

US EPA ARCHIVE DOCUMENT

**EXHIBIT 3-1
HAZARDOUS MINERAL PROCESSING WASTES BY COMMODITY SECTOR**

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form?
			Minimum	Expected	Maximum	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	23	0	0	9,545			Y			Y			N?	N?	N?	2
	Electrolysis waste	23	0	0	28,750					Y?				N?	N?	N?	2
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, or iron precipitation. Antimony also can be recovered hydrometallurgically by leaching and electrowinning.	Autoclave filtrate	7	54	8,050	50,960	Y?		Y?		Y?	Y?			Y?	N?	N?	0
	Stripped anolyte solids	2	0	0	0	Y?								N?	N?	N?	2
	Slag and furnace residue	9	0	16,200	32,400					Y?				N?	N?	N?	2
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	1	17,600	44,000	70,400						Y		N?	N?	N?	0	
	Bertrandite thickener slurry	1	0	185,000	370,000								Y?	N?	N?	1	
	Beryl thickener slurry	1	3,000	3,000	3,000								Y	N?	N?	1	
	Chip treatment wastewater	2	0	25,000	1,600,000				Y?					N?	N?	N?	0
	Filtration discard	2	0	23,000	90,000					Y?				N?	N?	N?	2
	Spent raffinate	1	76,000	190,000	304,000							Y		Y	N?	N?	1

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Refr	
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	1	0	1,500	6,000					Y?				N?	N?	N?	2
	Spent caustic soda	1	0	0	6,000					Y?				N?	N?	N?	1
	Electrolytic slimes	1	0	0	100					Y?				N?	N?	N?	2
	Lead and zinc chlorides	1	0	1,500	6,000					Y?				N?	N?	N?	2
	Metal chloride residues	1	0	1,500	3,000					Y?				N?	N?	N?	2
	Slag	1	0	500	10,000					Y?				N?	N?	N?	2
	Spent electrolyte	1	0	3,050	12,000					Y?				N?	N?	N?	1
	Spent soda solution	1	0	0	6,000					Y?				Y?	N?	N?	0
	Waste acid solutions	1	0	3,050	12,000									Y?	N?	N?	0
	Waste acids	1	0	25	160									Y?	N?	N?	0
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 fractional distillation followed by evaporation.	Waste liquor	3	0	0	0	Y?								N?	N?	N?	1

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Refr	
Cadmium Cadmium is obtained as a by-product 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 wash water	2	0	0	9,500			Y?						Y?	N?	N?	0
	Copper and lead sulfate filter cakes	2	0	0	9,500			Y?		Y?				N?	N?	N?	2
	Copper removal filter cake	2	0	0	9,500			Y?						N?	N?	N?	2
	Iron containing impurities	2	0	950	19,000			Y?						N?	N?	N?	2
	Spent leach solution	2	0	0	9,500	Y?		Y?		Y?				Y?	N?	N?	1
	Lead sulfate waste	2	0	0	9,500			Y?		Y?				N?	N?	N?	2
	Post-leach filter cake	2	0	950	19,000			Y?						N?	N?	N?	2
	Spent purification solution	2	0	950	19,000			Y?						Y?	N?	N?	0
	Scrubber wastewater	2	0	0	9,500			Y?						Y?	N?	N?	0
	Spent electrolyte	2	0	950	19,000			Y?						Y?	N?	N?	1
Zinc precipitates	2	0	0	9,500			Y?						N?	N?	N?	2	
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	1	0	0	0									Y?	N?	N?	2
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	1	0	0	52,000	Y						Y		N?	N?	N?	1

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Refr	
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	9	954,000	2,385,000	3,816,000	Y		Y	Y	Y	Y	Y	Y	Y	N?	N?	1
	APC dust/sludge	10	0	0	0	Y?								N?	N?	N?	2
	Spent bleed electrolyte	6	62,400	156,000	249,600	Y		Y	Y	Y		Y	Y	Y	N?	N?	1
	Waste contact cooling water	10	0	0	0	Y?								N?	N?	N?	0
	Process wastewaters	10	0	0	0	Y		Y		Y	Y	Y?		Y	N?	N?	1
	Scrubber blowdown	10	9,800	245,000	3,920,000	Y		Y			Y?	Y		N?	N?	N?	1 Copper (continued) Surface impoundment waste liquids 10 124,000 0 310,000 0 496,000 0 Y?Y?Y ?YN? ?1
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.	Tankhouse slimes	14	0	1,015	3,248	Y?				Y?		Y?	Y?	N?	N?	N?	2
	WWTP sludge	10	0	1,500	4,800			Y?		Y?				N?	N?	N?	2
	Dust	2	0	0	2,200			Y?						N?	N?	N?	2
	AFM rinsate	2	2,000	2,000	2,000			Y				Y		N?	N?	N?	1
	Furnace offgas solids	2	0	0	12,000			Y						N?	N?	N?	2
	Furnace scrubber blowdown	2	0	0	280,000			Y						YS	N?	N?	0
	Slag quenchwater	2	0	0	500,000			Y?		Y?				N?	N?	N?	0

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²
			Minimum	Expected	Maximum	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	3	0	3,750	36,000									Y?	N?	N?	0
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	4	0	550	3,200	Y?		Y?	Y?	Y?		Y?	Y?	Y?	N?	N?	0
	Chlorinator wet air pollution control sludge	4	0	53	320	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?	2
	Hydrolysis filtrate	4	0	106	400	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?	2
	Leach residues	3	0	5	10			Y?		Y?				N?	N?	N?	2
	Spent acid/leachate	4	0	550	3,200	Y?				Y?				Y?	N?	N?	0
	Waste still liquor	4	0	106	400	Y?		Y?	Y?	Y?		Y?	Y?	N?	Y?	N?	2

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ^a	
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Reclv		
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.	Refining wastes	16	0	184,000	720,000									Y?	Y?	N?	N?	2
	Slag	16	0	92,000	576,000									Y?	N?	N?	N?	2
	Spent Furnace Dust	16	0	0	0									Y?	N?	N?	N?	2
	Wastewater treatment sludge	16	0	92,000	576,000									Y?	N?	N?	N?	2
	Wastewater	16	0	0	880,000	Y?		Y?	Y?	Y?				Y?	N?	N?	N?	0
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	3	0	0	0	Y		Y		Y	Y?	Y		Y	N?	N?	N?	0
	Acid plant sludge	3	0	0	7,050									Y?	N?	N?	N?	2
	Baghouse dust	3	0	0	0			Y		Y					N?	N?	N?	2
	Baghouse incinerator ash	3	300	3,000	30,000			Y		Y					N?	N?	N?	2
	Process wastewater	4	800,000	2,000,000	3,200,000	Y		Y		Y	Y?	Y			N?	N?	N?	0
	Slurried APC Dust	3	0	0	0			Y		Y					N?	N?	N?	2
	Solid residues	3	0	0	195					Y?					N?	N?	N?	2
	Spent furnace brick	3	0	0	0					Y					N?	N?	N?	2
	Stockpiled miscellaneous plant waste	4	80	44,000	144,000			Y		Y					N?	N?	N?	2
	Surface impoundment waste liquids	1	0	275,000	880,000	Y?		Y?		Y?					N?	N?	N?	0
WWTP liquid effluent	4	0	0	0					Y?					Y	N?	N?	0	

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv	
	WWTP sludges/solids	4	0	0	0			Y?		Y?				Y	N?	N?	2
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 ₂ SO 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	1	0	0	3,800		Y?							N?	N?	N?	2

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form?	
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv		
	Smut	2	0	0	13,000		Y								N?	N?	N?	2 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

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form?	
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv		
	Dust	9	0	2	8						Y?			N?	N?	N?		2
	Furnace residue	9	0	50	99						Y?			N?	N?	N?		2

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²
			Minimum	Expected	Maximum	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 molybdc oxide is made by roasting concentrated ore. Pure molybdc oxide is produced from technical grade molybdc 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 molybdc oxide. Ferromolybdenum is typically produced by reaction of technical grade molybdc oxide and iron oxide with a conventional metallothermic process using silicon and/or aluminum as the reductant.	Flue dust/gases	12	0	138,000	540,000					Y?				N?	N?	N?	2
	Liquid residues	2	0	500	1,000	Y?		Y?		Y?		Y?		N?	N?	N?	0
	Molybdc oxide refining wastes	2	0	1,000	2,000						Y?			N?	N?	N?	2
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	3	0	0	225					Y?		Y?		N?	N?	N?	2
	Spent acids	3	0	855	3,000					Y?			Y?	Y?	N?	N?	0
	Spent solvents	3	0	855	3,000					Y?			Y?	N?	Y?	N?	0
Pyrobitumens, Mineral Waxes, and Natural Asphalts 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	2	0	23,000	90,000									N?	Y?	N?	2
	Waste catalysts	2	0	0	10,000			Y?				Y?		N?	N?	N?	0

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Refr	
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 known as mischmetal.	Spent ammonium nitrate processing solution	1	14,000	14,000	14,000									Y	N?	N?	0
	Spent lead filter cake	20	0	2,100	5,000					Y?				N?	N?	N?	2
	Electrolytic cell caustic wet APC sludge	1	0	0	0									Y?	N?	N?	2
	Process wastewater	1	1,400	3,500	5,600					Y				Y?	N?	N?	0
	Spent scrubber liquor	1	20	250,000	800,000									Y	N?	N?	0
	Solvent extraction crud	20	0	11,500	72,000									N?	Y?	N?	2
	Waste solvent	20	0	0	1,000,000									N?	Y?	N?	0
	Wastewater from caustic wet APC	1	0	125,000	800,000				Y?	Y?				Y?	N?	N?	0

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²	
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv		
	Waste zinc contaminated with mercury	20	0	11,500	72,000													2 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

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ^a
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Refr	
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 rhenium raffinate	2	0	44,000	88,000					Y?				N?	N?	N?	2
	Spent acids	7	0	1,960	7,000									Y?	N?	N?	0
	Spent solvents from solvent extraction	7	0	0	3,500									N?	Y?	N?	0
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	3	0	0	2,550						Y?		N?	N?	N?	2	
	Plant process wastewater	2	13,200	33,000	52,800				Y				Y	N?	N?	0	
	Slag	3	0	128	4,080						Y?		N?	N?	N?	2	
	Tellurium slime wastes	3	0	128	4,080						Y?		N	N?	N?	2	
	Waste solids	3	0	255	5,100						Y?		N?	N?	N?	2	
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 Benedito Cyclic process uses hydrochloric acid to leach iron from reduced ilmenite.	Spent iron oxide slurry	1	0	11,250	36,000			Y?	Y?				N?	N?	N?	2	
	APC dust/sludges	1	0	0	0			Y?	Y?				N?	N?	N?	2	
	Spent acid solution	1	0	0	0			Y?	Y?				Y?	N?	N?	0	

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²
			Minimum	Expected	Maximum	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	2	1,000	1,000	1,000									Y	N?	N?	2
	Process wastewater	2	0	0	75,000	Y?		Y?	Y?	Y?		Y?		Y	N?	N?	1
	Spent raffinate solids	2	2,000	2,000	2,000									Y	N?	N?	2
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	1	0	250	3,600							Y?		N?	N?	N?	2
	Solid waste residues	1	0	500	4,500							Y?		N?	N?	N?	2
	Waste electrolyte	1	0	500	10,000					Y?		Y?		N?	N?	N?	0
	Wastewater	1	0	0	0							Y?		Y	N?	N?	0

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ^a
			Minimum	Expected	Maximum	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	3	0	675	2,640			Y?	Y?	Y?				Y?	N?	N?	0
	Scrap milling scrubber water	1	0	1,250	4,800			Y?	Y?	Y?		Y?		N?	N?	N?	0
	Scrap detergent wash water	2	72,000	230,000	432,000			Y?	Y?	Y?		Y?		Y	N?	N?	0
	Smut from Mg recovery	2	0	0	23,000									N?	N?	Y	2
	Leach liquor and sponge wash water	2	76,000	240,000	464,000				Y?	Y?				Y	N?	N?	0
	Spent surface impoundment liquids	7	0	0	3,360				Y?	Y?				N?	N?	N?	2
	Spent surface impoundments solids	7	0	17,850	35,700				Y?	Y?				N?	N?	N?	2
	Waste acids (Chloride process)	7	9,800	24,500	39,200				Y?	Y?		Y?		Y	N	N	0
	Waste acids (Sulfate process)	2	200	40,000	78,000	Y			Y			Y	Y	Y	N	N	0
	Waste ferric chloride	7	0	0	0			Y	Y	Y			Y	Y?	N?	N?	0
	WWTP sludge/solids	7	420,000	420,000	420,000				Y					N	N	N	2
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	6	0	0	16,800								Y?	N?	N?	0	

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EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form?	
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv		
	Process wastewater	5	0	925	6,000										Y?	N?	N?	0 Uranium Uranium ore is recovered using either conventional milling or solution mining (<i>in situ leaching</i>). Beneficiation of conventionally mined ores involves crushing and grinding the extracted ores followed by a leaching circuit. <i>In situ</i> operations use a leach solution to dissolve desirable uraniumiferous minerals from deposits in-place. Uranium in either case is

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv	
	Vaporizer condensate	17	0	4,675	17,000									Y?	N?	N?	0
	Superheater condensate	17	0	4,675	17,000									Y?	N?	N?	0
	Slag	17	0	0	0									N?	Y?	N?	2
	Uranium chips from ingot production	17	0	0	1,700									N?	Y?	N?	2

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²
			Minimum	Expected	Maximum	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv	
<p>Zinc</p> <p>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.</p>	Acid plant blowdown	1	0	0	0	Y		Y	Y	Y?	Y?	Y	Y	Y	N	N	0
	Waste ferrosilicon	1	0	0	8,500					Y?				N?	N?	N?	2
	Process wastewater	4	0	0	3,400,000	Y		Y	Y	Y		Y	Y	Y	N?	N?	0
	Discarded refractory brick	1	0	500	1,000	Y?		Y?	Y?	Y?				N?	N?	N?	2
	Spent cloths, bags, and filters	4	0	0	0			Y?		Y?	Y?	Y?	Y?	N?	N?	N?	2
	Spent goethite and leach cake residues	3	0	0	0	Y		Y	Y	Y?	Y?	Y	Y	N?	N?	N?	2
	Spent surface impoundment liquids	4	504,000	1,260,000	2,016,000			Y?						Y	N?	N?	0
	Spent surface impoundment solids	4	0	500	1,000	Y?		Y?		Y?	Y?	Y?	Y?	N?	N?	N?	2 Zinc (continued) Spent synthetic gypsum 4 21,200 21,200 21,200 Y?Y? N?N?N ?2
TCA tower blowdown (ZCA Bartlesville, OK-Electrolytic plant)	1	0	63	200			Y?		Y?	Y?	Y?		Y?	N?	N?	0	
Wastewater treatment plant liquid effluent	4	0	880,000	2,816,000			Y?						N?	N?	N?	0	
Zinc-lean slag	1	0	0	8,500					Y?				N?	N?	N?	2	

EXHIBIT 3-1 (Continued)

Commodity	Waste Stream	# of Facilities with Process	Disposed (mt/yr)			TC Metals								Characteristics			Waste Form ²
			Minimum	Expected	Maximum	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 zirconium alloy production	2	0	0	860,000									Y?	N?	N?	0
	Spent acid leachate from zirconium metal production	2	0	0	1,600,000									Y?	N?	N?	0
	Leaching rinse water from zirconium alloy production	2	0	10,500	41,600									Y?	N?	N?	0
	Leaching rinse water from zirconium metal production	2	0	250,000	1,600,000									Y?	N?	N?	0

Key:
 Y EPA has actual analytical data demonstrating that the waste exhibits one or more of the RCRA hazardous characteristics.
 Y? EPA, based on professional judgement, believes that the waste may exhibit one or more of the RCRA hazardous characteristics.
 N The waste probably does not exhibit one or more of the RCRA hazardous characteristics.
 N? Insufficient data are available to analyze. Based on general knowledge of the industry, however, EPA believes that the waste probably does not exhibit one or more of the RCRA hazardous characteristics.
 Waste Form: 0 = Waste with < 1% Total Suspended Solids (TSS) (Wastewater); 1 = Waste with 1 - 10% (TSS) (Liquid Wastewater); 2 = Waste with > 10% (TSS) Nonwastewater.

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