in ASTM Standard D-3278-78 (incorporated by reference, see § 260.11), or as determined by an equivalent test method approved by the Administrator under procedures set forth in §§ 260.20 and 260.21.

(2) It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard.

(3) It is an ignitable compressed gas as defined in 49 CFR 173.300 and as determined by the test methods described in that regulation or equivalent test methods approved by the Administrator under §§ 260.20 and 260.21.

(4) It is an oxidizer as defined in 49 CFR 173.151.

(b) A solid waste that exhibits the characteristic of ignitability has the EPA Hazardous Waste Number of D001.

[45 FR 33119, May 19, 1980, as amended at 46 FR 35247, July 7, 1981; 55 FR 22684, June 1, 1990]

§ 261.22 Characteristic of corrosivity.

(a) A solid waste exhibits the characteristic of corrosivity if a representative sample of the waste has either of the following properties:

(1) It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5, as determined by a pH meter using either an EPA test method or an equivalent test method approved by the Administrator under the procedures set forth in §§ 260.20 and 260.21. The EPA test method for pH is specified as Method 5.2 in "Test Methods for the Evaluation of Solid Waste, Physical/Chemical Methods" (incorporated by reference, see § 260.11).

(2) It is a liquid and corrodes steel (SAE 1020) at a rate greater than 6.35 mm (0.250 inch) per year at a test temperature of 55°C (130°F) as determined by the test method specified in NACE (National Association of Corrosion Engineers) Standard TM-01-69 as standardized in "Test Methods for the Evaluation of Solid Waste, Physical/Chemical Methods" (incorporated by reference, see § 260.11) or an equivalent test method approved by the Administrator under the procedures set forth in §§ 260.20 and 260.21.

(b) A solid waste that exhibits the characteristic of corrosivity has the EPA Hazardous Waste Number of D002.

[45 FR 33119, May 19, 1980, as amended at 46 FR 35247, July 7, 1981; 55 FR 22684, June 1, 1990]

§ 261.23 Characteristic of reactivity.

(a) A solid waste exhibits the characteristic of reactivity if a representative sample of the waste has any of the following properties:

(1) It is normally unstable and readily undergoes violent change without detonating.

(2) It reacts violently with water.

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(3) It forms potentially explosive mixtures with water.

(4) When mixed with water, it generates toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.

(5) It is a cyanide or sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.

(6) It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.

(7) It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.

(8) It is a forbidden explosive as defined in 49 CFR 173.51, or a Class A explosive as defined in 49 CFR 173.53 or a Class B explosive as defined in 49 CFR 173.88.

(b) A solid waste that exhibits the characteristic of reactivity has the EPA Hazardous Waste Number of D003.

[45 FR 33119, May 19, 1980, as amended at 55 FR 22684, June 1, 1990]

§ 261.24 Toxicity characteristic.

(a) A solid waste exhibits the characteristic of toxicity if, using the test methods described in Appendix II or equivalent methods approved by the Administrator under the procedures set forth in §§ 260.20 and 260.21, the extract from a representative sample of the waste contains any of the contaminants listed in Table 1 at the concentration equal to or greater than the respective value given in that Table. Where the waste contains less than 0.5 percent filterable solids, the waste itself, after filtering using the methodology outlined in Appendix II, is considered to be the extract for the purpose of this section.

(b) A solid waste that exhibits the characteristic of toxicity has the EPA Hazardous Waste Number specified in Table I which corresponds to the toxic contaminant causing it to be hazardous.

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TABLE 1.—MAXIMUM CONCENTRATION OF CONTAMINANTS FOR THE TOXICITY CHARACTERISTIC

EPA HW No. ¹	Contaminant	CAS No. ²	Regulatory Level (mg/L)
D003	Arsenic.....	7440-38-2	5.0
D005	Barium.....	7440-39-3	100.0
D018	Benzene.....	71-43-2	0.5
D006	Cadmium.....	7440-43-9	1.0
D019	Carbon tetrachloride.....	56-23-5	0.5
D020	Chlordane.....	57-74-9	0.03
D021	Chlorobenzene.....	108-90-7	100.0
D022	Chloroform.....	67-66-3	6.0
D007	Chromium.....	7440-47-3	5.0
D023	o-Cresol.....	95-48-7	* 200.0
D024	m-Cresol.....	108-39-4	* 200.0
D025	p-Cresol.....	106-44-5	* 200.0
D026	Cresol.....		* 200.0
D016	2,4-D.....	94-75-7	10.0
D027	1,4-Dichlorobenzene.....	106-46-7	7.5
D026	1,2-Dichloroethane.....	107-06-2	0.5
D029	1,1-Dichloroethylene.....	75-35-4	0.7
D030	2,4-Dinitrotoluene.....	121-14-2	³ 0.13
D012	Endrin.....	72-20-8	0.02
D031	Heptachlor (and its epoxide).....	76-44-8	0.008
D032	Hexachlorobenzene.....	118-74-1	³ 0.13
D033	Hexachlorobutadiene.....	87-68-3	0.5
D034	Hexachloroethane.....	67-72-1	3.0
D008	Lead.....	7439-92-1	5.0
D013	Lindane.....	58-89-9	0.4
D009	Mercury.....	7439-97-6	0.2
D014	Methoxychlor.....	72-43-5	10.0
D035	Methyl ethyl ketone.....	78-93-3	200.0
D036	Nitrobenzene.....	98-95-3	2.0
D037	Pentachlorophenol.....	87-86-5	100.0
D038	Pyridine.....	110-86-1	³ 5.0
D010	Selenium.....	7782-49-2	1.0
D011	Silver.....	7440-22-4	5.0
D039	Tetrachloroethylene.....	127-18-4	0.7
D015	Toxaphene.....	8001-35-2	0.5
D040	Trichloroethylene.....	79-01-6	0.5
D041	2,4,5-Trichlorophenol.....	95-35-4	400.0
D042	2,4,6-Trichlorophenol.....	88-06-2	2.0
D017	2,4,5-TP (Silvex).....	93-72-1	1.0
D043	Vinyl chloride.....	75-01-4	0.2

¹ Hazardous waste number.

² Chemical abstracts service number.

³ Quantitation limit is greater than the calculated regulatory level. The quantitation limit therefore becomes the regulatory level.

* If o-, m-, and p-Cresol concentrations cannot be differentiated, the total cresol (D026) concentration is used. The regulatory level of total cresol is 200 mg/l.

[55 FR 11862, Mar. 29, 1990, as amended at 55 FR 22684, June 1, 1990; 55 FR 26987, June 29, 1990]

EFFECTIVE DATE NOTE: At 55 FR 11862, Mar. 29, 1990, § 261.24 was revised, effective September 25, 1990. At 55 FR 26987, June 29, 1990, the entry for "Heptachlor" in Table 1 was corrected, effective September 25, 1990. For the convenience of the user, the superseded text is set forth below:

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§ 261.24 Characteristic of EP toxicity.

(a) A solid waste exhibits the characteristic of EP toxicity if, using the test methods described in Appendix II or equivalent methods approved by the Administrator under the procedures set forth in §§ 260.20 and 260.21, the extract from a representative sample of the waste contains any of the contaminants listed in Table I at a concentration equal to or greater than the respective value given in that Table. Where the waste contains less than 0.5 percent filterable solids, the waste itself, after filtering, is considered to be the extract for the purposes of this section.

(b) A solid waste that exhibits the characteristic of EP toxicity, but is not listed as a hazardous waste in Subpart D, has the EPA Hazardous Waste Number specified in Table I which corresponds to the toxic contaminant causing it to be hazardous.

TABLE I—MAXIMUM CONCENTRATION OF CONTAMINANTS FOR CHARACTERISTIC OF EP TOXICITY

EPA hazardous waste number	Contaminant	Maximum concentration (milligrams per liter)
D004	Arsenic	5.0
D005	Barium	100.0
D006	Cadmium	1.0
D007	Chromium	5.0
D008	Lead	5.0
D009	Mercury	0.2
D010	Selenium	1.0
D011	Silver	5.0
D012	Endrin (1,2,3,4,10,10-hexachloro-1,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethano-naphthalene)	0.02
D013	Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer)	0.4
D014	Methoxychlor (1,1,1-Trichloro-2,2-bis (p-methoxyphenyl)ethane)	10.0
D015	Toxaphene (C ₁₂ H ₈ Cl ₆ , Technical chlorinated camphene, 67-69 percent chlorine)	0.5
D016	2,4-D, (2,4-Dichlorophenoxyacetic acid)	10.0
D017	2,4,5-TP Silvers (2,4,5-Trichlorophenoxypropionic acid)	1.0

unless it has been excluded from this list under §§ 260.20 and 260.22.

(b) The Administrator will indicate his basis for listing the classes or types of wastes listed in this subpart by employing one or more of the following Hazard Codes:

Ignitable Waste..... (I)
Corrosive Waste..... (C)
Reactive Waste ..... (R)
Toxicity Characteristic Waste .... (E)
Acute Hazardous Waste ..... (H)
Toxic Waste..... (T)

Appendix VII identifies the constituent which caused the Administrator to list the waste as a Toxicity Characteristic Waste (E) or Toxic Waste (T) in §§ 261.31 and 261.32.

(c) Each hazardous waste listed in this subpart is assigned an EPA Hazardous Waste Number which precedes the name of the waste. This number must be used in complying with the notification requirements of Section 3010 of the Act and certain record-keeping and reporting requirements under Parts 262 through 265, 268, and Part 270 of this chapter.

(d) The following hazardous wastes listed in § 261.31 or § 261.32 are subject to the exclusion limits for acutely hazardous wastes established in § 261.5: EPA Hazardous Wastes Nos. FO20, FO21, FO22, FO23, FO26, and FO27.

[45 FR 33119, May 19, 1980, as amended at 48 FR 14294, Apr. 1, 1983; 50 FR 2000, Jan. 14, 1985; 51 FR 40636, Nov. 7, 1986; 55 FR 11863, Mar. 29, 1990]

EFFECTIVE DATE NOTE: At 55 FR 11863, Mar. 29, 1990, § 261.30 paragraph (b) was revised, effective September 25, 1990. For the convenience of the user, the superseded text is set forth below:

§ 261.30 General.

• • • • •

(b) The Administrator will indicate his basis for listing the classes or types of wastes listed in this Subpart by employing one or more of the following Hazard Codes:

Ignitable Waste ..... (I)
Corrosive Waste ..... (C)
Reactive Waste ..... (R)
EP Toxic Waste ..... (E)

Subpart D—Lists of Hazardous Wastes

§ 261.30 General.

(a) A solid waste is a hazardous waste if it is listed in this subpart,

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Acute Hazardous Waste..... (H) waste as an EP Toxic Waste (E) or Toxic
Toxic Waste..... (T) Waste (T) in §§ 261.31 and 261.32.

Appendix VII identifies the constituent
which caused the Administrator to list the

§ 261.31 Hazardous wastes from non-specific sources.

The following solid wastes are listed hazardous wastes from non-specific sources unless they are excluded under §§ 260.20 and 260.22 and listed in Appendix IX.

Industry and EPA hazardous waste No.	Hazardous waste	Hazard code
Generic:		
F001.....	The following spent halogenated solvents used in degreasing: Tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; all spent solvent mixtures/blends used in degreasing containing, before use, a total of ten percent or more (by volume) of one or more of the above halogenated solvents or those solvents listed in F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.	(T)
F002.....	The following spent halogenated solvents: Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, ortho-dichlorobenzene, trichlorofluoromethane, and 1,1,2-trichloroethane; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above halogenated solvents or those listed in F001, F004, or F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.	(T)
F003.....	The following spent non-halogenated solvents: Xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol; all spent solvent mixtures/blends containing, before use, only the above spent non-halogenated solvents; and all spent solvent mixtures/blends containing, before use, one or more of the above non-halogenated solvents, and, a total of ten percent or more (by volume) of one or more of those solvents listed in F001, F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.	(T) (I)*
F004.....	The following spent non-halogenated solvents: Cresols and cresylic acid, and nitrobenzene; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.	(T)
F005.....	The following spent non-halogenated solvents: Toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine, benzene, 2-ethoxyethanol, and 2 nitropropane; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, or F004; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.	(I, T)
F006.....	Wastewater treatment sludges from electroplating operations except from the following processes: (1) Sulfuric acid anodizing of aluminum; (2) tin plating on carbon steel; (3) zinc plating (segregated basis) on carbon steel; (4) aluminum or zinc-aluminum plating on carbon steel; (5) cleaning/stripping associated with tin, zinc and aluminum plating on carbon steel; and (6) chemical etching and milking of aluminum.	(T)
F007.....	Spent cyanide plating bath solutions from electroplating operations.....	(R, T)
F008.....	Plating bath residues from the bottom of plating baths from electroplating operations where cyanides are used in the process.	(R, T)
F009.....	Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process.	(R, T)
F010.....	Quenching bath residues from oil baths from metal heat treating operations where cyanides are used in the process.	(R, T)
F011.....	Spent cyanide solutions from salt bath pot cleaning from metal heat treating operations.	(R, T)
F012.....	Quenching waste water treatment sludges from metal heat treating operations where cyanides are used in the process.	(T)
F019.....	Wastewater treatment sludges from the chemical conversion coating of aluminum except from zirconium phosphating in aluminum can washing when such phosphating is an exclusive conversion coating process.	(T)

Industry and EPA hazardous waste No.	Hazardous waste	Hazard code
F020.....	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri- or tetrachlorophenol, or of intermediates used to produce their pesticide derivatives. (This listing does not include wastes from the production of Hexachlorophene from highly purified 2,4,5-trichlorophenol.)	(H)
F021.....	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of pentachlorophenol, or of intermediates used to produce its derivatives.	(H)
F022.....	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzenes under alkaline conditions.	(H)
F023.....	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production of materials on equipment previously used for the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri- and tetrachlorophenols. (This listing does not include wastes from equipment used only for the production or use of Hexachlorophene from highly purified 2,4,5-trichlorophenol.)	(H)
F024.....	Process wastes, including but not limited to, distillation residues, heavy ends, tars, and reactor clean-out wastes, from the production of certain chlorinated aliphatic hydrocarbons by free radical catalyzed processes. These chlorinated aliphatic hydrocarbons are those having carbon chain lengths ranging from one to and including five, with varying amounts and positions of chlorine substitution. (This listing does not include wastewaters, wastewater treatment sludges, spent catalysts, and wastes listed in § 261.31 or § 261.32.)	(T)
F025.....	Condensed light ends, spent filters and filter aids, and spent desiccant wastes from the production of certain chlorinated aliphatic hydrocarbons, by free radical catalyzed processes. These chlorinated aliphatic hydrocarbons are those having carbon chain lengths ranging from one to and including five, with varying amounts and positions of chlorine substitution.	(T)
F026.....	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production of materials on equipment previously used for the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzene under alkaline conditions.	(H)
F027.....	Discarded unused formulations containing tri-, tetra-, or pentachlorophenol or discarded unused formulations containing compounds derived from these chlorophenols. (This listing does not include formulations containing Hexachlorophene synthesized from prepurified 2,4,5-trichlorophenol as the sole component.)	(H)
F028.....	Residues resulting from the incineration or thermal treatment of soil contaminated with EPA Hazardous Waste Nos. F020, F021, F022, F023, F026, and F027.	(T)
F039.....	Leachate resulting from the treatment, storage, or disposal of wastes classified by more than one waste code under Subpart D, or from a mixture of wastes classified under Subparts C and D of this part. (Leachate resulting from the management of one or more of the following EPA Hazardous Wastes and no other hazardous wastes retains its hazardous waste code(s): F020, F021, F022, F023, F026, F027, and/or F028.)	(T)

*(H,T) should be used to specify mixtures containing ignitable and toxic constituents.

[46 FR 4617, Jan. 16, 1981]

EDITORIAL NOTE For FEDERAL REGISTER citations affecting § 261.31, see the List of CFR Sections Affected in the Finding Aids section of this volume.

§ 261.32 Hazardous wastes from specific sources.

The following solid wastes are listed hazardous wastes from specific sources unless they are excluded under §§ 260.20 and 260.22 and listed in Appendix IX.

Industry and EPA hazardous waste No.	Hazardous waste	Hazard code
Wood preservation: K001.....	Bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol.	(T)
Inorganic pigments: K002.....	Wastewater treatment sludge from the production of chrome yellow and orange pigments.	(T)
K003.....	Wastewater treatment sludge from the production of molybdate orange pigments.....	(T)

Industry and EPA hazardous waste No.	Hazardous waste	Hazard code
K004	Wastewater treatment sludge from the production of zinc yellow pigments.	(T)
K005	Wastewater treatment sludge from the production of chrome green pigments.	(T)
K006	Wastewater treatment sludge from the production of chrome oxide green pigments (anhydrous and hydrated).	(T)
K007	Wastewater treatment sludge from the production of iron blue pigments.	(T)
K008	Oven residue from the production of chrome oxide green pigments.	(T)
Organic chemicals:		
K009	Distillation bottoms from the production of acetaldehyde from ethylene.	(T)
K010	Distillation side cuts from the production of acetaldehyde from ethylene.	(T)
K011	Bottom stream from the wastewater stripper in the production of acrylonitrile.	(R, T)
K013	Bottom stream from the acetonitrile column in the production of acrylonitrile.	(R, T)
K014	Bottoms from the acetonitrile purification column in the production of acrylonitrile.	(T)
K015	Still bottoms from the distillation of benzyl chloride.	(T)
K016	Heavy ends or distillation residues from the production of carbon tetrachloride.	(T)
K017	Heavy ends (still bottoms) from the purification column in the production of epichlorohydrin.	(T)
K018	Heavy ends from the fractionation column in ethyl chloride production.	(T)
K019	Heavy ends from the distillation of ethylene dichloride in ethylene dichloride production.	(T)
K020	Heavy ends from the distillation of vinyl chloride in vinyl chloride monomer production.	(T)
K021	Aqueous spent antimony catalyst waste from fluoromethanes production.	(T)
K022	Distillation bottom tars from the production of phenol/acetone from cumene.	(T)
K023	Distillation light ends from the production of phthalic anhydride from naphthalene.	(T)
K024	Distillation bottoms from the production of phthalic anhydride from naphthalene.	(T)
K025	Distillation bottoms from the production of nitrobenzene by the nitration of benzene.	(T)
K026	Stripping still tails from the production of methyl ethyl pyridines.	(T)
K027	Centrifuge and distillation residues from toluene diisocyanate production.	(R, T)
K028	Spent catalyst from the hydrochlorinator reactor in the production of 1,1,1-trichloroethane.	(T)
K029	Waste from the product steam stripper in the production of 1,1,1-trichloroethane.	(T)
K030	Column bottoms or heavy ends from the combined production of trichloroethylene and perchloroethylene.	(T)
K083	Distillation bottoms from aniline production.	(T)
K085	Distillation or fractionation column bottoms from the production of chlorobenzenes.	(T)
K093	Distillation light ends from the production of phthalic anhydride from ortho-xylene.	(T)
K094	Distillation bottoms from the production of phthalic anhydride from ortho-xylene.	(T)
K095	Distillation bottoms from the production of 1,1,1-trichloroethane.	(T)
K096	Heavy ends from the heavy ends column from the production of 1,1,1-trichloroethane.	(T)
K103	Process residues from aniline extraction from the production of aniline.	(T)
K104	Combined wastewater streams generated from nitrobenzene/aniline production.	(T)
K105	Separated aqueous stream from the reactor product washing step in the production of chlorobenzenes.	(T)
K107	Column bottoms from product separation from the production of 1,1-dimethylhydrazine (UDMH) from carboxylic acid hydrazides.	(C, T)
K108	Condensed column overheads from product separation and condensed reactor vent gases from the production of 1,1-dimethylhydrazine (UDMH) from carboxylic acid hydrazides.	(I, T)
K109	Spent filter cartridges from product purification from the production of 1,1-dimethylhydrazine (UDMH) from carboxylic acid hydrazides.	(T)
K110	Condensed column overheads from intermediate separation from the production of 1,1-dimethylhydrazine (UDMH) from carboxylic acid hydrazides.	(T)
K111	Product washwaters from the production of dinitrotoluene via nitration of toluene.	(C, T)
K112	Reaction by-product water from the drying column in the production of toluenediamine via hydrogenation of dinitrotoluene.	(T)
K113	Condensed liquid light ends from the purification of toluenediamine in the production of toluenediamine via hydrogenation of dinitrotoluene.	(T)
K114	Vicinals from the purification of toluenediamine in the production of toluenediamine via hydrogenation of dinitrotoluene.	(T)
K115	Heavy ends from the purification of toluenediamine in the production of toluenediamine via hydrogenation of dinitrotoluene.	(T)
K116	Organic condensate from the solvent recovery column in the production of toluene diisocyanate via phosgenation of toluenediamine.	(T)
K117	Wastewater from the reactor vent gas scrubber in the production of ethylene dibromide via bromination of ethene.	(T)
K118	Spent adsorbent solids from purification of ethylene dibromide in the production of ethylene dibromide via bromination of ethene.	(T)
K136	Still bottoms from the purification of ethylene dibromide in the production of ethylene dibromide via bromination of ethene.	(T)

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Industry and EPA hazardous waste No.	Hazardous waste	Hazard code
Inorganic chemicals:		
K071	Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used.	(T)
K073	Chlorinated hydrocarbon waste from the purification step of the diaphragm cell process using graphite anodes in chlorine production.	(T)
K108	Wastewater treatment sludge from the mercury cell process in chlorine production.	(T)
Pesticides:		
K031	By-product salts generated in the production of MSMA and cacodylic acid.	(T)
K032	Wastewater treatment sludge from the production of chlordane.	(T)
K033	Wastewater and scrub water from the chlorination of cyclopentadiene in the production of chlordane.	(T)
K034	Filter solids from the filtration of hexachlorocyclopentadiene in the production of chlordane.	(T)
K035	Wastewater treatment sludges generated in the production of creosote.	(T)
K036	Still bottoms from toluene reclamation distillation in the production of disulfoton.	(T)
K037	Wastewater treatment sludges from the production of disulfoton.	(T)
K038	Wastewater from the washing and stripping of phorate production.	(T)
K039	Filter cake from the filtration of diethylphosphorodithioic acid in the production of phorate.	(T)
K040	Wastewater treatment sludge from the production of phorate.	(T)
K041	Wastewater treatment sludge from the production of toxaphene.	(T)
K042	Heavy ends or distillation residues from the distillation of tetrachlorobenzene in the production of 2,4,5-T.	(T)
K043	2,6-Dichlorophenol waste from the production of 2,4-D.	(T)
K097	Vacuum stripper discharge from the chlordane chlorinator in the production of chlordane.	(T)
K098	Untreated process wastewater from the production of toxaphene.	(T)
K099	Untreated wastewater from the production of 2,4-D.	(T)
K123	Process wastewater (including supernates, filtrates, and washwaters) from the production of ethylenedithiocarbamic acid and its salt.	(T)
K124	Reactor vent scrubber water from the production of ethylenedithiocarbamic acid and its salts.	(C, T)
K125	Filtration, evaporation, and centrifugation solids from the production of ethylenedithiocarbamic acid and its salts.	(T)
K126	Baghouse dust and floor sweepings in milling and packaging operations from the production or formulation of ethylenedithiocarbamic acid and its salts.	(T)
K131	Wastewater from the reactor and spent sulfuric acid from the acid dryer from the production of methyl bromide.	(C, T)
K132	Spent absorbent and wastewater separator solids from the production of methyl bromide.	(T)
Explosives:		
K044	Wastewater treatment sludges from the manufacturing and processing of explosives.	(R)
K045	Spent carbon from the treatment of wastewater containing explosives.	(R)
K046	Wastewater treatment sludges from the manufacturing, formulation and loading of lead-based initiating compounds.	(T)
K047	Pink/red water from TNT operations.	(R)
Petroleum refining:		
K048	Desolved air flotation (DAF) float from the petroleum refining industry.	(T)
K049	Slop oil emulsion solids from the petroleum refining industry.	(T)
K050	Heat exchanger bundle cleaning sludge from the petroleum refining industry.	(T)
K051	API separator sludge from the petroleum refining industry.	(T)
K052	Tank bottoms (leaded) from the petroleum refining industry.	(T)
Iron and steel:		
K061	Emission control dust/sludge from the primary production of steel in electric furnaces.	(T)
K062	Spent pickle liquor generated by steel finishing operations of facilities within the iron and steel industry (SIC Codes 331 and 332).	(C, T)
Primary copper:		
K064	Acid plant blowdown slurry/sludge resulting from the thickening of blowdown slurry from primary copper production.	(T)
Primary lead:		
K065	Surface impoundment solids contained in and dredged from surface impoundments at primary lead smelting facilities.	(T)
Primary zinc:		
K066	Sludge from treatment of process wastewater and/or acid plant blowdown from primary zinc production.	(T)
Primary aluminum:		
K068	Spent potliners from primary aluminum reduction.	(T)
Ferroalloys:		
K090	Emission control dust or sludge from ferrochromium alloy production.	(T)
K091	Emission control dust or sludge from ferrochromium production.	(T)

Industry and EPA hazardous waste No.	Hazardous waste	Hazard code
Secondary lead: K089	Emission control dust/sludge from secondary lead smelting.....	(T)
K100	Waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting.	(T)
Veterinary pharmaceuticals: K084	Wastewater treatment sludges generated during the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.	(T)
K101	Distillation tar residues from the distillation of aniline-based compounds in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.	(T)
K102	Residue from the use of activated carbon for decolorization in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.	(T)
Ink formulation: K086	Solvent washes and sludges, caustic washes and sludges, or water washes and sludges from cleaning tubs and equipment used in the formulation of ink from pigments, driers, soaps, and stabilizers containing chromium and lead.	(T)
Coking: K080	Ammonia still lime sludge from coking operations.....	(T)
K087	Decanter tank tar sludge from coking operations.....	(T)

[46 FR 4618, Jan. 16, 1981]

EDITORIAL NOTE: For FEDERAL REGISTER citations affecting § 261.32, see the List of CFR Sections Affected in the Finding Aids section of this volume.

EFFECTIVE DATE NOTE: At 55 FR 18505, May 2, 1990, the table in § 261.32 was amended by adding to the subgroup "Organic chemicals" the entries for EPA hazardous waste numbers K107, K108, K109 and K110, effective November 2, 1990.

§ 261.33 Discarded commercial chemical products, off-specification species, container residues, and spill residues thereof.

The following materials or items are hazardous wastes if and when they are discarded or intended to be discarded as described in § 261.2(a)(2)(i), when they are mixed with waste oil or used oil or other material and applied to the land for dust suppression or road treatment, when they are otherwise applied to the land in lieu of their original intended use or when they are contained in products that are applied to the land in lieu of their original intended use, or when, in lieu of their original intended use, they are produced for use as (or as a component of) a fuel, distributed for use as a fuel, or burned as a fuel.

(a) Any commercial chemical product, or manufacturing chemical intermediate having the generic name listed in paragraph (e) or (f) of this section.

(b) Any off-specification commercial chemical product or manufacturing chemical intermediate which, if it met specifications, would have the generic name listed in paragraph (e) or (f) of this section.

(c) Any residue remaining in a container or in an inner liner removed

from a container that has held any commercial chemical product or manufacturing chemical intermediate having the generic name listed in paragraphs (e) or (f) of this section, unless the container is empty as defined in § 261.7(b) of this chapter.

(Comment: Unless the residue is being beneficially used or reused, or legitimately recycled or reclaimed; or being accumulated, stored, transported or treated prior to such use, re-use, recycling or reclamation, EPA considers the residue to be intended for discard, and thus, a hazardous waste. An example of a legitimate re-use of the residue would be where the residue remains in the container and the container is used to hold the same commercial chemical product or manufacturing chemical intermediate it previously held. An example of the discard of the residue would be where the drum is sent to a drum reconditioner who reconditions the drum but discards the residue.)

(d) Any residue or contaminated soil, water or other debris resulting from the cleanup of a spill into or on any land or water of any commercial chemical product or manufacturing chemical intermediate having the generic name listed in paragraph (e) or (f) of this section, or any residue or contaminated soil, water or other debris resulting from the cleanup of a spill, into or on any land or water, of

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any off-specification chemical product and manufacturing chemical intermediate which, if it met specifications, would have the generic name listed in paragraph (e) or (f) of this section.

[Comment: The phrase "commercial chemical product or manufacturing chemical intermediate having the generic name listed in . . ." refers to a chemical substance which is manufactured or formulated for commercial or manufacturing use which consists of the commercially pure grade of the chemical, any technical grades of the chemical that are produced or marketed, and all formulations in which the chemical is the sole active ingredient. It does not refer to a material, such as a manufacturing process waste, that contains any of the substances listed in paragraph (e) or (f). Where a manufacturing process waste is deemed to be a hazardous waste because it contains a substance listed in paragraph (e) or (f), such waste will be listed in either § 261.31 or § 261.32 or will be identified as a hazardous

waste by the characteristics set forth in Subpart C of this part.]

(e) The commercial chemical products, manufacturing chemical intermediates or off-specification commercial chemical products or manufacturing chemical intermediates referred to in paragraphs (a) through (d) of this section, are identified as acute hazardous wastes (H) and are subject to be the small quantity exclusion defined in § 261.5(e).

[Comment: For the convenience of the regulated community the primary hazardous properties of these materials have been indicated by the letters T (Toxicity), and R (Reactivity). Absence of a letter indicates that the compound only is listed for acute toxicity.]

These wastes and their corresponding EPA Hazardous Waste Numbers are:

Haz- ardous waste No.	Chemical abstracts No.	Substance
P023	107-20-0	Acetaldehyde, chloro-
P002	591-08-2	Acetamide, N-(aminothiozomethyl)-
P057	640-19-7	Acetamide, 2-thio-
P058	62-74-8	Acetic acid, fluoro-, sodium salt
P002	591-08-2	1-Acetyl-2-thiourea
P003	107-02-8	Acrolein
P070	118-08-3	Aldicarb
P004	309-00-2	Aldrin
P005	107-18-8	Allyl alcohol
P006	20858-73-8	Aluminum phosphide (R,T)
P007	2763-98-4	5-(Aminomethyl)-3-oxazolid
P008	504-24-5	4-Aminopyridine
P009	131-74-8	Ammonium picrate (R)
P119	7803-55-8	Ammonium vanadate
P099	506-61-6	Argentate(1-), bis(cyano-C)-, potassium
P010	7778-39-4	Arsenic acid H ₃ AsO ₄
P012	1327-53-3	Arsenic oxide As ₂ O ₃
P011	1303-28-2	Arsenic oxide As ₂ O ₃
P011	1303-28-2	Arsenic pentoxide
P012	1327-53-3	Arsenic trioxide
P038	692-42-2	Arsine, diethyl-
P036	698-28-6	Arsinous dichloride, phenyl-
P054	151-58-4	Azidine
P087	75-55-8	Azidine, 2-methyl-
P013	542-62-1	Benzum cyanide
P024	106-47-8	Benzenamine, 4-chloro-
P077	100-01-6	Benzenamine, 4-nitro-
P028	100-44-7	Benzene, (chloromethyl)-
P042	51-43-4	1,2-Benzenediol, 4-[(1-hydroxy-2-(methylamino)ethyl)-, (R)-
P048	122-09-8	Benzeneethanamine, alpha, alpha-dimethyl-
P014	106-98-5	Benzenethiol
P001	181-81-2	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1-phenylbutyl)-, & salts, when present at concentrations greater than 0.3%
P028	100-44-7	Benzyl chloride
P015	7440-41-7	Beryllium
P017	598-31-2	Bromoacetone
P018	357-57-3	Brucine
P045	39196-18-4	2-Butanone, 3,3-dimethyl-1-(methylthio)-, O-(methylamino)carbonyl oxime

Haz- ardous waste No.	Chemical abstracts No.	Substance
P021	592-01-8	Calcium cyanide
P021	592-01-8	Calcium cyanide $\text{Ca}(\text{CN})_2$
P022	75-15-0	Carbon disulfide
P095	75-44-5	Carbonic dichloride
P023	107-20-0	Chloroacetaldehyde
P024	108-47-8	p-Chloroaniline
P026	5344-82-1	1-(o-Chlorophenyl)thiourea
P027	542-76-7	3-Chloropropionitrile
P029	544-92-3	Copper cyanide
P029	544-92-3	Copper cyanide $\text{Cu}(\text{CN})$
P030		Cyanides (soluble cyanide salts), not otherwise specified
P031	480-19-5	Cyanogen
P033	506-77-4	Cyanogen chloride
P033	506-77-4	Cyanogen chloride $(\text{CN})\text{Cl}$
P034	131-89-5	2-Cyclohexyl-4,6-dinitrophenol
P016	542-86-1	Dichloromethyl ether
P036	696-28-6	Dichlorophenylarsine
P037	80-57-1	Diiodine
P038	692-42-2	Diethylarsine
P041	311-45-5	Diethyl-p-nitrophenyl phosphate
P040	297-97-2	O,O-Diethyl O-pyrazinyl phosphorothioate
P043	55-91-4	Diisopropylfluorophosphate (DFP)
P004	309-00-2	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexa- chloro-1,4,4a,5,8,8a,-hexahydro-, (1alpha,4alpha,4abeta,5alpha,8alpha,8abeta)-
P060	465-73-6	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexa- chloro-1,4,4a,5,8,8a,-hexahydro-, (1alpha,4alpha,4abeta,5beta,8beta,8abeta)-
P037	60-57-1	2,7,3,6-Dimethanonaphth(2,3-b)oxrene, 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aalpha,2beta,2aalpha,3beta,6beta,6aalpha,7beta,7aalpha)-
P051	72-20-8	2,7,3,6-Dimethanonaphth(2,3-b)oxrene, 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aalpha,2beta,2abeta,3alpha,6abeta,6alpha,7beta,7aalpha)- & metabolites
P044	60-51-5	Dimethoate
P046	122-09-8	alpha, alpha-Dimethylphenethylamine
P047	534-52-1	4,6-Dinitro-o-cresol, & salts
P048	51-28-5	2,4-Dinitrophenol
P020	88-85-7	Dinoseb
P065	152-16-9	Diphosphoramide, octamethyl-
P111	107-48-3	Diphosphoric acid, tetraethyl ester
P039	298-04-4	Disulficion
P049	541-53-7	Orthobutyl
P050	115-29-7	Endosulfan
P068	145-73-3	Endothall
P051	72-20-8	Endrin
P051	72-20-8	Endrin, & metabolites
P042	51-43-4	Epinephrine
P031	460-19-5	Ethanedinitrile
P066	16752-77-5	Ethanemidothioic acid, N-(((methylamino)carbonyl)oxy)-, methyl ester
P101	107-12-0	Ethyl cyanide
P054	151-56-4	Ethylenamine
P097	52-85-7	Famphur
P056	7782-41-4	Fluorine
P057	640-19-7	Fluoroacetamide
P058	62-74-8	Fluoroacetic acid, sodium salt
P065	628-86-4	Fulminic acid, mercury(2+) salt (R,T)
P059	76-44-8	Heptachlor
P062	757-58-4	Hexaethyl tetraphosphate
P116	79-19-6	Hydrazinecarbothioamide
P068	60-34-4	Hydrazine, methyl-
P063	74-90-8	Hydrocyanic acid
P063	74-90-8	Hydrogen cyanide
P096	7803-51-2	Hydrogen phosphide
P060	465-73-6	Isoendrin
P007	2763-96-4	3(2H)-isoxazolone, 5-(aminomethyl)-
P092	62-38-4	Mercury, (acetato-C)phenyl-
P065	628-86-4	Mercury fulminate (R,T)
P082	62-75-9	Methanamine, N-methyl-N-nitroso-
P064	624-83-9	Methane, isocyanato-
P016	542-86-1	Methane, oxybis(chloro-
P112	509-14-8	Methane, tetranitro- (R)

Haz- ardous waste No.	Chemical abstracts No.	Substance
P118	75-70-7	Methanethiol, trichloro-
P050	115-29-7	6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-, 3-oxide
P059	76-44-8	4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-
P066	16752-77-5	Methomyl
P068	60-34-4	Methyl hydrazine
P064	624-83-9	Methyl isocyanate
P069	75-86-5	2-Methylacetonitrile
P071	298-00-0	Methyl parathion
P072	86-88-4	alpha-Naphthylthiourea
P073	13463-39-3	Nickel carbonyl
P073	13463-39-3	Nickel carbonyl Ni(CO) ₄ , (T-4)-
P074	557-19-7	Nickel cyanide
P074	557-19-7	Nickel cyanide Ni(CN) ₂
P075	54-11-5	Nicotine, & salts
P076	10102-43-9	Nitric oxide
P077	100-01-6	p-Nitroaniline
P078	10102-44-0	Nitrogen dioxide
P076	10102-43-9	Nitrogen oxide NO
P078	10102-44-0	Nitrogen oxide NO ₂
P081	55-63-0	Nitroglycerine (R)
P082	62-75-9	N-Nitrosodimethylamine
P084	4549-40-0	N-Nitrosomethylvinylamine
P085	152-16-9	Octamethylpyrophosphoramide
PC87	20816-12-0	Osmium oxide OsO ₃ , (T-4)-
P087	20816-12-0	Osmium tetroxide
P088	145-73-3	7-Oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid
P089	56-38-2	Parathion
P034	131-89-5	Phenol, 2-cyclohexyl-4,6-dinitro-
P048	51-28-5	Phenol, 2,4-dinitro-
P047	534-52-1	Phenol, 2-methyl-4,6-dinitro-, & salts
P020	88-85-7	Phenol, 2-(1-methylpropyl)-4,6-dinitro-
P009	131-74-8	Phenol, 2,4,6-trinitro-, ammonium salt (R)
P092	82-38-4	Phenylmercury acetate
P093	103-85-5	Phenylthiourea
P094	298-02-2	Phorate
P095	75-44-5	Phosgene
P096	7803-51-2	Phosphine
P041	311-45-5	Phosphonic acid, diethyl 4-nitrophenyl ester
P039	298-04-4	Phosphorodithioic acid, O,O-diethyl S-(2-(ethylthio)ethyl) ester
P094	298-02-2	Phosphorodithioic acid, O,O-diethyl S-((ethylthio)methyl) ester
P044	60-51-5	Phosphorodithioic acid, O,O-dimethyl S-[2-(methylamino)-2-oxoethyl] ester
P043	55-81-4	Phosphorofluoric acid, bis(1-methylethyl) ester
P089	56-38-2	Phosphorothioic acid, O,O-diethyl O-(4-nitrophenyl) ester
P040	297-97-2	Phosphorothioic acid, O,O-diethyl O-pyraznyl ester
P097	52-85-7	Phosphorothioic acid, O-[4-((dimethylamino)sulfonyl)phenyl] O,O-dimethyl ester
P071	298-00-0	Phosphorothioic acid, O,O-dimethyl O-(4-nitrophenyl) ester
P110	78-00-2	Plumbane, tetraethyl-
P098	151-50-8	Potassium cyanide
P098	151-50-8	Potassium cyanide K(CN)
P099	506-61-6	Potassium silver cyanide
P070	118-08-3	Propanal, 2-methyl-2-(methylthio)-, O-((methylamino)carbonyl)oxime
P101	107-12-0	Propanenitrile
P027	542-78-7	Propanenitrile, 3-chloro-
P089	75-86-5	Propanenitrile, 2-hydroxy-2-methyl-
P081	55-63-0	1,2,3-Propanetriol, trisate (R)
P017	598-31-2	2-Propanone, 1-bromo-
P102	107-19-7	Propargyl alcohol
P003	107-02-8	2-Propanal
P005	107-18-6	2-Propan-1-ol
P067	75-55-8	1,2-Propylenamine
P102	107-19-7	2-Propyn-1-ol
P008	504-24-5	4-Pyridinamine
P075	54-11-5	Pyridine, 3-(1-methyl-2-pyrrolidinyl)-, (S)-, & salts
P114	12039-52-0	Selenious acid, diethylum(1-) salt

Haz- ardous waste No	Chemical abstracts No.	Substance
P103	630-10-4	Selenourea
P104	506-64-9	Silver cyanide
P104	506-64-9	Silver cyanide Ag(CN)
P105	26628-22-8	Sodium azide
P106	143-33-9	Sodium cyanide
P106	143-33-9	Sodium cyanide Na(CN)
P107	1314-96-1	Strontium sulfide SrS
P108	¹ 57-24-9	Strychnidin-10-one, & salts
P018	357-57-3	Strychnidin-10-one, 2,3-dimethoxy-
P108	¹ 57-24-9	Strychnine, & salts
P115	7446-18-6	Sulfuric acid, diethalium(1+) salt
P109	3689-24-5	Tetraethylthiopyrophosphate
P110	78-00-2	Tetraethyl lead
P111	107-49-3	Tetraethyl pyrophosphate
P112	509-14-8	Tetraethyromethane (R)
P062	757-58-4	Tetraphosphoric acid, hexaethyl ester
P113	1314-32-5	Thallic oxide
P113	1314-32-5	Thallium oxide Tl ₂ O ₃
P114	12039-52-0	Thallium(I) selenite
P115	7446-18-6	Thallium(I) sulfate
P109	3689-24-5	Thiodiphosphoric acid, tetraethyl ester
P045	39196-18-4	Thiofloxaz
P049	541-53-7	Thiomidodicarbonic diamide [(H ₂ N)C(S)] ₂ NH
P014	109-96-5	Thiophenol
P116	79-19-6	Thiosemicarbazide
P026	5344-82-1	Thiourea, (2-chlorophenyl)-
P072	86-88-4	Thiourea, 1-naphthalenyl-
P093	103-85-5	Thiourea, phenyl-
P123	8001-35-2	Toxaphene
P118	75-70-7	Trichloromethanethiol
P119	7803-55-6	Vanadic acid, ammonium salt
P120	1314-62-1	Vanadium oxide V ₂ O ₅
P120	1314-62-1	Vanadium pentoxide
P064	4549-40-0	Vinylamine, N-methyl-N-nitroso-
P001	¹ 81-81-2	Warfarin, & salts, when present at concentrations greater than 0.3%
P121	557-21-1	Zinc cyanide
P121	557-21-1	Zinc cyanide Zn(CN) ₂
P122	1314-84-7	Zinc phosphide Zn ₃ P ₂ , when present at concentrations greater than 10% (R,T)

¹ CAS Number given for parent compound only.

(f) The commercial chemical products, manufacturing chemical intermediates, or off-specification commercial chemical products referred to in paragraphs (a) through (d) of this section, are identified as toxic wastes (T), unless otherwise designated and are subject to the small quantity generator exclusion defined in § 261.5 (a) and (g).

(Comment: For the convenience of the regulated community, the primary hazardous properties of these materials have been indicated by the letters T (Toxicity), R (Reactivity), I (Ignitability) and C (Corrosivity). Absence of a letter indicates that the compound is only listed for toxicity.)

These wastes and their corresponding EPA Hazardous Waste Numbers are:

Haz- ardous waste No	Chemical abstracts No	Substance
U001	75-07-0	Acetaldehyde (I)
U034	75-87-6	Acetaldehyde, trichloro-
U187	62-44-2	Acetamide, N-(4-ethoxyphenyl)-
U005	53-96-3	Acetamide, N-9H-fluoren-2-yl-
U240	¹ 94-75-7	Acetic acid, (2,4-dichlorophenoxy)-, salts & esters
U112	141-78-6	Acetic acid ethyl ester (I)
U144	301-04-2	Acetic acid, lead(2+) salt
U214	562-68-8	Acetic acid, thallium(1+) salt

Hazardous waste No.	Chemical abstracts No.	Substance
see F027	93-76-5	Acetic acid, (2,4,5-trichlorophenoxy)-
U002	67-64-1	Acetone (I)
U003	75-05-6	Acetonitrile (I,T)
U004	98-86-2	Acetophenone
U005	53-98-3	2-Acetylaminofluorene
U006	75-36-5	Acetyl chloride (C,R,T)
U007	79-06-1	Acrylamide
U008	79-10-7	Acrylic acid (I)
U009	107-13-1	Acrylonitrile
U011	61-82-5	Amivale
U012	62-53-3	Aniline (I,T)
U136	75-60-5	Arsinic acid, dimethyl-
U014	492-80-6	Auramine
U015	115-02-6	Azaserine
U010	50-07-7	Azino[2',3':3,4]pyrrolo[1,2-a]indole-4,7-dione, 6-amino-8-[[[(aminocarbonyloxy)methyl]-1,1a,2,8,8a,8b-hexahydro-8a-methoxy-5-methyl-, [1aS-(1aalpha, 8beta,8aalpha,8balpha)]]-
U157	56-49-5	Benz[<i>j</i>]aceanthrylene, 1,2-dihydro-3-methyl-
U016	225-51-4	Benz[<i>c</i>]acridine
U017	98-87-3	Benzal chloride
U192	23950-58-5	Benzamide, 3,5-dichloro-N-(1,1-dimethyl-2-propynyl)-
U018	56-55-3	Benz[<i>a</i>]anthracene
U094	57-97-6	Benz[<i>a</i>]anthracene, 7,12-dimethyl-
U012	62-53-3	Benzenamine (I,T)
U014	492-80-6	Benzenamine, 4,4'-carbonimidoylbis(N,N-dimethyl-
U049	3165-93-3	Benzenamine, 4-chloro-2-methyl-, hydrochloride
U093	60-11-7	Benzenamine, N,N-dimethyl-4-(phenylazo)-
U328	95-53-4	Benzenamine, 2-methyl-
U353	106-48-0	Benzenamine, 4-methyl-
U158	101-14-4	Benzenamine, 4,4'-methylenebis(2-chloro-
U222	636-21-5	Benzenamine, 2-methyl-, hydrochloride
U181	99-55-8	Benzenamine, 2-methyl-5-nitro-
U019	71-43-2	Benzene (I,T)
U038	510-15-6	Benzenesacetic acid, 4-chloro-alpha-(4-chlorophenyl)-alpha-hydroxy-, ethyl ester
U030	101-55-3	Benzene, 1-bromo-4-phenoxy-
U035	305-03-3	Benzenesulfonic acid, 4-[(bis(2-chloroethyl)amino)-
U037	106-90-7	Benzene, chloro-
U221	25376-45-8	Benzenediamine, <i>ar</i> -methyl-
U028	117-81-7	1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester
U069	84-74-2	1,2-Benzenedicarboxylic acid, dibutyl ester
U088	84-66-2	1,2-Benzenedicarboxylic acid, diethyl ester
U102	131-11-3	1,2-Benzenedicarboxylic acid, dimethyl ester
U107	117-84-0	1,2-Benzenedicarboxylic acid, diethyl ester
U070	95-50-1	Benzene, 1,2-dichloro-
U071	541-73-1	Benzene, 1,3-dichloro-
U072	106-46-7	Benzene, 1,4-dichloro-
U060	72-54-6	Benzene, 1,1'-(2,2-dichloroethyldiene)bis(4-chloro-
U017	98-87-3	Benzene, (dichloromethyl)-
U223	26471-62-5	Benzene, 1,3-dicyanatomethyl- (R,T)
U239	1330-20-7	Benzene, dimethyl- (I,T)
U201	108-46-3	1,3-Benzenediol
U127	118-74-1	Benzene, hexachloro-
U056	110-82-7	Benzene, hexahydro- (I)
U220	106-88-3	Benzene, methyl-
U105	121-14-2	Benzene, 1-methyl-2,4-dinitro-
U106	606-20-2	Benzene, 2-methyl-1,3-dinitro-
U055	98-82-8	Benzene, (1-methylethyl)- (I)
U169	98-95-3	Benzene, nitro-
U183	606-93-5	Benzene, pentachloro-
U185	82-68-8	Benzene, pentachloronitro-
U020	98-09-6	Benzenesulfonic acid chloride (C,R)
U020	98-09-9	Benzenesulfonyl chloride (C,R)
U207	95-94-3	Benzene, 1,2,4,5-tetrachloro-
U061	50-29-3	Benzene, 1,1'-(2,2,2-trichloroethyldiene)bis(4-chloro-
U247	72-43-5	Benzene, 1,1'-(2,2,2-trichloroethyldiene)bis(4-methoxy-
U023	98-07-7	Benzene, (trichloromethyl)-
U234	98-35-4	Benzene, 1,3,5-trinitro-
U021	92-87-5	Benzidine
U202	181-07-2	1,2-Benzisothiazol-3(2H)-one, 1,1-dioxide, & salts
U203	94-59-7	1,3-Benzodioxole, 5-(2-propenyl)-

Haz- ardous waste No.	Chemical abstracts No.	Substance
U141	120-58-1	1,3-Benzodioxole, 5-(1-propenyl)-
U090	94-58-6	1,3-Benzodioxole, 5-propyl-
U064	189-55-9	Benzo[<i>a</i>]pentaphene
U248	181-81-2	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1-phenyl-butyl)-, & salts, when present at concentrations of 0.3% or less
U022	50-32-8	Benzo[<i>a</i>]pyrene
U197	106-51-4	p-Benzoquinone
U023	98-07-7	Benzo[<i>a</i>]trichloride (C,R,T)
U085	1464-53-5	2,2'-Bioxirane
U021	92-87-5	[1,1'-Biphenyl]-4,4'-diamine
U073	91-94-1	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dichloro-
U091	119-90-4	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethoxy-
U095	119-93-7	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethyl-
U225	75-25-2	Bromoforn
U030	101-55-3	4-Bromophenyl phenyl ether
U128	87-68-3	1,3-Butadiene, 1,1,2,3,4,4-hexachloro-
U172	924-16-3	1-Butanamine, N-butyl-N-nitroso-
U031	71-36-3	1-Butanol (I)
U159	78-93-3	2-Butanone (I,T)
U160	1338-23-4	2-Butanone, peroxide (R,T)
U053	4170-30-3	2-Butenal
U074	764-41-0	2-Butene, 1,4-dichloro- (I,T)
U143	303-34-4	2-Butenoic acid, 2-methyl-, 7-[[2,3-dihydroxy-2-(1-methoxyethyl)-3-methyl-1-oxobutoxy]methyl]-, 2,3,5,7a-tetrahydro-1H-pyrrolizin-1-yl ester, [(1S-[1alpha(Z),7(2S*,3R*),7aalpha)]-
U031	71-36-3	n-Butyl alcohol (I)
U136	75-60-5	Cacodylic acid
U032	13765-19-0	Calcium chromate
U238	51-79-6	Carbamic acid, ethyl ester
U178	615-53-2	Carbamic acid, methylnitroso-, ethyl ester
U097	79-44-7	Carbamic chloride, dimethyl-
U114	111-54-6	Carbamodithioic acid, 1,2-ethanedithiois-, salts & esters
U062	2303-16-4	Carbamothioic acid, bis(1-methylethyl)-, S-(2,3-dichloro-2-propenyl) ester
U215	6533-73-9	Carbonic acid, dithallum(1+) salt
U033	353-50-4	Carbonic difluoride
U156	79-22-1	Carbonochloridic acid, methyl ester (I,T)
U033	353-50-4	Carbon oxyfluoride (R,T)
U211	56-23-5	Carbon tetrachloride
U034	75-87-6	Chloral
U035	305-03-3	Chlorambucil
U036	57-74-9	Chlorane, alpha & gamma isomers
U026	494-03-1	Chloranaphazin
U037	108-90-7	Chlorobenzene
U038	510-15-6	Chlorobenzilate
U039	59-50-7	p-Chloro-m-cresol
U042	110-75-8	2-Chloroethyl vinyl ether
U044	47-66-3	Chloroforn
U046	107-30-2	Chloromethyl methyl ether
U047	91-58-7	beta-Chloronaphthalene
U048	95-57-8	o-Chlorophenol
U049	3185-83-3	4-Chloro-o-toluidine, hydrochloride
U032	13765-19-0	Chromic acid H ₂ CrO ₄ , calcium salt
U050	218-01-9	Chrysene
U051		Cresote
U052	1319-77-3	Cresol (Cresylic acid)
U053	4170-30-3	Crotonaldehyde
U055	98-82-8	Cumene (I)
U246	506-68-3	Cyanogen bromide (CN)Br
U197	106-51-4	2,5-Cyclohexadiene-1,4-dione
U056	110-82-7	Cyclohexane (I)
U129	58-89-9	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1alpha,2alpha,3beta,4alpha,5alpha,6beta)-
U057	108-94-1	Cyclohexanone (I)
U130	77-47-4	1,3-Cyclopentadiene, 1,2,3,4,5,5-hexachloro-
U058	50-18-0	Cyclophosphamide
U240	94-75-7	2,4-D, salts & esters
U059	20830-81-3	Daunomycin
U060	72-54-8	DDD

Hazardous waste No.	Chemical abstracts No.	Substance
U061	50-29-3	DDT
U062	2303-16-4	Diallate
U063	53-70-3	Dibenz(a,h)anthracene
U064	189-55-9	Dibenzo(a,i)pyrene
U066	96-12-8	1,2-Dibromo-3-chloropropane
U069	84-74-2	Diethyl phthalate
U070	95-50-1	o-Dichlorobenzene
U071	541-73-1	m-Dichlorobenzene
U072	106-46-7	p-Dichlorobenzene
U073	91-94-1	3,3'-Dichlorobenzidine
U074	764-41-0	1,4-Dichloro-2-butene (l,t)
U075	75-71-8	Dichlorodifluoromethane
U078	75-35-4	1,1-Dichloroethylene
U079	156-60-5	1,2-Dichloroethylene
U025	111-44-4	Dichloroethyl ether
U027	106-60-1	Dichloroisopropyl ether
U024	111-91-1	Dichloromethoxy ethane
U081	120-83-2	2,4-Dichlorophenol
U082	87-65-0	2,6-Dichlorophenol
U084	542-75-6	1,3-Dichloropropene
U085	1464-53-5	1,2,3,4-Dichlorobutane (l,t)
U108	123-91-1	1,4-Diethyleneoxide
U028	117-81-7	Diethylhexyl phthalate
U086	1615-80-1	N,N'-Diethylhydrazine
U087	3288-58-2	O,O-Diethyl S-methyl dithiophosphate
U088	84-66-2	Diethyl phthalate
U089	56-53-1	Diethylstilbestrol
U090	94-58-6	Dihydrosalrole
U091	119-90-4	3,3'-Dimethoxybenzidine
U092	124-40-3	Dimethylamine (l)
U093	60-11-7	p-Dimethylaminobenzene
U094	57-97-6	7,12-Dimethylbenz(a)anthracene
U095	119-93-7	3,3'-Dimethylbenzidine
U096	80-15-9	alpha,alpha-Dimethylbenzylhydroperoxide (R)
U097	79-44-7	Dimethylcarbamoyl chloride
U098	57-14-7	1,1-Dimethylhydrazine
U099	540-73-8	1,2-Dimethylhydrazine
U101	105-67-9	2,4-Dimethylphenol
U102	131-11-3	Dimethyl phthalate
U103	77-78-1	Dimethyl sulfate
U105	121-14-2	2,4-Dinitrotoluene
U106	608-20-2	2,6-Dinitrotoluene
U107	117-84-0	Di-n-octyl phthalate
U108	123-91-1	1,4-Dioxane
U109	122-66-7	1,2-Diphenylhydrazine
U110	142-84-7	Dipropylamine (l)
U111	621-64-7	Di-n-propylnitrosamine
U041	106-89-8	Epichlorohydrin
U001	75-07-0	Ethanol (l)
U174	55-18-5	Ethanamine, N-ethyl-N-nitroso-
U155	91-80-5	1,2-Ethanediamine, N,N-dimethyl-N'-2-pyridinyl-N'-(2-thenylmethyl)-
U067	106-93-4	Ethane, 1,2-dibromo-
U076	75-34-3	Ethane, 1,1-dichloro-
U077	107-06-2	Ethane, 1,2-dichloro-
U131	67-72-1	Ethane, hexachloro-
U024	111-91-1	Ethane, 1,1'-(methylenbis(oxy))bis(2-chloro-
U117	60-29-7	Ethane, 1,1'-oxybis(l)
U025	111-44-4	Ethane, 1,1'-oxybis(2-chloro-
U184	76-01-7	Ethane, pentachloro-
U208	630-20-6	Ethane, 1,1,1,2-tetrachloro-
U209	79-34-5	Ethane, 1,1,2,2-tetrachloro-
U218	62-55-5	Ethanethioamide
U226	71-55-6	Ethane, 1,1,1-trichloro-
U227	79-00-5	Ethane, 1,1,2-trichloro-
U359	110-80-5	Ethanol, 2-ethoxy-
U173	1116-54-7	Ethanol, 2,2'-(nitrosomino)bis-
U004	98-86-2	Ethanone, 1-phenyl-
U043	75-01-4	Ethene, chloro-
U042	110-75-8	Ethene, (2-chloroethoxy)-
U078	75-35-4	Ethene, 1,1-dichloro-

Haz- ardous waste No.	Chemical abstracts No.	Substance
U079	158-60-5	Ethene, 1,2-dichloro-, (E)-
U210	127-18-4	Ethene, tetrachloro-
U228	78-01-6	Ethene, trichloro-
U112	141-78-6	Ethyl acetate (I)
U113	140-88-5	Ethyl acrylate (I)
U238	51-79-6	Ethyl carbamate (urethane)
U117	60-29-7	Ethyl ether (I)
U114	111-54-6	Ethylenebis(dithiocarbamic acid, salts & esters
U067	108-93-4	Ethylene dibromide
U077	107-06-2	Ethylene dichloride
U359	110-80-5	Ethylene glycol monoethyl ether
U115	75-21-8	Ethylene oxide (I,T)
U116	98-45-7	Ethylenethiourea
U076	75-34-3	Ethylidene dichloride
U118	97-63-2	Ethyl methacrylate
U119	62-50-0	Ethyl methanesulfonate
U120	208-44-0	Fluoranthene
U122	50-00-0	Formaldehyde
U123	64-18-6	Formic acid (C,T)
U124	110-00-9	Furan (I)
U125	98-01-1	2-Furancarboxaldehyde (I)
U147	108-31-6	2,5-Furandione
U213	109-99-9	Furan, tetrahydro-(I)
U125	98-01-1	Furfural (I)
U124	110-00-9	Furfuran (I)
U208	18883-66-4	Glucopyranose, 2-deoxy-2-(3-methyl-3-nitrosoureido)-, D-
U208	18883-66-4	D-Glucose, 2-deoxy-2-[[[(methylnitrosoamino)- carbonyl]amino]-
U126	765-34-4	Glycidylaldehyde
U163	70-25-7	Guandine, N-methyl-N'-nitro-N-nitroso-
U127	118-74-1	Hexachlorobenzene
U128	87-68-3	Hexachlorobutadiene
U130	77-47-4	Hexachlorocyclopentadiene
U131	67-72-1	Hexachloroethane
U132	70-30-4	Hexachlorophene
U243	1888-71-7	Hexachloropropene
U133	302-01-2	Hydrazine (R,T)
U066	1615-80-1	Hydrazine, 1,2-diethyl-
U098	57-14-7	Hydrazine, 1,1-dimethyl-
U099	540-73-8	Hydrazine, 1,2-dimethyl-
U109	122-66-7	Hydrazine, 1,2-diphenyl-
U134	7664-39-3	Hydrofluoric acid (C,T)
U134	7664-39-3	Hydrogen fluoride (C,T)
U135	7783-06-4	Hydrogen sulfide
U135	7783-06-4	Hydrogen sulfide H ₂ S
U096	80-15-9	Hydroperoxide, 1-methyl-1-phenylethyl-, (R)
U116	98-45-7	2-Imidazolidinethione
U137	193-39-5	Indeno(1,2,3-cd)pyrene
U190	85-44-9	1,3-Isobenzofurandione
U140	78-63-1	Isobutyl alcohol (I,T)
U141	120-58-1	Isosafrole
U142	143-50-0	Kepone
U143	303-34-4	Lasocarpine
U144	301-04-2	Lead acetate
U146	1335-32-6	Lead, bis(acetato-O)tetrahydroxy-
U145	7446-27-7	Lead phosphate
U146	1335-32-6	Lead subacetate
U129	58-89-9	Lindane
U163	70-25-7	MNNG
U147	108-31-6	Maleic anhydride
U148	123-33-1	Maleic hydrazide
U149	108-77-3	Meisonitrile
U150	148-82-3	Meiphsien
U151	7439-97-6	Mercury
U152	126-66-7	Methacrylonitrile (I, T)
U092	124-40-3	Methanamine, N-methyl-, (I)
U029	74-83-9	Methane, bromo-
U045	74-87-3	Methane, chloro-, (I, T)
U046	107-30-2	Methane, chloromethoxy-
U068	74-95-3	Methane, dibromo-

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Haz- ardous waste No.	Chemical abstracts No.	Substance
U080	75-09-2	Methane, dichloro-
U075	75-71-8	Methane, dichlorodifluoro-
U138	74-88-4	Methane, iodo-
U119	62-50-0	Methanesulfonic acid, ethyl ester
U211	56-23-5	Methane, tetrachloro-
U153	74-93-1	Methanethiol (l, T)
U225	75-25-2	Methane, tribromo-
U044	67-66-3	Methane, trichloro-
U121	75-69-4	Methane, trichlorofluoro-
U036	57-74-9	4,7-Methano-1H-indene, 1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-
U154	67-56-1	Methanol (l)
U155	91-80-5	Methapyrene
U142	143-50-0	1,3,4-Metheno-2H-cyclobuta[cd]pentalen-2-one, 1,1a,3,3a,4,5,5,5a,5b,6-decachlorooctahydro-
U247	72-43-5	Methoxychlor
U154	67-56-1	Methyl alcohol (l)
U029	74-83-9	Methyl bromide
U186	504-60-9	1-Methylbutadiene (l)
U045	74-87-3	Methyl chloride (l, T)
U156	79-22-1	Methyl chloroacetate (l, T)
U226	71-55-6	Methyl chloroform
U157	56-49-5	3-Methylcholanthrene
U158	101-14-4	4,4'-Methylenebis(2-chloroaniline)
U068	74-95-3	Methylene bromide
U080	75-09-2	Methylene chloride
U159	78-93-3	Methyl ethyl ketone (MEK) (l, T)
U160	1338-23-4	Methyl ethyl ketone peroxide (R, T)
U138	74-88-4	Methyl iodide
U161	108-10-1	Methyl isobutyl ketone (l)
U162	80-62-6	Methyl methacrylate (l, T)
U161	108-10-1	4-Methyl-2-pentanone (l)
U164	56-04-2	Methylthiouracil
U010	50-07-7	Mitomycin C
U059	20830-81-3	5,12-Naphthacenedione, 8-acetyl-10-[(3-amino-2,3,6-indexyl)-alpha-L-xylo-hexopyranosyl]oxy]-7,8,9,10-tetrahydro-6,8,11-trihydroxy-1-methoxy-, (8S-cis)-
U167	134-32-7	1-Naphthalenamine
U168	91-59-8	2-Naphthalenamine
U026	494-03-1	Naphthalenamine, N,N'-bis(2-chloroethyl)-
U165	91-20-3	Naphthalene
U047	91-58-7	Naphthalene, 2-chloro-
U166	130-15-4	1,4-Naphthalenedione
U236	72-57-1	2,7-Naphthalenedisulfonic acid, 3,3'-[(3,3'-dimethyl[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis(5-amino-4-hydroxy)-, tetrasodium salt
U166	130-15-4	1,4-Naphthoquinone
U167	134-32-7	alpha-Naphthylamine
U168	91-59-8	beta-Naphthylamine
U217	10102-45-1	Nitric acid, thallium(1+) salt
U169	98-95-3	Nitrobenzene (l, T)
U170	100-02-7	p-Nitrophenol
U171	79-46-9	2-Nitropropane (l, T)
U172	924-16-3	N-Nitrosod-n-butylamine
U173	1116-54-7	N-Nitrosodethanolamine
U174	55-18-5	N-Nitrosodethylamine
U176	759-73-9	N-Nitroso-N-ethylurea
U177	684-93-5	N-Nitroso-N-methylurea
U178	615-53-2	N-Nitroso-N-methylurethane
U179	100-75-4	N-Nitrosopropidine
U180	930-55-2	N-Nitrosopyrrolidine
U181	99-55-8	5-Nitro-o-toluidine
U193	1120-71-4	1,2-Oxathiolane, 2,2-dioxide
U058	50-18-0	2H-1,3,2-Oxazaphosphorin-2-amine, N,N-bis(2-chloroethyl)tetrahydro-, 2-oxide
U115	75-21-8	Oxirane (l, T)
U126	765-34-4	Oxiranecarboxaldehyde
U041	106-89-8	Oxirane, (chloromethyl)-
U182	123-63-7	Paraldehyde
U183	608-93-5	Pentachlorobenzene
U184	76-01-7	Pentachloroethane
U185	82-68-8	Pentachloronitrobenzene (PCNB)
See	87-86-5	Pentachlorophenol

F027

Haz- ardous waste No.	Chemical abstract No.	Substance
U161	108-10-1	Pentanol, 4-methyl-
U166	504-60-9	1,3-Pentadiene (I)
U187	62-44-2	Phenacetin
U188	108-95-2	Phenol
U048	95-57-8	Phenol, 2-chloro-
U039	59-50-7	Phenol, 4-chloro-3-methyl-
U081	120-83-2	Phenol, 2,4-dichloro-
U082	87-65-0	Phenol, 2,6-dichloro-
U089	56-53-1	Phenol, 4,4'-(1,2-diethyl-1,2-ethenediyl)bis-, (E)-
U101	105-67-9	Phenol, 2,4-dimethyl-
U052	1318-77-3	Phenol, methyl-
U132	70-30-4	Phenol, 2,2'-methylenebis(3,4,6-trichloro-
U170	100-02-7	Phenol, 4-nitro-
See F027	87-86-5	Phenol, pentachloro-
See F027	58-90-2	Phenol, 2,3,4,6-tetrachloro-
See F027	95-95-4	Phenol, 2,4,5-trichloro-
See F027	88-06-2	Phenol, 2,4,6-trichloro-
U150	148-82-3	L-Phenylalanine, 4-(bis(2-chloroethyl)amino)-
U145	7446-27-7	Phosphonic acid, lead(2+) salt (2:3)
U087	3288-58-2	Phosphorodithioic acid, O,O-diethyl S-methyl ester
U169	1314-80-3	Phosphorus sulfide (R)
U190	85-44-9	Phthalic anhydride
U191	109-06-8	2-Picoline
U179	100-75-4	Piperidine, 1-nitroso-
U192	23950-58-5	Pronamide
U194	107-10-8	1-Propanamine (I,T)
U111	621-64-7	1-Propanamine, N-nitroso-N-propyl-
U110	142-84-7	1-Propanamine, N-propyl- (I)
U066	96-12-8	Propane, 1,2-dibromo-3-chloro-
U083	78-87-5	Propane, 1,2-dichloro-
U149	109-77-3	Propenedinitrile
U171	79-46-9	Propane, 2-nitro- (I,T)
U027	108-60-1	Propane, 2,2'-oxybis(2-chloro-
U193	1120-71-4	1,3-Propane sultone
See F027	93-72-1	Propanoic acid, 2-(2,4,5-trichlorophenoxy)-
U235	126-72-7	1-Propanol, 2,3-dibromo- phosphate (3:1)
U140	78-83-1	1-Propanol, 2-methyl- (I,T)
U002	67-64-1	2-Propanone (I)
U007	79-06-1	2-Propanamide
U084	542-75-6	1-Propene, 1,3-dichloro-
U243	1888-71-7	1-Propene, 1,1,2,3,3,3-hexachloro-
U009	107-13-1	2-Propenenitrile
U152	126-98-7	2-Propenenitrile, 2-methyl- (I,T)
U008	79-10-7	2-Propenoic acid (I)
U113	140-88-5	2-Propenoic acid, ethyl ester (I)
U118	97-63-2	2-Propenoic acid, 2-methyl-, ethyl ester
U162	80-62-6	2-Propenoic acid, 2-methyl-, methyl ester (I,T)
U194	107-10-8	n-Propylamine (I,T)
U083	78-87-5	Propylene dichloride
U146	123-33-1	3,6-Pyridazinedione, 1,2-dihydro-
U196	110-86-1	Pyridine
U191	109-06-8	Pyridine, 2-methyl-
U237	66-75-1	2,4-(1H,3H)-Pyrimidinedione, 5-(bis(2-chloro-ethyl)amino)-
U164	56-04-2	4(1H)-Pyrimidinone, 2,3-dihydro-6-methyl-2-thio-
U180	930-55-2	Pyrrolidine, 1-nitroso-
U200	50-55-5	Reserpine
U201	108-46-3	Resorcinol
U202	81-07-2	Saccharin, & salts
U203	94-59-7	Saltol
U204	7783-00-8	Selenous acid
U204	7783-00-8	Selenium dioxide
U205	7488-56-4	Selenium sulfide
U205	7488-56-4	Selenium sulfide SeS ₂ (R,T)
U015	115-02-6	L-Serine, diazoacetate (ester)

Hazardous waste No.	Chemical abstracts No.	Substance
See F027	93-72-1	Silvex (2,4,5-TP)
U208	18883-68-4	Streptozotocin
U103	77-78-1	Sulfonic acid, dimethyl ester
U189	1314-80-3	Sulfur phosphide (R)
See F027	93-78-5	2,4,5-T
U207	95-94-3	1,2,4,5-Tetrachlorobenzene
U208	630-20-8	1,1,1,2-Tetrachloroethane
U209	79-34-5	1,1,2,2-Tetrachloroethane
U210	127-18-4	Tetrachloroethylene
See F027	58-90-2	2,3,4,6-Tetrachlorophenol
U213	109-99-9	Tetrahydrofuran (I)
U214	563-68-8	Thallium(I) acetate
U215	6533-73-9	Thallium(I) carbonate
U216	7791-12-0	Thallium(I) chloride
U216	7791-12-0	Thallium chloride TlCl
U217	10102-45-1	Thallium(I) nitrate
U218	62-55-5	Thioacetamide
U153	74-93-1	Thiomethanol (I,T)
U244	137-26-8	Thioperoxydicarbonic diimide ((H ₂ N)C(S)) ₂ S ₂ , tetramethyl-
U219	62-56-6	Thiourea
U244	137-26-8	Thiram
U220	108-88-3	Toluene
U221	25376-45-8	Toluenediamine
U223	26471-82-5	Toluene diisocyanate (R,T)
U328	95-53-4	o-Toluidine
U353	106-49-0	p-Toluidine
U222	636-21-5	o-Toluidine hydrochloride
U011	61-82-5	1H-1,2,4-Triazol-3-amine
U227	79-00-5	1,1,2-Trichloroethane
U228	79-01-6	Trichloroethylene
U121	75-89-4	Trichloromono-fluoromethane
See F027	95-95-4	2,4,5-Trichlorophenol
See F027	88-06-2	2,4,6-Trichlorophenol
U234	99-35-4	1,3,5-Trinitrobenzene (R,T)
U182	123-83-7	1,3,5-Trioxane, 2,4,6-trimethyl-
U235	126-72-7	Tris(2,3-dibromopropyl) phosphate
U236	72-57-1	Trypan blue
U237	66-75-1	Uracil mustard
U176	759-73-9	Urea, N-ethyl-N-nitroso-
U177	684-83-5	Urea, N-methyl-N-nitroso-
U043	75-01-4	Vinyl chloride
U248	¹ 81-81-2	Warfium, & salts, when present at concentrations of 0.3% or less
U239	1330-20-7	Xylene (I)
U200	50-55-5	Yohimben-16-carboxylic acid, 11,17-dimethoxy-18-((3,4,5-trimethoxybenzoyloxy)-, methyl ester, (3beta,16beta,17alpha,18beta,20alpha)-
U249	1314-84-7	Zinc phosphide Zn ₃ P ₂ , when present at concentrations of 10% or less

¹ CAS Number given for parent compound only.

(Approved by the Office of Management and Budget under control number 2050-0047)
[45 FR 78529, 78541, Nov. 25, 1980]

EDITORIAL NOTE: For FEDERAL REGISTER citations affecting § 261.33, see the List of CFR Sections Affected in the Finding Aids section of this volume.

APPENDIX I—REPRESENTATIVE SAMPLING METHODS

The methods and equipment used for sampling waste materials will vary with the form and consistency of the waste materials to be sampled. Samples collected using the

sampling protocols listed below, for sampling waste with properties similar to the indicated materials, will be considered by the Agency to be representative of the waste.

Extremely viscous liquid—ASTM Standard D140-70 Crushed or powdered material—ASTM Standard D346-75 Soil or rock-like

Appendix B

Waste Minimization Voluntary Assessment Forms

WASTE MINIMIZATION VOLUNTARY ASSESSMENT

SUMMARY INFORMATION

Fill Out One for Each Location

Location Name: _____ Date: _____

Address: _____ Assessor: _____

Nature of Business: _____

Currently have waste minimization program? Yes: _____ No: _____

If so, describe: _____

Are the costs associated with generating the waste assigned to individual production units?

Yes: ____ No: ____ If not, how are they assigned?

Fill Out One for Each Location

[illegible]

Products and Specs

Name	Specification	Cost/unit	Units/year

Name	Specification

WASTE MINIMIZATION VOLUNTARY ASSESSMENT SUMMARY INFORMATION

(one form per waste stream)

Waste Stream Number: _____

1. Waste stream name: _____
(waste oil, still bottoms, vents, etc.)
2. Source of waste stream: _____
(Enter process or equipment from which waste streams are discharged)
3. Waste stream flow/quantity: _____
(minimum, maximum, and average flow)
4. Is waste stream continuous or intermittent? _____
5. Which of the following is the cause of the waste? Mark all that apply.

A. Process Chemistry _____

Describe _____

_____
_____
_____

1. Reaction Stoichiometry _____

2. Kinetics _____

3. Yield _____

4. Conversion _____

5. Other, Explain _____

_____

B. Engineering Design _____

Describe _____

_____
_____
_____

1. Capacity _____

2. Bottlenecks _____

3. Pressure _____

4. Temperature Limitations _____

5. Process Layout _____

6. Process Control Philosophy _____

7. Instrumentation _____

8. Other, Explain _____

_____

**WASTE MINIMIZATION VOLUNTARY ASSESSMENT
SUMMARY INFORMATION (continued)**

(one form per waste stream)

Waste Stream Number: _____

C. Operations _____ Describe _____ _____ _____	1. Operating Rates _____ 2. Order of Addition _____ 3. Fate of Residuals at Shutdown _____ 4. Scheduling of Campaigns _____ 5. Other, Explain _____ _____

D. Maintenance _____ Describe _____ _____ _____	1. Leaking Equipment _____ 2. Spills _____ 3. Corrosion _____ 4. Calibration of Instruments _____ 5. Maintenance Chemicals _____ 6. Cleaning Procedures _____ 7. Other, Explain _____ _____

6. What are the components of the Waste Stream?

Component

Component Origin

Component No. 1

Name _____ Conc., ppm _____ Raw Mat. ☐ Product ☐
Usable By-product ☐ Nonusable By-product ☐ Solvent ☐ Catalyst ☐ Impurities ☐

Component No. 2

Name _____ Conc., ppm _____ Raw Mat. ☐ Product ☐
Usable By-product ☐ Nonusable By-product ☐ Solvent ☐ Catalyst ☐ Impurities ☐

**WASTE MINIMIZATION VOLUNTARY ASSESSMENT
SUMMARY INFORMATION (continued)**

(one form per waste stream)

Waste Stream Number: _____

Component No. 3

Name _____ Conc., ppm _____ Raw Mat. ☐ Product ☐
Usable By-product ☐ Nonusable By-product ☐ Solvent ☐ Catalyst ☐ Impurities ☐

Component No. 4

Name _____ $\mu\text{Ci/g}$ _____ Raw Mat. ☐ Product ☐ Usable By-product ☐
Nonusable By-product ☐ Solvent ☐ Catalyst ☐ Impurities ☐

Component No. 5

Name _____ $\mu\text{Ci/g}$ _____ Raw Mat. ☐ Product ☐ Usable By-product ☐
Nonusable By-product ☐ Solvent ☐ Catalyst ☐ Impurities ☐

8. What is the current onsite disposition of the waste stream? _____
_____

9. What are the current criteria and disposal limitations?

pH _____ Radionuclide No. 1. $\mu\text{Ci/g}$ _____
TSS, ppm _____ Radionuclide No. 2. $\mu\text{Ci/g}$ _____
TDS, ppm _____
BOD, ppm _____
COD, ppm _____
TOC, ppm _____

Heavy Metals:

Heavy Metal No. 1	_____	Conc., ppm	_____
Heavy Metal No. 2	_____	Conc., ppm	_____
Heavy Metal No. 3	_____	Conc., ppm	_____
Heavy Metal No. 4	_____	Conc., ppm	_____
Heavy Metal No. 5	_____	Conc., ppm	_____

**WASTE MINIMIZATION VOLUNTARY ASSESSMENT
SUMMARY INFORMATION (continued)**

(one form per waste stream)

Waste Stream Number: _____

9. (continued)

Organics:

Organic No. 1 _____ Conc., ppm _____

Organic No. 2 _____ Conc., ppm _____

Organic No. 3 _____ Conc., ppm _____

Organic No. 4 _____ Conc., ppm _____

Organic No. 5 _____ Conc., ppm _____

10. What are the permits relative to waste stream disposition?

A. NPDES _____

B. RCRA Part B _____

C. Air _____

D. TSCA _____

E. 10CFR61 _____

F. State, Explain _____
_____

11. a. What is the current offsite disposition of the waste stream? _____
_____

b. Disposition Rate _____

Units: lbs/min _____

gal/min _____

Cost Per Unit _____

Total Cost, Dollars _____

**WASTE MINIMIZATION VOLUNTARY ASSESSMENT
SUMMARY INFORMATION (continued)**

(one form per waste stream)

Waste Stream Number: _____

12. What is the cost of chemicals currently lost in the process?

Chemical No. 1 _____

Form: Solid _____ Sludge _____ Liquid _____ Emission _____

Rate of Loss _____

Units: lbs/min _____ gals/min _____ ft³/min _____

Cost Per Unit (dollars) _____

Total Chemical No. 1: Lost Per Day _____

Chemical No. 2 _____

Form: Solid _____ Sludge _____ Liquid _____ Emission _____

Rate of Loss _____

Units: lbs/min _____ gals/min _____ ft³/min _____

Cost Per Unit (dollars) _____

Total Chemical No. 2: Lost Per Day _____

Chemical No. 3 _____

Form: Solid _____ Sludge _____ Liquid _____ Emission _____

Rate of Loss _____

Units: lbs/min _____ gals/min _____ ft³/min _____

Cost Per Unit (dollars) _____

Total Chemical No. 3: Lost Per Day _____

Total Cost Lost Chemicals _____

**WASTE MINIMIZATION VOLUNTARY ASSESSMENT
SUMMARY INFORMATION (continued)**

(one form per waste stream)

Waste Stream Number: _____

13. Is waste stream currently being treated?

No _____

Yes _____

Treatment Process:

A. Carbon Adsorption _____

B. Stripping _____

C. Incineration _____

D. Biological _____

E. Precipitation/Coagulation/
Flocculation/Sedimentation _____

F. Filtration _____

G. Distillation _____

H. Ion Exchange _____

I. Drying _____

J. Membrane Separations _____

K. Chemical Oxidation _____

L. Extraction _____

M. Evaporation _____

N. Neutralization _____

O. Wet Air Oxidation _____

P. Hydrolysis _____

Q. Photolysis _____

R. Chemical Reaction _____

S. UV Catalyzed Oxidation _____

Treatment Parameters:

A. Are Chemicals Used?

No _____

Yes _____

Chemical _____

Consumption _____

Units: gal/min _____ lbs/min _____ ft³/min _____

**WASTE MINIMIZATION VOLUNTARY ASSESSMENT
SUMMARY INFORMATION (continued)**

(one form per stream)

Waste Stream Number: _____

B. What are the treatment conditions?

Temperature, °F _____

pH _____

Flow Rate _____

Units: lbs/min _____ gal/min _____ ft³/min _____

Treatment Time, Minutes _____

C. Is there existing treatment equipment? More than one may apply.

No _____

Yes _____

What Type?

A. Carbon Adsorbers _____ Size _____ Type _____

B. Ion Exchange _____ Size _____ Type _____

C. Reverse Osmosis/Membrane Processes _____ Size _____ Type _____

D. Incinerator _____ Size _____ Type _____

E. Precipitation _____ Size _____ Type _____

F. Filtration _____ Size _____ Type _____

G. Stripper _____ Size _____ Type _____

H. Bioreactor _____ Size _____ Type _____

I. Distillation Column _____ Size _____ Type _____

J. Dryer _____ Size _____ Type _____

K. Chemical Reactor _____

Type

1. Neutralization _____ Size _____

2. Wet Air Oxidation _____ Size _____

3. UV Catalyzed Oxidation _____ Size _____ UV Light Wattage _____

4. Hydrolysis _____ Size _____

**WASTE MINIMIZATION VOLUNTARY ASSESSMENT
SUMMARY INFORMATION (continued)**

(one form per waste stream)

Waste Stream Number: _____

L. Photolysis Reactor _____ Size _____ Radiation Source _____

M. Other _____

_____

D. Other Pertinent Information _____

_____

_____

_____

Appendix C
EPA Cost Information Forms

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet <u>1</u> of <u>6</u> Page <u> </u> of <u> </u>

WORKSHEET
15a

COST INFORMATION

WM Option Description _____

CAPITAL COSTS - Include all costs as appropriate.

TOTALS

☐ Purchased Process Equipment		
Price (fob factory)	_____	
Taxes, freight, insurance	_____	
Delivered equipment cost	_____	
Price for initial Spare Parts Inventory	_____	_____
☐ Estimated Materials Cost		
Piping	_____	
Electrical	_____	
Instruments	_____	
Structural	_____	
Insulation/Piping	_____	_____
☐ Estimated Costs for Utility Connections and New Utility Systems		
Electricity	_____	
Steam	_____	
Cooling Water	_____	
Process Water	_____	
Refrigeration	_____	
Fuel (Gas or Oil)	_____	
Plant Air	_____	
Inert Gas	_____	_____
☐ Estimated Costs for Additional Equipment		
Storage & Material Handling	_____	
Laboratory/Analytical	_____	
Other	_____	_____
☐ Site Preparation		
(Demolition, site clearing, etc.)		_____
☐ Estimated Installation Costs		
Vendor	_____	
Contractor	_____	
In-house Staff	_____	_____

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet <u>2</u> of <u>6</u> Page ____ of ____

WORKSHEET
15b

COST INFORMATION
(continued)

CAPITAL COSTS (Cont.)

TOTALS

☐ **Engineering and Procurement Costs (In-house & outside)**

Planning _____
Engineering _____
Procurement _____
Consultants _____

☐ **Start-up Costs**

Vendor _____
Contractor _____
In-house _____

☐ **Training Costs**

_____

☐ **Permitting Costs**

Fees _____
In-house Staff Costs _____

☐ **Initial Charge of Catalysts and Chemicals**

Item #1 _____

Item #2 _____

☐ **Working Capital (Raw Materials, Product, Inventory, Materials and Supplies (not elsewhere specified)).**

Item #1 _____

Item #2 _____

Item #3 _____

Item #4 _____

☐ **Estimated Salvage Value (if any)**

_____

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet <u>3</u> of <u>6</u> Page <u> </u> of <u> </u>

WORKSHEET
15c

COST INFORMATION

(continued)

CAPITAL COST SUMMARY

Cost Item	Cost
Purchased Process Equipment	
Materials	
Utility Connections	
Additional Equipment	
Site Preparation	
Installation	
Engineering and Procurement	
Start-up Cost	
Training Costs	
Permitting Costs	
Initial Charge of Catalysts and Chemicals	
Fixed Capital Investment	
Working Capital	
Total Capital Investment	
Salvage Value	

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet <u>4</u> of <u>6</u> Page <u> </u> of <u> </u>

WORKSHEET
15d

COST INFORMATION

(continued)

☐ **Estimated Decrease (or Increase) in Utilities**

Utility	Unit Cost \$ per unit	Decrease (or Increase) in Quantity Unit per time	Total Decrease (or Increase) \$ per time
Electricity			
Steam			
Cooling Process			
Process Water			
Refrigeration			
Fuel (Gas or Oil)			
Plant Air			
Inert Air			

INCREMENTAL OPERATING COSTS - Include all relevant operating savings. Estimate these costs on an incremental basis (i.e., as decreases or increases over existing costs).

☐ **BASIS FOR COSTS**   Annual _____ Quarterly _____ Monthly _____ Daily _____ Other _____

☐ **Estimated Disposal Cost Saving**

Decrease in TSDF Fees _____

Decrease in State Fees and Taxes _____

Decrease in Transportation Costs _____

Decrease in Onsite Treatment and Handling _____

Decrease in Permitting, Reporting and Recordkeeping _____

Total Decrease in Disposal Costs _____

☐ **Estimated Decrease in Raw Materials Consumption**

Materials	Unit Cost \$ per unit	Reduction in Quantity Units per time	Decrease in Cost \$ per time

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet <u>5</u> of <u>6</u> Page <u> </u> of <u> </u>

WORKSHEET
15e

COST INFORMATION

(continued)

☐ Estimated Decrease (or Increase) in Ancillary Catalysts and Chemicals

Catalyst/Chemical	Unit Cost \$ per unit	Decrease (or Increase) in Quantity Unit per time	Total Decrease (or Increase) \$ per time

☐ Estimated Decrease (or Increase) in Operating Costs and Maintenance Labor Costs
(Include cost of supervision, benefits and burden).

_____

_____

☐ Estimated Decrease (or Increase) in Operating and Maintenance Supplies and Costs.

_____

_____

☐ Estimated Decrease (or Increase) in Insurance and Liability Costs (explain).

_____

_____

☐ Estimated Decrease (or Increase) in Other Operating Costs (explain).

_____

_____

INCREMENTAL REVENUES

☐ Estimated Incremental Revenues from an Increase (or Decrease) in Production or Marketable By-products (explain).

_____

_____

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet <u>6</u> of <u>6</u> Page <u> </u> of <u> </u>

WORKSHEET
15 f

COST INFORMATION

(continued)

INCREMENTAL OPERATING COST AND REVENUE SUMMARY (ANNUAL BASIS)

Decreases in Operating Cost or Increases in Revenue are Positive.
Increases in Operating Cost or Decrease in Revenue are Negative.

Operating Cost/Revenue Item	\$ per year
Decrease in Disposal Cost	
Decrease in Raw Materials Cost	
Decrease (or Increase) in Utilities Cost	
Decrease (or Increase) in Catalysts and Chemicals	
Decrease (or Increase) in O & M Labor Costs	
Decrease (or Increase) in O & M Supplies Costs	
Decrease (or Increase) in Insurance/Liabilities Costs	
Decrease (or Increase) in Other Operating Costs	
Incremental Revenues from Increased (Decreased) Production	
Incremental Revenues from Marketable By-products	
Net Operating Cost Savings	

Appendix D

Technologies for Treating Mixed Wastes

APPENDIX D

TECHNOLOGIES FOR TREATING MIXED WASTES

1. Introduction

When mixed waste generators have derived all the benefits that waste minimization techniques can provide, they may find that they are still generating quantities of mixed wastes that require disposal or storage. Presently there are very few options open to generators who want to dispose of their mixed wastes. With few exceptions, there are no hazardous waste facilities that can accept radioactive wastes and, similarly, no radioactive disposal facilities that can accept hazardous wastes. The options open to the mixed waste generator who cannot find suitable disposal for their mixed waste are (a) to store the mixed waste until such time that suitable disposal is available or until enough of the radioactive component has decayed so that the waste can be disposed of as a hazardous waste, or (b) to treat the mixed waste so that it is either no longer a hazardous and radioactive waste mixture (separation of the hazardous from the radioactive components), or (c) to treat the waste so that it is no longer hazardous.

For mixed wastes that are considered hazardous because they exhibit one or more characteristics that meet any of the definitions specified in 40 CFR 261.21 through 261.24 (D listed wastes), there is the option of removing the hazardous characteristics from this waste by treating the waste thereby making it suitable for disposal LLW. If the mixed waste is considered hazardous because it contains a listed hazardous chemical, then the only option for delisting the waste is to either destroy or remove the hazardous component from the waste.

This appendix lists many of the technologies that can be used to treat mixed wastes. The technologies listed are only to illustrate potential usefulness and not a complete description of all possible alternatives. The treatment of mixed wastes and waste in general is everchanging and new methods and applications for old technologies emerge almost daily. Usually a treatment technology is designed to meet one or more of three objectives: destruction of wastes, separation of wastes, or stabilization of wastes. The technology discussions have been grouped by objective.

2. Destruction Technologies

2.1 Thermal Destruction/Oxidation

Thermal oxidation refers to a variety of treatment processes that seek to achieve a controlled, high-temperature oxidation reaction between combustible substances and air or oxygen. The process must be run under controlled conditions of retention time, temperature, and turbulence within dedicated single or multiple combustion chambers of proper geometric configuration and size. The incineration oxidation reaction changes the composition and physical state of the waste, usually resulting in substantial volume reduction and destruction of some hazardous components.

A number of different types of thermal treatment equipment are currently being used to treat organic contaminated soil and solid wastes. For relatively volatile organic compounds or where treatment criteria are not stringent (high residual organic concentrations are acceptable), lower treatment temperatures can be used. This type of thermal treatment equipment is usually used to treat soil containing solvents or hydrocarbon fuels. For polyaromatic hydrocarbons (PAHs), or where very low residual contaminant concentrations must be achieved, higher temperatures are required. Thermal treatment equipment that falls into this category includes indirect-fired calciners and dryers and direct-fired rotary kilns and fluid bed incinerators. Indirect-fired thermal treatment processes and rotary kiln incinerators consist of a primary (combustion) chamber, where the soil/solids are mixed and heated to drive off (desorb) moisture and organics, and the secondary combustion chamber, which oxidizes the volatilized contaminants from the primary combustion chamber. Pyrolysis or oxidation of nonvolatile organics can also take place in the primary chamber; this may be important in meeting criteria for residual organics. The predominant type of system used for large-scale treatment of organic-contaminated soils has been rotary kiln incinerators.

Incinerators, if properly designed, can accept and effectively treat a wide variety of waste forms (i.e., liquids, solids, sludges, containerized waste), making them versatile. For instance, liquid injection systems can handle pumpable liquid organic wastes, although they are unsuitable for inorganics and heavy metal contaminated waste. A pyrolysis system can handle viscous liquids, sludges, solids, high ash content materials, salts, metals, and halogenated wastes. The limitations of this system are that it requires homogeneous waste input and that metals and salts in the residue may be leachable thus requiring further treatment. Rotary kiln incinerators can handle solid, liquid, or gaseous organic wastes. Disadvantages of the rotary kiln process are that containerized wastes are difficult to handle, high

inorganic salt or heavy metal content wastes require special consideration, and fine particulate matter must be limited to ensure proper operation of the system.

Costs for thermal treatment systems vary greatly depending on the type of system installed.

2.2 Supercritical Water Oxidation

This is a relatively new technology used for the complete destruction of organic matter in waste streams to water, carbon dioxide, nitrogen gas, and inorganic salts. The process is based on using water above its critical point (375°F and 218 atm) as the medium for a rapid and highly efficient oxidation reaction. Key to the success of the process of oxidizing organic compounds is the fact that gases, including oxygen, and organic substances are completely soluble in supercritical water, whereas inorganic salts exhibit greatly reduced solubilities under these process conditions. Thus it is possible to carry out oxidation reactions by dissolving organic substances and oxygen in the supercritical medium, thereby bringing them to the intimate, single-phase contact at temperatures and molecular densities that allow conventional oxidation reactions to proceed rapidly to completion, and inorganic components can be separated out as solid salts for safe disposal.

This process has been developed through bench- and pilot-scale tests in the laboratory on both pure chemicals and synthesized mixtures of chemicals, but applicability to mixed waste has not been demonstrated as of this date.

2.3 Photochemical Oxidation

Photochemical oxidation is a process by which light energy from the sun or an artificial light source, such as an ultraviolet (UV) lamp, is used to photodegrade certain organic contaminants. Key process variables include the molecular structure and concentration of the contaminant, the light intensity, and the degree of mixing (i.e., exposure). For solution-phase applications, variations in reaction conditions such as pH, dissolved oxygen level, and turbidity can strongly affect the rates and products of the photolytic reaction. For soil applications, mobilization and solubilization of the organic contaminants into an aqueous/solvent slurry is likely to be necessary for effective photolysis. Other important process variables are expected to be soil particle size, mineral composition, moisture content, and light absorption characteristics (i.e., soil color).

For UV treatment to be effective, the light should have adequate energy and should be of a wavelength that is absorbed by the target chemical; the rate of a photochemical reaction (or photolysis) is wavelength dependent. The presence of humic substances and other organic matter in the soil also affects the efficiency of the desired photolytic reactions, especially for in situ soil treatment.

For most photolytic processes that would be used to treat aqueous streams or slurried soils, the primary capital cost element is expected to be the photoreactor. Cost of the reactor system depends on factors such as the nature of the contaminants, the initial concentration, the flow rate, the residence time, and the treatment efficiency required. For in situ soil treatment using surface mixing, capital cost components include the UV lamp system, the power supply, and the vehicle used to till the soil and to move the UV system across the treatment area.

The most significant operating cost is expected to be the electric power used for artificial UV irradiation. Utility costs for photochemical treatment are minimal when natural sunlight is used as a UV source. However, in that case, the total time for treatment is likely to be longer and the associated operating costs higher.

2.4 UV Peroxide/Ozone Oxidation

UV peroxide/ozone oxidation treatment uses UV radiation as a catalyst to improve the performance of a hydrogen peroxide and ozone treatment system. Hydrogen peroxide and ozone are two powerful oxidizing agents that have been applied to groundwater, wastewater, and to a very limited extent, soil treatment. Carried to completion, organic material would be oxidized to carbon dioxide, water, and oxides of sulfur and nitrogen if sulfur or nitrogen-containing compounds are treated. The rate of reaction, degree of conversion, reaction mechanism, and resulting oxidation products will depend on the particular chemical reaction conditions (i.e., temperature, pH), oxidant species, and presence of other substances that could interact with and potentially consume the oxidant. Incomplete reaction could result in oxygenated by-products of smaller molecular weight than found in the original waste material. These oxidation products could be more mobile in the environment. For complex-cyanide wastewater treatment using hydrogen peroxide or ozone, UV irradiation is required to decompose the complexes to fragments that are susceptible to oxidation.

The primary capital cost element for aqueous waste treatment is the reactor system. The principal factors affecting equipment cost are the residence time required to achieve treatment criteria and the aqueous flow rate. High treatment efficiencies and difficult-to-oxidize wastes will significantly increase the reactor system cost.

Principal operating costs for aqueous treatment depend on the type of process. For hydrogen peroxide or ozone generation, electrical power represents a potentially significant cost. Costs for catalyst additives, if used, are typically minor. Electrical power can be the largest (i.e., 30 to 60%) operating cost when UV irradiation is employed.

Total unit operating costs, which include capital related charges, vary greatly for different aqueous streams depending on oxidant dosage, UV energy, system capacity, and effluent limits (i.e., treatment efficiency).

2.5 Radio-Frequency Heating/Microwave Heating

These technologies consist of heating an area with electromagnetic waves of varying frequencies to thermally decompose, vaporize, and/or distill hazardous components. The vapors and gases generated during the process are collected on the surface by a vapor barrier that acts as a holding area for escaping gases and condensate. The liquids and gases can be either treated as part of the process or can be transported to an appropriate treatment and/or disposal facility. The range of frequencies used in a radio-frequency heating system varies between 2 and 45 megahertz. The radio waves are transmitted through the soil via electrodes placed horizontally above the contaminated area.

Radio-frequency and microwave heating techniques are most applicable to volatile contaminants with low boiling points and easily decomposed organics in soil.

Both technologies are relatively new and little information is currently available regarding the factors affecting the cost of implementing either technology. It is assumed that power consumption and soil moisture content will be the primary factors affecting the cost of a system.

2.6 Biological Processes

Biological processes destroy the organic components of mixed wastes thereby allowing it to be disposed of as LLW. Typical contaminants that are suitable for biological processes include petroleum wastes, such as sludges, and PAHs; chemical manufacturing products, such as acetone; and ethanol paint solvents. Some possible contaminants for biological processes include: trichloroethylene (TCE), perchloroethylene (PCE), trichlorethane (TCA), polychlorinated biphenyls (PCB), complex PAHs (greater than 5 rings), trinitrotoluene (TNT), and dichloro diphenyl trichlorethane (DDT). Biological processes will not destroy metals (but may alter them by oxidation/reduction), brine, or highly

halogenated compounds. Some, however, can bioaccumulate many metals, including radioactive ones, which can be used as part of a treatment process.

Biological processes for the destruction of the hazardous components of mixed wastes are usually some form of aerobic respiration because this process is usually faster than anaerobic digestion and does not produce the methane and hydrogen sulfide gases that are common with anaerobic processes. On the other hand, aerobic processes are not as effective in breaking down halogenated chemicals as are anaerobic processes; therefore, it is important to know all the components of the waste before choosing a process.

Costs for biological treatment vary greatly depending on the type of system installed. Contaminant concentration levels, however, substantially affect any choice of biological treatment.

3. Separation Technologies

3.1 Metals Precipitation

Metals precipitation is carried out by adding acid or base to a waste solution to adjust the pH to a point where the metal(s) of concern have a low solubility. Often coagulants are added to the solution to aid in the precipitation process.

One process that was developed for the precipitation of radionuclides is the Tru/Clear process. Tru/Clear was developed at the Los Alamos National Laboratory and is marketed by Analytical Development Corporation (ADC). The process uses potassium ferrate as an inorganic coagulant to remove radionuclides and other priority pollutants from wastewaters, thus reducing them to extremely low levels.

3.2 Ion Exchange

Ion exchange technology utilizes resins charged with exchangeable ions to remove toxic metal ions from waste solutions and concentrate them for recovery or disposal. The benefit of this technology is that under ideal conditions it could actually be used to separate a mixed waste into hazardous and radioactive components. This technology is effective on cations such as Ni^{2+} , Cd^{2+} , and Hg^{2+} , and on

anions such as CrO_4^{2-} , SeO_4^{2-} , and HAsO_4^{2-} . Some limiting factors of this technology are the selectivity of the resins and exchange ions with respect to the contaminant that is the desired target, and the competition of other ionic components of the waste streams that may be removed preferentially thereby "poisoning" the resin. Other limiting factors are pH, concentration of contaminants, and suspended solids.

3.3 Carbon Adsorption

Carbon adsorption is a technique that involves the removal of organic and inorganic contaminants from liquid wastes with activated carbon. The process works through the adsorption of the contaminants onto a carbon matrix and is a common technology used primarily in wastewater treatment systems. The carbon used is in either granular or powdered form, depending on its application. Typically, carbon granules are placed in columns or vessels that are operated until the effectiveness of the carbon columns reaches the point of diminishing return. During the treatment process the carbon becomes "spent" and must be regenerated by the use of steam or furnace heating depending on the contaminant adsorbed. The time required for the carbon to become spent will depend on the flow rate through the carbon and the concentration of contaminants in the wastewater stream. The regenerating unit may be designed to be part of the system or it may be offsite. The size and capacity of the system will determine the cost-effectiveness of either choice.

The effectiveness of a carbon adsorption system is directly proportional to the extent of surface area of the activated carbon. This is due to the fact that adsorption is a surface process. Generally, surface areas range from 600 to 1,000 m^2/g for activated carbon systems. Another factor affecting the effectiveness of a system is the type of contaminant. Organic compounds that are less soluble in water are more likely to be adsorbed on activated carbon. Carbon adsorption is unsuitable for the removal of metals or oil and grease. Generally, systems are limited to volatile organic compound concentrations less than 100 parts per million.

The cost-effectiveness of a carbon adsorption system is determined by the concentration of the contaminants in the influent as this will determine the replacement frequency of the activated carbon. Generally, carbon adsorption is used in conjunction with some form of pretreatment to reduce the influent concentrations to a level that will make the system function cost-effectively.

3.4 Reverse Osmosis

Reverse osmosis refers to a process in which a solvent flows through a semipermeable membrane. The flow direction is controlled by the application of a differential pressure that exceeds the osmotic pressure of the membrane, that is, the pressure that will just prevent the passage of solvent through the semipermeable membrane. The components of a reverse osmosis system are the membrane, a membrane support structure, a containing vessel, and a high pressure pump. The system is used to reduce the concentration of dissolved solids, both organic and inorganic.

Reverse osmosis is an effective technology for the removal of dissolved solids, assuming that the influent is properly pretreated. The technology is primarily effective in treating aqueous streams containing less than 400 parts per million heavy metals, high molecular weight organics, and dissolved gases. However, the technology is not reliable for treatment of wastes with a high organic content, as the membrane may dissolve in the waste. Reverse osmosis can be used for the removal of ions such as chromate and phosphate and for the selective rejection of toxic organic compounds. The effectiveness of the system is highly dependent on the characteristics of the influent and on the design of the semipermeable membrane.

Costs of reverse osmosis systems are determined primarily by the cost of the individual reverse osmosis modules. More than 85% of equipment costs are for the modules. Operation and maintenance costs are primarily associated with the antifouling chemicals that are required to keep the system operating properly.

3.5 Distillation

Distillation of solvent wastes to recover solvents for reuse, while decreasing the volume of the waste stream, may be more favorable than incineration of solvents. The reasons for this include cost savings incurred by reusing the recovered solvent, and the expense of the added fuel required for incineration (Handbook of Separations Techniques for Chemical Engineers). For nonradiologically contaminated wastes, the economy of scale will often dictate whether the distillation process is carried out by the generator or sent to a company that specializes in solvent recovery. Sending the waste off site to a solvent recovery company is not as simple with mixed wastes because these companies usually do not accept mixed wastes; therefore, distillation separation of mixed solvents will most likely be feasible for the large generator.

3.6 Refining Contaminated Lead

The Idaho National Engineering Laboratory (INEL) has done some bench-scale refining tests to determine if radioactive contamination could be removed from lead by melting the lead and separating the dross from it. They added a flux to the molten lead to promote fusion of the contamination with the dross. The dross was then removed from the surface. The leachable lead in the dross was determined to be below the land-ban, and therefore, the dross could be disposed of as a mixed waste. The average decontamination factor for the lead with a known isotope concentration was determined to be about 4,700. As a result of these bench-scale tests, a decontamination/recycling facility will be established for the INEL.

4. Immobilization or Stabilization Technologies

4.1 Cement/Grout/Pozzolan Processes

These technologies are similar in that all require mixing some form of setting agent such as portland cement, grout, or lime-based pozzolanic material to dewater, stabilize, and solidify the mixed waste. This technology can be used to treat characteristically hazardous wastes by eliminating, or reducing below a level of concern, the characteristic that caused the wastes to be considered hazardous. The stabilized treated waste then can be disposed of in LLW landfills.

Cement/grout/lime-based pozzolanic technologies have been commercially available and in wide use for some time, but treatability studies should always be done to verify that the end product meets the desired requirements. Contaminants that can affect the process parameters and the success of the solidification include dissolved sulfates and metallic anions such as arsenic and borates.

4.2 Stabilization by Polymers

This technology is similar to cement stabilization in that a stabilizing agent is mixed with the waste to form a stable solid mass. The difference is that in this technology, a monomer is added to the waste and mixed to form a fairly homogeneous mixture; then a catalyst is added to convert the monomer to

a stable polymeric product that encapsulates the waste. If proper treatability tests have been performed, the end product is chemically, physically, and biologically stable.

Polymerization technology can be used to treat characteristically hazardous wastes by eliminating or reducing below a level of concern the characteristic that caused the wastes to be considered hazardous. The stabilized treated waste then can be disposed of in LLW landfills. Polymerization can also be used to stabilize listed wastes for storage until treatment or disposal options can be found or until the radioactive decay has progressed to the point where the waste is no longer considered a radioactive waste. Then the waste can be disposed of at an appropriate hazardous waste disposal facility.

Polymerization shows good potential for stabilizing wastes containing organics including aromatics, aliphatics, styrene, vinyl chloride, isoprene, and monomers such as acrylonitrile.

4.3 Vitrification

In the vitrification process, high temperatures are utilized to convert the waste into a glass product. This glass product displays extremely low leaching characteristics and is very stable. The process uses high currents of electricity between two electrodes to generate sufficient heat to evaporate any moisture and produce a "melt" that slowly moves through the waste destroying some of the organics and trapping others, along with the inorganics, in a glass matrix when the melt cools.

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