requires only that the effluent concentration be achieved; once achieved, the waste may be land disposed. The waste does not have to be treated by the technology identified as BDAT; in fact, concentration-based treatment standards provide flexibility in the choice of a treatment technology. Any treatment, including recycling or any combination of treatment technologies, unless prohibited (e.g., impermissible dilution) or defined as land disposal (e.g., land treatment), may be used to achieve these standards.

DISCLAIMER STATEMENT

The technical and analytical findings and recommendations contained in this document are those of the author(s) and should not be construed as an official U.S. Environmental Protection Agency position, policy, or decision. This disclaimer page may only be removed by EPA.

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1.0 INTRODUCTION

In accordance with the amendments to the Resource Conservation and Recovery Act (RCRA) enacted in the Hazardous and Solid Waste Amendments (HSWA) of November 8, 1984, the U.S. Environmental Protection Agency (EPA or the Agency) is proposing Best Demonstrated Available Technology (BDAT) treatment standards for Toxicity Characteristic (TC) metal wastes identified in Title 40, Code of Federal Regulations, Section 261.24 (40 CFR 261.24) as D004-D011. Compliance with these treatment standards, once promulgated, is a prerequisite for land disposal of restricted wastes, as defined in 40 CFR Part 268. EPA may grant a variance from the applicable treatment standards under 40 CFR 268.44 and under 40 CFR 268.6. EPA may grant waste- and site-specific waivers from the applicable treatment standards in 268.40.

On May 19, 1980, under RCRA, the Agency instituted a framework for identifying hazardous waste (45 FR 33084). Under this framework, the Agency defines which solid wastes are hazardous by either identifying the characteristics of hazardous waste or listing particular hazardous wastes EPA's approach for defining hazardous waste characteristics was to determine which properties of a waste would result in harm to human health or to the environment when improperly managed, and then to establish test methods and regulatory levels for each characteristic property. The Extraction Procedure (EP) Toxicity Characteristic was one of four hazardous waste characteristics that EPA identified and promulgated in May 1980 (40 CFR 261.24). A solid waste was classified as extraction procedure (EP) toxic if the liquid waste extract obtained using the EP contained any of 14 specified toxic constituents at concentrations equal to or greater than the corresponding regulatory level. These constituents consisted of eight metals, four insecticides, and two herbicides. The eight metals were assigned the hazardous waste codes D004-D011. Treatment standards for the four insecticides and two herbicides (D012-D017) were promulgated in the Third Third final rule on June 1, 1990 (55 FR 22520). The nonwastewater standards were revised in the Phase II rule on September 19, 1994 (50 FR 47982). (See the Final Best Demonstrated Available Technology (BDAT) Background

Document for Organic Toxicity Characteristic Wastes (D018-D043) and Addendum to Nonwastewater Forms of Pesticide Toxicity Characteristic Wastes (D012-D017) (Reference 25).

On March 29, 1990, EPA promulgated the Toxicity Characteristic (TC) rule, which replaced the EP with the Toxicity Characteristic Leaching Procedure (TCLP) (55 FR 11798). The list of the constituents regulated in the final TC rule and their corresponding regulatory levels are presented in Table 1-1. Treatment standards based on BDAT for D004-D011 wastes were promulgated in the Land Disposal Restrictions (LDR) for the Third Third scheduled wastes on June 1, 1990 (55 FR 22520).

This Background Document provides the Agency's rationale and technical support for developing BDAT treatment standards for both nonwastewater and wastewater forms of the eight TC metal wastes (D004-D011). EPA's rationale to develop treatment standards and to issue variances from the treatment standards is summarized in EPA's Final Best Demonstrated Available Technology (BDAT) Background Document for Quality Assurance, Quality Control Procedures, and Methodologies (Methodology Background Document)(3).

1.1 Regulatory Background

This section presents the regulatory background for the Toxicity Characteristic metal wastes (D004-D011). The TC regulatory levels and leachate procedure, as well as the BDAT treatment standards for these wastes, are discussed in this section. A list of the Federal Register notices related to the development of the Toxicity Characteristic regulations is presented in Table 1-2.

1.1.1 Toxicity Characteristic Regulatory Levels

On May 19, 1980 (45 FR 33084), the Agency instituted the Extraction Procedure (EP) leaching procedure to identify wastes that pose a hazard to human health and the environment

due to their potential to leach significant concentrations of a hazardous constituent. The Agency identified eight metal (D004-D011) and six pesticide constituents (D012-D017) that, if present in the EP waste extract in excess of specified concentrations, caused the waste to be identified as hazardous. The regulatory concentration levels were determined by the multiplication of constituent-specific chronic toxicity levels (the National Interim Primary Drinking Water Standards (DWS)) by a generic dilution/attenuation factor of 100, to reflect both the concentration at which the constituent is harmful to human health and the environment and the fate of the constituent in the environment.

On January 14, 1986, the Agency proposed a framework for a regulatory program to implement the congressionally-mandated Land Disposal Restrictions (51 FR 1602). This framework required a leaching test, known as the Toxicity Characteristic Leaching Procedure (TCLP), for use in the LDR program in developing hazardous waste treatment standards and determining whether these standards have been achieved. TCLP was intended to serve as an improved leaching method that would be suitable for use in evaluating wastes containing both organic and inorganic constituents.

On June 13, 1986 (51 FR 21648), the Agency proposed to revise the existing hazardous waste identification regulations by (1) expanding the list of TC constituents, (2) replacing the EP leaching method with the TCLP, and (3) applying constituent-specific dilution/attenuation factors (DAFs) for each organic constituent included on the TC list, while retaining the 100-fold DAF for the metal and pesticide constituents (D004-D017). The proposal specifically identified regulatory concentration levels for 52 TC constituents, including the existing 14 metal and pesticide constituents and 38 additional organic constituents. The Agency used a subsurface fate and transport model to develop the constituent-specific DAFs for the organic TC constituents. The subsurface fate and transport model, named EPASMOD, was a modification of the model used to develop the regulatory levels for solvents and dioxins in the January 14, 1986, proposed rule. This model was based on a mismanagement scenario of co-disposal of TC wastes with municipal wastes in a Subtitle D sanitary landfill. The Agency also identified chronic toxicity

reference levels for these 38 additional compounds, which, when multiplied by the DAF, determined the regulatory concentration level. EPA promulgated the TCLP for use in developing BDAT treatment standards and monitoring BDAT compliance for certain spent solvent wastes and dioxin-contaminated wastes (51 FR 40572, November 7, 1986).

Three additional notices published concerning this proposed rule are described below. On May 18, 1987, the Agency published a Supplemental Notice of Proposed Rulemaking (52 FR 18583) in response to numerous comments on the June 1986 proposal concerning the application of the revised Toxicity Characteristic rule to wastewaters. The main concern of the commenters was that it may be inappropriate to apply the TC mismanagement scenario (co-disposal of hazardous wastes with municipal wastes in an unlined landfill) to wastewaters managed in surface impoundments. The Supplemental Notice outlined several alternatives for the application of the TC to wastewaters that would result in a separate set of regulatory levels for these wastes. The alternative scenario for wastewaters assumed that the subject wastes would be managed in an unlined impoundment instead of being co-disposed in a municipal landfill.

The Agency then published a Notice of Data Availability and Request for Comments on May 19, 1988 (53 FR 18024), as a result of commenters' concern about uncertainties and technical difficulties associated with developing sufficiently representative DAFs for the 38 organic constituents. The Agency proposed two alternative approaches for establishing DAFs for these constituents. The first alternative involved setting the DAFs in two phases that would initially bring the wastes with the highest concentrations of hazardous constituents into the hazardous waste regulatory system. In the first phase, the Agency would use generic DAFs for all 38 new organic TC constituents while the development of the constituent-specific DAFs proceeded; once the development of these constituent-specific DAFs was completed, they would be implemented at the second phase. The Agency also considered, as the second alternative, to promulgate the 38 organic TC constituents in one phase, using a generic DAF. The Agency specifically requested comment on the use of a generic DAF for the two-phased approach. The

Agency also updated the chronic toxicity reference levels for a number of constituents based on newly available information.

On August 1, 1988, the Agency published a Supplement to the Proposed Rule (53 FR 28892), introducing potential modifications to the subsurface fate and transport model used to calculate the constituent-specific DAFs. In addition, the Agency presented currently available hydrogeological data on municipal waste landfills and proposed to modify the subsurface fate and transport model to more accurately reflect conditions in municipal waste landfills.

The Agency promulgated the revisions to the Toxicity Characteristic rule on March 29, 1990 (55 FR 11798). The final rule retained many of the features of the June 13, 1986, proposal. The Agency replaced the EP leaching test with the TCLP, added 26 organic compounds to the list of TC constituents (identified as D018-D043 wastes), and established regulatory concentration levels for these organic constituents based on health-based concentration thresholds and a generic DAF that was developed using a subsurface fate and transport model. In response to the comments received on the proposed rule and related notices, the final rule incorporated a number of modifications to the leaching procedure, the list of TC constituents, the chronic toxicity reference levels, and the fate and transport model.

1.1.2 Treatment Standards for Toxicity Characteristic Metal Wastes

The Agency first proposed treatment standards for the Toxicity Characteristic wastes under the LDR program in the Third Thirds rule on November 22, 1989 (54 FR 48372). The proposed treatment standards were expressed as methods of treatment and concentration levels for wastewater and nonwastewater forms of the metal characteristic wastes (D004-D011).

The Agency determined that BDAT for nonwastewater forms of the metal TC wastes (D004-D011) was vitrification or stabilization, and promulgated treatment standards as concentrations equivalent to the characteristic level except for selenium wastes (D010). The

Agency promulgated the treatment standard for D010 wastes, based on the performance of stabilization, at a concentration greater than the characteristic level.

1.2 Summary of BDAT Treatment Standards and Rationale for Applying UTS to TC Metals

The Agency is proposing revised BDAT treatment standards for nonwastewater and wastewater forms of TC metal wastes (D004-D011). This section discusses the BDAT treatment standards for these wastes.

As discussed above, in the final rule for the Third Thirds wastes (55 FR 22520), the Agency promulgated treatment standards for those D004-D011 wastes identified as hazardous using both the TCLP and EP leaching procedures.

The Agency is proposing treatment standards for both wastewater and nonwastewater forms of D004-D011 wastes as numerically equivalent to the universal treatment standards (UTS) (i.e., universal standards). A universal standard is a single treatment standard established for a specific constituent regardless of the waste matrix in which it is present, i.e., the same treatment standard applies to a particular constituent in each waste code in which it is regulated.

Universal standards for the constituents regulated in nonwastewater forms of D004-D011 wastes were based upon treatment performance data from vitrification for arsenic, stabilization for chromium, acid leaching for mercury (low subcategory), and HTMR for the other metals. These data represent BDAT for wastes included in previous rulemakings and, therefore, have been judged to meet the Agency's requirements of BDAT. Thus, the technologies mentioned above were determined to be BDAT for the metals of interest in universal standards. EPA believes that the performance data used to develop UTS for metals are comprehensive and represent a diverse group of waste matrices. Further, the available data suggest that the UTS can generally be achieved for most metals. The Agency notes that in some cases where the data

did not achieve the UTS, further optimization of the treatment process may improve the technology performance. Hence, in consideration of the above, the Agency believes it is appropriate to transfer the BDAT for UTS metals to TC metals. A more detailed discussion of the Agency's rationale and technical support for establishing universal standards for nonwastewater forms of waste is provided in the Final Best Demonstrated Available Technology (BDAT) Background Document for Universal Standards, Volume A: Universal Standards for Nonwastewater Forms of Listed Hazardous Wastes (1).

The universal standards for wastewater forms of wastes are based on treatment performance data from several sources, including the BDAT data base, the National Pollutant Discharge Elimination System (NPDES) data base, the Water Engineering Research Laboratory (WERL) data base, EPA-collected Wet Air Oxidation/Powdered Activated Carbon Addition to Activated Sludge Treatment (WAO/PACT®) data, the Engineering and Analysis Division (EAD) data base, industry-submitted leachate treatment performance data, data submitted by the California Toxic Substances Control Division, data in literature that were already not part of the WERL data base, and data in literature submitted by industry on the WAO and PACT®. These standards reflect the performance of numerous industrial wastewater treatment systems. A detailed discussion of the Agency's rationale and technical support for establishing universal standards for wastewater forms of wastes is provided in its Final Best Demonstrated Available Technology (BDAT) Background Document for Universal Standards, Volume B: Universal Standards for Wastewater Forms of Listed Hazardous Wastes (2).

A summary of the development of universal standards for the constituents regulated in nonwastewater forms of D004-D011 wastes is presented in Appendix A of this document. A more detailed discussion of the Agency's rationale and technical support for establishing universal standards for nonwastewater forms of wastes is provided in its Final Best Demonstrated Available Technology (BDAT) Background Document for Universal Standards, Volume A: Universal Standards for Nonwastewater Forms of Listed Hazardous Wastes (1).

EPA has investigated the impact of revising the BDAT treatment standards for TC metal wastes. The results of this investigation, presented in the Capacity Analysis for this proposed rulemaking, show that revising the treatment standards from the TC levels to the UTS may cause additional volumes of material to be covered by these treatment standards (28).

1.3 Treatment Standards for Previously Stabilized Mixed Radioactive and Characteristic Metal Waste

The Agency has concerns about the impact of the proposal on previously stabilized mixed radioactive metal wastes. Some radioactive wastes that exhibit a hazardous characteristic for a metal have been stabilized to meet the existing LDR standards, but may not be land disposed until after Phase IV is finalized. Such circumstances could result in treated wastes not meeting the revised standards based on UTS. For example, as part of the West Valley Demonstration Project, approximately 21,000 drums of mixed radioactive/formerly metal characteristic wastes have been stabilized to meet the current LDR treatment standards for metals. The wastes at the West Valley site are being stored awaiting development of disposal capacity. Additional technical background information concerning the West Valley Demonstration project may be found in the Administrative Record for this proposed rule (26). Because of siting difficulties for radioactive wastes, it is expected to take more than 3 years to develop disposal capacity. There is a good possibility that when these treated wastes are disposed, the Phase IV final rule will be in effect, and the metal portion will be subject to the UTS levels. If this is the case, the wastes might require additional treatment to achieve UTS prior to disposal. Opening the drums and grinding the already treated mass of stabilized waste to prepare the waste for further treatment could expose workers, and possibly others, to unacceptable levels of metal containing dusts and radioactivity. Therefore, the Agency is proposing to allow characteristic metal mixed wastes, which have undergone stabilization prior to the effective date of the Phase IV final rule, to comply with the LDR metal standards that were in effect at the time the waste was stabilized. Mixed radioactive characteristic metal wastes that are stabilized after the effective date of Phase IV would be subject to the metal treatment standards in the Phase IV rule.

1.4 Discussion of the Issue of Grab Sampling Versus Composite Sampling

The Agency knows that many commenters are concerned about the variability inherent in grab sampling. As such, the EPA incorporated a variability factor that reflects the grab sampling approach in its determination of LDR treatment levels.

Several commenters on the Third Thirds rule and subsequent rules have raised concerns regarding the Agency's preference to the use of grab sampling to demonstrate compliance with the LDRs. EPA continues to believe that grab sampling is preferable to composite sampling for LDRs. Treatment of hazardous wastes is rarely performed on a continuous basis for a significant period of time for any given waste code; even if the system is itself a continuous process, any given waste is, in general, treated for a short time and then collected and stored in preparation for disposal. If the standards were based on composite sampling (i.e., taking multiple samples of treated and stored wastes), this would add another layer of complexity to regulatory compliance determinations. For example, in these situations, standards would have been developed by taking several samples over discrete time intervals; however, enforcement personnel would be faced with having to perform composite sampling from a group of drums that may or may not have any correlation with the composite sample technique used when treatment standards were developed. On the other hand, enforcement in such a situation would not be difficult if treatment standards are based on grab samples. Under these circumstances, enforcement personnel could simply take a grab sample from any drum and, thereby, make a compliance determination.

Further, an individual facility's waste analysis plan will provide the basis for that facility's compliance monitoring. This plan must be adequate to assure compliance with Part 268. Additional information on waste analysis plans may be found in the Administrative Record for this proposed rule in the Waste Analysis at Facilities that Generate, Treat, and Dispose of Hazardous Wastes: a Guidance Manual, April 1994 (27). However, a facility remains strictly liable for meeting the treatment standards; if it disposes of a waste that does not meet a

treatment standard, it is in violation of the land disposal restrictions. In other words, a waste analysis plan cannot immunize land disposal of prohibited wastes, although such plans may be written to authorize types of sampling and monitoring different from those used to develop the treatment standard(s).

If a waste analysis plan authorizes a different mode of sampling or monitoring, the generator or treater needs to demonstrate that the plan (and the specific deviation feature) is adequate to assure compliance with Part 268. (See 40 CFR 264.13(a).) This might require, for example, a demonstration of statistical equivalence between a composite sampling protocol and one based on grab sampling, or a demonstration of why monitoring for a subset of pollutants assures compliance of those not monitored.

However, the Agency notes that, in some cases, EPA's data base contains a few data points based on composite sampling upon which BDAT numerical standards are based. However, the Agency has used the best data available from the chosen technology and believes that the statistical methods used to calculate the variability factors compensate for this small data base. In fact, the Agency points out that the development of UTS for metals targeted data that represented the most difficult to treat wastestreams. This methodology (i.e., using a variability factor in developing standards) allows greater flexibility with respect to meeting the treatment standards, thus the issue of grab versus composite should be minimized.

BDAT treatment standards are, with few exceptions, based on analysis of multiple grab samples. The average of the treated grab samples is then multiplied by a factor (referred to as a variability factor) that accounts for treatment process variations and analytical variations. Accordingly, enforcement based on grab samples is consistent with the manner in which the standards were developed. EPA's enforcement position that the sample be representative refers to the waste "representing" the specific waste of interest, not to the sample representing the full range of treatment levels of that waste. Accordingly, EPA does not recognize any

inconsistencies between this requirement and the requirement to comply with any single grab sample.

1.5 Revision of the Beryllium Nonwastewater Standard in UTS

In addition to the proposed revision of the TC metals standards, EPA is proposing to change the UTS for beryllium from 0.014 to 0.04 mg/L (TCLP). After UTS were promulgated, additional data on TC metals were submitted to the Agency. These grab sample data were from a High Temperature Metals Recovery (HTMR) facility and were comprised of 480 data points from their in-house metal treatment processes. These data were submitted under the auspices of "Confidential Business Information." While UTS nonwastewater limits for metals specify a grab sample, the data used to develop the standards included both grab and composite samples. These data demonstrated HTMR could not necessarily achieve the limits using grab samples. Out of the 40 data points for beryllium, 5 exhibited levels exceeding the UTS level of 0.014 mg/L (TCLP). A log-normal statistical analysis, based on Quality Assurance/Quality Control (QA/QC) Methodology, was performed on these beryllium data points. Based on this analysis, the Agency is proposing to modify the beryllium UTS level to 0.04 mg/l (TCLP). The Agency believes that this proposed level provides assurance that metal nonwastewater standards can comply with UTS using grab samples.

1.6 RCRA Subtitle C Overview and Applicability of the TC Rule and BDAT for TC Metal Wastes to Various Wastestreams

Under Subtitle C of RCRA, wastes that are determined to exhibit the Toxicity Characteristic are defined as RCRA hazardous wastes (See 40 CFR 261.24). These TC wastes are subject not only to the land disposal restrictions under 40 CFR 268, but are also subject to the provisions of 40 CFR 260 through 270, as well as other applicable regulations. The Subtitle C requirements cover the generation through ultimate disposal of a waste (i.e., "cradle to grave"). Wastes that exhibit the toxic characteristic for metals are referred to as TC metal

wastes. These wastes are identified as EPA Hazardous Wastes Nos. D004 through D011. Once the BDAT treatment standards for TC metal wastes are promulgated, these standards will apply to all wastes exhibiting the toxicity characteristic for metals (except for wastes that are specifically exempted), regardless of the process or industry that generates the waste. Examples of industrial operations that could generate wastes that could qualify as TC hazardous include electroplating, mineral processing, automotive manufacturing, painting, wastewater treatment, and battery manufacturing. Additional information on the industries and processes that may generate TC metal wastes are discussed in Section 2 of this background document.

1.7 Contents of This Document

The organization of this document is as follows:

- Section 2.0--Industries affected by the land disposal restrictions for D004-D011 wastes, current treatment and management practices, and information on environmental releases of constituents of concern.
- Section 3.0--BDAT treatment standards for nonwastewater forms of D004-D011 wastes based upon universal treatment standards.
- Section 4.0--BDAT treatment standards for wastewater forms of D004-D011.
- Section 5.0--Acknowledgements
- Section 6.0--References
- Appendix A--Treatment Performance Data base and Methodology for Identifying Universal Standards for Constituents in nonwastewater Forms of D004-D011 Wastes.
- Appendix B--Treatment Performance Data base and Methodology for Identifying Universal Standards for Constituents in Wastewater Forms of D004-D011 Wastes.

Table 1-1
Universal Treatment Standards and Toxicity Characteristic Levels for Metal-Bearing Wastes

		Characteristic Level		Universal Treatment Standard	
Waste Code	Metal	Nonwastewater (mg/L) (TCLP extract)	Wastewater (mg/L) (total composition)	Nonwastewater (mg/L) (TCLP extract)	Wastewater (mg/L) (total composition)
D004	Arsenic	5.0	5.0	5.0	1.4
D005	Barium	100	100	7.6	1.2
D006	Cadmium	1.0	1.0	0.19	0.69
D007	Chromium	5.0	5.0	0.86	2.77
D008	Lead	5.0	5.0	0.37	0.69
D009	Mercury	0.2	0.2	0.20[1]/0.025[2]	0.15
D010	Selenium	1.0	1.0	0.16	0.82
D011	Silver	5.0	5.0	0.30	0.43
N/A	Antimony	N/A	N/A	2.1	1.9
N/A	Beryllium	N/A	N/A	0.014	0.82
N/A	Nickel	N/A	N/A	5.0	3.98
N/A	Thallium	N/A	N/A	0.078	1.4
N/A	Vanadium	N/A	N/A	0.23	4.3
N/A	Zinc	N/A	N/A	5.3	2.61

N/R = Not regulated
N/A = Not applicable

[1]Low mercury subcategory (<260 mg/kg mercury) - RMERC residues
[2]Low mercury subcategory (<260 mg/kg mercury) - non-RMERC residues

RMERC = Mercury recovery by roasting/retorting

Source: Reference 1

Table 1-2. Federal Register Notices Discussing Toxicity Characteristic Regulations

Federal Register Notice	Topic	Regulatory Component				
		CTRLs[a]	Model[b]	TCLP/EP[c]	Regulatory Levels	BDAT Treatment Standards
May 19, 1980, 45 FR 33084	Final Rule for Identification and Listing of Hazardous Waste: Use of EP Toxicity Test Procedure	X			X	
January 14, 1986, 51 FR 1602	Proposed Land Disposal Restrictions Framework: Use of TCLP for Compliance with Treatment Standards		X	X		
July 9, 1986, 51 FR 24856	Notice of Availability of Reports That Support the TCLP			X		
June 13, 1986, 51 FR 21648	Proposed Revisions to the Identification and Listing of Hazardous Waste: Use of the TCLP and Addition of Constituents to the Toxicity Characteristic	X	X	X	X	
November 7, 1986, 51 FR 40572	Final Land Disposal Restrictions Approach: Use of the TCLP for Compliance with Treatment Standards			X		
May 18, 1987, 52 FR 18583	Supplemental Notice of Proposed Rulemaking: Consideration of Separate Wastewater TC		X	X	X	
May 19, 1988, 53 FR 18024	Notice of Data Availability and Request for Comments; Supplement to Proposed Rule: Use of a Generic DAF and Chronic Toxicity Reference Level Revisions	X	X		X	
May 24, 1988, 53 FR 18792	Proposed Revisions to TCLP to Replace Particle Reduction Step			X		
August 1, 1988, 53 FR 28892	Proposed Modifications to Groundwater Model		X			
November 22, 1989, 54 FR 48372	Proposed Land Disposal Restrictions for Third Third Scheduled Wastes					X
March 29, 1990, 55 FR 11798	Identification and Listing of Hazardous Wastes: Toxicity Characteristic Revisions, Final Rule	X	X	X	X	
June 1, 1990, 55 FR 22520	Final Rule for Land Disposal Restrictions for Third Third Scheduled Wastes					X

Table 1-2 (continued)

Federal Register Notice	Topic	Regulatory Component				
		CTRLs[a]	Model[b]	TCLP/EP[c]	Regulatory Levels	BDAT Treatment Standards
June 29, 1990, 55 FR 26986	Corrections to March 29, 1990 Toxicity Characteristic Revisions			X		
October 24, 1991, 56 FR 55160	ANPRM and Request for Comment and Data for the Approach for Establishing BDAT Treatment Standards for D004-D043					X

[a]CTRLs - Chronic Toxicity Reference Levels.
[b]Model - Groundwater Fate and Transport Model.
[c]TCLP/EP - Toxicity Characteristic Leaching Procedure or Extraction Procedure Leaching Test.

Source - Reference 25.

2.0 INDUSTRIES AFFECTED AND WASTE CHARACTERIZATION

This section describes the industries potentially affected by the BDAT treatment standards for D004-D011 wastes and then presents available characterization data for TC metal wastes. Each toxic metal is presented in a separate subsection. The discussion also includes current waste management and treatment practices and information on the environmental releases of the constituents of concern from these wastes. EPA notes that the proposed change in the TC metal treatment standards to the UTS levels may cause increases in the volume of TC metal waste requiring treatment.

Note that most of the information presented in this section is derived from work done in the Third Third rulemaking. (The reference numbers (as shown in the reference section) corresponding to the background document for each TC metal are the following: 23-cadmium, 24-arsenic and selenium, 29-barium, 30-chromium, 31-lead, 32-mercury, and 33-silver).

TC metal wastes can be generated in many different forms by many different industrial processes. The processes by which TC metal wastes are generated are similar for many of the various metals. Descriptions of processes for manufacturing some of the metal compounds of interest are detailed further in the subsections for each type of metal. Metals may enter a wastestream by the following means: mechanical processing, reaction with other chemicals during manufacturing, electroplating operations, residues from treatment of wastewaters, and other surface treatment operations.

Numerous industries are affected, including chemical manufacturing and various industries using the specific metals to manufacture products. Table 2-1 lists the compounds used in manufacturing, and industries affected for each TC metal. The electronics, electroplating, and battery manufacturing industries are users of several different metals and generators of

Table 2-1
Industries Affected for Each TC Metal

Waste Code	Metal	Industries Affected	Compound of Interest
D004	Arsenic	Copper and lead smelters processing arsenopyritic ores (Manufacturer) (None active in U.S./one marketing arsenic trioxide from previous production)	Arsenic oxide (trioxide)
		Wood Preserving (User) Wood Preserving (Manufacturer/User)	Arsenic oxide (trioxide), Arsenic acid Copper chrome arsenate
		Agricultural Chemicals-Pesticides/Herbicides (Ores) Agricultural Chemicals-Pesticides/Herbicides (Manufacturing)	Arsenic oxide (trioxide) Cacodylic acid and salts, Monosodium methanearsonate, Disodium methanearsonate
		Glass-Making (User)	Arsenic trioxide Arsenic acid
		Lead- and Copper-Based Alloys (User)	Metallic arsenic
		Electronics (User)	High purity arsenic metal
		Veterinary Pharmaceuticals (Manufacturer)	Organoarsenic compounds
D005	Barium	Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Barium sulfate Barium metal, Barium sulfide, Barium carbonate, Barium sulfate, Barium nitrate, Barium chloride
		Bricks and Ceramics (User)	Barium carbonate
		Oil Drilling (User)	Barium carbonate
		Photographic (User)	Barium carbonate
		Medicines (User)	Barium carbonate
		Glass-Making (User)	Barium carbonate
		Pigments and Colors (User)	Barium chloride
		Pyrotechnics (User)	Barium nitrate
		Electronics (User)	Barium metal
D006	Cadmium	Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Cadmium metal Various inorganic compounds, including salts (cadmium chloride, sulfate, and nitrate)
		Cadmium Pigments (User) Cadmium Pigments (Manufacturer)	Cadmium metal Cadmium-sulfide-based pigments

Table 2-1 (continued)

Waste Code	Metal	Industries Affected	Compound of Interest
		Electroplating (User)	Cadmium chloride, Cadmium sulfate, Cadmium nitrate
		Batteries (User)	Cadmium hydroxide
		Electronics and Semiconductors (User)	High-purity cadmium sulfide, Cadmium oxide
D007	Chromium	Metallurgical-Steel Production/Ferroalloys/Chromium Metal (User) Metallurgical (Manufacturer)	Chromite ore, Chromic oxide, Calcium chromate Chromium ferroalloys
		Chemical (User) Chemical (Manufacturer)	Chromite ore Sodium chromate, Sodium dichromate, Sodium chromate, Sodium dichromate, Chromic acid, Potassium chromate, Potassium dichromate, Basic chromic sulfate, Chromium pigments, Chronic sulfate, Calcium chromate
		Chromium Plating (User) Chemical Conversion Coatings (User)	Chromic acid Chromic acid
		Metal Finishing (User)	Potassium chromate, Potassium dichromate
		Tanning Compounds (User)	Potassium chromate, Chromic sulfate, Potassium dichromate
		Pigments (User)	Potassium chromate, Potassium dichromate, Chromic sulfate
		Wastewater Treatment-Corrosion Inhibitor (User)	Chromium compounds
		Wood Preserving (User)	Chromated copper arsenate
		Refractory (Manufacturer)	Chrome brick, Chrome-magnesite brick
		Glass Manufacturing (User)	Chromium compounds
		Nonferrous Metals Production (User)	Chromium compounds
		Primary Metals Smelting (User)	Chromite ore
		Ceramics Production (User)	Chromium compounds
D008	Lead	Chemical Manufacturing (User)	Metallic lead, Lead monoxide, Lead acetate, Lead carbonate

Table 2-1 (continued)

Waste Code	Metal	Industries Affected	Compound of Interest
		Chemical Manufacturing (Manufacturer)	Lead monoxide, Lead acetate, Lead carbonate, Lead tetroxide, Lead sulfate, Basic lead sulfate, Tetraethyl lead
		Batteries (User)	Lead compounds
		Pigments (User)	Lead compounds
		Primary and Secondary Lead Smelters (User)	Metallic lead
		Metallurgical-Lead Alloys (User)	Metallic lead, Lead compounds
		Metal Fabricators (User)	Lead alloys
		Petroleum (User)	Tetraethyl lead
D009	Mercury	Batteries (User)	Mercuric oxide, Metallic mercury
		Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Metallic mercury Chlorine, Potassium hydroxide, Caustic soda, Mercury compounds
		Fungicide/Bactericide (User)	Phenylmercuric acetate, Phenylmercuric oleate
		Electrical Equipment (User)	Metallic mercury
		Instruments (User)	Metallic mercury
		Explosives (User)	Mercury fulminate
		Catalysts (User)	Mercuric chloride
		Agricultural Chemicals (User)	Mercurous chloride, Mercuric chloride
		Antiseptic Pharmaceuticals (User)	Various organic and inorganic mercury compounds

Table 2-1 (continued)

Waste Code	Metal	Industries Affected	Compound of Interest
D010	Selenium	Copper Refining (Manufacturer)	Elemental selenium
		Electronics (User)	Elemental selenium
		Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Elemental selenium, selenium dioxide Selenic acid, Selanate salts
		Pigments (User)	Cadmium selenide
		Electroplating (User)	Selenic acid
		Glass (User)	Elemental selenium
D011	Silver	Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Metallic silver, Silver nitrate Silver salts: Silver chloride, Silver bromide, Silver iodide, Silver oxide, Silver carbonate, Silver sulfide, Silver nitrate, Silver cyanide
		Mirrors (User)	Silver nitrate
		Photographic (User)	Silver chloride, Silver bromide, Silver iodide
		Brazing Solders (User)	Silver chloride
		Batteries (User)	Silver oxide
		Electroplating (User)	Silver cyanide and salts

Sources: References 23, 24, 29, 30, 31, 32, and 33.

several types of waste. The subsections below provide a further description of users of the various TC metals and industries generating specific TC wastes.

The majority of the waste characterization data available is from EPA's 1986 National Survey of Hazardous Waste Generators. A summary of the available data is presented in the subsection for each metal.

2.1 Arsenic (D004)

The primary commercial source of arsenic is arsenic oxide (arsenic trioxide), which is generally recovered from flue dusts generated by copper and lead smelters processing arsenopyritic ores. Currently, no smelters in the United States produce arsenic oxide, so the supply is dependent on imported arsenic oxide. Approximately 30,000 metric tons of arsenic oxide, 600 metric tons of arsenic metal, and 1,100 tons of arsenic compounds (e.g., arsenic sulfide, arsenic acid, sodium arsenate, and lead arsenate) were consumed in the United States in 1988.

The estimated end-use distribution of arsenic in 1988 was 69 percent in wood preservatives, 23 percent in agricultural chemicals, 4 percent in glass, 2 percent in nonferrous alloys, and 2 percent in other uses.

2.1.1 Industries Generating Arsenic Waste

Because of the diverse nature and magnitude of industries generating arsenic-containing wastestreams (D004), the Agency has not attempted to describe every industry that could generate these wastes. Instead, the most important industries and users of arsenic are described below, including industries associated with the process-specific listed wastes (K031, K084, K101, and K102).

The largest consumption of arsenic (as arsenic oxide) is for the production of inorganic arsenates for use as wood preservatives. Chromated copper arsenate, the most important of the arsenical wood preservatives, is a waterborne, leach-resistant wood preservative prepared by mixing arsenic acid with copper oxide or sulfate and chromic acid. (The general process for the production of inorganic arsenates involves oxidation of arsenic trioxide to arsenic acid and then reaction of the arsenic acid with an oxide or carbonate metal salt.) Subsequent treatment of wastewaters from these processes generates nonwastewaters containing metal arsenates. Furthermore, use of arsenate salts for wood impregnation results in process sludges and wastewater treatment residues that contain metal arsenates. These arsenic-containing wood preserving wastes are listed as F035, and EPA is in the process of proposing LDRs for these wastes.

The second largest user of arsenic oxide is the pesticides industry, for the production of monosodium methanearsonate (MSMA), cacodylic acid, and similar compounds. The principal agricultural market for arsenicals has been in cotton growing, where arsenic acid is used as a desiccant to aid in mechanical stripper harvesting of cotton. Other arsenical chemicals, such as MSMA and disodium methanearsonate, have been used as herbicides for control of grassy and broadleaf weeds. Several proprietary production processes are involved in the manufacture of these products. All of the processes generate wastewater treatment sludges containing inorganic and organic arsenic compounds. Pesticide formulators using these organoarsenic compounds also generate wastewater treatment sludges, spilled materials, and off-specification formulations containing organoarsenic compounds.

Arsenic trioxide and arsenic acid are used in the glass industry as fining agents to remove tiny, dispersed air bubbles, and as decolorizing agents. Use in recent years has been limited to the pressed and blown glass sectors for products such as tableware, lead glass, optical glass, and glass ceramics.

The bulk of metallic arsenic is used in lead- and copper-based alloys by the battery manufacturing industry as a minor additive (about 0.01 to 0.5 percent) to increase strength in the posts and grids of lead-acid storage batteries and to improve corrosion resistance and tensile strength in copper alloys.

High-purity arsenic metal is used in the electronics industry. Gallium arsenide and its alloys have been used in such products as light-emitting diodes and displays, room-temperature lasers, microwave devices, solar cells, and photoemissive surfaces. Because of their superior qualities, gallium arsenide integrated circuits are expected to have extensive military and commercial applications.

Veterinary pharmaceuticals containing organoarsenic compounds are produced by two facilities by proprietary processes. Wastes from these facilities are classified as K084, K101, and K102, and may contain inorganic and organic arsenic compounds.

Although arsenic is not used in the process, production of chemicals from elemental phosphorus is a significant source of arsenic-bearing wastes. Elemental phosphorus is produced from phosphate rock, and arsenic impurities become incorporated as elemental arsenic in the product. One metric ton of phosphorus typically contains about 0.3 kilogram of arsenic. Conversion of the phosphorus to other products such as phosphoric acid, phosphorus trichloride, or phosphorus pentasulfide generates solid and liquid wastes containing either arsenic chlorides or arsenic sulfides. The phosphorus segment of the inorganic chemicals industry generates product purification sludges and distillation bottoms containing arsenic sulfides and arsenic trichloride, respectively.

2.1.2 Waste Characterization (D004)

In 1985, 38,538 tons of D004 were generated. The Agency examined data from the 1986 Treatment, Storage, Disposal, and Recycling (TSDR) Survey, the Generator Survey, EPA

Table 1-2 (continued)

Federal Register Notice	Topic	Regulatory Component				
		CTRLs[a]	Model[b]	TCLP/EP[c]	Regulatory Levels	BDAT Treatment Standards
June 29, 1990, 55 FR 26986	Corrections to March 29, 1990 Toxicity Characteristic Revisions			X		
October 24, 1991, 56 FR 55160	ANPRM and Request for Comment and Data for the Approach for Establishing BDAT Treatment Standards for D004-D043					X

[a]CTRLs - Chronic Toxicity Reference Levels.
[b]Model - Groundwater Fate and Transport Model.
[c]TCLP/EP - Toxicity Characteristic Leaching Procedure or Extraction Procedure Leaching Test.

Source - Reference 25.

2.0 INDUSTRIES AFFECTED AND WASTE CHARACTERIZATION

This section describes the industries potentially affected by the BDAT treatment standards for D004-D011 wastes and then presents available characterization data for TC metal wastes. Each toxic metal is presented in a separate subsection. The discussion also includes current waste management and treatment practices and information on the environmental releases of the constituents of concern from these wastes. EPA notes that the proposed change in the TC metal treatment standards to the UTS levels may cause increases in the volume of TC metal waste requiring treatment.

Note that most of the information presented in this section is derived from work done in the Third Third rulemaking. (The reference numbers (as shown in the reference section) corresponding to the background document for each TC metal are the following: 23-cadmium, 24-arsenic and selenium, 29-barium, 30-chromium, 31-lead, 32-mercury, and 33-silver).

TC metal wastes can be generated in many different forms by many different industrial processes. The processes by which TC metal wastes are generated are similar for many of the various metals. Descriptions of processes for manufacturing some of the metal compounds of interest are detailed further in the subsections for each type of metal. Metals may enter a wastestream by the following means: mechanical processing, reaction with other chemicals during manufacturing, electroplating operations, residues from treatment of wastewaters, and other surface treatment operations.

Numerous industries are affected, including chemical manufacturing and various industries using the specific metals to manufacture products. Table 2-1 lists the compounds used in manufacturing, and industries affected for each TC metal. The electronics, electroplating, and battery manufacturing industries are users of several different metals and generators of

Table 2-1
Industries Affected for Each TC Metal

Waste Code	Metal	Industries Affected	Compound of Interest
D004	Arsenic	Copper and lead smelters processing arsenopyritic ores (Manufacturer) (None active in U.S./one marketing arsenic trioxide from previous production)	Arsenic oxide (trioxide)
		Wood Preserving (User) Wood Preserving (Manufacturer/User)	Arsenic oxide (trioxide), Arsenic acid Copper chrome arsenate
		Agricultural Chemicals-Pesticides/Herbicides (Ores) Agricultural Chemicals-Pesticides/Herbicides (Manufacturing)	Arsenic oxide (trioxide) Cacodylic acid and salts, Monosodium methanearsonate, Disodium methanearsonate
		Glass-Making (User)	Arsenic trioxide Arsenic acid
		Lead- and Copper-Based Alloys (User)	Metallic arsenic
		Electronics (User)	High purity arsenic metal
		Veterinary Pharmaceuticals (Manufacturer)	Organoarsenic compounds
D005	Barium	Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Barium sulfate Barium metal, Barium sulfide, Barium carbonate, Barium sulfate, Barium nitrate, Barium chloride
		Bricks and Ceramics (User)	Barium carbonate
		Oil Drilling (User)	Barium carbonate
		Photographic (User)	Barium carbonate
		Medicines (User)	Barium carbonate
		Glass-Making (User)	Barium carbonate
		Pigments and Colors (User)	Barium chloride
		Pyrotechnics (User)	Barium nitrate
		Electronics (User)	Barium metal
D006	Cadmium	Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Cadmium metal Various inorganic compounds, including salts (cadmium chloride, sulfate, and nitrate)
		Cadmium Pigments (User) Cadmium Pigments (Manufacturer)	Cadmium metal Cadmium-sulfide-based pigments

Table 2-1 (continued)

Waste Code	Metal	Industries Affected	Compound of Interest
		Electroplating (User)	Cadmium chloride, Cadmium sulfate, Cadmium nitrate
		Batteries (User)	Cadmium hydroxide
		Electronics and Semiconductors (User)	High-purity cadmium sulfide, Cadmium oxide
D007	Chromium	Metallurgical-Steel Production/Ferroalloys/Chromium Metal (User) Metallurgical (Manufacturer)	Chromite ore, Chromic oxide, Calcium chromate Chromium ferroalloys
		Chemical (User) Chemical (Manufacturer)	Chromite ore Sodium chromate, Sodium dichromate, Sodium chromate, Sodium dichromate, Chromic acid, Potassium chromate, Potassium dichromate, Basic chromic sulfate, Chromium pigments, Chromic sulfate, Calcium chromate
		Chromium Plating (User) Chemical Conversion Coatings (User)	Chromic acid Chromic acid
		Metal Finishing (User)	Potassium chromate, Potassium dichromate
		Tanning Compounds (User)	Potassium chromate, Chromic sulfate, Potassium dichromate
		Pigments (User)	Potassium chromate, Potassium dichromate, Chromic sulfate
		Wastewater Treatment-Corrosion Inhibitor (User)	Chromium compounds
		Wood Preserving (User)	Chromated copper arsenate
		Refractory (Manufacturer)	Chrome brick, Chrome-magnesite brick
		Glass Manufacturing (User)	Chromium compounds
		Nonferrous Metals Production (User)	Chromium compounds
		Primary Metals Smelting (User)	Chromite ore
		Ceramics Production (User)	Chromium compounds
D008	Lead	Chemical Manufacturing (User)	Metallic lead, Lead monoxide, Lead acetate, Lead carbonate

Table 2-1 (continued)

Waste Code	Metal	Industries Affected	Compound of Interest
		Chemical Manufacturing (Manufacturer)	Lead monoxide, Lead acetate, Lead carbonate, Lead tetroxide, Lead sulfate, Basic lead sulfate, Tetraethyl lead
		Batteries (User)	Lead compounds
		Pigments (User)	Lead compounds
		Primary and Secondary Lead Smelters (User)	Metallic lead
		Metallurgical-Lead Alloys (User)	Metallic lead, Lead compounds
		Metal Fabricators (User)	Lead alloys
		Petroleum (User)	Tetraethyl lead
D009	Mercury	Batteries (User)	Mercuric oxide, Metallic mercury
		Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Metallic mercury Chlorine, Potassium hydroxide, Caustic soda, Mercury compounds
		Fungicide/Bactericide (User)	Phenylmercuric acetate, Phenylmercuric oleate
		Electrical Equipment (User)	Metallic mercury
		Instruments (User)	Metallic mercury
		Explosives (User)	Mercury fulminate
		Catalysts (User)	Mercuric chloride
		Agricultural Chemicals (User)	Mercurous chloride, Mercuric chloride
		Antiseptic Pharmaceuticals (User)	Various organic and inorganic mercury compounds

Table 2-1 (continued)

Waste Code	Metal	Industries Affected	Component of Interest
D010	Selenium	Copper Refining (Manufacturer)	Elemental selenium
		Electronics (User)	Elemental selenium
		Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Elemental selenium, selenium dioxide Selenic acid, Selenate salts
		Pigments (User)	Cadmium selenide
		Electroplating (User)	Selenic acid
		Glass (User)	Elemental selenium
D011	Silver	Inorganic Chemicals (User) Inorganic Chemicals (Manufacturer)	Metallic silver, Silver nitrate Silver salts: Silver chloride, Silver bromide, Silver iodide, Silver oxide, Silver carbonate, Silver sulfide, Silver nitrate, Silver cyanide
		Mirrors (User)	Silver nitrate
		Photographic (User)	Silver chloride, Silver bromide, Silver iodide
		Brazing Solders (User)	Silver chloride
		Batteries (User)	Silver oxide
		Electroplating (User)	Silver cyanide and salts

Sources: References 23, 24, 29, 30, 31, 32, and 33.

several types of waste. The subsections below provide a further description of users of the various TC metals and industries generating specific TC wastes.

The majority of the waste characterization data available is from EPA's 1986 National Survey of Hazardous Waste Generators. A summary of the available data is presented in the subsection for each metal.

2.1 Arsenic (D004)

The primary commercial source of arsenic is arsenic oxide (arsenic trioxide), which is generally recovered from flue dusts generated by copper and lead smelters processing arsenopyritic ores. Currently, no smelters in the United States produce arsenic oxide, so the supply is dependent on imported arsenic oxide. Approximately 30,000 metric tons of arsenic oxide, 600 metric tons of arsenic metal, and 1,100 tons of arsenic compounds (e.g., arsenic sulfide, arsenic acid, sodium arsenate, and lead arsenate) were consumed in the United States in 1988.

The estimated end-use distribution of arsenic in 1988 was 69 percent in wood preservatives, 23 percent in agricultural chemicals, 4 percent in glass, 2 percent in nonferrous alloys, and 2 percent in other uses.

2.1.1 Industries Generating Arsenic Waste

Because of the diverse nature and magnitude of industries generating arsenic-containing wastestreams (D004), the Agency has not attempted to describe every industry that could generate these wastes. Instead, the most important industries and users of arsenic are described below, including industries associated with the process-specific listed wastes (K031, K084, K101, and K102).

The largest consumption of arsenic (as arsenic oxide) is for the production of inorganic arsenates for use as wood preservatives. Chromated copper arsenate, the most important of the arsenical wood preservatives, is a waterborne, leach-resistant wood preservative prepared by mixing arsenic acid with copper oxide or sulfate and chromic acid. (The general process for the production of inorganic arsenates involves oxidation of arsenic trioxide to arsenic acid and then reaction of the arsenic acid with an oxide or carbonate metal salt.) Subsequent treatment of wastewaters from these processes generates nonwastewaters containing metal arsenates. Furthermore, use of arsenate salts for wood impregnation results in process sludges and wastewater treatment residues that contain metal arsenates. These arsenic-containing wood preserving wastes are listed as F035, and EPA is in the process of proposing LDRs for these wastes.

The second largest user of arsenic oxide is the pesticides industry, for the production of monosodium methanearsonate (MSMA), cacodylic acid, and similar compounds. The principal agricultural market for arsenicals has been in cotton growing, where arsenic acid is used as a desiccant to aid in mechanical stripper harvesting of cotton. Other arsenical chemicals, such as MSMA and disodium methanearsonate, have been used as herbicides for control of grassy and broadleaf weeds. Several proprietary production processes are involved in the manufacture of these products. All of the processes generate wastewater treatment sludges containing inorganic and organic arsenic compounds. Pesticide formulators using these organoarsenic compounds also generate wastewater treatment sludges, spilled materials, and off-specification formulations containing organoarsenic compounds.

Arsenic trioxide and arsenic acid are used in the glass industry as fining agents to remove tiny, dispersed air bubbles, and as decolorizing agents. Use in recent years has been limited to the pressed and blown glass sectors for products such as tableware, lead glass, optical glass, and glass ceramics.

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High-purity arsenic metal is used in the electronics industry. Gallium arsenide and its alloys have been used in such products as light-emitting diodes and displays, room-temperature lasers, microwave devices, solar cells, and photoemissive surfaces. Because of their superior qualities, gallium arsenide integrated circuits are expected to have extensive military and commercial applications.

Veterinary pharmaceuticals containing organoarsenic compounds are produced by two facilities by proprietary processes. Wastes from these facilities are classified as K084, K101, and K102, and may contain inorganic and organic arsenic compounds.

Although arsenic is not used in the process, production of chemicals from elemental phosphorus is a significant source of arsenic-bearing wastes. Elemental phosphorus is produced from phosphate rock, and arsenic impurities become incorporated as elemental arsenic in the product. One metric ton of phosphorus typically contains about 0.3 kilogram of arsenic. Conversion of the phosphorus to other products such as phosphoric acid, phosphorus trichloride, or phosphorus pentasulfide generates solid and liquid wastes containing either arsenic chlorides or arsenic sulfides. The phosphorus segment of the inorganic chemicals industry generates product purification sludges and distillation bottoms containing arsenic sulfides and arsenic trichloride, respectively.

2.1.2 Waste Characterization (D004)

In 1985, 38,538 tons of D004 were generated. The Agency examined data from the 1986 Treatment, Storage, Disposal, and Recycling (TSDR) Survey, the Generator Survey, EPA

reports, and literature sources regarding those facilities that generate and manage wastes containing arsenic. Data from the Generator Survey show D004 wastes are divided into eight categories: aqueous organic liquids, contaminated soil, inorganic liquids, inorganic sludges, inorganic solids, lab packs, organic liquids, and organic solids. Of the D004 wastes generated in 1986, inorganic liquids account for approximately 85 percent, organic liquids account for approximately 12 percent, inorganic solids account for 2 percent, and the remaining categories account for 1 percent.

The arsenic concentration in D004 wastewaters ranges from 1 ppb to 1,000 ppm. For D004 arsenic nonwastewaters, the highest concentrations of arsenic are 75 to 90 percent generated from the "discarding of out-of-date products or chemicals" and greater than 90 percent for "laboratory wastes." Both of these types of wastes are generated in small volumes (approximately 30 tons per year). The wood preserving industry generates an inorganic solid from a filtration/centrifuging process that also contains greater than 90 percent arsenic. The volume of this wastestream is unknown. The semiconductor industry generates inorganic nonwastewaters with a total concentration of 10 to 25 percent arsenic, and the chemical products industry generates an organic solid nonwastewater containing 25 to 50 percent arsenic. The D004 wastes from the semiconductor industry also have high arsenic concentrations; however, most D004 nonwastewaters appear to contain 1 to 10 percent arsenic.

2.2 Barium (D005)

The major barium minerals are barium sulfate (baryte) and barium carbonate (witherite). Barium sulfate is mined in the United States to produce barium metal and its compounds. Barium sulfate can be reduced to barium sulfide by calcining with coke in a rotary kiln. After quenching in water, the resulting solution may be used to produce other barium salts such as barium carbonate, barium chloride, barium nitrate, and barium sulfate.

2.2.1 Industries Generating Barium Waste

Barium carbonate is the most widely used barium compound. It is used in the manufacture of bricks and ceramics, in oil drilling fluids such as "muds" and lubricating precursors, in the precipitation of "synthetic" barium sulfate for photographic and medicinal end uses, and in the manufacture of glass. Barium chloride is used in production of pigments and colors. Barium nitrate is widely used in the pyrotechnics industry for the production of tracer bullets, flares, and detonators. Other barium compounds are used as lubricating oils and greases and as metallic soaps. Black ash can be processed to provide barium metal, which is highly reactive and is used as a "getter" in electronics equipment and vacuum tubes.

2.2.2 Waste Characterization (D005)

The Agency has information from 57 facilities generating D005 wastes. These facilities reported generating 67 D005 wastestreams in 1985. Forty-eight of the wastestreams generated were nonwastewater forms of D005, 10 were wastewaters, and 9 wastestreams were indeterminable. Barium concentrations in D005 wastes were as follows:

Barium Concentration in Wastes	No. of Facilities
50 - 75%	1 Facility
25 - 50%	5 Facilities
10 - 25%	3 Facilities
1 - 10%	2 Facilities
0.1 - 1%	8 Facilities
500 ppm - 0.1%	2 Facilities
100 - 500 ppm	13 Facilities
10 - 100 ppm	5 Facilities
Unknown	18 Facilities

Most D005 wastes are inorganic matrices. However, Generator Survey data indicated that D005 wastes are sometimes present in a matrix containing significant quantities of organic

constituents such as F001 - F005 spent solvents or waste oils. The levels of organics reported in D005 wastestreams by two facilities were 98 and 25 percent.

2.3 Cadmium (D006)

Cadmium occurs in a cadmium sulfide ore (greenockite) containing zinc sulfide. It may also be present in lead and copper ores containing zinc. Cadmium may be derived by direct distillation from cadmium-bearing zinc or by recovery from electrolytic zinc processing. Cadmium dust from roasting zinc may also be collected in an electrostatic precipitator followed by leaching, precipitation, and distillation (Ref. 34).

2.3.1. Industries Generating Cadmium Waste

The major manufactured cadmium compounds may be classified into three groups: (1) cadmium pigments, (2) soluble cadmium salts used in the electroplating and battery industries, and (3) high-purity cadmium sulfide and cadmium oxide used in the semiconductor and electronics industries.

The largest single use of cadmium is by electroplating in the form of soluble cadmium salts. Soluble cadmium salts include cadmium chloride, sulfate, and nitrate, which are all produced by dissolving cadmium metal in the appropriate mineral acids, and then evaporating the resulting solutions to recover the desired products. Use of cadmium salts in electroplating rinsewaters results in the generation of a number of cadmium-containing wastes, some of which may be identified as F006, F007, F008, and F009 and are addressed in the BDAT Background Document for F006 and the BDAT Background Document for Cyanide Wastes. Small amounts of wastewaters from manufacture of cadmium salts are generally combined with wastewaters from other production areas prior to chemical treatment before discharge. This chemical treatment usually generates wastewater treatment sludges containing cadmium.

The second largest use of cadmium compounds is the use of cadmium pigments for colorization of plastics and paints. Cadmium pigments are a group of cadmium sulfide-based pigments ranging in color from light yellow to deep red. Cadmium pigments are produced by digestion of cadmium metal in sulfuric acid to form a cadmium sulfate solution. Variations in color are achieved by adding zinc, selenium, and barium salts to the process. After addition of a sulfide-containing solution, the pigment precipitate is recovered and packaged for sale. Use of cadmium pigments involves mechanical formulation operations of paint, ink, and plastic products. The processes used to manufacture these products generate cadmium-containing wastes including rinse waters and spilled and off-specification products that contain cadmium. Treatment of wastewaters from the manufacture of cadmium pigments generates wastewater treatment sludges that contain high levels of cadmium compounds.

The third largest use of cadmium compounds is in the battery manufacturing industry. Cadmium salts such as cadmium hydroxide are used by the battery manufacturing industry as the active anode material in silver-cadmium and nickel-cadmium batteries. Manufacture of these anodes may generate spilled materials containing cadmium. Incorporation of the anodes into finished batteries may generate additional wastes of off-specification anodes and batteries. Washdown of production areas generates wastewaters containing cadmium. Chemical treatment of the wastewaters generates cadmium-containing waste sludges.

High-purity cadmium sulfide and cadmium oxide are produced by proprietary processes for use in component fabrication operations in the semiconductor and electronics industries. The available information indicates that cadmium-containing wastes (both nonwastewaters and wastewaters) are likely to be generated by these processes. The use of high-purity cadmium oxide and cadmium sulfide in the production of electronic components generates cadmium-containing wastes from component fabrication operations. Most of these wastes consist of particulates and scrap solids high in cadmium content.

2.3.2 Waste Characterization (D006)

The Agency has information on cadmium wastes from manufacturers of cadmium pigments and from facilities generating cadmium wastes. Waste composition information was obtained from 3007 Questionnaire responses from the three manufacturers of cadmium pigments. The wastewater treatment sludges generated by these facilities contain approximately 50 percent cadmium sulfide, with smaller amounts of cadmium selenide and zinc sulfide. EPA Office of Water also has detailed composition information on the wastewaters from which the sludges were generated.

The Agency has information from 145 facilities generating D006 wastes. Sixty-three of these facilities generated nonwastewater forms of D006, 76 generated wastewaters, and the remainder generated both (or the form could not be determined). Data for these facilities obtained from the Generator Survey are insufficient to present a comprehensive picture of current waste generated by process and region. Cadmium concentrations in the wastes were as follows:

Cadmium Concentrations in Wastes	No. of Facilities
10% to 25%	2 Facilities
25% to 50%	2 Facilities
Over 50%	2 Facilities
Below 1 ppm	24 Facilities
1-10 ppm	46 Facilities
10-100 ppm	37 Facilities
100-500 ppm	11 Facilities
500-1,00 ppm	6 Facilities
1,000-10,000 ppm	6 Facilities

Twenty-five generators reported generation of cadmium wastes that contained organics. Levels of organics present in these wastes were as follows:

Organic Concentration in Wastes	No. of Facilities
Less than 10%	16 Facilities
10% to 50%	8 Facilities
Over 50%	1 Facility

The organics present were those usually associated with paint, paint removal, or plastics manufacturing (e.g., methyl ethyl ketone, methyl isobutyl ketone, toluene, acetone, methylene chloride, and phthalate esters).

Several facilities showed cyanide to be present, resulting from electroplating operations. Most plants reported the presence of other TC metals in the wastes in addition to cadmium. The metals most frequently identified were lead, zinc, and chromium. Some of these facilities were foundries or other metalworking operations.

2.4 Chromium (D007)

All chromium metal and chromium compounds produced in the United States are derived from various grades of chromite ore. Chromite ores are generally classified according to the type of production process in which the chromite ore is eventually used. Metallurgical chromite refers to high chromium content chromite ore; chemical chromite refers to high iron content chromite ore; and refractory chromite refers to high aluminum/low chromium content chromite ore.

2.4.1 Industries Generating Chromium Waste

Chromium is used in industry as the metal and as various inorganic and organic chromium compounds. The major products containing chromium are chromium ore, alloys, chemicals, and the metal itself. The major industries affected by the land disposal restrictions for D007 wastes are (1) the metallurgical industry, which produces chromium ferroalloys; (2)

the chemical industry, which produces chromates, chromic acid, chromium pigments, and a wide range of chromium chemicals; and (3) the refractory industry, which produces chromite to make refractory bricks for metallurgical furnaces. Chromium consumption can also be attributed to these three groups or industries. The metallurgical industry uses approximately 71.4 percent of all chromium in the United States, the chemical industry uses 15.1 percent, and the refractory industry uses 13.5 percent.

Uses of chromium by the metallurgical industry include the production of stainless steels steels, carbon steels, alloy steels, and other metallurgical products, including cast iron and nonferrous alloys. These chromium products are used primarily in the manufacture of transportation, electrical, and construction equipment; heavy machinery; and fabricated metal products. Specific chromium-containing listed wastes generated by the metallurgical industry include K061, K062, and F006 and are discussed in the BDAT background documents for these waste codes.

Chromium is used in the refractory industry to produce chrome brick, chrome-magnesite brick, and other refractory materials to line furnaces, kilns, incinerators, and other high-temperature industrial equipment. Other industrial sectors consuming chromium include glass manufacturing, nonferrous metals production, primary metals smelting, and ceramics production.

Chromium is used in the chemical industry to manufacture a wide variety of chromium chemicals; sodium chromate and sodium dichromate are the most commercially significant and are produced in the largest volume. Almost all chromium compounds are produced using either sodium chromate or sodium dicromate as the primary feedstock material. The more important secondary chromium chemicals include chromic acid, potassium chromate and dichromate, basic chromic sulfate, and chromium pigments.

Potassium chromate and dichromate are used in tanning, dyeing, pigment applications, and metal finishing. Listed wastes associated with the production of chromium pigments are

K002, K003, K004, K005, K006, K007, and K008. Potassium dichromate is also used as an analytical standard. Potassium dichromate is made by reacting sodium dichromate with an equivalent amount of potassium chloride in a crystallization process. Potassium chromate is prepared by the reaction of potassium dichromate and potassium hydroxide.

Chromic acid is used in chromium plating and for the production of chemical conversion coatings. Chromium is plated from solutions in which it is present as an anion onto various substrates such as steel, brass, aluminum, plastics, and zinc die castings. The deposition of chromium from chromic acid solutions provides the substrate with a decorative and corrosion-resistant surface. In chemical conversion coating, chromate conversion coatings are produced on metals by chemical or electrochemical treatment with mixtures of hexavalent chromium and other compounds. These treatments convert metal surface to a layer containing a complex mixture of chromium compounds that will prevent oxidation and provide corrosion protection. These operations consume large quantities chromic acid and generate waste electroplating and conversion coating solutions and sludges generated from wastewater treatment. Listed wastes associated with these operations are F006 and F019.

Chromic acid is produced by mixing sulfuric acid and sodium dichromate dihydrate in a reactor, heating externally, and stirring. Upon cooling, the molten chromic acid separates from the sodium bisulfate byproduct, and the molten chromic acid layer is tapped from the reactor to produce the commercial product.

Chromic oxide is used in the manufacture of chromium metal and aluminum-chromium master alloys and in pigments that are used where chemical and heat resistance are required.

Chromic sulfate is used in leather tanning liquors and in textile mordants and dyes. It is manufactured by the sulfur dioxide reduction of sodium dichromate in an acid-resistant tank. After reduction is complete, steam is bubbled through the solution to decompose any impurities and remove excess sulfur dioxide.

Other uses of chromium compounds include the manufacture of metal corrosion inhibitors for circulating water systems and for wood preservation. The use of chromium compounds in wood preservation has been largely attributable to the success of chromated copper arsenate as a wood treatment. Wood preserving wastes containing chromium are listed as F035, and EPA is currently proposing LDRs for these wastes.

Calcium chromate is used as an oxidizing agent in the production of ferrochromium and is used in the production of pigments and metal finishing compounds. Calcium chromate is manufactured by a proprietary process as a specialty chemical product.

The above uses of chromium generate a variety of chromium-containing nonwastewaters and wastewaters. Treatment of the wastewaters usually generates chromium-bearing nonwastewater residues.

2.4.2 Waste Characterization (D007)

Data on the approximate composition of various types of D007 wastes were obtained from the Generator Survey. The nonwastewater forms of D007 contain from 5.0 to 700,000 ppm chromium. Other BDAT list metals may also be present at concentrations as high as the percent level. Most wastewaters contain very low levels of organics.

The wastewater forms of D007 contain from 5.0 to 10,000 ppm chromium. Other metals are also frequently present. In a few cases, organics may be present at concentrations up to 1 percent.

2.5 Lead (D008)

Lead is used in industry in its elemental form and as various inorganic and organic lead compounds. Lead monoxide is produced by the reaction of molten lead with air or oxygen in

a furnace. Lead acetate, often used for the preparation of other lead salts, is made by dissolving lead monoxide or lead carbonate in strong acetic acid. Lead carbonate is made by passing carbon dioxide into a cold dilute solution of lead acetate, or by mixing a suspension of a lead salt less soluble than the carbonate with ammonium carbonate at a low temperature. Lead tetroxide, or red lead, is manufactured by heating lead monoxide in a reverbatory furnace in the presence of air until the desired composition is obtained. Lead sulfate is prepared by treating lead oxide, hydroxide, or carbonate with warm sulfuric acid, or by treating a soluble lead salt with sulfuric acid, and filtering and drying the resulting precipitate. Basic lead sulfate and tribasic lead sulfate are prepared by high-temperature fusing of lead oxide and lead sulfate or by boiling aqueous suspensions of these two compounds.

2.5.1 Industries Generating Lead Waste

The industries affected by the land disposal restrictions for D008 wastes are (1) the inorganic chemicals industry, which produces various inorganic lead compounds; (2) manufacturers of organolead compounds; (3) manufacturers and recyclers of lead-acid batteries; and (4) several industries that use lead compounds to manufacture various products. Specific industries using lead chemicals and products from which D008 may be derived include lead-acid battery manufacturers, primary and secondary lead smelters, producers of lead-containing alloys, metal fabricators producing parts containing such alloys (e.g., castings, sleeve bearings, bushings), the mining and construction industries, producers of lead sheathing for cable insulation, and producers of lead pigments.

The largest use of lead is in the manufacture of automobile batteries. Over 50 percent of the lead consumed in the United States are used in the manufacture of plates and terminals for automotive lead-acid batteries. Other uses include the manufacture of pigments for use in paints and inks, the manufacture of additives for use in textile dyeing and printing, and in the ceramic industry for electrical insulators and capacitors. All of these processes generate a

variety of lead-containing nonwastewaters and wastewaters. Treatment of the wastewaters generates lead-bearing nonwastewater residues.

2.5.2 Waste Characterization (D008)

Although the Agency has data from the National Survey of Hazardous Waste Generators on the facilities generating D008 wastes, these waste characterization data show a wide range of component concentrations. Consequently, no general statement can be made with respect to the characterization of these wastes, except that they are extremely diverse.

2.6 Mercury (D009)

Mercury occurs naturally in combination with sulfur to form more than a dozen minerals; the most important commercial mineral is red sulfide or cinnabar. Mercury is produced by mining and smelting of ores containing mercury. It is recovered as a by-product in the mining and processing of other metals and may also be recovered from waste products, scrap material, tailings piles, municipal sludge, etc. (Ref. 35).

2.6.1 Industries Generating Mercury Waste

D009 can be generated in many different forms by many different industrial processes. Metallic mercury and inorganic mercury compounds are used in many industries.

The largest use of mercury, amounting to 48 percent of all mercury used in 1983 (the year for which data are available), is in the manufacture of mercuric oxide batteries, primarily the mercuric oxide/zinc dry cell. Mercuric oxide is used as the cathode material in these batteries. Metallic mercury is often amalgamated with other metals (e.g., silver and zinc) and used as the anode material in batteries. Both nonwastewaters and wastewaters containing mercury can be generated from battery manufacturing. Wastewaters containing mercury can be

generated from cleanup of spills of mercuric oxide, spilled mercury, or wastewater treatment sludges generated from the treatment of mercury-containing wastewaters.

The second largest use of mercury, amounting to 16 percent of the total mercury consumed in 1983, is in the manufacture of chlorine by the mercury cell process. Note that this process may not be as widely used as it has been in the past. Metallic mercury is used in this process as the cathode material in electrolytic cells that decompose a sodium chloride brine solution into sodium hydroxide and chlorine. All caustic soda and potassium hydroxide and over 90 percent of the chlorine produced in the United States are made by this process. Treatment of plant process wastewaters by chemical precipitation generates a wastewater treatment sludge classified as the listed waste K106 and is usually generated by sulfide precipitation.

The next largest use of mercury is as a fungicide and bactericide in latex paints. The primary compound used in this application is phenylmercuric acetate (P092). Phenylmercuric oleate and other organic mercury compounds are also reportedly used. Phenylmercuric acetate is made from mercuric acetate. In paint formulation operations, pigments are mixed with solvents, carriers, and other additives. Phenylmercury compounds are added in very small quantities (less than 1 percent) as preservatives for latex paints. Washing of equipment used in paint formulation may result in the generation of wastes containing organomercury compounds such as phenylmercuric acetate, and sometimes contain other organic compounds as well.

Other uses of mercury metal are in electrical equipment such as industrial control instruments, in mercury vapor lamps, in wiring and switching devices as an electrical connection, and in barometers and thermometers. Mercury compounds are also used as initiating explosives (mercury fulminate), as homogeneous catalysts (mercuric chloride), as components of agricultural fungicides (mercurous chloride and mercuric chloride), and as antiseptic pharmaceuticals (various organic and inorganic mercury compounds).

2.6.2 Waste Characterization (D009)

EPA data from the National Survey of Hazardous Waste Generators provide the composition of D009 wastes. These data show that D009 wastes may contain organic compounds (usually when mixed with solvent wastes). Also, some wastes generated in the production of organomercury compounds for fungicide/bactericide and pharmaceutical uses and generated in organic chemicals and polymers manufacturing where mercuric chloride catalyst is used may contain mercury in an organic waste matrix. Overall, the mercury concentrations of D009 wastes (organic and inorganic) range from less than 1 ppm to greater than 75 percent.

Additional characterization data for D009 wastes generated in the organomercury chemicals and battery manufacturing industries are available. These data show that the wastes generated during manufacture of phenylmercuric acetate are in the form of wastewaters, with mercury concentrations ranging from 100 - 1,000 ppm. Petroleum hydrocarbons (i.e., benzene and toluene) are also present in these wastes. D009 wastes from recycle of batteries contained more than 92.6 percent (1,490 ppm by TCLP) mercury, while D009 wastes generated during manufacture of batteries contained 27,200 ppm (1.83 ppm by TCLP) of mercury. These wastestreams also contained total organic carbon at levels of 6,600 - 10,700 ppm, and other metals (i.e., barium, copper, nickel, silver) in detectable amounts. Zinc was also high for the samples of zinc/mercury amalgam.

2.7 Selenium (D010)

Elemental selenium is recovered from anode slime as a byproduct of electrolytic copper refining at five copper refineries. In 1988, approximately 280 metric tons of selenium were produced, and 660 metric tons were consumed in the United States. The estimated consumption of selenium by end use in 1988 is as follows: electronic and photocopier components (43 percent), glass manufacturing (20 percent), chemicals and pigments (20 percent), and other,

including metallurgy and agriculture (17 percent). Selenic acid is the major selenium compound manufactured. It is produced via a selenium dioxide intermediate.

2.7.1 Industries Generating Selenium Waste

Almost half of the selenium produced is used by the electronics industry, where it is incorporated into individual electronic components. The major electronic use of elemental selenium is as a photoreceptor in plain paper electrophotographic copiers. During manufacturing, the selenium is melted and cast into desired shapes, machined, and further processed. Wastes from these operations consist of fines, scrap, and off-specification materials that have a high selenium content. Most of these wastes are reprocessed either onsite or offsite.

The U.S. automobile and construction industries contribute to the demand for selenium-containing pigments. These pigments, ranging in color from light orange to maroon, are used as colorants for plastics, glass, and ceramics. The chief pigment produced is cadmium red, a double salt of cadmium sulfide and cadmium selenide. The production of cadmium red pigment generates wastewater treatment sludges that contain cadmium, zinc, and selenium. These are generally sold to reclaimers to recover metal values.

The primary use of selenium in the glass industry in 1986 was for decoloring of container glass. Selenium is also used in architectural plate glass in combination with cobalt oxide and iron oxide to reduce solar heat transmission.

Selenic acid is used chiefly as an additive to bright copper and bright chromium electroplating baths. (Thus, selenium may appear as a constituent in wastewater treatment sludges generated by the metal finishing industries.) Lesser amounts of selenic acid are consumed in the manufacture of inorganic selenate salts, used at trace levels as soil nutrients. Production volumes of selenic acid and its salts are low, averaging only a few hundred pounds per year.

Other selenium compounds (selenic acid, etc.) are produced only in small quantities at three facilities. EPA does not have process-specific information on these operations. The amounts of selenium-bearing wastes produced by these processes are likely to be small. According to the Biennial Report of 1985, only 765 tons of D010 were generated. No selenium-bearing wastes were reported from the three facilities manufacturing selenic acid and its derivatives.

Research amounts of organoselenium compounds are produced using selenic acid as a feedstock material. Selenium dioxide, the intermediate in selenic acid production, is sold only in research quantities.

2.7.2 Waste Characterization (D010)

Data available from EPA show D010 in wastewater and nonwastewater forms. The wastewaters contain up to 500 ppm of selenium, and the nonwastewaters contain up to 25 percent selenium. Approximately 99 percent of the D010 waste generated in 1986 contain 98 percent water and up to 10 ppm selenium and are generated by one generator from the petroleum refining industry.

2.8 Silver (D011)

Silver is used in industry as the metal and as various silver compounds. Eight silver compounds are produced in commercial quantities: silver nitrate, silver salts (silver chloride, silver bromide, silver iodide, silver oxide, silver carbonate, silver sulfide), and silver cyanide.

2.8.1 Industries Generating Silver Waste

Silver nitrate represents the largest volume of silver-containing chemicals manufactured. Silver nitrate is used in the production of mirrors, where two separate solutions, one of

ammonia-complexed silver nitrate and the other containing an organic compound such as formaldehyde, are reacted on the glass surface to be coated. A coating of silver forms on the glass surface. The process generates waterborne wastes containing silver. Subsequent treatment of the wastewaters generates silver-bearing residues. The production of silver nitrate involves digestion of silver in nitric acid to form a silver nitrate solution that is partially evaporated and fed to crystallizers to recover silver nitrate crystals. Wastes from this production process are in the form of wastewaters. Treatment of these wastewaters generates silver-containing residues that are reclaimed when the silver content is high enough.

Other silver salts are produced from the silver nitrate. Silver chloride, silver bromide, and silver iodide are produced by reaction of silver nitrate in solution with sodium chloride, sodium bromide, or sodium iodide. The insoluble product is collected as a precipitate. Wastewaters are generated by these processes, resulting in silver-bearing residues after treatment. Silver oxide, silver carbonate, and silver sulfide are made by similar processes involving reaction in aqueous solution of silver nitrate with sodium hydroxide, sodium carbonate, or sodium sulfide, respectively. In all cases, the products precipitate from solution and are then collected by filtration and dried.

The largest use of silver compounds is in the photographic industry, where silver chloride, silver bromide, and silver iodide are used in the manufacture of photographic films. Both the manufacturing and developing of films generate a variety of silver-containing nonwastewaters and wastewaters. Wastewater treatments generate silver-bearing sludges, which are usually reclaimed for silver value.

Brazing solders frequently contain silver chloride as a fluxing agent. The manufacture and use of these products generate wastes containing silver chloride. The production of silver oxide-zinc batteries gives rise to wastewaters and nonwastewaters containing silver. The same is true for the production and reclamation of silver oxide catalysts.

Electroplating operations consume considerable quantities of silver cyanide and complex silver cyanide salts, such as potassium silver cyanide. The listed wastes generated by these operations (F006, F007, F008, and F009) are discussed in EPA's BDAT Background Document for F006 and BDAT Background Document for Cyanide Wastes. Silver cyanide is produced by reaction of sodium cyanide and silver nitrate in solution under carefully controlled conditions. Again, the insoluble product precipitates from solution and is collected for packaging. Treatment of the wastewaters generated by this production process yields silver-bearing residues.

2.8.2 Waste Characterization (D011)

EPA has data from the National Survey of Hazardous Waste Generators on the approximate composition of the types of D011 wastes being generated. These wastes may be in the form of wastewaters or nonwastewaters.

The nonwastewater forms of D011 contain from 0.1 to 100,000 ppm of silver. Other metals are typically present at comparable concentrations. Most nonwastewaters contain very low levels of organics.

The wastewater forms of D011 contain from 0.1 to 10,000 ppm of silver. Frequently, other metals are also present. In a few cases, organics may be present at concentrations up to 1 percent. Most of the companies reporting D011 wastes in the Generator Survey were plants producing photographic chemicals, electronics equipment, or aerospace-related products. The nature of the individual processes generating the wastestreams is quite varied and includes most of the operations identified as significant consumers of silver salts.

3.0 BDAT TREATMENT STANDARDS FOR NONWASTEWATER FORMS OF D004-D011 WASTES

This section discusses the identification of the Best Demonstrated Available Technology for treatment of nonwastewater forms of D004-D011 wastes and presents development of the BDAT treatment standards for the regulated constituents.

3.1 Identification of BDAT

This section discusses the Agency's determination of applicable and demonstrated technologies and BDAT for treatment of nonwastewater forms of D004-D011 wastes.

In order to establish BDAT, the Agency first identifies which technologies are applicable for treatment of the waste of interest. To be applicable, a technology must be usable to treat the waste in question or a waste that is judged to be similar in terms of parameters that affect treatment selection. Detailed descriptions of technologies that are applicable for the treatment of listed hazardous wastes are provided in EPA's Treatment Technology Background Document (Reference 4). The identification of treatment technologies as applicable for treating listed hazardous wastes is based on current waste management practices, current literature sources, field testing, data submitted by equipment manufacturers, industrial concerns, plus the engineering judgement of EPA technical staff personnel.

The Agency next determines which applicable technologies are demonstrated for treatment of the wastes. To be demonstrated, a technology must be used in a full-scale operation for treatment of the waste of interest or a similar waste. Technologies that are available only at pilot- or bench-scale operations are not considered in identifying demonstrated technologies.

The Agency determines which demonstrated technologies are "best" based on treatment performance data for the constituents of interest and determines whether this "best" demonstrated

technology is also commercially "available." If the "best" demonstrated technology is considered to be "available," then that technology is determined to represent BDAT.

3.2 Applicable and Demonstrated Technologies for Metals

This section describes the technologies that are both applicable and demonstrated for treatment of nonwastewater forms of D004-D011 for which EPA is proposing UTS as the standard.

Applicable treatment technologies for metals include those that immobilize or reduce the total amount of metal constituents in a waste. The technologies listed below are applicable and have been demonstrated to treat metal constituents in nonwastewater forms of TC metal wastes.

Acid Leaching

Acid leaching is used to treat metal bearing wastes in solid or slurry form. The metal constituents are soluble in strong acid solutions or can be converted by reaction with a strong acid to a soluble form. The process concentrates the metal constituents leached by the acid solutions. The metal constituents can then be filtered to remove residual solids and neutralized to precipitate solids containing high concentrations of the constituents of interest.

Stabilization

Stabilization is a broad class of treatment technologies that reduce the mobility of metal constituents in a waste; the metals are chemically bound into a solid matrix that resists leaching when water or a mild acid solution comes into contact with the waste material. Organic materials usually are not stabilized effectively and may, in fact, inhibit the stabilization of metals. Hence, stabilization is applicable to nonwastewaters only after the organics have been removed by other treatment.

Pyrometallurgical Recovery Processes (High Temperature Metals Recovery)

Pyrometallurgical recovery processes are those treatment technologies that use physical and chemical reactions at elevated temperatures for extraction/separation of metals, ores, salts, and other materials. For the purposes of the LDR Program, pyrometallurgical processes are referred to as High Temperature Metals Recovery (HTMR). Some examples of HTMR systems include rotary kilns, flame reactors, electric furnaces, plasma arc furnaces, slag reactors, and rotary hearth/electric furnaces. These thermal reduction processes use carbon, limestone, and silica (sand) as raw materials. The carbon acts as a reducing agent and reacts with metal oxides in a high temperature processing unit (e.g., kiln, furnace) to produce carbon dioxide and a free metal. This process yields a metal product for reuse and reduces the concentration of metals in the residuals.

Retorting

Retorting is a specialized form of HTMR that is performed primarily to recover mercury from wastes. Retorting operates at much lower temperatures than conventional HTMR because mercury is an extremely volatile metal. However, like HTMR, essentially two streams are produced within the retort: the condensate stream, consisting of condensed mercury liquid in a relatively pure state; and the residual stream that is left in the retort, which may also be recyclable (e.g., if the waste is crushed fluorescent light bulbs, mercury is volatilized into the condensate stream, while the glass portion of the bulbs may be recycled back into the glassmaking process).

Hydrometallurgical Recovery Processes

Hydrometallurgical recovery processes extract and recover materials by using acidic solutions. These processes are most effective with wastes containing high concentrations of metals that are soluble in a strong acid solution or that can be converted by reaction with a

strong acid to a soluble form. Some hydrometallurgical processes include chemical precipitation, leaching, ion exchange, solvent extraction, and electrowinning.

The Agency is aware that some facilities are using a series of technologies, including chemical precipitation, ion exchange, and electrowinning, to recover metals from various metal-bearing wastestreams. Some of these facilities claim that these hydrometallurgical processes, unlike other processes, generate no residuals for land disposal.

Recycling

For some metal-bearing wastes, recycling may be an applicable technology. An example is nonwastewater forms of K061 wastes, electric arc furnace dust, which may be recycled directly back into the electric furnaces from which it was originally produced. Such practices facilitate the recovery of metals in steelmaking while reducing or eliminating the material to be land disposed.

3.2.1 Identifying BDAT for D004-D011

The Agency has identified HTMR and stabilization as BDAT for metal constituents in nonwastewater forms of D004-D011 wastes, with the exception of arsenic, and mercury in low-mercury subcategory wastes (i.e., wastes containing less than 260 mg/kg mercury). HTMR processes include rotary kilns, flame reactors, electric furnaces, plasma arc furnaces, slag reactors, and rotary hearth/electric furnaces.

BDAT for arsenic is slag vitrification, rather than stabilization and HTMR, because this technology is demonstrated, commercially available, and achieves substantial treatment of arsenic. The vitrification process is capable of managing a wide variety of arsenic-bearing wastes. At the temperatures at which the vitrification process is normally operable (1,100 to 1,400°C), organoarsenic compounds will be combusted to arsenic oxide, carbon dioxide, and

water. The arsenic oxide formed will react with the other glass-forming constituents and become immobilized in the glass formed. The Agency has data indicating that arsenic can be vitrified into slag at concentrations of up to 24 percent arsenic, and that this slag will pass the EP-toxicity test for arsenic. Treatment performance data for arsenic are shown in Appendix A, Table A-1.

BDAT for mercury in low-mercury subcategory wastes is acid leaching, rather than stabilization and HTMR, because this technology is demonstrated, commercially available, and achieves substantial treatment of mercury in low-mercury subcategory wastes. The acid leaching treatment performance data presented in Appendix A, Table A-1 of this document represent the "best" available treatment performance data for mercury in low-mercury subcategory wastes. Because the acid leaching performance data presented in Appendix A, Table A-1 represent BDAT for wastes included in previous rulemakings, acid leaching has been judged previously to meet the criteria for "best" treatment technology.

The Agency used the following rationale for identifying HTMR on stabilization as BDAT for most metal constituents in nonwastewater forms of listed hazardous wastes. Because metals cannot be destroyed, treatment options for metal-bearing wastes are limited. Typically, these options include technologies that either can recover the metal or incorporate the metal into a stable matrix resistant to leaching. The Agency believes that the "best" treatment for metal constituents is recovery, especially in cases of high waste metal concentrations. Of the applicable technologies, HTMR appears to be the most matrix-independent (i.e., it consistently achieves the same levels of treatment performance regardless of influent matrix composition). HTMR also generally decreases the amount of material sent for land disposal, recovers valuable resources, and incorporates metals that are not recoverable into a stable slag matrix.

The Agency's review of the HTMR performance data indicated that the slag residues for land disposal leach concentrations of metals that are comparable to (and, for most metals, less than) residues from stabilization of similar wastes. Furthermore, the use of HTMR is consistent with the national policy, identified in HSWA, to reduce the quantity of hazardous constituents

disposed in landfills (this is in contrast to nonrecovery technologies, such as stabilization, which are not intended to reduce the total concentration or quantity of hazardous constituents in the waste and, in fact, can increase the volume being sent to landfills). In addition, because metals are recovered instead of land disposed, ore processing is reduced, thus saving energy and pollution from those processes. All HTMR data included in Appendix A, Table A-1 represent BDAT for wastes included in previous rulemakings and, therefore, previously have been judged to meet the conditions for identification of "best" technology described in EPA's Methodology Background Document (3).

EPA recommends, however, that if recovery is not feasible because the metal content in the waste is too low or the material contains constituents that may adversely affect recovered products, then the generator should investigate alternative ways to generate wastes that are amenable to recovery (e.g., segregation) or to substitute materials that are suitable for recovery in their processes, for those unrecoverable materials that will eventually become wastes.

The Agency realizes that recovery of metals from all wastes is not practical; at some level of metal concentration (EPA believes this to be approximately 1 percent total BDAT List metal constituents), recovery efforts typically cease, and the remaining metals must be incorporated into a leach-resistant matrix for safe disposal.

The Agency notes, however, that when it establishes concentration-based treatment standards, the regulated community may use any nonprohibited technology to treat the waste to meet the treatment standards. Compliance with a concentration-based treatment standard requires only that the effluent concentration be achieved; once achieved, the waste may be land disposed. The waste does not have to be treated by the technology identified as BDAT; in fact, concentration-based treatment standards provide flexibility in the choice of a treatment technology. Any treatment, including recycling or any combination of treatment technologies, unless prohibited (e.g., impermissible dilution) or defined as land disposal (e.g., land treatment), may be used to achieve these standards.

3.3 Identification of BDAT Treatment Standards

The Agency is transferring universal standards to the constituents regulated in nonwastewater forms of D004-D011 wastes. A universal standard is a concentration limit established for a specific constituent regardless of the waste matrix in which it is present. Table 3-1 presents the specific treatment performance data used to determine the universal standards for the constituents regulated in these wastes.

Universal standards for the constituents regulated in nonwastewater forms of D004-D011 wastes were based upon treatment performance data from vitrification for arsenic, acid leaching for mercury, and stabilization and HTMR for the other metals. These data represent BDAT for wastes included in previous rulemakings and, therefore, have been judged to meet the Agency's requirements of BDAT. Thus, the technologies described above were determined to be BDAT for the metals of interest in universal standards. EPA believes that the performance data used to develop UTS for metals are comprehensive and represent a diverse group of waste matrices. The Agency notes that treatment performance data from the most difficult to treat waste matrices were used in developing UTS. The Agency notes that in some cases where the data did not achieve the UTS, further optimization of the treatment process may improve the technology performance. Hence, in consideration of the above, the Agency believes it is appropriate to transfer the BDAT for UTS metals to TC metals.

Table 3-1. Determination of BDAT Treatment Standards for Nonwastewater Forms of D004-D011 Based on Universal Standards

Waste Code and Regulated Constituent	Waste Code from Which the Universal Treatment Standard Data Were Transferred	Treatment Test from Which Performance Data[a] Were Transferred	Average Concentration in Treated Waste (mg/L)	Accuracy Correction Factor (Matrix Spike % Recovery)	Variability Factor	BDAT Treatment Standard (mg/kg)
D004 - Arsenic	D004	-	-	-	-	5.0
D005 - Barium	D005	K061: SKF, IMS	2.51	1.08	2.8	7.6
D006 - Cadmium	D006	K061: HRD	<0.060	1.15 (87)[b]	2.8	0.19
D007 - Chromium	D007	D007: CyanoKEM	0.16	1.0 (105)[b]	5.4	0.86
D008 - Lead	D008	K061: HRD	<0.10	1.32 (76)[b]	2.8	0.37
D009 - Mercury	D009	K061, U151, P065, P092: Low mercury[c], RMERC[d] residues	-	-	-	0.20
		K071, F039, K106, U151: Low mercury, non-RMERC[d] residues P065, P092: Low mercury[c] incinerator residues	0.0043	1.05 (95)	5.47	0.025
D010 - Selenium	D010	K061: INMETCO	<0.05	1.11 (90)[b]	2.8	0.16
D011 - Silver	D011	K061: HRD	<0.080	1.32 (76)[b]	2.8	0.30

< - Indicates a detection limit value.
[1] - No matrix spike data were available for these data. Matrix spike data were transferred from the IMS test.
[a]Performance data consist of concentration in treated waste, accuracy correction factor, and variability factor.
[b]This number represents a constituent-specific matrix spike.
[c]Low-mercury subcategory wastes = mercury wastes with mercury concentrations less than 260 mg/kg
[d]RMERC = mercury recovery by roasting/retorting.

HRD - Horsehead Resource Development Co. HTMR data.
SKF - SKF Plasma Technologies HTMR data.
IMS - International Mill Service HTMR data.
INMETCO - International Metals Reclamation Company HTMR data.
Source: Reference 1

4.0 BDAT TREATMENT STANDARDS FOR WASTEWATER FORMS OF D004-D011 WASTES

This section discusses the identification of Best Demonstrated Available Technology for treatment of wastewater forms of D004-D011 wastes and presents the development of the BDAT treatment standards for the regulated constituents.

4.1 Identification of BDAT

This section discusses the Agency's determination of applicable and demonstrated technologies and BDAT for treatment of wastewater forms of D004-D011 wastes. However, any treatment technology that reduces the concentration of regulated constituents to the level of the treatment standards and is not considered impermissible dilution is also acceptable.

In order to establish BDAT, the Agency first identifies that technologies are "applicable" for treatment of the constituents of interest. An applicable technology is one which, in theory, can treat the waste in question or a waste similar to the waste in question in terms of parameters that affect treatment selection. Detailed descriptions of the technologies identified as applicable for the treatment of listed hazardous wastes are provided in EPA's Treatment Technology Background Document (Reference 4). The basis for identifying treatment technologies as applicable for treating BDAT List constituents is evaluation of current waste management practices, current literature sources, field testing, data submitted by equipment manufacturers, industrial concerns, plus the engineering judgement of EPA technical staff personnel.

The Agency next determines which applicable technologies are "demonstrated" for treatment of the wastes. To be designated as demonstrated, a technology must be used in a full-scale operation for treatment of the waste of interest or a similar waste. Technologies that are available only at pilot- or bench-scale operations are not considered demonstrated technologies.

The procedure used to identify BDAT for the wastewater forms of D004-D011 wastes follows the methodology described in EPA's Methodology Background Document. All applicable and demonstrated treatment technologies are identified for the wastes of interest, and performance data are examined to identify the technologies that perform "best." The treatment performance data are evaluated to determine:

- Whether the data represent operation of a well-designed and well-operated treatment system;
- Whether sufficient analytical quality assurance/quality control measures were used to ensure the accuracy of the data; and
- Whether the appropriate measure of performance was used to assess the performance of the particular treatment technology.

The Agency then determines whether the best demonstrated technology is "available." To be "available," a technology (1) must provide substantial treatment and (2) must be commercially available.

The Agency determined the best demonstrated technology for each constituent selected for regulation in D004-D011 wastes based on a thorough review of all treatment performance data available for each constituent. Appendix B presents the treatment performance data evaluated by EPA for these constituents.

The demonstrated technologies identified and determined to be "best" for each constituent are all commercially available. In addition, treatment performance data included in Appendix B show substantial treatment of each constituent by the corresponding technology identified as best. Therefore, the technologies selected as best and demonstrated for each constituent are also considered to be available, and as such, BDAT for that constituent. BDATs for the constituents regulated in the wastewater forms of D004-D011 wastes are shown in Table 4-1 at the end of this chapter.

4.1.1 Applicable Treatment Technologies for Metal Constituents

Because wastewater forms of listed hazardous wastes may contain metal constituents at treatable concentrations, applicable technologies include those that reduce the total amount of metal compounds in the wastewater. Therefore, the technologies listed below are applicable and have been demonstrated to treat metal constituents in wastewater forms of TC metals wastes.

Biological Treatment

Biological treatment is a destruction technology that biodegrades hazardous constituents in wastewaters. This technology generates two treatment residuals: a treated effluent and a waste biosludge. Waste biosludge may be land disposed without further treatment if it meets the applicable BDAT treatment standards for regulated constituents. The Agency notes that biotreatment is a technology that is <u>not</u> designed to treat hazardous metals, but results in incidental removal.

Chemically-Assisted Clarification

Chemically-assisted clarification, including chemical precipitation, is a separation technology that removes organic and inorganic constituents from wastewater by the addition of chemicals that cause precipitates to form. The solids formed are then separated from the wastewater by settling, clarification, and/or polishing filtration. This technology generates two treatment residuals: treated wastewater effluent and separated solid precipitate. The solid precipitate may be land disposed without further treatment if it meets the applicable BDAT treatment standards for the regulated constituents in nonwastewater forms of waste.

Chemical Oxidation

Chemical oxidation is a destruction technology that oxidizes inorganic cyanide, some dissolved organic compounds, and sulfides to yield carbon dioxide, water, salts, simple organic acids, and sulfates. This technology generates one treatment residual: treated effluent.

Chemical Reduction Treatment

Chemical reduction treatment, consisting of chemical reduction followed by precipitation, sedimentation, and filtration, is a separation technology that chemically reduces metal constituents from a higher oxidation state to a lower oxidation state. The reduced metal is then in a form amenable to chemical precipitation and subsequent sedimentation and/or filtration. For example, hexavalent chromium (Cr^{+6}) can be reduced to the less soluble trivalent (Cr^{+3}) chromium ion. This technology generates two treatment residuals: a treated effluent and a settled or filtered solid containing the precipitated metal. The solid residual may require additional treatment, prior to land disposal, to meet applicable BDAT treatment standards in nonwastewater forms of waste for regulated constituents remaining in the residual.

Electrochemical Treatment

Electrochemical treatment consisting of electrochemical treatment followed by chemically assisted clarification treatment, is a separation technology in which direct current is applied to iron electrodes, generating ferrous ions. Metal constituents are removed by adsorbing and coprecipitating within insoluble ferrous ion matrices formed by the iron electrodes. These matrices are then settled out of solution using chemically-assisted clarification. This technology generates two treatment residuals: a treated effluent and a settled solid containing the precipitated metal. The solid residual may require additional treatment, prior to land disposal, to meet applicable BDAT treatment standards in nonwastewater forms of waste for regulated constituents remaining in the residual.

Lime, Sedimentation, Filtration

Lime, sedimentation, and filtration is a separation technology in which wastewaters are mixed with lime, causing metal constituents in the wastewater to produce an insoluble metal hydroxide material that settles out of solution. The metal hydroxide precipitate is then filtered out of the wastewater solution. This technology generates two treatment residuals: a treated effluent and filter cake containing lime and metal oxides. The filter cake may require additional treatment, prior to land disposal, to meet applicable BDAT treatment standards in nonwastewater forms of waste for regulated constituents remaining in the filter cake.

4.1.2 Demonstrated Treatment Technologies

Demonstrated treatment technologies are those which have been demonstrated in full-scale operation for treatment of the wastes of interest or a similar waste. The Agency has identified all of the applicable treatment technologies for wastewater forms of D004-D011 wastes as shown in Table 4-1 to be demonstrated technologies, from an analysis of the available treatment performance data presented in Appendix B. Treatment performance data for the constituents regulated in wastewater forms of D004-D011 wastes, presented in Appendix B, include data from bench-, pilot-, and full-scale treatment using these technologies.

4.2 Identification of BDAT Treatment Standards

The Agency is proposing to transfer universal standards to the constituents regulated in wastewater forms of D004-D011 wastes. A universal standard is a concentration limit established for a specific constituent regardless of the waste matrix in which it is present. Appendix B presents the specific treatment performance data used as the basis of the universal standards for the constituents regulated in these wastes. Table 4-1 presents the treatment standards for TC metals.

Universal standards in wastewater forms of wastes are based on treatment performance data from several sources including the BDAT data base, the NPDES data base, the WERL data base, EPA-collected WAO/PACT® data, the EAD data base, industry-submitted leachate treatment performance data, data submitted by the Chemical Manufacturers Association's Carbon Disulfide Task Force, data submitted by the California Toxic Substances Control Division, data in literature that were not already part of the WERL data base, and data in literature submitted by industry on the WAO and PACT® treatment processes. Because these standards reflect the performance of numerous industrial wastewater treatment systems on the most difficult to treat wastes, the Agency believes it is appropriate to transfer the universal standards for wastewaters to the constituents regulated in wastewater forms of D004-D011 wastes.

The treatment performance data base and methodology for identifying universal standards for constituent in wastewater forms of toxicity characteristic wastes are presented in Appendix B of this document. A more detailed discussion concerning the determination of the universal standards for nonwastewater forms of listed hazardous wastes is provided in EPA's Final Best Demonstrated Available Technology (BDAT) Background Document for Universal Standards, Volume B: Universal Standards for Wastewater Forms of Listed Hazardous Wastes (2).

Table 4-1. Determination of BDAT Treatment Standards for Constituents in Wastewater Forms of D004-D011 Wastes Based on Universal Standards

Waste Code	Regulated Constituent	Treatment Technology	Data Base Reference	Average Effluent Concentration (mg/L)	Accuracy Correction Factor	Variability Factor	BDAT Treatment Standard (mg/L)
D004	Arsenic	L + Sed + Fil	EAD - CMDB	0.34	-	4.1	1.4
D005	Barium	L + Sed + Fil	EAD - CMDB	0.28	-	4.1	1.2
D006	Cadmium	L + Sed	EAD - MF	0.13	-	5.3	0.69
D007	Chromium (total)	L + Sed	EAD - MF	0.57	-	4.9	2.77
D008	Lead	L + Sed	EAD - MF	0.20	-	3.5	0.68
D009	Mercury	L + Sed + Fil	EAD - CMDB	0.036	-	4.1	0.15
D010	Selenium	L + Sed + Fil	EAD - CMDB	0.20	-	4.1	0.82
D011	Silver	L + Sed	EAD - MF	0.096	-	4.5	0.43

L + Sed + Fil = lime conditioning followed by sedimentation and filtration.
L + Sed = lime conditioning followed by sedimentation.
EAD - Engineering and Analysis Division.
CMDB - Combined Metals Data Base.
MF - Metal Finishing Data Base.

Source: Reference 2

5.0 ACKNOWLEDGEMENTS

Radian Corporation provided technical support for the development of this document to the U.S. Environmental Protection Agency, Office of Solid Waste under Contract Number 68-W3-0001. This document was prepared under the direction of Richard Kinch, Chief, Waste Treatment Branch; Larry Rosengrant, Section Chief, Treatment Technology Section; and Carolyn Cunningham and David Levy, Project Officers. Anita Cummings served as the Project Manager for this document. Steve Silverman served as EPA legal advisor.

The following personnel from Radian Corporation supported the development of this document: Gayle Kline, Program Manager; Richard Weisman, Project Director; and the Versar Team: Jerome Strauss, Versar Associate Program Manager; Stan Moore, Principal Investigator; and Suzanne Wade and Kelly O'Rourke, Engineering Team.