

US EPA ARCHIVE DOCUMENT

MERCURY

A. Commodity Summary

Mercury, also known as quicksilver, is a liquid metal at room temperature, and is used in batteries, lighting, thermometers, manometers, and switching devices. Mercury compounds are used in agriculture as bactericides and disinfectants, in pharmaceutical applications in diuretics, antiseptics, skin preparations, and preservatives, and in the production of caustics, such as sodium and potassium hydroxide. Mercury is also used as a catalyst for production of anthraquinone derivatives, vinyl chloride monomers, and urethane foams. Mercury can be found in nature in more than a dozen minerals, including cinnabar, which is the most common. None of these minerals are currently mined in the United States. Mercury is recovered in small quantities as a byproduct of gold mining.¹ According to the U.S. Bureau of Mines, nine gold mining operations in California, Nevada, and Utah recovered mercury as a by-product in 1994, as shown in Exhibit 1.²

EXHIBIT 1

Summary of Mines Producing Mercury as a By-Product in 1994^{a,b}

Company Name	Mine	Location
Barrick Mercur Gold Mines Inc.	Mercur	Toole, UT
FMC Gold Co.	Getchell	Humboldt, NV
FMC Gold Co.	Paradise Peak	Nye, NV
Homestake Mining Co.	McLaughlin	Napa, CA
Independence Mining Co. Inc.	Enfield Bell	Elko, NV
Newmont Gold Co.	Carlin Mines Complex	Eureka, NV
Pinson Mining Co.	Pinson and Kramer Hill	Humboldt, NV
Placer Dome U.S.	Alligator Ridge	White Pine, NV
Western Hog Ranch Co.	Hog Ranch	Washoe, NV

^a - "Mercury," Minerals Yearbook. Volume 1. Metals and Minerals. U.S. Bureau of Mines, 1991, p. 989.

^b - Personal Communication between ICF Incorporated and Steven M. Jasinski, U.S. Bureau of Mines, November 1994.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Mercury can be produced from mercury ores and gold-bearing ores by reduction roasting or calcining. The primary mercury production process is described below.

2. Generalized Process Flow Diagram

Exhibit 2 is a typical production flow diagram, illustrating the primary production of mercury. Although currently not in use domestically, mercury is recovered from primary mining operations by crushing the ore, and concentrating the mercury by flotation (not shown). The flotation operation produces a tailings stream. The concentrate

¹ U.S. Environmental Protection Agency, "Mercury, Hg," from 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes, 1988, pp. 1-2.

² Jasinski, S.M., "Mercury," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 108.

is heated in a furnace to vaporize the mercury, and the resulting vapor is condensed.^{3,4} The sulfur in the ore is oxidized to sulfur dioxide (SO₂). Some water may condense with the mercury and is discharged as a waste stream (labelled stream No. 4 in Exhibit 2). The mercury is recovered from the condenser and may be washed before being sold (creating wastewater stream No. 5). The sulfur dioxide and other gaseous emissions from the mercury roasting furnace are controlled with a multistage scrubber (creating stream No. 1). After SO₂ removal, the clean stack gases are cooled with contact cooling water and discharged to the atmosphere (stream No. 3). Waste streams may also result from the quenching of calciner wastes to reduce the temperature prior to disposal (stream No. 5).⁵

Recovering mercury from gold ore is shown in Exhibit 3, and is similar to recovery from cinnabar ore. If the gold ore is a sulfide ore, it is typically sent to a roasting step prior to leaching. This roasting operation is similar to primary mercury ore roasting, in that the mercury and sulfide are both volatilized. The exhaust gases are passed through wet electrostatic precipitators (ESPs), and if necessary, through carbon condensers. The sulfur dioxide is removed by lime prior to venting. If the treated sulfide ore has a high mercury content, the primary mercury recovery process occurs from the wet ESPs. However, if the concentration is sufficiently low, no attempt is made to recover mercury for sale.⁶

If the gold ore is an oxide-based ore, the crushed ore is mixed with water, and sent to a classifier, followed by a concentrator, which reduces the water content. The concentrate is sent to an agitator containing cyanide leach solution. The slurry from the agitators is filtered; the filter cake is disposed, and the filtrate, which contains the gold and mercury, is transferred to the electrowinning process. If the carbon-in-pulp process is used, the cyanide pulp in the agitators is treated with activated carbon to adsorb the gold and mercury. The carbon is filtered from the agitator tanks and treated with an alkaline cyanide alcohol solution to desorb the metals. This liquid is then transferred to the electrowinning tanks. In the electrowinning process, the gold and mercury are electrodeposited onto a stainless steel wool cathode, which is sent to a retort to remove mercury and other volatile impurities. The stainless steel wool containing the gold is transferred from the retort to a separate smelting furnace where the gold is melted and recovered as crude bullion.⁷ The exhaust gas from the retort, containing mercury, SO₂, particulates, water vapor, and other volatile components, passes through condenser tubes where the mercury condenses as a liquid and is collected under water in the launders. Slag quenchwater is stored prior to being recycled to the carbon-in-leach circuit (CIL). From the launders, the mercury is purified and sent to storage.⁸

³ Personal communication between ICF Incorporated and Steve Jasinski, U.S. Bureau of Mines, March 1994.

⁴ Carrico, L.C., "Mercury," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, p. 501.

⁵ U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Volume V, Office of Water Regulations and Standards, May 1989, pp. 2167-68, 2178.

⁶ Personal Communication between ICF Incorporated and Steven M. Jasinski, November 1994.

⁷ U.S. Environmental Protection Agency, Technical Resources Document: Extraction and Beneficiation of Ores and Minerals, Volume 2: Gold, Office of Solid Waste, July 1994, p. 1-31.

⁸ Personal Communication between ICF Incorporated and Steven M. Jasinski, November 1994.

EXHIBIT 2

PRODUCTION OF METALLIC MERCURY FROM PRIMARY MERCURY ORES

Graphic Not Available.

Source: Development Document for Effluent Limitations Guidelines and Standards
for the Nonferrous Metals Manufacturing Point Source Category, 1989, p. 2175.

Source: Personal Communication between ICF Incorporated and Steven M. Jasinski, November 1994. Mercury is also recovered from industrial scrap and waste materials, such as discarded dental amalgams, batteries, lamps, switches, measuring devices, control instruments, and wastes and sludges generated in laboratories and electrolytic refining plants. Scrap products are broken down to liberate metallic mercury or its compounds, heated in retorts to vaporize the mercury, and cooled to condense the mercury.⁹ This secondary recovery of mercury is outside primary mineral processing, and is therefore outside the scope of the this report.

3. Identification/Discussion of Novel (or otherwise distinct) Process(es)

There are several alternative processing options, including leaching with sodium sulfide and sodium hydroxide, followed by precipitation with aluminum or electrolysis. Alternatively, mercury can be dissolved in sodium hypochlorite solution, then passed through activated carbon to adsorb the mercury. The mercury is recovered from the carbon by heating, producing elemental mercury. Neither of these processes are in use today. A third option, also not in use, is electrooxidation.¹⁰ Research is continuing on the best way to recover mercury from gold and silver solutions for byproduct mercury production.^{11,12,13}

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in Section B.

⁹ "Mercury," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd Ed., Vol. XV, 1981, pp. 147-48.

¹⁰ Carrico, L.C., 1985, Op. Cit., p. 501.

¹¹ "Mercury," 1981, Op. Cit., p. 148.

¹² Simpson, W.W., W.L. Staker, and R.G. Sandberg, "Calcium Sulfide Precipitation of Mercury From Gold-Silver Cyanide Leach Slurries," from Report of Investigations 9042, U.S. Bureau of Mines, 1986. p. 1.

¹³ Sandberg, R.G., W.W. Simpson, and W.L. Staker, "Calcium Sulfide Precipitation of Mercury During Cyanide Leaching of Gold Ores," from Report of Investigations 8907, U.S. Bureau of Mines, 1984. p. 1.

EXHIBIT 3

PRODUCTION OF METALLIC MERCURY FROM GOLD ORES

Production of Metallic Mercury from Primary Mercury Ore

EPA determined that for the production of metallic mercury from primary mercury ore, the beneficiation/processing line occurs between calcining/roasting and condensing since there is no leaching directly after the roasting step and the resulting product undergoes further beneficiation (i.e., cleaning). Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Production of Metallic Mercury from Gold Ores

Since mercury is being recovered as a byproduct of other metals, all of the wastes generated during mercury recovery are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral, see the report for gold presented elsewhere in this document.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

The following wastes may be generated by extraction and beneficiation operations: **gangue, flotation tailings, spent flotation reagents, and wastewater.**¹⁴

2. Mineral Processing Wastes

Primary Retorting is not currently used in the United States, due to the economics of mining primary mercury ores. Therefore, the waste associated with primary retorting are not included in the tables summarizing waste stream generation rates and waste characteristics. These waste streams, however, are included in this report for completeness.

Furnace Calcines. Approximately 10 metric tons of furnace calcines were produced annually in the United States in 1992. Available data do not indicate the waste exhibits hazardous characteristics.¹⁵ No other information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography.

SO₂ Scrubber Effluent. Approximately 3,000 metric tons of SO₂ scrubber effluent were produced annually in the United States in 1992. Available data do not indicate the waste exhibits hazardous characteristics.¹⁶ No other information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography.

Particulate Control Effluent. Approximately 2,000 metric tons of particulate control effluent were produced annually in the United States in 1992. Available data do not indicate the waste exhibits hazardous characteristics.¹⁷ No other information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography.

Lastly, no information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography for the wastes listed below.

¹⁴ Harty, D.M., and P.M. Terlecky, Characterization of Wastewater and Solid Wastes generated in Selected Ore Mining Subcategories, (Sb, Hg, Al, V, W, Ni, Ti), U.S. Environmental Protection Agency, August 21, 1981, pp. II-36 - II-40.

¹⁵ U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Volume I, Office of Solid Waste, August 1992, p. I-6.

¹⁶ Ibid.

¹⁷ Ibid.

**Cleaning Bath Water
Condenser Blowdown
Stack Gas Cooling Water
Calclner Quench Water**

Byproduct Retorting. The wastes produced in byproduct retorting will vary greatly depending on the input materials. It is possible that the wastes may contain other metals.

Dust. Approximately 10 metric tons of dust are produced annually in the U.S..¹⁸ Although no published information regarding waste characteristics was found, we used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for mercury. We also used best engineering judgement to determine that this waste stream may be partially recycled. This waste stream is classified as a sludge.

Furnace Residues. Approximately 100 metric tons of furnace residues are produced annually in the United States.¹⁹ Although no published information regarding waste characteristics was found, we used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for mercury. This waste stream is not recycled.

Quenchwater. During the retorting process, mercury gas is vaporized from the gold filter cake. The mercury gas is quenched with a direct contact water spray and condensed to form liquid mercury, which is collected for sale. Waste mercury quench water is generated at a rate of 20 to 30 gallons per minute at the facility, and is recycled to the CIL circuit. This waste generation rate corresponds to low, medium, and high sector-wide generation rates of 81,000 mt/y, 99,000 mt/y, and 540,000 mt/y, respectively. This waste may be toxic for lead and mercury. This waste stream is classified as a spent material.

D. Ancillary Hazardous Wastes

Ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, tank cleaning wastes, and polychlorinated biphenyls from electrical transformers and capacitors. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

¹⁸ Ibid.

¹⁹ Ibid.

BIBLIOGRAPHY

- Carrico, L.C. "Mercury." From Mineral Facts and Problems. U.S. Bureau of Mines. 1985. pp. 499-508.
- Harty, D.M., and P.M. Terlecky. Characterization of Wastewater and Solid Wastes generated in Selected Ore Mining Subcategories, (Sb, Hg, Al, V, W, Ni, Ti). U.S. Environmental Protection Agency. August 21, 1981. pp. II-36 - II-40.
- Jasinski, S.M. "Mercury." From Mineral Commodity Summaries. U.S. Bureau of Mines. January 1995. pp. 108-109.
- "Mercury." Kirk-Othmer Encyclopedia of Chemical Technology. 3rd Ed. Vol. XV. 1981. pp. 143-148.
- Personal Communication between ICF Incorporated and Steve Jasinski, U.S. Bureau of Mines. March 1994.
- Personal Communication between ICF Incorporated and Steve Jasinski, U.S. Bureau of Mines. November 1994.
- Sandberg, R.G., W.W. Simpson, and W.L. Staker. "Calcium Sulfide Precipitation of Mercury During Cyanide Leaching of Gold Ores." From Report of Investigations 8907. U.S. Bureau of Mines 1984. pp. 1-13.
- Simpson, W.W., W.L. Staker, and R.G. Sandberg. "Calcium Sulfide Precipitation of Mercury From Gold-Silver Cyanide Leach Slurries." From Report of Investigations 9042. U.S. Bureau of Mines. 1986. pp. 1-9.
- U.S. Bureau of Mines. "Mercury." From An Appraisal of Minerals Availability for 34 Commodities. 1987. pp. 185-190.
- U.S. Bureau of Mines. "Mercury." From Minerals Yearbook, Volume 1. Metals and Minerals. 1991. p. 989.
- U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category. Volume V. Office of Water Regulations and Standards. May 1989.
- U.S. Environmental Protection Agency. "Mercury," 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes. 1988. pp. 3-9 - 3-13.
- U.S. Environmental Protection Agency. Newly Identified Mineral Processing Waste Characterization Data Set. Office of Solid Waste. August 1992.
- U.S. Environmental Protection Agency. Technical Resources Document: Extraction and Beneficiation of Ores and Minerals. Volume 2: Gold. Office of Solid Waste. July 1994.