FINAL

Technical Background Document

Identification and Description of Mineral Processing Sectors and Waste Streams

United States
Environmental Protection Agency
Office of Solid Waste
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This technical background document, *Identification and Description of Mineral Processing Sectors and Waste Streams*, was submitted for public review to EPA's RCRA Docket # F-95-PH4A-FFFFF. It provides supplementary information and support for the January 25, 1996 Supplemental Proposed Rule, *Land Disposal Restrictions---Supplemental Proposal to Phase IV: Clarification of Bevill Exclusion for Mining Wastes, Changes to the Definition of Solid Waste for Mineral Processing Wastes, Treatment Standards for Characteristic Mineral Processing Wastes, and Associated Issues* (61 FR 2338). The Agency has received comments from the public on this document and has listed these comments and Agency responses in the final section of the document. The Agency finalizes this document as of April, 1998 and submits it to RCRA Docket # F-98-2P4F-FFFFF to provide supplementary information and support for the April, 1998 Final Rule, *Land Disposal Restrictions Phase IV: Final Rule Promulgating Treatment Standards for Metal Wastes and Mineral Processing Wastes; Mineral Processing Secondary Materials and Bevill Exclusion Issues; Treatment Standards for Hazardous Soils, and Exclusion of Recycled Wood Preserving Wastewaters.*

DISCLAIMER

This document is intended solely to provide information to the public and the regulated community regarding the wastes that are potentially subject to the requirements of this rule. This information was also utilized by the Agency to assist in evaluating the potential impacts on the industry associated with complying with the rule. While the guidance contained in this document may assist the industry, public and federal and state regulators in applying statutory and regulatory requirements of RCRA, the guidance is not a substitute for those legal requirements; nor is it a regulation itself. Thus, it does not impose legally-binding requirements on any party, including EPA, States or the regulated community. Based on the circumstances, the conclusions in this document may not apply to a particular situation, and EPA and State decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where determined to be appropriate based on the facts of the case and applicable statutes and regulations.

I. EXECUTIVE SUMMARY

The purpose of this executive summary is to describe EPA's review of mineral commodities that may generate hazardous wastes as defined by RCRA Subtitle C. These wastes and the facilities and commodity sectors that generate them may be affected by the establishment of Land Disposal Restrictions for mineral processing wastes. Through a series of rulemakings (see Background below) EPA has established and applied criteria to determine 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 or more of the four characteristics of a hazardous waste if disposed on the land must be made subject to the Land Disposal Restrictions (LDRs). Accordingly, EPA has promulgated treatment standards (Best Demonstrated Available Technology, or BDAT) for newly identified mineral processing wastes.

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 Mines' 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 a draft technical background document (TBD) on the production of particular mineral commodities and associated operations that generate mineral processing wastes. This draft was made available for public comment in January 1996 (docket No. F-95-PH4A-FFFFF). Numerous public comments were submitted to the Agency addressing the draft TBD. In addition, although the Agency did not request further comments on the draft TBD in a subsequent Federal Register notice articulating modifications to the proposed Phase 4 LDR rule (62 FR 26041), several comments were submitted that included process information or other data that were relevant to the TBD; these comments may be found in docket No. F-97-2P4P-FFFFF. This final TBD addresses and provides EPA's responses to all of these comments and information contained therein, where appropriate.

The Agency cautions that this 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 mining waste exclusion. This report has been extensively revised from the previous draft and should be used as guidance for EPA.

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 (also known as the "Bevill Amendment"), which was added in the 1980 Solid Waste Disposal Act Amendments. The Bevill Amendment precluded EPA from regulating these wastes (as well as several other "special wastes") until the Agency performed a study and submitted a Report to Congress, as directed by §8002, 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 were to 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. In addition, in preparing this final Technical Background Document, EPA carefully considered and, where appropriate, incorporated or otherwise addressed new information and suggested corrections to the draft document offered in public comment on the Agency's proposed rules (61 FR 2338, 62 FR 26041) and supporting documents. These comments were submitted to, and may be found in, docket Nos. F-95-PH4A-FFFFF and F-97-2P4P-FFFFF, respectively. 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);

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[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.

- waste stream characteristics (total constituent concentration data, and statements regarding whether the waste stream exhibits or is expected to exhibit 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

- whether the waste stream is 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 represents 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 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 the 1993, 1994, and 1995 "Mineral Commodity Summaries" prepared by the Bureau of Mines (BOM) for salient statistics on commodity production.[2]

- 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 (now USGS) 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.

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[2] Following elimination of the U.S. Bureau of Mines in 1995, responsibility for certain mineral commodity-related activities was transferred to the U.S. Geological Survey (USGS).

- 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.

In preparing the commodity sector reports, EPA used its 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. Establish whether the waste and the operation that generates it are uniquely associated with mineral production.

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

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

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.[3]

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[3] 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. In today’s final rule, EPA is reinstating the application of the TCLP to mineral processing wastes in response to a Court remand. For further discussion, see the preamble to today’s final rule.

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 that may generate mineral processing wastes. Omission or inclusion on this list does not relieve the generator of the responsibility for appropriately managing wastes that would be subject to RCRA Subtitle C requirements.

EPA used waste stream characterization data obtained from numerous sources to document whether a particular waste stream exhibits one (or more) of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity). 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 exhibits 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. 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. The precise methodology employed 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 (several editions), EPA's Effluent Guideline Documents (see sector reports for specific references), EPA survey instruments, and the literature. Because the available process 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 are managed. For example, process descriptions and process flow charts found through the Agency's electronic literature search process often focus on the production process of the mineral product and omit any description or identification of how or where waste streams are managed. In such cases, the Agency has used professional judgment to determine how and where specific waste streams are managed. Specifically, EPA considered (1) how similar waste streams are managed at mineral processing facilities for which the Agency has management practice information, (2) the waste form and whether it is 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 whether it contains material of value. If EPA determined that the waste stream is or could be fully/partially recycled, it initially used the definitions provided in 40 CFR §§ 260.10 and 261.1 to categorize each waste stream as either a by-product, sludge, or spent material. In today's final rule, however, these distinctions have been eliminated in the context of the primary minerals industry. This final document nonetheless contains references to this former classification scheme, because it is used extensively in other analyses (e.g., the Regulatory Impact Analysis) that EPA has prepared in support of today's rule.

EPA, through the process of researching and preparing mineral commodity analysis reports for the mineral commodities, identified a total of 553 waste streams that are believed to be generated at facilities involved in mineral production operations. The Agency then evaluated each of the 553 waste streams to remove waste streams that would not be affected by the Phase IV LDRs. Specifically, EPA removed the following materials:

- All of the extraction and beneficiation waste streams;
- The "Special 20" Bevill-Exempt mineral processing waste streams;
- Waste streams that are known to be fully recycled in process; and

- All of the mineral processing waste streams that do not or are unlikely to exhibit one or more of the RCRA characteristics of a hazardous waste (based on either actual analytical data or professional judgment).

Finally, as noted above, EPA made a number of corrections and other modifications to the draft TBD in response to new information provided in written comments received in response to the two proposed rules and the draft TBD.

As a result of this evaluation process, EPA narrowed the potential universe of waste streams that could potentially be affected by the Phase IV LDRs to the 133 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 primarily on a 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 associated total constituent concentrations. 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/or 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[4]. 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.

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[4] 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.

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).

Through this process, EPA identified a total of 553 waste streams from a review of all mineral sectors. After careful analysis, EPA determined that 40 commodity sectors generated a total of 358 waste streams that could be classified as mineral processing wastes, 133 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 an 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 final 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.

2. Alphabetical Listing of Mineral Commodities and Waste Streams

A listing of the mineral commodity sectors that are likely to generate newly identified 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. The Agency's assumptions concerning the characteristics of the wastes are indicated in Exhibit 1-2 as follows:

Y = known to be hazardous
Y? = suspected to be hazardous
N? = suspected to be not hazardous
N = believed to be not hazardous

EXHIBIT 1-2

LISTING OF HAZARDOUS MINERAL PROCESSING WASTES BY COMMODITY SECTOR

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		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	19	19	19	23			Y			Y			N?	N?	N?
	Electrolysis waste	58	58	58	58	23					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	NA	0.32	27	54	6	Y?		Y?		Y?	Y?			Y?	N?	N?
	Stripped anolyte solids	0.19	0.19	0.19	0.19	2	Y?								N?	N?	N?
	Slag and furnace residue	21	21	21	21	6					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.	Chip treatment wastewater	NA	0.2	100	2000	2				Y?					N?	N?	N?
	Spent barren filtrate	55	55	55	55	1							Y		N?	N?	N?
	Filtration discard	NA	0.2	45	90	2					Y?				N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
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	NA	0.1	3	6	1					Y?				N?	N?	N?
	Spent caustic soda	NA	0.1	6.1	12	1					Y?				N?	N?	N?
	Electrolytic slimes	NA	0	0.02	0.2	1					Y?				N?	N?	N?
	Lead and zinc chlorides	NA	0.1	3	6	1					Y?				N?	N?	N?
	Metal chloride residues	3	3	3	3	1					Y?				N?	N?	N?
	Slag	NA	0.1	1	10	1					Y?				N?	N?	N?
	Spent electrolyte	NA	0.1	6.1	12	1					Y?				N?	N?	N?
	Spent soda solution	NA	0.1	6.1	12	1					Y?				Y?	N?	N?
	Waste acid solutions	NA	0.1	6.1	12	1									Y?	N?	N?
	Waste acids	NA	0	0.1	0.2	1									Y?	N?	N?
CadmiumCadmium 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	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Copper and lead sulfate filter cakes	NA	0.19	1.9	19	2			Y?		Y?				N?	N?	N?
	Copper removal filter cake	NA	0.19	1.9	19	2			Y?						N?	N?	N?
	Iron containing impurities	NA	0.19	1.9	19	2			Y?						N?	N?	N?
	Spent leach solution	NA	0.19	1.9	19	2	Y?		Y?		Y?				Y?	N?	N?
	Lead sulfate waste	NA	0.19	1.9	19	2			Y?		Y?				N?	N?	N?
	Post-leach filter cake	NA	0.19	1.9	19	2			Y?						N?	N?	N?
	Spent purification solution	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Scrubber wastewater	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Spent electrolyte	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Zinc precipitates	NA	0.19	1.9	19	2			Y?						N?	N?	N?
Calcium 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	0.04	1									Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Chromium and Ferrochromium Chromite ore is prepared for processing using several methods, depending on the ore source and the end use requirements, although many of these beneficiation operations may not be conducted in the United States. Either ferrochromium or sodium chromate is initially produced, and may be sold or further processed to manufacture other chromium compounds, as well as chromium metal. Ferrochromium is made by smelting chromite ore in an electric arc furnace with flux materials and carbonaceous redcutant.	ESP dust	3	3	3	3	1				Y			Y		N?	N?	N?
	GCT sludge	NA	0.03	0.3	3	1				Y?					N?	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	NA	0	0	65	1	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	5300	5300	5300	5300	10	Y		Y	Y	Y	Y	Y	Y	Y	N?	N?
	APC dusts/sludges	NA	1	220	450	10	Y?								N?	N?	N?
	Waste contact cooling water	13	13	13	13	10	Y?								N?	N?	N?
	Tankhouse slimes	4	4	4	4	10	Y?				Y?		Y?	Y?	N?	N?	N?
	Spent bleed electrolyte	310	310	310	310	10	Y		Y	Y	Y		Y	Y	Y	N?	N?
	Spent furnace brick	3	3	3	3	10				Y?					N?	N?	N?
	Process wastewaters	4900	4900	4900	4900	10	Y		Y		Y	Y	Y?		Y	N?	N?
	WWTP sludge	6	6	6	6	10			Y?		Y?				N?	N?	N?
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.	Andersen Filter Media	0.46	0.46	0.46	0.46	2			Y						N?	N?	N?
	Precipitator slurry	160	160	160	160	2			Y?						N?	Y	Y
	NOSAP slurry	160	160	160	160	2									N?	N?	Y
	Phossy Water	670	670	670	670	2			Y?						N?	Y	Y
	Furnace scrubber blowdown	410	410	410	410	2			Y						Y	N?	N?
	Furnace Building Washdown	700	700	700	700	2			Y						N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
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	NA	0	15	44	3									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	NA	0.4	2.2	4	4	Y?		Y?	Y?	Y?		Y?	Y?	Y?	N?	N?
	Chlorinator wet air pollution control sludge	NA	0.01	0.21	0.4	4	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?
	Hydrolysis filtrate	NA	0.01	0.21	0.4	4	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?
	Leach residues	0.01	0.01	0.01	0.01	3			Y?		Y?				N?	N?	N?
	Spent acid/leachate	NA	0.4	2.2	4	4	Y?				Y?				Y?	N?	N?
	Waste still liquor	NA	0.01	0.21	0.4	4	Y?		Y?	Y?	Y?		Y?	Y?	N?	Y?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		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 consistes 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 dore is sent to refining.	Slag	NA	0.1	360	720	16								Y?	N?	N?	N?
	Spent furnace dust	NA	0.1	360	720	16								Y?	Y?	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 sludge	14	14	14	14	3									Y?	N?	N?
	Baghouse incinerator ash	NA	0.3	3	30	3			Y		Y				N?	N?	N?
	Slurried APC Dust	7	7	7	7	3			Y		Y				N?	N?	N?
	Solid residues	0.4	0.4	0.4	0.4	3					Y?				N?	N?	N?
	Spent furnace brick	1	1	1	1	3					Y				N?	N?	N?
	Stockpiled miscellaneous plant waste	NA	0.3	67	130	3			Y		Y				N?	N?	N?
	WWTP solids/sludges	380	380	380	380	3			Y?		Y?				Y	N?	N?
	WWTP liquid effluent	2600	2600	2600	2600	3					Y?				Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Magnesium and Magnesia from Brines Magnesium is recovered 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	NA	0.076	0.76	7.6	1		Y?							N?	N?	N?
	Smut	26	26	26	26	2		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	0.007	0.007	0.007	0.007	7						Y?			N?	N?	N?
	Quench water	NA	63	77	420	7					Y?	Y?			N?	N?	N?
	Furnaceresidue	0.077	0.077	0.077	0.077	7						Y?			N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
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	NA	1.1	250	500	11					Y?				N?	N?	N?
	Liquid residues	1	1	1	1	2	Y?		Y?		Y?		Y?		N?	N?	N?
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	NA	0.0046	0.046	0.46	3					Y?		Y?		N?	N?	N?
	Spent acids	NA	0.3	1.7	3	3					Y?			Y?	Y?	N?	N?
	Spent solvents	NA	0.3	1.7	3	3					Y?			Y?	N?	Y?	N?
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	14	14	14	1									Y	N?	N?
	Electrolytic cell caustic wet APC sludge	NA	0.07	0.7	7	1									Y?	N?	N?
	Process wastewater	7	7	7	7	1					Y				Y?	N?	N?
	Spent scrubber liquor	NA	0.1	500	1000	1									Y?	N?	N?
	Solvent extraction crud	NA	0.1	2.3	4.5	1									N?	Y?	N?
	Spent lead filter cake	NA	0.17	0.21	0.25	1					Y?				N?	N?	N?
	Waste solvent	NA	0.1	50	100	1									N?	Y?	N?

EXHIBIT 1-2 (Continued)

			Est./Reported Generation (1000mt/yr)				TC Metals								Other Hazardous Characteristics		
Commodity	Waste Stream	Reported Generation (1000mt/yr)	Min	Avg.	Max	Number of Facilities with Process	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
	Wastewater from caustic wet APC	NA	0.1	500	1000	1				Y?	Y?				Y?	N?	N?
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	NA	0	0.1	0.2	2							Y?		N?	N	N
	Spent rhenium raffinate	88	88	88	88	2					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	NA	0.7	3.9	7	7									Y?	N?	N?
	Spent solvents from solvent extraction	NA	0.7	3.9	7	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	NA	0.05	0.5	5	3							Y?		N?	N?	N?
	Plant process wastewater	66	66	66	66	2					Y				Y	N?	N?
	Slag	NA	0.05	0.5	5	3							Y?		N?	N?	N?
	Tellurium slime wastes	NA	0.05	0.5	5	3							Y?		N	N?	N?
	Waste solids	NA	0.05	0.5	5	3							Y?		N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
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.	Spent iron oxide slurry	45	45	45	45	1			Y?	Y?					N?	N?	N?
	APC dust/sludges	30	30	30	30	1			Y?	Y?					N?	N?	N?
	Spent acid solution	30	30	30	30	1			Y?	Y?					Y?	N?	N?
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	1	1	1	2									Y?	N?	N?
	Process wastewater	150	150	150	150	2	Y?		Y?	Y?	Y?		Y?		Y	N?	N?
	Spent raffinate solids	2	2	2	2	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	NA	0.2	2	9	2							Y?		N?	N?	N?
	Solid waste residues	NA	0.2	2	9	2							Y?		N?	N?	N?
	Waste electrolyte	NA	0.2	2	20	2					Y?		Y?		N?	N?	N?
	Wastewater	NA	0.2	20	40	2							Y?		Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
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.	Pickle liquor and wash water	NA	2.2	2.7	3.2	3			Y?	Y?	Y?				Y?	N?	N?
	Scrap milling scrubber water	NA	4	5	6	1			Y?	Y?	Y?		Y?		N?	N?	N?
	Smut from Mg recovery	NA	0.1	22	45	2									N?	N?	Y
	Leach liquor and sponge wash water	NA	380	480	580	2				Y?	Y?				Y	N?	N?
	Spent surface impoundment liquids	NA	0.63	3.4	6.7	7				Y?	Y?				N?	N?	N?
	Spent surface impoundments solids	36	36	36	36	7				Y?	Y?				N?	N?	N?
	Waste acids (Sulfate process)	NA	0.2	39	77	2	Y			Y			Y	Y	Y	N	N
	Waste acids (Chloride process)	49	49	49	49	7				Y?	Y?		Y?		Y	N	N
	WWTP sludge/solids	420	420	420	420	7				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	NA	0	0	21	6									Y?	N?	N?
	Process wastewater	NA	2.2	4.4	9	6									Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
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 UO2 production	NA	1.7	2.5	3.4	17									Y?	N?	N?
	Vaporizer condensate	NA	1.7	9.3	17	17									Y?	N?	N?
	Superheater condensate	NA	1.7	9.3	17	17									Y?	N?	N?
	Slag	NA	0	8.5	17	17									N?	Y?	N?
	Uranium chips from ingot production	NA	1.7	2.5	3.4	17									N?	Y?	N?
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	130	130	130	1	Y		Y	Y	Y?	Y?	Y	Y	Y	N	N
	Waste ferrosilicon	17	17	17	17	1					Y?				N?	N?	N?
	Process wastewater	5000	5000	5000	5000	3	Y		Y	Y	Y		Y	Y	Y	N?	N?
	Discarded refractory brick	1	1	1	1	1	Y?		Y?	Y?	Y?				N?	N?	N?
	Spent cloths, bags, and filters	0.15	0.15	0.15	0.15	3			Y?		Y?	Y?	Y?	Y?	N?	N?	N?
	Spent goethite and leach cake residues	15	15	15	15	3	Y		Y	Y	Y?	Y?	Y	Y	N?	N?	N?
	Spent surface impoundment liquids	1900	1900	1900	1900	3			Y?						Y	N?	N?
	WWTP Solids	0.75	0.75	0.75	0.75	3	Y?		Y?		Y?	Y?	Y?	Y?	N?	N?	N?
	Spent synthetic gypsum	16	16	16	16	3	Y?		Y		Y?				N?	N?	N?
	TCA tower blowdown	0.25	0.25	0.25	0.25	1			Y?		Y?	Y?	Y?		Y?	N?	N?
	Wastewater treatment plant liquid effluent	2600	2600	2600	2600	3			Y?						N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
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 Zr alloy prod.	NA	0	0	850	2									Y?	N?	N?
	Spent acid leachate from Zr metal prod.	NA	0	0	1600	2									Y?	N?	N?
	Leaching rinse water from Zr alloy prod.	NA	34	42	51	2									Y?	N?	N?
	Leaching rinse water from Zr metal prod.	NA	0.2	1000	2000	2									Y?	N?	N?

/ Corr., Ignit., and Rctv. refer to the RCRA hazardous characteristics of corrosivity, ignitability, and reactivity.

C. SUMMARY OF FINDINGS

EPA has determined that 48 commodity sectors generate a total of 553 waste streams that could be classified as either extraction/beneficiation or mineral processing wastes. After careful review, EPA determined that 40 commodity sectors generate a total of 358 waste streams that could be classified as mineral processing wastes.

Of the 358 mineral processing waste streams identified by the Agency, EPA has sufficient information (based on either analytical test data or engineering judgment) to determine that 133 waste streams (from 30 commodity sectors) are possibly RCRA hazardous wastes because they exhibit one or more of the RCRA hazardous waste characteristics. Exhibit 1-3 identifies the mineral processing commodity sectors that are likely to generate RCRA hazardous mineral processing wastes and therefore are likely to be subject to the Land Disposal Restrictions. Exhibit 1-3 also summarizes the total number of hazardous waste streams by sector and the estimated total volume of hazardous wastes generated annually. At this time, however, EPA has insufficient information to determine whether the following sectors also generate wastes that could be classified as hazardous mineral processing wastes: Bromine, Gemstones, Iodine, Lithium, Lithium Carbonate, Soda Ash, Sodium Sulfate, and Strontium.

EXHIBIT 1-3

IDENTIFICATION OF HAZARDOUS MINERAL PROCESSING WASTE STREAMS LIKELY SUBJECT TO THE LDRS

		Estimated Annual Generation Rate (1,000 mt/yr) (Rounded to the Nearest 2 Significant Figures)		
Mineral Processing Commodity Sectors	**Number of Waste Streams 1/**	**Low Estimate**	**Medium Estimate**	**High Estimate**
Alumina and Aluminum	2	77	77	77
Antimony	3	22	48	75
Beryllium	3	55	200	2,100
Bismuth	10	3.7	35	73
Cadmium	11	2.1	21	210
Calcium Metal	1	0.040	0.040	0.040
Chromium and Ferrochromium	2	3.0	3.3	6.0
Coal Gas	1	0	0	65
Copper	8	10,500	10,800	11,000
Elemental Phosphorus	6	2,100	2,100	2,100
Fluorspar and Hydrofluoric Acid	1	0	15	45
Germanium	6	0.84	5.0	9.2
Gold and Silver	2	0.2	720	1400
Lead	8	3,000	3,080	3,200
Magnesium and Magnesia from Brines	2	26	27	34
Mercury	3	63	77	420
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	2	2.1	250	500
Platinum Group Metals	3	0.45	3.5	6.5
Rare Earths	8	21	1,050	2,100

EXHIBIT 1-3 (Continued)

Mineral Processing Commodity Sectors	Number of Waste Streams 1/	Estimated Annual Generation Rate (1,000 mt/yr) (Rounded to the Nearest 2 Significant Figures)		
		Low Estimate	Medium Estimate	High Estimate
Rhenium	2	88	88	88
Scandium	2	1.4	7.8	14
Selenium	5	66	68	86
Synthetic Rutile	3	100	100	100
Tantalum, Columbium, and Ferrocolumbium	3	150	150	150
Tellurium	4	0.80	26	78
Titanium and Titanium Dioxide	9	890	1,050	1,250
Tungsten	2	2.2	4.4	30
Uranium	5	6.8	32	58
Zinc	11	9,800	9,800	9,800
Zirconium and Hafnium	4	34	1,000	4,500
TOTAL:	133	27,016	30,838	39,575

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).

Exhibit 1-4 identifies those solid wastes from the processing of ores and minerals that are exempt from RCRA Subtitle C regulation (as defined in 40 CFR Part 261.4(b)(7).

EXHIBIT 1-4

1	Slag from primary copper processing
2	Slag from primary lead processing
3	Red and brown muds from bauxite refining
4	Phosphorgympsum from phosphoric acid production
5	Slag from elemental phosphorus production
6	Gasifier ash from coal gasification
7	Process wastewater from coal gasification

EXHIBIT 1-4 (continued)

8	Calcium sulfate wastewater treatment plant sludge from primary copper processing
9	Slag tailings from primary copper processing
10	Fluorogypsum from hydrofluoric acid production
11	Process wastewater from hydrofluoric acid production
12	Air pollution control dust/sludge from iron blast furnaces
13	Iron blast furnace slag
14	Treated residue from roasting/leaching of chrome ore
15	Process wastwater from primary magnesium processing by the anhydrous process
16	Process wastewater fromphosphoric acid productions
17	Basic oxigen furnace and open hearth furnace air pollution control dust/sludge from carbon steel production
18	Basic oxygen furnace and open hear furnace slag from carbon steel production
19	Chloride proces waste solids from titanium tetrachloride production
20	Slag from primary zinc processing

D. Structure of the Document

The remainder of this document is organized into three additional sections. Section II discusses the data sources and methodology used to develop the mineral commodity reports and to identify waste streams potentially subject to RCRA Subtitle C. Section III presents the individual commodity summaries 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 waste streams generated by each process. Section IV summarizes the findings of this study.

E. Disclaimer

This document is intended solely to provide information to the public and the regulated community regarding the wastes that are potentially subject to the requirements of this rule. This information was also utilized by the Agency to assist in evaluating the potential impacts on the industry associated with complying with the rule. While the guidance contained in this document may assist the industry, public and federal and state regulators in applying statutory and regulatory requirements of RCRA, the guidance is not a substitute for those legal requirements; nor is it a regulation itself. Thus, it does not impose legally-binding requirements on any party, including EPA, States or the regulated community. Based on the circumstances, the conclusions in this document may not apply to a particular situation, and EPA and State decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where determined to be appropriate based on the facts of the case and applicable statutes and regulations.