I. EXECUTIVE SUMMARY

The purpose of this executive summary is to summarize EPA's review of mineral commodities which may produce hazardous wastes as defined by RCRA Subtitle C. EPA studied mineral commodities as part of the RCRA requirements to establish treatment standards for newly identified RCRA hazardous wastes. Through a series of rulemakings (see Background below) EPA has established criteria for which mineral processing wastes are no longer exempt from Subtitle C regulation. These wastes are termed "newly identified" mineral processing wastes.

Any newly identified mineral processing waste that exhibits one of the four characteristics of a hazardous waste must be made subject to the Land Disposal Restrictions (LDRs). Accordingly, EPA will be proposing treatment standards (Best Demonstrated Available Technology, or BDAT) for newly identified mineral processing wastes, and expects to promulgate these standards by 1996. This work has required EPA to perform further data collection and analysis activities in order to better identify "newly identified" wastes and to develop BDAT treatment standards that are both adequately protective and achievable.

As part of this effort, EPA reviewed the 36 industrial sectors (commodities) and 97 different general categories of wastes identified in a previously published Advanced Notice of Public Rule Making (ANPRM) (October 21, 1991). EPA also reviewed a listing of more than 100 mineral commodities prepared by the U.S. Bureau of Mines (Bureau of Mine's 1987 Minerals Year Book, 1989-1995 Mineral Commodities Summary, and 1985 Mineral Facts and Problems). This information, in addition to data collected in previous EPA studies, was used to compile a comprehensive list of mineral commodity sectors. In the process, the Agency identified a total of 62 mineral commodities that could generate mineral processing waste streams that could potentially exhibit one of the characteristics of a RCRA hazardous waste.

The Agency used publicly available information to prepare this draft technical background document on the production of particular mineral commodities and associated operations that generate mineral processing wastes.

This document, available in the RCRA docket, represents the Agency's view that the wastes discussed are, in fact, mineral processing wastes, rather than beneficiation wastes (beneficiation wastes would be exempt from Subtitle C, because all beneficiation wastes remain within the scope of the Mining Waste Exclusion). The Agency will be soliciting comment on this document and expects to revise it during the course of this rulemaking. The Agency is also seeking comments as to whether this document, when finalized, should be a binding Agency determination. The other alternative is for the discussions of the wastes to be merely interpretive, as are letters that are sometimes provided to parties inquiring about the regulatory status of particular wastes. Such letters are non-binding and are not considered to be "final agency action" within the meaning of the Administrative Procedures Act, but provide useful guidance as to the Agency's initial assessment of the matter.

The Agency cautions that this draft document should not be construed to be an exclusive list of mineral processing and associated waste streams; other types of mineral processing wastes may exist. Moreover, the omission or inclusion of a waste stream in this background document does not relieve the generator from the responsibility for correctly determining whether each of its particular wastes is covered by the Bevill exemption.

A. METHODS AND DATA SOURCES

1. Background

Under the provisions of the Mining Waste Exclusion of the Resource Conservation and Recovery Act (RCRA), solid waste from the extraction, beneficiation, and processing of ores and minerals is exempt from regulation as hazardous waste under Subtitle C of RCRA, as amended. The Mining Waste Exclusion was established in response to §3001(b)(3) of the statute, which was added in the 1980 Solid Waste Disposal Act Amendments (also known as the "Bevill Amendment"). The Bevill Amendment precluded EPA from regulating these wastes until the Agency performed a study and submitted a Report to Congress, as directed by §8002(f) and (p), and determined either to promulgate regulations under Subtitle C or that such regulations were unwarranted, (i.e., that the Exclusion should continue), as directed by §3001(b)(3)(C) of the statute. In response to the Bevill Amendment, EPA modified its final hazardous waste regulations in November 1980 to reflect this new exemption, and issued a preliminary and very broad interpretation of the scope of its coverage ("solid waste from the exploration, mining, milling, smelting and refining of ores and minerals" (45 FR 76618, November 19, 1980)).

In 1984, the Agency was sued for failing to complete the required Report to Congress and regulatory determination in conformance with the statutory deadline (*Concerned Citizens of Adamstown v. EPA*, No. 84-3041, D.D.C., August 21, 1985). In responding to this lawsuit, EPA explained that it planned to propose a narrower interpretation of the scope of the Exclusion, and proposed to the Court two schedules: one for completing the §8002 studies of mineral extraction and beneficiation wastes and submitting the associated Report to Congress, and one for proposing and promulgating a reinterpretation for mineral processing wastes. In so doing, the Agency, in effect, split the wastes that might be eligible for exclusion from regulation into two groups: mining (extraction and beneficiation) wastes and mineral processing wastes. The Court agreed to this approach and established a schedule for completing the two initiatives.

The Report to Congress on mining wastes was published on December 31, 1985, and on July 3, 1986 (51 FR 24496) EPA published the regulatory determination for these wastes, which stated that, in the Agency's judgment, Subtitle C regulation of these wastes was unwarranted. In keeping with its agreement, EPA also proposed to narrow the scope of the Mining Waste Exclusion for mineral processing wastes on October 2, 1985 (50 FR 40292). In this proposal, however, the Agency did not specify the criteria that it used to distinguish the mineral processing wastes that qualified for the Exclusion from those that did not.

In response to the proposed rule, many companies and industry associations "nominated" wastes that they believed should be retained within the Exclusion. Faced with an inability at that time to articulate criteria that could be used to distinguish exempt from non-exempt wastes and the approaching Court-ordered deadline for final action, EPA withdrew its proposal on October 9, 1986 (51 FR 36233); the Agency was promptly sued by a coalition of environmental/public interest groups. In July 1988, the Court in *Environmental Defense Fund v. EPA* held that EPA's withdrawal of the 1985 proposal was arbitrary and capricious, and ordered the Agency to define the specific mineral processing wastes that were eligible for the Mining Waste Exclusion. The Court also directed the Agency to restrict the scope of the Exclusion to include only "large volume, low hazard" wastes, based upon the legislative history of the special wastes concept.

During the three years that followed this decision, EPA proposed and promulgated several rules that redefined the boundaries of the Exclusion for mineral processing wastes. These rulemaking notices included explicit criteria for defining mineral beneficiation and processing, and large volume and low hazard, as well as evaluations of which specific mineral industry wastes were in conformance with these criteria and thus, eligible for special waste status. This rulemaking process was completed with the publication of final rules on September 1, 1989 (54 FR 36592) and January 23, 1990 (54 FR 2322). EPA's evaluations led to the finding that only 20 specific mineral processing wastes fulfilled the newly promulgated special wastes criteria; all other mineral processing wastes were removed from the Mining Waste Exclusion. The 20 special wastes were studied in a comprehensive Report to Congress published on July 30, 1990. Subsequently, EPA ruled, after considering public comment and performing additional analysis, that Subtitle C regulation was unwarranted for these 20 waste streams.

How LDR Relates to Mineral Processing Wastes

As a consequence of the rulemaking process described above, all but 20 mineral processing wastes have been removed from the Mining Waste Exclusion. These newly non-exempt wastes have the same regulatory status as any other industrial solid waste. That is, if they exhibit characteristics of hazardous waste or are listed as hazardous wastes, they must be managed in accordance with RCRA Subtitle C or equivalent state standards. Existing waste characterization data suggest that some of these wastes may exhibit the characteristic of toxicity for metals (waste codes D004-D011), corrosivity (D002), and/or reactivity (D003).

EPA considers these wastes to be "newly identified" because they were brought into the RCRA Subtitle C system after the date of enactment of the Hazardous and Solid Waste Act (HSWA) Amendments on November 8,

1984. EPA declined to include newly identified wastes within the scope of the Land Disposal Restrictions (LDRs) for Subtitle C characteristic hazardous wastes ("Third Third" Rule) published on June 1, 1990, deciding instead to promulgate additional treatment standards (Best Demonstrated Available Technology, or BDAT) in several phases that would be completed in 1997. The rationale for this decision is articulated at 55 FR 22667. In brief, at that time, EPA had not performed the technical analyses necessary to determine whether the treatment standards being promulgated for characteristic hazardous wastes were feasible for the newly non-exempt mineral processing wastes. The issue was further complicated by the fact that the list of non-exempt wastes was not final at that time, because the regulatory determination for the 20 wastes studied in the 1990 Report to Congress had not yet been promulgated. The boundaries of the Exclusion have now been firmly established, and the Agency is ready to characterize and establish treatment standards for all newly identified hazardous mineral processing wastes.

More recent work performed by OSW's Waste Treatment Branch (WTB) on the composition and other characteristics of the mineral processing wastes that have been removed from the Exclusion suggests that some of these wastes may pose unique treatability and/or capacity problems. Accordingly, there was a need for EPA to perform further data collection and analysis activities in order to develop BDAT treatment standards that are both adequately protective and achievable.

2. Scope of the Report

In order to provide the necessary foundation to both develop a fully comprehensive inventory of mineral commodity sectors, facilities, and waste streams that may be affected by the LDRs program and identify applicable treatment technologies, EPA conducted an extensive effort to collect information. Specifically, EPA: (1) conducted electronic literature searches; (2) reviewed documents, including the 1989 mineral processing survey instruments (NSSWMPF), public comments on the 1991 ANPRM, and various articles and conference proceedings; (3) reviewed documents prepared by the Office of Solid Waste, various Agency contractors, state regulatory authorities, and the Bureau of Mines (BOM); (4) reviewed the "Mineral Commodity Summaries" prepared by the BOM; and (5) contacted BOM Commodity Specialists. Information collected included detailed process descriptions and identification of waste streams. The specific methodology that EPA employed for this effort is described in detail in Section 3, Methods and Data Sources, below.

Based on this information, EPA prepared 49 separate analyses covering the 62 commodity groups presented in Exhibit 1-1. Each analysis includes the following:

- A commodity summary describing the uses and salient statistics of the particular mineral commodity;
- A process description section with detailed, current process information and process flow diagram(s); and
- A process waste stream section that identifies -- to the maximum extent practicable -- individual waste streams, sorted by the nature of the operation (i.e., extraction/beneficiation or mineral processing).[1] Within this section, EPA also identified:
  - waste stream sources and form (i.e., wastewater (<1 percent solids and total organic content), 1-10 percent solids, and >10% solids);
  - Bevill-Exclusion status of the waste stream (i.e., extraction/beneficiation waste stream, mineral processing waste stream, or non-uniquely associated waste stream).
  - waste stream characteristics (total constituent concentration data, and statements on whether the waste stream exhibited one of the RCRA hazardous waste characteristics of toxicity, ignitability, corrosivity, or reactivity);
  - annual generation rates (reported or estimated);
  - management practices (e.g., tank treatment and subsequent NPDES discharge, land disposal, or in-process recycling); and

[1] EPA strongly cautions that the process information and identified waste streams presented in the commodity analysis reports should not be construed to be the authoritative list of processes and waste streams. These reports represent a best effort, and clearly do not include every potential process and waste stream. Furthermore, the omission of an actual waste stream (and thus its not being classified as either an extraction/beneficiation or mineral processing waste in this report) does not relieve the generator from its responsibility of correctly determining whether the particular waste is covered by the Mining Waste Exclusion.

- whether the waste stream was being (or could potentially be) recycled, and thus be classified as either as a sludge, by-product, or spent material.

The list provided in this report represent EPA's best effort to date, and generators continue to be responsible for determining whether any wastes omitted from these lists are non-exempted and subject to Subtitle C controls.

3. Methodology and Major Data Sources

EPA researched and obtained information characterizing the mineral processing operations and wastes associated with the mineral commodities listed above in Exhibit 1-1. This information was used by EPA both to update existing data characterizing mineral processing wastes obtained through past Agency efforts and to obtain characterization information on newly identified waste streams not previously researched.

To provide the necessary foundation to both (1) develop a fully comprehensive inventory of mineral commodity sectors, facilities, and waste streams that may be affected by the LDRs program and (2) identify applicable treatment technologies, EPA embarked on an information collection program. Specifically, to capitalize on information collected through past efforts, as well as to collect more recent data, we conducted the following activities:

- Reviewed mineral processing survey instruments (NSSWMPF) and public comments (submitted in response to the 1991 ANPRM) for process-related information (e.g., process flow diagrams, waste characterization data, and waste management information) contained in our in-house files.

- Reviewed numerous documents provided by EPA (e.g., contractor reports and various Bureau of Mines reports) for process-related information.

- Reviewed both the 1993, 1994, and 1995 "Mineral Commodity Summaries" prepared by the Bureau of Mines (BOM) for salient statistics on commodity production.

- Partially reviewed and summarized damage case information presented in the "Mining Sites on the National Priorities List, NPL Site Summary Reports" to support work on assessing the appropriateness of the Toxicity Characteristic Leaching Procedure (TCLP) for mineral processing wastes.

- Contacted the BOM Commodity Specialists associated with the commodity sectors of interest to (1) obtain current information on mining companies, processes, and waste streams, and (2) identify other potential sources of information.

- Retrieved applicable and relevant documents from the BOM's FAXBACK document retrieval system. Documents retrieved included monthly updates to salient statistics, bulletins, and technology review papers.

- Conducted an electronic query of the 1991 Biennial Reporting System (BRS) for waste generation and management information on 34 mineral processing-related Standard Industrial Classification (SIC) numbers.

- Conducted an electronic literature search for information related to mineral processing and waste treatment technologies contained in numerous technical on-line databases, including: NTIS, Compendex Plus, METADEX, Aluminum Industry Abstracts, ENVIROLINE, Pollution Abstracts, Environmental Bibliography, and GEOREF.

EPA searched for relevant information (published since 1990) on the mineral commodities listed in Exhibit 1-1. We chose 1990 as the cutoff year so as not to duplicate past information collection activities conducted by EPA and EPA contractors, and to obtain information on mineral processes "retooled" since clarification of the Bevill Amendment to cover truly "high volume, low hazard" wastes.

EXHIBIT 1-1

MINERAL COMMODITIES OF POTENTIAL INTEREST

1) Alumina
2) Aluminum
3) Ammonium Molybdate
4) Antimony
5) Arsenic Acid
6) Asphalt (natural)
7) Beryllium
8) Bismuth
9) Boron
10) Bromine (from brines)
11) Cadmium
12) Calcium Metal
13) Cerium, Lanthanides, and Rare Earth metals
14) Cesium/Rubidium
15) Chromium
16) Coal Gas
17) Copper
18) Elemental Phosphorus
19) Ferrochrome
20) Ferrochrome-Silicon
21) Ferrocolumbium
22) Ferromanganese
23) Ferromolybdenum
24) Ferrosilicon
25) Gemstones
26) Germanium
27) Gold and Silver
28) Hydrofluoric Acid
29) Iodine (from brines)
30) Iron and Steel
31) Lead
32) Lightweight Aggregate
33) Lithium (from ores)
34) Lithium Carbonate
35) Magnesia (from brines)
36) Magnesium
37) Manganese and MnO_2
38) Mercury
39) Mineral Waxes
40) Molybdenum
41) Phosphoric Acid
42) Platinum Group Metals
43) Pyrobitumens
44) Rhenium
45) Scandium
46) Selenium
47) Silicomanganese
48) Silicon
49) Soda Ash
50) Sodium Sulfate
51) Strontium
52) Sulfur
53) Synthetic Rutile
54) Tantalum/Columbium
55) Tellurium
56) Tin
57) Titanium/TiO_2
58) Tungsten
59) Uranium
60) Vanadium
61) Zinc
62) Zirconium/Hafnium

NOTE: This list represents EPA's best efforts at identifying mineral commodities which may generate mineral processing wastes. Omission or inclusion on this list does not relieve the generator from managing wastes that would be subject to RCRA Subtitle C requirements.

In preparing the commodity sector reports, we used EPA's established definitions and techniques for establishing which operations and waste streams might be subject to LDR standards. EPA decisions concerning whether individual wastes are within the scope of the RCRA Mining Waste Exclusion were based upon a number of different factors. The Agency examined these factors in sequence, in such a way as to yield unambiguous and consistent decisions from sector to sector. The step-wise methodology used for this analysis is presented below:

1. Ascertain whether the material is considered a solid waste under RCRA.

2. Determine whether the waste is generated by a primary mineral production step, and, more generally, whether or not primary production occurs in the sector/within a process type.

3. Establish whether the waste and the operation that generates it are uniquely associated with mineral production.

4. Determine whether the waste is generated by a mineral extraction, beneficiation, or processing step.

5. Check to see whether the waste, if a processing waste, is one of the 20 special wastes from mineral processing.

This analytical sequence results in one of three outcomes: 1) the material is not a solid waste and hence, not subject to RCRA; 2) the material is a solid waste but is exempt from RCRA Subtitle C because of the Mining Waste Exclusion; or 3) the material is a solid waste that is not exempt from RCRA Subtitle C and is subject to regulation as a hazardous waste if it is listed as a hazardous waste or it exhibits any of the characteristics of hazardous waste.[2]

EPA used waste stream characterization data obtained from numerous sources to document whether a particular waste stream exhibited one (or more) of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity). Where documented waste generation rates and analytical data were not available, EPA used a step-wise methodology for estimating waste characteristics for individual waste streams to present mineral commodity profiles that were as complete as possible. Specifically, due to the paucity of waste characterization data (particularly, TCLP data), EPA used total constituent data (if available) or engineering judgment to determine whether a particular waste exhibited one of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity).

When data were available, EPA used actual waste generation rates reported by facilities in various Agency survey instruments and background documents. However, to account for the general lack of data for many of the mineral commodity sectors and waste streams, the Agency developed a step-wise method for estimating mineral processing waste stream generation rates when actual data were unavailable. Specifically, EPA developed an "expected value" estimate for each waste generation rate using draft industry profiles, supporting information, process flow diagrams, and professional judgment. From the "expected value" estimate, EPA developed upper and lower bound estimates, which reflect the degree of uncertainty in our data and understanding of a particular sector, process, and/or waste in question. Precise methodology for determining waste generation rates varied depending on the quantity and quality of available information.

To determine waste stream management practices, EPA reviewed process descriptions and process flow diagrams obtained from numerous sources including, Kirk-Othmer, EPA's Effluent Guideline Documents, EPA survey instruments, and the literature. Since the available process

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[2] RCRA Subtitle C regulations define toxicity as one of the four characteristics of a hazardous waste. EPA uses the Toxicity Characteristic Leaching Procedure (TCLP) to assess whether a solid waste is a hazardous waste due to toxicity. The TCLP as applied to mineral processing wastes was recently remanded to the agency, for further discussion, see the Applicability of TCLP Technical Background Document elsewhere in today's docket.

descriptions and process flow diagrams varied considerably in both quality and detail, EPA often needed to interpret the information to determine how specific waste streams were managed. For example, process descriptions and process flow charts found through the Agency's electronic literature search process often focused on the production process of the mineral product and omitted any description or identification of how or where waste streams were managed. In such cases, the Agency used professional judgment to determine how and where specific waste streams were managed. For example, EPA considered (1) how similar waste streams were managed at mineral processing facilities for which the Agency had management information, (2) the waste form and whether it was amenable to tank treatment, (3) generation rates, and (4) proximity of the point of waste generation to the incoming raw materials, intermediates, and finished products to predict the most likely waste management practice.

As was the case for the other types of waste stream specific information discussed above, EPA was unable to locate published information showing that many of the identified mineral processing waste streams were being recycled. Therefore, the Agency developed a work sheet to assist EPA staff in making consistent determinations of whether the mineral processing waste streams could potentially be recycled, reused, or recovered. This work sheet, shown in Appendix C, was designed to capture the various types of information that could allow one, when using professional judgment, to determine whether a particular waste stream could be recycled or if it contained material of value. If EPA determined that the waste stream was or could be fully/partially recycled, it used the definitions provided in 40 CFR §§ 260.10 and 261.1 to categorize the waste streams as either by-products, sludges, or spent materials.

EPA, through the process of researching and preparing mineral commodity analysis reports for the mineral commodities, identified a total of 527 waste streams that are believed to be generated at facilities involved in mineral production operations. The Agency then evaluated each of the 527 waste streams to remove waste streams that would not be affected by the Phase IV LDRs. Specifically, EPA removed:

- All of the extraction and beneficiation waste streams;
- The “Special 20” Bevill-Exempt mineral processing waste streams;
- Waste streams that were known to be fully recycled in process; and
- All of the mineral processing waste streams that did not exhibit one or more of the RCRA characteristics of a hazardous waste (based on either actual analytical data or professional judgment).

As a result of this evaluation process, EPA narrowed the potential universe of waste streams that could potentially be affected by the proposed Phase IV LDRs to 148 hazardous mineral processing waste streams presented in Exhibit 1-2.

4. Caveats and Limitations of Data Analysis

The results and information presented in this report are based on the review of publicly available information. The accuracy and representativeness of the collected information are only as good as the source documents. As a result of this limited data quality review, EPA notes that in some instances, Extraction Procedure (EP) leachate data reported by various sources are greater than 1/20th of the total constituent concentration. Generally one would expect, based on the design of the EP testing procedure, the total constituent concentrations to be at least 20-times the EP concentrations. This apparent discrepancy, however, can potentially be explained if the EP results were obtained from total constituent analyses of liquid wastes (i.e., EP tests conducted on wastes that contain less than one-half of one percent solids content are actually total constituent analyses).

In addition, to present mineral commodity profiles that were as complete as possible, EPA used a step-wise methodology for estimating both annual waste generation rates and waste characteristics for individual waste streams when documented waste generation rates and analytical data were not available. EPA's application of this methodology to estimate waste generation rates resulted in the development of

low, medium, and high annual waste generation rates for non-wastewaters and wastewaters that were bounded by zero and 45,000 metric tons/yr/facility and by zero and 1,000,000 metric tons/yr/facility, respectively (the thresholds for determining whether a waste stream was a high volume, Bevill-exempt waste). Due to the paucity of waste characterization data (particularly, TCLP data), EPA used total constituent data (if available) or best engineering judgment to determine whether a particular waste exhibited one of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity).

To determine whether a waste might exhibit the characteristic of toxicity, EPA first compared 1/20th of the total constituent concentration of each TC metal to its respective TC level[3]. In cases where total constituent data were not available, EPA then used best engineering judgment to evaluate whether the waste stream could potentially exhibit the toxicity characteristic for any of the TC metals. For example, if a particular waste stream resulted through the leaching of a desired metal from an incoming concentrated feed, we assumed that the precipitated leach stream contained high total constituent (and therefore, high leachable) concentrations of non-desirable metals, such as arsenic. Continuing through the step-wise methodology, we relied on EPA's best engineering judgment to determine, based on our understanding of the nature of a particular processing step that generated the waste in question, whether the waste could possibly exhibit one (or more) of the characteristics of ignitability, corrosivity, or reactivity. The Agency acknowledges the inherent limitations of this conservative, step-wise methodology and notes that it is possible that EPA may have incorrectly assumed that a particular waste does (or does not) exhibit one or more of the RCRA hazardous waste characteristics.

B. MINERAL OPERATIONS THAT MAY GENERATE HAZARDOUS WASTE

1. Introduction

EPA collected, evaluated for relevance (both applicability and age), and compiled publicly available information to prepare 49 analyses covering 62 commodity groups. Each commodity analysis consists of a commodity summary describing the uses of and salient statistics pertaining to the particular commodity, a process description section with detailed, current process information and process flow diagram(s), and a process waste stream section that identifies -- to the maximum extent practicable -- individual wastes, sorted by the nature of the operation (i.e., extraction/beneficiation or mineral processing).

EPA identified a total of 527 waste streams from a review of all mineral sectors. After careful analysis, EPA determined that 41 commodity sectors generated a total of 354 waste streams that could be classified as mineral processing wastes, 148 of which are believed to exhibit one or more of the characteristics of a hazardous waste. At this time, EPA has insufficient information to determine whether the following commodity sectors also generate wastes that could be classified as mineral processing wastes: Bromine, Gemstones, Iodine, Lithium, Lithium Carbonate, Soda Ash, Sodium Sulfate, and Strontium.

EPA strongly cautions that the process information and identified waste streams presented in the commodity reports should not be construed as the authoritative list of processes and waste streams. These reports represent a best effort, and clearly do not include every potential process and waste stream affected by today's proposed rule. Furthermore, the omission of an actual waste stream (and thus it's not being classified as either an extraction/beneficiation or mineral processing waste in this report) does not relieve the generator from its responsibility of correctly determining whether the particular waste is covered by the Mining Waste Exclusion.

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[3] Based on the assumption of a theoretical worst-case leaching of 100 percent and the design of the TCLP extraction test, where 100 grams of sample is diluted with two liters of extractant, the maximum possible TCLP concentration of any TC metal would be 1/20th of the total constituent concentration.

2. Alphabetical Listing of Mineral Commodities and Waste Streams

A listing of the mineral commodity sectors that are likely to generate hazardous wastes is presented in Exhibit 1-2. Exhibit 1-2 also presents a brief description of the production operations used to generate the mineral processing wastes, estimated/reported annual waste generation rates, and the specific RCRA characteristics causing individual wastes to be hazardous. This table lists only those mineral processing wastes which EPA believes are or may be hazardous.

EXHIBIT 1-2

LISTING OF HAZARDOUS MINERAL PROCESSING WASTES BY COMMODITY SECTOR

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Alumina and Aluminum Metallurgical grade alumina is extracted from bauxite by the Bayer process and aluminum is obtained from this purified ore by electrolysis via the Hall-Heroult process. The Bayer process consists of the following five steps: (1) ore preparation, (2) bauxite digestion, (3) clarification, (4) aluminum hydroxide precipitation, and (5) calcination to anhydrous alumina. In the Hall-Heroult process, aluminum is produced through the electrolysis of alumina dissolved in a molten cryolite-based bath, with molten aluminum being deposited on a carbon cathode.	Cast house dust	19	-	-	-			Y			Y			N?	N?	N?
	Electrolysis waste	58	-	-	-					Y?				N?	N?	N?
Antimony Primary antimony is usually produced as a by-product or co-product of mining, smelting, and refining of other antimony-containing ores such as tetrahedrite or lead ore. Antimony can be produced using either pyrometallurgical processes or a hydrometallurgical process. For the pyrometallurgical processes, the method of recovery depends on the antimony content of the sulfide ore, and will consist of either volatilization, smelting in a blast furnace, liquation, or iron precipitation. Antimony also can be recovered hydrometallurgically by leaching and electrowinning.	Autoclave filtrate	-	0.38	32	64	Y?		Y?		Y?	Y?			Y?	N?	N?
	Slag and furnace residue	32	-	-	-					Y?				N?	N?	N?
	Stripped anolyte solids	0.19	-	-	-	Y?								N?	N?	N?
Beryllium Bertrandite and beryl ores are treated using two separate processes to produce beryllium sulfate, $BeSO_4$: a counter-current extraction process and the Kjellgren-Sawyer process. The intermediates from the two ore extraction processes are combined and fed to another extraction process. This extraction process removes impurities solubilized during the processing of the bertrandite and beryl ores and converts the beryllium sulphate to beryllium hydroxide, $Be(OH)_2$. The beryllium hydroxide is further converted to beryllium fluoride, BeF_2, which is then catalytically reduced to form metallic beryllium.	Spent barren filtrate streams	88	-	-	-							Y		N?	N?	N?
	Bertrandite thickener slurry	370	-	-	-									Y?	N?	N?
	Beryl thickener slurry	3	-	-	-									Y	N?	N?
	Chip treatment wastewater	-	0.2	100	2000				Y?					N?	N?	N?
	Filtration discard	-	0.2	45	90					Y?				N?	N?	N?
	Spent raffinate	380	-	-	-							Y		Y	N?	N?
Bismuth Bismuth is recovered mainly during the smelting of copper and lead ores. Bismuth-containing dust from copper smelting operations is transferred to lead smelting operations for recovery. At lead smelting operations bismuth is recovered either by the Betterton-Kroll process or the Betts Electrolytic process. In the Betterton-Kroll process, magnesium and calcium are mixed with molten lead to form a dross that contains bismuth. The dross is treated with chlorine or lead chloride and oxidized by using air or caustic soda to remove impurities. In the Betts Electrolytic process, lead bullion is electrolyzed. The resulting impurities, including bismuth, are smelted, reduced and refined.	Alloy residues	-	0.1	3	6					Y?				N?	N?	N?
	Spent caustic soda	-	0.1	6.1	12					Y?				N?	N?	N?
	Electrolytic slimes	-	0	0.02	0.2					Y?				N?	N?	N?
	Lead and zinc chlorides	-	0.1	3	6					Y?				N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
	Metal chloride residues	3	-	-	-					Y?				N?	N?	N?
	Slag	-	0.1	1	10					Y?				N?	N?	N?
	Spent electrolyte	-	0.1	6.1	12					Y?				N?	N?	N?
	Spent soda solution	-	0.1	6.1	12					Y?				Y?	N?	N?
	Waste acid solutions	-	0.1	6.1	12									Y?	N?	N?
	Waste acids	-	0	0.1	0.2									Y?	N?	N?
Boron Boron (borax) is either recovered from ores or from natural mineral-rich lake brines by two companies in the U.S. Recovery from ores involves the following steps: (1) ore is dissolved in water; (2) the resulting insoluble material is separated from the solution; and (3) crystals of sodium borate are separated from the weak solution and dried. Boron is recovered from brines involves solvent extraction, acidification, and fractional distillation followed by evaporation.	Waste liquor	-	0.3	150	300	Y?								N?	N?	N?
Cadmium Cadmium is obtained as a byproduct of zinc metal production. Cadmium metal is obtained from zinc fumes or precipitates via a hydrometallurgical or a pyrometallurgical process. The hydrometallurgical process consists of the following steps: (1) precipitates leached with sulfuric acid, (2) cadmium precipitated with a zinc dust addition, (3) precipitate filtered and pressed into filter cake, (4) impurities removed from filter cake to produce sponge, (5) sponge dissolved with sulfuric acid, (6) electrolysis of solution, and (7) cadmium metal melted and cast. The pyrometallurgical process consists of the following steps: (1) cadmium fumes converted to water- or acid-soluble form, (2) leached solution purified, (3) galvanic precipitation or electrolysis, and (4) metal briquetted or cast.	Caustic washwater	-	0.19	1.9	19			Y?						Y?	N?	N?
	Copper and lead sulfate filter cakes	-	0.19	1.9	19			Y?		Y?				N?	N?	N?
	Copper removal filter cake	-	0.19	1.9	19			Y?						N?	N?	N?
	Iron containing impurities	-	0.19	1.9	19			Y?						N?	N?	N?
	Spent leach solution	-	0.19	1.9	19	Y?		Y?		Y?				Y?	N?	N?
	Lead sulfate waste	-	0.19	1.9	19			Y?		Y?				N?	N?	N?
	Post-leach filter cake	-	0.19	1.9	19			Y?						N?	N?	N?
	Spent purification solution	-	0.19	1.9	19			Y?						Y?	N?	N?
	Scrubber wastewater	-	0.19	1.9	19			Y?						Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
	Spent electrolyte	-	0.19	1.9	19			Y?						Y?	N?	N?
	Zinc precipitates	-	0.19	1.9	19			Y?						N?	N?	N?
Calcium Metal Calcium metal is produced by the Aluminothermic method. In the Aluminothermic method, calcium oxide, obtained by quarrying and calcining calcium limestone, is blended with finely divided aluminum and reduced under a high temperature vacuum. The process produces 99% pure calcium metal which can be further purified through distillation.	Dust with quicklime	-	0.04	0.04	0.04									Y?	N?	N?
Coal Gas Coal is crushed and gasified in the presence of steam and oxygen, producing carbon dioxide and carbon monoxide, which further react to produce carbon oxides, methane and hydrogen. The product gas is separated from the flue gas, and is processed and purified to saleable methane.	Multiple effects evaporator concentrate	-	0	0	65	Y						Y		N?	N?	N?
Copper Copper is recovered from ores using either pyrometallurgical or hydrometallurgical processes. In both cases, the copper-bearing ore is crushed, ground, and concentrated (except in dump leaching). Pyrometallurgical processing can take as many as five steps: roasting, smelting, converting, fire refining, and electrorefining. Hydrometallurgical processing involves leaching, followed by either precipitation or solvent extraction and electrowinning.	Acid plant blowdown	4800	-	-	-	Y		Y	Y	Y	Y	Y	Y	Y	N?	N?
	APC dusts/sludges	-	1	220	450	Y?								N?	N?	N?
	Spent bleed electrolyte	310	-	-	-	Y		Y	Y	Y		Y	Y	Y	N?	N?
	Waste contact cooling water	13	-	-	-	Y?								N?	N?	N?
	Process wastewaters	4900	-	-	-	Y		Y		Y	Y	Y?		Y	N?	N?
	Scrubber blowdown	-	49	490	4900	Y		Y			Y?	Y		N?	N?	N?
	Surface impoundment waste liquids	620	-	-	-	Y?				Y?		Y?		Y	N?	N?
	Tankhouse slimes	4	-	-	-	Y?				Y?		Y?	Y?	N?	N?	N?
	WWTP sludge	6	-	-	-			Y?		Y?				N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Elemental Phosphorus Phosphate rock or sintered/agglomerated fines are charged into an electric arc furnace with coke and silica. This yields calcium silicate slag and ferrophosphorus, which are tapped. Dusts are removed from the furnace offgases and phosphorus is removed from the dusts by condensation.	Dust	4.4	-	-	-			Y?						N?	N?	N?
	AFM rinsate	2	-	-	-			Y				Y		N?	N?	N?
	Furnace offgas solids	24	-	-	-			Y						N?	N?	N?
	Furnace scrubber blowdown	-	-	-	270			Y						YS	N?	N?
	Slag quenchwater	-	0	0	1000			Y?		Y?				N?	N?	N?
Fluorspar and Hydrofluoric Acid Raw fluorspar ore is crushed, ground, and concentrated. Acid grade fluorspar (a pure form of concentrate) is mixed with sulfuric acid in a heated retort kiln, reacting to produce hydrogen fluoride gas and fluorogypsum. The gas is cooled, scrubbed, and condensed, and sold as either hydrofluoric acid solution or anhydrous hydrogen fluoride.	Off-spec fluosilicic acid	-	0	15	44									Y?	N?	N?
Germanium Germanium is recovered as a by-product of other metals, mostly copper, zinc, and lead. Germanium-bearing residues from zinc-ore processing facilities, a main source of germanium metal, are roasted and sintered. The sintering fumes, containing oxidized germanium, are leached with sulfuric acid to form a solution. Germanium is precipitated from the solution by adding zinc dust. Following precipitation, the germanium concentrates are refined by adding hydrochloric acid or chlorine gas to produce germanium tetrachloride, which is hydrolyzed to produce solid germanium dioxide. The final step involves reducing germanium dioxide with hydrogen to produce germanium metal.	Waste acid wash and rinse water	-	0.4	2.2	4	Y?		Y?	Y?	Y?		Y?	Y?	Y?	N?	N?
	Chlorinator wet air pollution control sludge	-	0.01	0.21	0.4	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?
	Hydrolysis filtrate	-	0.01	0.21	0.4	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?
	Leach residues	0.01	-	-	-			Y?		Y?				N?	N?	N?
	Spent acid/leachate	-	0.4	2.2	4	Y?				Y?				Y?	N?	N?
	Waste still liquor	-	0.01	0.21	0.4	Y?		Y?	Y?	Y?		Y?	Y?	N?	Y?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Gold and Silver Gold and silver may be recovered from either ore or the refining of base metals. Extracted ore is crushed or ground and then subjected to oxidation by roasting, autoclaving, bio-oxidation, or chlorination, and then cyanide leaching (heap, vat, or agitation). The metals are recovered by activated carbon loading or the Merrill Crowe process. Activated carbon loading involves bringing precious metal leach solutions into contact with activated carbon by the carbon-in-column, carbon-in-pulp, or carbon-in-leach process. Gold and silver are then separated by acid leaching or electrolysis. The Merrill Crowe process consists of filtering and deaerating the leach solution and then precipitating the precious metals with zinc powder. The solids are filtered out, melted, and cast into bars. The recovery of precious metals from lead refinery slimes is a normal part of the operation called "desilverizing." Lead from previous stages of refining is brought into contact with a zinc bath which absorbs the precious metals. Base metals are removed and the doré is sent to refining.	Spent furnace dust	-	0.1	360	720								Y?	Y?	N?	N?
	Refining wastes	-	0.1	360	720								Y?	N?	N?	N?
	Slag	-	0.1	360	720								Y?	N?	N?	N?
	Wastewater treatment sludge	-	0.1	360	720								Y?	N?	N?	N?
	Wastewater	-	440	870	1700	Y?		Y?	Y?	Y?			Y?	N?	N?	N?
Lead Lead ores are crushed, ground, and concentrated. Pelletized concentrates are then fed to a sinter unit with other materials (e.g., smelter byproducts, coke). The sintered material is then introduced into a blast furnace along with coke and fluxes. The resulting bullion is drossed to remove lead and other metal oxides. The lead bullion may also be decopperized before being sent to the refining stages. Refining operations generally consist of several steps, including (in sequence) softening, desilverizing, dezincing, bismuth removal and final refining. During final refining, lead bullion is mixed with various fluxes and reagents to remove remaining impurities.	Acid plant blowdown	560	-	-	-	Y		Y		Y	Y?	Y		Y	N?	N?
	Acid plant sludge	14	-	-	-									Y?	N?	N?
	Baghouse dust	46	-	-	-			Y		Y				N?	N?	N?
	Baghouse incinerator ash	-	0.7	3	30			Y		Y				N?	N?	N?
	Process wastewater	4000	-	-	-	Y		Y		Y	Y?	Y		N?	N?	N?
	Slurried APC dust	7	-	-	-			Y		Y				N?	N?	N?
	Solid residues	0.4	-	-	-					Y?				N?	N?	N?
	Spent furnace brick	1	-	-	-					Y				N?	N?	N?
Lead (continued)	Stockpiled miscellaneous plant waste	-	0.4	80	100			Y		Y				N?	N?	N?
	Surface impoundment waste liquids	1100	-	-	-	Y?		Y?		Y?				N?	N?	N?
	WWTP liquid effluent	3500	-	-	-					Y?				Y	N?	N?
	WWTP sludges/solids	380	-	-	-			Y?		Y?				Y	N?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Magnesium and Magnesia from Brines Magnesium is recover through two processes: (1) electrolytic and (2) thermal. In electrolytic production with hydrous feed, magnesium hydroxide is precipitated from seawater and settled out. The underflow is dewatered, washed, reslurried with wash water, and neutralized with Hcl and H_2SO_4. The brine is filtered, purified, dried, and fed into the electrolytic cells. Alternatively, surface brine is pumped to solar evaporation ponds, where it is dried, concentrated, and purified. The resulting powder is melted, fed into the electrolytic cells, and then casted. The two thermal production processes for magnesium are the carbothermic process and the silicothermic process. In the carbothermic process, magnesium oxide is reduced with carbon to produce magnesium in the vapor phase, which is recovered by shock cooling. In the silicothermic process, silica is reacted with carbon to give silicon metal which is subsequently used to produce magnesium. Magnesia is produced by calcining magnesite or magnesium hydroxide or by the thermal decomposition of magnesium chloride, magnesium sulfate, magnesium sulfite, nesquehonite, or the basic carbonate.	Cast house dust	-	0.076	0.76	7.6		Y?							N?	N?	N?
	Smut	26	-	-	-		Y							N?	N?	N?
Mercury Mercury currently is recovered only from gold ores. Sulfide-bearing gold ore is roasted, and the mercury is recovered from the exhaust gas. Oxide-based gold ore is crushed and mixed with water, and sent to a classifier, followed by a concentrator. The concentrate is sent to an agitator, where it is leached with cyanide. The slurry is filtered and the filtrate is sent to electrowinning, where the gold and mercury are deposited onto stainless steel wool cathodes. The cathodes are sent to a retort, where the mercury vaporizes with other impurities. The vapor is condensed to recover the mercury which is then purified.	Dust	0.01	-	-	-						Y?			N?	N?	N?
	Mercury quench water	-	81	99	540					Y?	Y?			N?	N?	N?
	Furnace residue	0.1	-	-	-						Y?			N?	N?	N?
Molybdenum, Ferromolybdenum, and Ammonium Molybdate Production of molybdenum and molybdenum products, including ammonium molybdate, begins with roasting. Technical grade molybdic oxide is made by roasting concentrated ore. Pure molybdic oxide is produced from technical grade molybdic oxide either by sublimation and condensing, or by leaching. Ammonium molybdate is formed by reacting technical grade oxide with ammonium hydroxide and crystallizing out the pure molybdate. Molybdenum powder is formed using hydrogen to reduce ammonium molybdate or pure molybdic oxide. Ferromolybdenum is typically produced by reaction of technical grade molybdic oxide and iron oxide with a conventional metallothermic process using silicon and/or aluminum as the reductant.	Flue dust/gases	-	1.2	270	540					Y?				N?	N?	N?
	Liquid residues	1	-	-	-	Y?		Y?		Y?		Y?		N?	N?	N?
	Molybdic oxide refining wastes	2	-	-	-						Y?			N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Platinum Group Metals Platinum-group metals can be recovered from a variety of different sources, including electrolytic slimes from copper refineries and metal ores. The production of platinum-group metals from ore involves mining, concentrating, smelting, and refining. In the concentrating step, platinum ore is crushed and treated by froth flotation. The concentrates are dried, roasted, and fused in a smelter furnace, which results in the formation of platinum-containing sulfide matte. Solvent extraction is used to separate and purify the six platinum-group metals in the sulfide matte.	Slag	-	0.0046	0.046	0.46					Y?		Y?		N?	N?	N?
	Spent acids	-	0.3	1.7	3					Y?			Y?	Y?	N?	N?
	Spent solvents	-	0.3	1.7	3					Y?			Y?	N?	Y?	N?
Pyrobitumens, Mineral Waxes, and Natural Asphalt The production process for pyrobitumens consists of cracking in a still, recondensation, and grading. Mineral wax processing consists of solvent extraction from lignite or cannel coal. To produce natural asphalt, ore is processed through a vibrating bed dryer, and sorted according to particle size. The material is either loaded directly as bulk product, fed to a bagging machine, or fed into a pulverizer for further size reduction.	Still bottoms	-	0.002	45	90									N?	Y?	N?
	Waste catalysts	-	0.002	10	20			Y?				Y?				
Rare Earths Rare earth elements are produced from monazite and bastnasite ores by sulfuric and hydrochloric acid digestion. Processing of rare earths involves fractional crystallization and precipitation followed by solvent extraction to separate individual rare earth elements from one another. Ion exchange or calcium reduction produces highly pure rare earths in small quantities. Electrolytic reduction of rare earth chlorides followed by crushing produces a complex alloy of rare earth metals commonly known as mischmetal.	Spent ammonium nitrate processing solution	14	-	-	-									Y	N?	N?
	Electrolytic cell caustic wet APC waste	-	0.07	0.7	7									Y?	N?	N?
	Spent lead filter cake	-	3.3	4.2	5					Y?				N?	N?	N?
	Process wastewater	7	-	-	-					Y				Y?	N?	N?
	Spent scrubber liquor	-	0.1	500	1000									YS	N?	N?
	Solvent extraction crud	-	2	45	90									N?	Y?	N?
	Waste solvent	-	2	1000	2000									N?	Y?	N?
	Wastewater from caustic wet APC	-	0.1	500	1000				Y?	Y?				Y?	N?	N?
	Waste zinc contaminated with mercury	-	2	45	90						Y?			N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Rhenium In general, rhenium is recovered from the off-gases produced when molybdenite, a byproduct of the processing of porphyry copper ores for molybdenum, is roasted. During the roasting process, molybdenite concentrates are converted to molybdic oxide and rhenium is converted to rhenium heptoxide. The rhenium oxides are sublimed and carried off with the roaster flue gas. Rhenium is then recovered from the off-gases by the following five steps: (1) scrubbing; (2) solvent extraction or ion exchange; (3) precipitation (addition of H_2S and Hcl) and filtration; (4) oxidation and evaporation; and (5) reduction.	Spent barren scrubber liquor	-	0	0.1	0.2							Y?		N?	N	N
	Spent rhenium raffinate	88	-	-	-					Y?				N?	N?	N?
Scandium Scandium is generally produced by small bench-scale batch processes. The principal domestic scandium resource is fluorite tailings containing thortveitite and associated scandium-enriched minerals. Scandium can be recovered from thortveitite using several methods. Each method involves a distinct initial step (i.e., acid digestion, grinding, or chlorination) followed by a set of common recovery steps, including leaching, precipitation, filtration, washing, and ignition at 900 °C to form scandium oxide.	Spent acids	-	0.7	3.9	7									Y?	N?	N?
	Spent solvents from solvent extraction	-	0.7	3.9	7									N?	Y?	N?
Selenium The two principle processes for selenium recovery are smelting with soda ash and roasting with soda ash. Other methods include roasting with fluxes, during which the selenium is either volatilized as an oxide and recovered from the flue gas, or is incorporated in a soluble calcine that is subsequently leached for selenium. In some processes, the selenium is recovered both from the flue gas and from the calcine. To purify the crude selenium, it is dissolved in sodium sulfite and filtered to remove unwanted solids. The resulting filtrate is acidified with sulfuric acid to precipitate selenium. The selenium precipitate is distilled to drive off impurities.	Spent filter cake	-	0.05	0.5	5							Y?		N?	N?	N?
	Plant process wastewater	66	-	-	-					Y				Y	N?	N?
	Slag	-	0.05	0.5	5							Y?		N?	N?	N?
	Tellurium slime wastes	-	0.05	0.5	5							N?		Y?	N?	N?
	Waste solids	-	0.05	0.5	5							Y?		N?	N?	N?
Synthetic Rutile Synthetic rutile is manufactured through the upgrading of ilmenite ore to remove impurities (mostly iron) and yield a feedstock for production of titanium tetrachloride through the chloride process. The various processes developed can be organized in three categories: (1) processes in which the iron in the ilmenite ore is completely reduced to metal and separated either chemically or physically; (2) processes in which iron is reduced to the ferrous state and chemically leached from the ore; and (3) processes in which selective chlorination is used to remove the iron. In addition, a process called the Benelite Cyclic process uses hydrochloric acid to leach iron from reduced ilmenite.	APC dust/sludges	30	-	-	-			Y?	Y?					N?	N?	N?
	Spent iron oxide slurry	45	-	-	-			Y?	Y?					N?	N?	N?
	Spent acid solution	30	-	-	-			Y?	Y?					Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Tantalum, Columbium, and Ferrocolumbium Tantalum and columbium ores are processed by physically and chemically breaking down the ore to form columbium and tantalum salts or oxides, and separating the columbium and tantalum salts or oxides from one another. These salts or oxides may be sold, or further processed to reduce the salts to the respective metals. Ferrocolumbium is made by smelting the ore with iron, and can be sold as a product or further processed to produce tantalum and columbium products.	Digester sludge	1	-	-	-									Y	N?	N?
	Process wastewater	150	-	-	-	Y?		Y?	Y?	Y?		Y?		Y	N?	N?
	Spent raffinate solids	2	-	-	-									Y	N?	N?
Tellurium The process flow for the production of tellurium can be separated into two stages. The first stage involves the removal of copper from the copper slimes. The second stage involves the recovery of tellurium metal and purification of the recovered tellurium. Copper is generally removed from slimes by aeration in dilute sulfuric acid, oxidative pressure-leaching with sulfuric acid, or digestion with strong acid. Tellurous acid (in the form of precipitates) is then recovered by cementing, leaching the cement mud, and neutralizing with sulfuric acid. Tellurium is recovered from the precipitated tellurous acid by the following three methods: (1) direct reduction; (2) acid precipitation; and (3) electrolytic purification.	Slag	-	0.1	1	4.5							Y?		N?	N?	N?
	Solid waste residues	-	0.1	1	4.5							Y?		N?	N?	Y?
	Waste electrolyte	-	0.1	1	10					Y?		Y?		N?	N?	N?
	Wastewater	-	0.1	10	20							Y?		Y	N?	N?
Titanium and Titanium Dioxide Titanium ores are utilized in the production of four major titanium-based products: titanium dioxide (TiO_2) pigment, titanium tetrachloride ($TiCl_4$), titanium sponge, and titanium ingot/metal. The primary titanium ores for manufacture of these products are ilmenite and rutile. TiO_2 pigment is manufactured through either the sulfate, chloride, or chloride-ilmenite process. The sulfate process employs digestion of ilmenite ore or TiO_2-rich slag with sulfuric acid to produce a cake, which is purified and calcined to produce TiO_2 pigment. In the chloride process, rutile, synthetic rutile, or high-purity ilmenite is chlorinated to form $TiCl_4$, which is purified to form TiO_2 pigment. In the chloride-ilmenite process, a low-purity ilmenite is converted to $TiCl_4$ in a two-stage chlorination process. Titanium sponge is produced by purifying $TiCl_4$ generated by the chloride or chloride-ilmenite process. Titanium sponge is cast into ingots for further processing into titanium metal.	Waste ferric chloride	-	22	29	35			Y	Y	Y			Y	Y?	N?	N?
	Pickle liquor and wash water	-	2.2	2.7	3.2			Y?	Y?	Y?				Y?	N?	N?
	Scrap milling scrubber water	-	4	5	6			Y?	Y?	Y?		Y?		N?	N?	N?
	Scrap detergent wash water	-	360	450	540			Y?	Y?	Y?		Y?		Y	N?	N?
	Smut from Mg recovery	-	0.1	22	45									N?	N?	Y
	Leach liquor and sponge wash water	-	380	480	580				Y?	Y?				Y	N?	Y?
	Spent surface impoundment liquids	-	.63	3.4	6.7				Y?	Y?				N?	N?	N?
	Spent surface impoundments solids	36	-	-	-				Y?	Y?				N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
	Waste acids (Chloride process)	49	-	-	-				Y?	Y?		Y?		Y	N	N
	Waste acids (Sulfate process)	-	0.2	39	77	Y			Y			Y	Y	Y	N	N
	WWTP sludge/ solids	420	-	-	-				Y					N	N	N
Tungsten Tungsten production consists of four distinct stages: (1) ore preparation, (2) leaching, (3) purification to APT, and (4) reducing APT to metal. Ore preparation involves gravity and flotation methods. Concentration is usually accomplished by froth flotation, supplemented by leaching, roasting, or magnetic or high tension separation. The concentrate is then processed to APT via either sodium tungstate or tungstic acid (which was digested with aqueous ammonia) to solubilize the tungsten as ammonia tungstate. Further purification and processing yields APT. APT is converted to tungsten oxide by calcining in a rotary furnace. Tungsten oxides are reduced to metal powder in high temperature furnaces. Tungsten carbide is formed by reducing APT or tungsten oxides in the presence of carbon.	Spent acid and rinse water	-	0	0	21									Y?	N?	N?
	Process wastewater	-	1.8	3.7	7.3									Y?	N?	N?
Uranium Uranium ore is recovered using either conventional milling or solution mining (*in situ leaching*). Beneficiation of conventionally mined ores involves crushing and grinding the extracted ores followed by a leaching circuit. *In situ* operations use a leach solution to dissolve desirable uraniferous minerals from deposits in-place. Uranium in either case is removed from pregnant leach liquor and concentrated using solvent extraction or ion exchange and precipitated to form yellowcake. Yellowcake is then processed to produce uranium fluoride (UF_6), which is then enriched and further refined to produce the fuel rods used in nuclear reactors.	Waste nitric acid from UO_2 production	-	1.7	2.5	3.4									Y?	N?	N?
	Vaporizer condensate	-	1.7	9.3	17									Y?	N?	N?
	Superheater condensate	-	1.7	9.3	17									Y?	N?	N?
	Slag	-	0	8.5	17									N?	Y?	N?
	Uranium chips from ingot production	-	1.7	2.5	3.4									N?	Y?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Zinc Zinc-bearing ores are crushed and undergo flotation to produce concentrates of 50 to 60% zinc. Zinc is then processed through either of two primary processing methods: electrolytic or pyrometallurgical. Electrolytic processing involves digestion with sulfuric acid and electrolytic refining. In pyrometallurgical processing, calcine is sintered and smelted in batch horizontal retorts, externally-heated continuous vertical retorts, or electrothermic furnaces. In addition, zinc is smelted in blast furnaces through the Imperial Smelting Furnace process, which is capable of recovering both zinc and lead from mixed zinc-lead concentrates.	Acid plant blowdown	130	-	-	-	Y		Y	Y	Y?	Y?	Y	Y	Y	N	N
	Waste ferrosilicon	17	-	-	-					Y?				N?	N?	N?
	Spent goethite and leach cake residues	15	-	-	-	Y		Y	Y	Y?	Y?	Y	Y	N?	N?	N?
	Process wastewater	6600	-	-	-	Y		Y	Y	Y		Y	Y	Y	N?	N?
	Discarded refractory brick	1	-	-	-	Y?		Y?	Y?	Y?				N?	N?	N?
	Spent cloths, bags, and filters	0.2	-	-	-			Y?		Y?	Y?	Y?	Y?	N?	N?	N?
	Spent surface impoundment liquids	2500	-	-	-			Y?						Y	N?	N?
	Spent surface impoundment solids	1	-	-	-	Y?		Y?		Y?	Y?	Y?	Y?	N?	N?	N?
	Spent synthetic gypsum	21	-	-	-	Y?		Y		Y?				N?	N?	N?
	TCA tower blowdown (ZCA Bartlesville, OK-Electrolytic plant)	.25	-	-	-			Y?		Y?	Y?	Y?		Y?	N?	N?
	WWTP liquid effluent	3500	-	-	-			Y?						N?	N?	N?
	Zinc-lean slag	17	-	-	-					Y?				N?	N?	N?
Zirconium and Hafnium The production processes used at primary zirconium and hafnium manufacturing plants depend largely on the raw material used. Six basic operations may be performed: (1) sand chlorination, (2) separation, (3) calcining, (4) pure chlorination, (5) reduction, and (6) purification. Plants that produce zirconium and hafnium from zircon sand use all six of these process steps. Plants which produce zirconium from zirconium dioxide employ reduction and purification steps only.	Spent acid leachate from zirconium alloy production	-	0	0	850									Y?	N?	N?
	Spent acid leachate from zirconium metal production	-	0	0	1600									Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity and Summary Description	Waste Stream	Reported Generation (1000 mt/yr)	Estimated Generation (1000 mt/yr)			TC Metals								Other Hazardous Characteristics 1/		
			Low	Med.	High	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
	Leaching rinse water from zirconium alloy production	-	34	42	51									Y?	N?	N?
	Leaching rinse water from zirconium metal production	-	0.2	1000	2000									Y?	N?	N?

EXHIBIT 1-3 (Continued)

1/ In calculating the total number of waste streams per mineral sector, EPA included both non-wastewaters and wastewater mineral processing wastes and assumed that each of the hazardous mineral processing waste streams were generated in all three waste generation scenarios (low, medium, and high).