Waste Specific Evaluation of RMERC Treatment Standard

July 6, 1998

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EPA Contract No. 68-W4-0005, WA No. R11032
TechLaw Subcontract No. G-200-010
SAIC Project No. 06-6312-08-5226-008

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I. Introduction

EPA has established Land Disposal Restrictions (LDRs) treatment standards for all mercury-bearing hazardous wastes (i.e., EPA waste codes D009, K071, K106, P065, P092, and U151). Within these waste codes, EPA has established subcategories for the treatment standards. Wastes containing less than 260 mg/kg total mercury (i.e., low mercury subcategory wastes) generally are subject to numerical treatment standards.[1] Wastes containing greater than or equal to 260 mg/kg total mercury (i.e., high mercury subcategory wastes) can be treated by roasting or retorting (RMERC), or if the waste also contains organics, it can be incinerated (IMERC). The definitions of IMERC and RMERC are as follows: (condensed from 40 CFR Part 268.42):

- IMERC - Incineration of wastes containing organics and mercury in units operated in accordance with the technical operating requirements of 40 CFR part 264, subpart O, and part 265 subpart O.
- RMERC - Retorting or roasting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery.

If a high mercury subcategory waste contains organics and is not a residue from incineration, the waste can be incinerated or retorted or roasted in order to separate and recovery the mercury. If a high mercury subcategory waste does not contain organics or is an incinerator or retort residue, the waste is subject to the RMERC treatment standard. Thus, RMERC must be used to treat high mercury subcategory wastes unless the waste contains organics and can be incinerated.

In the Third Third Final Rule, EPA cited Congress' preference for "treatment standards to be based on recovery, where possible" (S.Rpt. 98-284, p. 17). In addition, the Agency cited technical reasons for not promulgating stabilization as the preferred treatment technology for high mercury subcategory wastes. Specifically, data available to support the Third Third Final Rule indicated that the metal stabilization agents actually increased the mobility of mercury in the stabilized matrix.

Commenters and petitioners to the Agency have stated that certain types of high mercury subcategory wastes are not amenable to RMERC, including inorganic salts, corrosive wastes, incineration residues, and wastewater treatment sludges. Since these wastes have no organic content, IMERC is not a treatment option. The Agency previously held that these wastes could be preheated to facilitate mercury recovery, but this step may not be practical or realistic. To address these concerns, the Agency is reviewing available RMERC data to assess the quantities of wastes currently managed by RMERC, facilities currently conducting RMERC to treat wastes, the economics of mercury recovery through retort, the possible alternatives to RMERC, and the similarities and differences between RMERC production of mercury and other secondary mercury production processes. This report documents EPA's research and evaluation efforts associated with the RMERC treatment standard. Specifically, this report presents information and findings on:

- the types of wastes that RMERC facilities accept and treat,

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[1] Elemental mercury contaminated with radioactive materials must be treated by amalgamation (AMLGM). Hydraulic oil contaminated with mercury that also is radioactive must be treated by incineration (IMERC).

- the wastes that RMERC facilities are restricted from accepting,
- the costs of mercury recovery and sale, and
- the air emissions from these facilities.

The information in this document is based on data from the 1995 Biennial Reporting System (BRS), conversations with a select group of EPA officials and State Agencies regarding waste restrictions at retort facilities, and other sources that are cited throughout the document..

II. Data Analysis

A. Waste Characterization

As noted in Section I of this report, EPA's hazardous waste classification system identifies six mercury-bearing wastes:

- **D009**: Characteristic mercury wastes.
- **K071**: Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used.
- **K106**: Wastewater treatment sludge from the mercury cell process in chlorine production.
- **P065**: Mercury fulminate.
- **P092**: Phenyl mercuric acetate.
- **U151**: Mercury wastes.

These wastes may exist in a number of forms. For example, industry processes may generate mercury-bearing hazardous wastes that are sludges or solids. Facility operations may generate wastes containing elemental mercury, soils contaminated with mercury, or mercury-containing lab packs.

Table 1 presents data obtained from the 1995 BRS for wastes being managed by retort. Approximately 85 percent of the wastes retorted (2,724 of the 3,203 tons total) were characteristically hazardous waste (D009) in the form of inorganic solids. In fact, inorganic solids accounted for 94 percent of all wastes managed by retort, according to the 1995 BRS. The only other wastes reported to be managed by retort are K106 and U151 wastes.

Table 1: Quantity of Mercury-Bearing Hazardous Wastes Managed by Retorting in 1995
By Waste Code (Including Both On-site and Off-site Management), Tons[a, b]

Waste Type	All Waste Codes	D009	K071	K101	K102	K106	P065	P092	U151
Elemental Mercury[c]	95	94	0	0	0	0	0	0	8
Inorganic Sludges[d]	0	0	0	0	0	0	0	0	0
Inorganic Solids Other Than Soil[e]	3,007	2,724	0	0	0	283	0	0	15
Soil[f]	36	36	0	0	0	0	0	0	0
Lab Packs[g]	36	36	0	0	0	0	0	0	0
Organic Solids[h]	7	7	0	0	0	0	0	0	0
Inorganic Liquids Other Than Waste Liquid Mercury[i]	22	22	0	0	0	0	0	0	0
Total	**3,203**	**2,919**	**0**	**0**	**0**	**283**	**0**	**0**	**23**

Source: 1995 Biennial Reporting System, GM and WR Forms Data

Table Notes:
[a] - Retorting is defined as BRS system type code M012.
[b] - Columns do not sum to the total for all waste codes because waste streams may carry more than one waste code, resulting in double counting.
[c] - This category is defined as BRS form code B117.
[d] - This category is defined as BRS form codes B501-B516 and B519.
[e] - This category is defined as BRS form codes B303-B316 and B319.
[f] - This category is defined as BRS form codes B301 and B302.
[g] - This category is defined as BRS form codes B001-B004 and B009.
[h] - This category is defined as BRS form codes B401-B407 and B409.
[i] - This category is defined as BRS form codes B101-B116 and B119.

1. Mercury-Bearing Hazardous Wastes

D009 Wastes - Characteristic Mercury Wastes. D009 wastes are extremely variable in composition, and depend on the industry and process that generate the waste. Some of the more common types of D009 wastes include miscellaneous wastes from chlor-alkali production facilities (especially cell room trench sludge and activated carbon for liquid or gas purification), used fluorescent lamps, batteries, switches, and thermometers. D009 wastes are also generated in the production of organomercury compounds for fungicide/bactericide and pharmaceutical uses, and during organic chemicals manufacturing where mercuric chloride catalyst is used.[2]

In general, D009 wastes include both high and low mercury subcategory wastes. Mercury concentrations within D009 wastes may range from 0.20 mg/L TCLP to greater than 75 percent of the total waste composition. D009 wastes may also contain organic compounds, usually when mixed with solvent wastes.

Although characterization data for D009 wastes are limited, some conclusions can be made regarding potential treatment concerns. Wastes with greater than 500 ppm Appendix VIII organics (such as benzene) are reportedly problematic for commercial retorting facilities due to the permitting requirements for boiler and industrial furnaces (BIF) (40 CFR 266.100(c)). At least two facilities are unable to handle wastes with these levels of volatile organics due to the additional permitting that would be required. However, these two facilities are capable of treating non-volatile activated carbons.

Table 2: Available Waste Characterization Data for Selected D009 Wastes[a]

Constituents	Phenylmercuric acetate waste (mg/l)[b]	Mercuric oxide waste (mg/kg)[c]	Zinc/mercury amalgam (mg/kg)[d]
Antimony	-	<2.4	<2.4
Arsenic	-	<1.0	<1.0
Barium	-	0.36	42
Beryllium	-	<0.1	<0.1
Cadmium	-	<0.5	6.8
Chromium (total)	-	4.8	5.0
Copper	-	2.1	73
Lead	-	<0.5	6.6
Mercury	100 - 1,000	>900,000*	27,200
Nickel	-	2.8	11

[2] U.S. EPA, Best Demonstrated Available Technology (BDAT) Background Document for Mercury Wastes, Nov 1989, page 2-18.

Constituents	Phenylmercuric acetate waste (mg/l) [b]	Mercuric oxide waste (mg/kg)[c]	Zinc/mercury amalgam (mg/kg)[d]
Selenium	-	<0.5	<0.5
Silver	-	1.1	111
Thallium	-	<1.0	<1.0
Vanadium	-	<0.4	0.67
Zinc	-	<0.3	29,600
Benzene	50 - 1,000	-	-
Toluene	0.01 - 100	-	-
Total Organic Carbon	-	10,700	6,620

Table Notes:
[a] Waste Characterization Data Appendix for Atmospheric Emissions From Best Demonstrated Available Technologies for Treating Hazardous Wastes, September 1992, pg. A-39.
[b] Data set from waste generated from the manufacture of phenyl mercuric acetate from Cosan Chemical Corporation, Response to Questionnaire, 1989.
[c] Data set for mercuric oxide waste generated during battery recycling from U.S. EPA, Onsite Engineering Waste Collection Visit for Mercury Refining Corporation, Albany, NY, 1989.
[d] Data set from a zinc/mercury amalgam from battery manufacturing from U.S. EPA, Mercury Refining Corporation Visit, 1989.
*Accurate quantification is very difficult at such high concentrations of mercury using analytical methods of this source.

K071 Wastes - Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used. K071 wastes are generated by the chlor-alkali industry in the mercury cell process. In this process, the raw material sodium chloride is dissolved to form a saturated brine solution. The brine solution is purified by precipitation, using hydroxides, carbonates, or sulfates. The precipitate is dewatered to form K071 wastes, while the purified brine continues in the process. Depleted solution from the mercury cell is ultimately recycled to the initial step of the process.

Available analytical information for K071 brine purification muds show that these wastes consist primarily of inorganic solids and water. The mercury is present as metallic mercury and/or soluble mercuric chloride.[3] The mercury in K071 wastes is typically recovered using a wet process, reflecting the BDAT for this waste. K071 wastes are typically below 260 ppm total mercury. Therefore, retorting is neither presently required nor is it actually conducted.

Table 3: Available Waste Characterization Data for K071 Wastes*

[3] U.S. EPA, BDAT Document for Mercury Wastes, November 1989, page 2-11.

Constituents	Brine Purification Muds		Saturator Insolubles	
	Data Source	Concentration Range (mg/l)	Data Source	Concentration Range (mg/l)
Antimony	b	10.0		Not detected
Arsenic		Not detected		Not detected
Barium	a	0.57 - 1.1	a	1.4
Beryllium		Not detected		Not detected
Cadmium	b	3.8		Not detected
Chromium	b	5.9		Not detected
Copper	b	184.7		Not detected
Lead	b	47.8		Not detected
Mercury	a, b, c, d, e	4.4 - 172.8	a, c	1.12 - 2.2
Nickel	a, b	3.15 - 90.3	a	7.9
Selenium		Not detected		Not detected
Silver		Not detected		Not detected
Thallium	a	7.74 - <43		Not detected
Vanadium		Not detected		Not detected
Zinc	a	2.29 - 3.18	a	2.5
Bromodichloro-methane	a	62 ug/l	a	<25 ug/l
Bromoform (tribromo-methane)	a	550 ug/l	a	<25 ug/l
Chlorodibromo-methane	a	170 ug/l	a	<25 ug/l
Chloroform	a	200 ug/l	a	<25 ug/l
Cellulose Fiber	e	30%		
Calcium Carbonate	e	20%		
Magnesium Hydroxide	e	3%		
Ferric Hydroxide	e	0.3%		
Moisture (water)	e	46.7%		

Table Notes:

*- U.S. EPA, Best Demonstrated Available Technology (BDAT) Background Document for K071, April 1988, pg. 54.
a- U.S. EPA, Onsite Engineering Report of Treatment Technology Performance and Operation for Vulcan Materials Company, Port Edwards, WI, 1988.
b- U.S. EPA, Summary of Available Waste Composition Data from Review of Literature and Data Bases, 1986.
c- Bennett, Memorandum from B.L. Bennett, Plant Manager, Stauffer Chemical Company, St. Gabriel, LA, to Jim Berlow, U.S. EPA, Office of Solid Waste, 1986.
d- Olin Chemicals, 1986.
e- International Minerals & Chemical Corporation, Delisting Petition, 1982.

K106 Wastes - Wastewater treatment sludge from the mercury cell process in chlorine production. Like K071 wastes, K106 wastes are generated from chlorine production using the mercury cell process. Effluent from the mercury cell includes spent brine, a portion of which is recycled and a portion of which is purged to wastewater treatment. Other plant area wastewaters (e.g., stormwater, washdown waters) are also typically sent to this treatment system. The wastewater treatment process generates a sludge through precipitation and filtering, which is K106 waste. Sulfides have been commonly used as a precipitation agent (either sodium sulfide, Na_2S, or sodium bisulfide, NaHS) for at least the last 10 years (1988 to 1998), according to data from the Chlorine Institute. Sludges generated in this manner are comprised, in part, of mercuric sulfide. Other (minor) precipitation agents result in the formation of mercury hydroxide or in elemental mercury. However, sulfide precipitation is preferable to hydroxide precipitation using hydrazine because mercury hydroxide is susceptible to matrix dissolution over a wide range of pH under oxidizing conditions.

According to available analytical data, K106 waste is primarily composed of water and diatomaceous earth filter aid. This is true for K106 wastes generated by both sulfide and hydrazine treatment. K106 wastes from sulfide precipitation contain approximately 4.4% mercury, as mercuric sulfide, while K106 wastes from hydrazine treatment contain approximately 0.5% mercury, as mercurous hydroxide.[4]

Characterization data for K106 wastes is presented in Table 4. The mercury concentration is consistently greater than 260 mg/kg and, therefore, retorting is a required technology for this waste. K106 wastes typically contain significant levels of sulfides/sulfates, sodium chloride, and organics, although the mercury is likely in an elemental or a sulfide form.

Table 4: Available Waste Characterization Data for K106 Wastes

Constituent	US EPA 1988 (mg/kg)[a]	Versar (mg/kg)[b]	US EPA 1985 (mg/kg)[c]	The Chlorine Institute (mg/kg)[d]	Occidental Chemical 1987 (mg/kg)[e]
Antimony	<3.8	-	-	0 - <52	-
Arsenic	1.1	-	-	0 - <100	-
Barium	74	-	-	0 - 1300	-

[4] U.S. EPA, BDAT Document for Mercury Wastes, November 1989, pg. 2-11.

Constituent	US EPA 1988 (mg/kg)[a]	Versar (mg/kg)[b]	US EPA 1985 (mg/kg)[c]	The Chlorine Institute (mg/kg)[d]	Occidental Chemical 1987 (mg/kg)[e]
Beryllium	<0.1	-	-	0 - <1.5	-
Cadmium	2.3	-	-	0 - <100	-
Chromium	6.3	-	-	0 - 750	-
Copper	133	-	-	0 - 861	-
Lead	50	-	-	0 - 456	-
Mercury	25,900	2,000 - 150,000	4,300 - 146,000	4,098 - 161,000	2,000 - 5,500
Nickel	14	-	-	0 - 260	-
Selenium	<5.0	-	-	0 - <100	-
Silver	131	-	-	0 - <100	-
Thallium	<8.6	-	-	0 - <5	-
Vanadium	0.46	-	-	0 - 9	-
Zinc	443	-	-	0 - 3,940	-
Aluminum	168	-	-	-	-
Calcium	478	-	-	-	-
Cobalt	1.3	-	-	-	-
Iron	833	-	none - 400	-	-
Magnesium	132	-	-	-	-
Manganese	6.5	-	-	-	-
Potassium	7,870	-	-	-	-
Sodium	4,120	-	-	-	-
Tin	<5.5	-	-	-	-
Sulfide	-	-	-	0 - 7,493	-
Total Solids	41.5	-	-	43% - 76%[f]	-
Paint Filter Test	pass	-	-	-	-
Diatomaceous Earth	-	-	none - 950,000	-	-
Water	-	-	none - 150,000	50,000 - 690,000	-

Constituent	US EPA 1988 (mg/kg)[a]	Versar (mg/kg)[b]	US EPA 1985 (mg/kg)[c]	The Chlorine Institute (mg/kg)[d]	Occidental Chemical 1987 (mg/kg)[e]
Sodium Chloride	-	-	none - 100,000	-	-
Chloride	not analyzed	not analyzed	not analyzed	0 - 47,000	-
Sulfate	not analyzed	not analyzed	not analyzed	0 - 19,100	-
Total Organic Carbon	not analyzed	not analyzed	not analyzed	0 - 39,600	-
Oil and Grease	not analyzed	not analyzed	not analyzed	0 - 22,500	-

Table Notes:
[a] U.S. EPA, Onsite Engineering Report for Waterways Experiment Station for K106, 1988.
[b] Versar Inc., Summary of Available Waste Composition Data, 1986.
[c] U.S. EPA, Characterization of Waste Streams listed in 40 CFR Section 261: Waste Profiles, Volume II, 1985.
[d] The Chlorine Institute, Waste Characterization Data for K106 Wastes, 1988. [Statistics for up to 20 plants, depending on analyte. In particular, mercury data are based on data from 10 plants; all but one use a sulfide process.]
[e] U.S. EPA, BDAT Document for Mercury Wastes, November 1989, pages 4-8 thru 4-11.
[f] U.S. EPA, Arsenic & Mercury, August 1992.

U151 Wastes - Mercury. Waste characterization data on U151 listed wastes comes mainly from the Generator Survey conducted by the EPA in 1986. The majority of U151 wastes which were reported as a single waste code have mercury concentrations greater than 50 percent. The principal constituent of U151 is metallic mercury.[5]

P092 Wastes - Phenyl mercuric acetate. There are very little data available on the composition of P092 listed wastes. The primary constituent of P092 listed wastes is phenyl mercuric acetate; organic constituents (in particular, benzene) are also expected to be present.[6] The use of phenylmercury acetate as a preservative in latex paint was phased out in 1991. Thus, the quantity of P092 waste is expected to decline dramatically as the stock of mercury-bearing paint is depleted.[7]

P065 Wastes - Mercury fulminate. There is no waste characterization data available for P065 listed wastes. The quantity of P065 waste is also expected to have declined, as the military has phased out its use in explosives.[8]

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5 U.S. EPA, BDAT Document for Mercury Wastes, November 1989, pg. 2-17.
6 U.S. EPA, BDAT Document for Mercury Wastes, November 1989, page 2-17.
7 Mercury Treatment and Storage Options Summary Report, A.T. Kearney report for USEPA Reg 5, May 1997, page 1.
8 Mercury Treatment and Storage Options Summary Report, A.T. Kearney report for USEPA Reg 5, May 1997, page 1.

2. Retort Treated Wastes

EPA's definition of RMERC is "roasting or retorting in a thermal processing unit capable of volatilizing mercury and subsequently condensing the volatilized mercury for recovery." The roasting or retorting units must also be subject to one or more of the following: (a): a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for mercury; (b) a Best Available Control Technology (BACT) or Lowest Achievable Emission Rate (LAER) standard for mercury imposed pursuant to a Prevention of Significant Deterioration (PSD) permit; or (3) a state permit that establishes emission limitations (within meaning of section 302 of the Clean Air Act) for mercury.

Most retort processes use a batch vessel. The mercury-containing waste is sealed in the vessel and volatile gases, including mercury, are released under heat and vacuum. The mercury vapor is condensed, collected, and subsequently purified by successive distillation. The BDAT Background Document also describes roasting, where air is introduced to the hot waste to oxidize and volatilize the mercury.

In any thermal unit, air pollution control devices are necessary to limit releases of mercury and odorous compounds. A scrubber or a fixed bed of activated carbon may be used. The temperature of the vessel is typically in the range of 700 to 1000°F. The time required for batch retorting typically ranges from 4 to 20 hours.

Retorting results in the generation of elemental mercury. Therefore, the process is most effective for wastes containing elemental mercury. Wastes containing mercury in other forms may require pretreatment, or different processing conditions (e.g., temperature and time) to convert the mercury compound to elemental mercury.

Waste characterization data for retort treated wastes are available for retort residues from K106 wastes, D009 wastes, and wastes generated from the retort of byproduct mercury from gold production. Wastes created from the retorting of byproduct mercury from gold mining are unlike most wastes created from the retorting process. Since most of these wastes still contain gold, they are normally put back through the retorting process or treated in the furnace.[9] K106 wastes that have been retorted contain a number of other BDAT listed constituents. The mercury recovery ratio for the four samples from the BDAT document ranged from 97.7% to 98.4%.

Mercury concentrations in retort residues are usually, but not consistently, less than 260 mg/kg, as shown in Table 5. The Oxychem data show occasional levels greater than 260 mg/kg, but these data were collected prior to implementation of the Land Disposal Restrictions, which have created an incentive for generating wastes below this level. More recent verbal information from the Chlorine Institute show that chlor-alkali facilities can consistently generate retorting residues less than 260 mg/kg.[10]

Table 5: Available Data for Retorting Residues of Mercury Waste (mg/kg)*

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9 IT Corporation, Newly Identified Wastes From Byproduct Mercury Retorting. Trip Report: Pinson Mine, September 1992, pg. 8.

10 Telephone Conversation, Art Dungan, Chlorine Institute, and John Vierow, SAIC, July 1, 1998.

Constituent	K106 Hydrazine sludge - sample 1[a]	K106 Hydrazine sludge - sample 2[a]	K106 Hydrazine sludge - sample 3[a]	K106 Hydrazine sludge - sample 4[a]	D009[b]	K106[b]
Arsenic	2.5	2.7	1.1	1.0	-	-
Barium	48	44	45	40	-	-
Cadmium	3	2.8	3.9	4.6	-	-
Chromium	38	35	68	53	-	-
Lead	56	99	85	71	-	-
Mercury	100	90	47	41	32 - 2042	10.5 - 1564
Nickel	39	35	42	33	-	-
Selenium	<0.6	<0.6	<0.6	<0.6	-	-
Silver	6.5	8.3	9.9	9.5	-	-

Table Notes:

[a] U.S. EPA, BDAT Document for Mercury Wastes, November 1989, pages 4-8 thru 4-11.

[b] OxyChem. Letter to EPA December 19, 1989. Data from 35 samples from 1988-1989.

*Mercury concentrations for untreated wastes are presented in the K106 table, under Occidental Chemical 1987.

B. Facility Information

This section presents information on facilities that treat mercury-bearing wastes using retort or roasting technologies. When possible, information was collected on each type of mercury-bearing waste treated by each facility, the amount of mercury-bearing waste treated, the methods for treating mercury-bearing wastes, and the manner in which treated residuals were ultimately disposed. For some facilities, information on waste concentrations was available for untreated and/or treated wastes.

The information presented was extracted from a number of sources. The 1995 BRS supplied waste type, waste volume, and waste treatment and disposal information. Chlor-alkali industry National Emission Standards for Hazardous Air Pollutants (NESHAP) development information was used to validate BRS information. In most cases, the NESHAP information confirmed information reported to the BRS by facilities. In some cases, information was extracted from facility delisting petitions submitted to the Agency. Facility specific information was collected from previous EPA correspondence, permits, and from more recent company literature.

1. Chlor-Alkali Facilities that Use Retort/Roasting

Based on EPA data from the NESHAP program, 14 facilities operate the mercury cell process and generate mercury-bearing wastes. Six of the facilities conduct onsite retorting, while

two others ship their wastes off-site to a facility owned by the same parent company. These eight facilities are as follows:

- Occidental, Deer Park, TX (batch retort system)
- Occidental, Muscle Shoals, AL (batch retort system)
- Occidental, Delaware City, DE (batch retort system)
- Olin Chemical, Charleston, TN (rotary kiln system)
- Olin, Augusta, GA (ships to Olin in Charleston)
- PPG, Westlake, LA (rotary kiln system)
- PPG, New Martinsville, WV (ships to PPG in Westlake)
- Vulcan, Port Edwards, WI (batch retort system)

The rotary kiln retort process was developed in 1991.[11] Wastes are fed to a rotary kiln furnace with a two stage afterburner. The offgas is cooled by multiple stages of scrubbing using water and sodium hydroxide, with metallic mercury recovered at each stage. The offgas is finally passed through carbon and released to the atmosphere.

Air pollution control devices vary, but include caustic scrubbers in conjunction with carbon adsorbers.[12] The facilities have overcome the difficulties in treating a high chloride waste through careful temperature control.[13] For this reason, the chlor-alkali facilities do not face the same restrictions with chloride that commercial facilities have. Also, chloride is present mainly as sodium chloride, whereas the chloride in a commercial stream can be more variable.

Based on the characterization data presented in Table 4, most or all K106 waste is expected to be high mercury subcategory waste and therefore require retorting or roasting. However, facilities currently use one of the following four options to dispose of their mercury wastes: thermal treatment in a rotary kiln; thermal treatment in a batch retort; wet treatment via the Universal Dynamics mercury recovery process; or offsite landfilling in Canada. In total, approximately 850 tons of K106 waste were retorted onsite.

Most chlor-alkali facilities generate D009 wastes in conjunction with their listed wastes. The 1995 BRS data shows that many options exist for managing this waste, depending on the mercury content of the waste.

Occidental, Deer Park, TX

BRS data show that 283 tons of K106 waste were generated in 1995. The K106 waste was managed by onsite retorting, with the residues shipped to an offsite landfill. No data for K071 waste was reported. The facility also reported onsite retorting for 39.86 tons of D009 waste, although they also reported shipping about 35 tons of this waste offsite without any treatment at all. The NESHAP information confirms that this facility operates a batch retort system.

Occidental, Muscle Shoals, AL

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[11] Arthur E. Dungan, "Development of BDAT for the Thermal Treatment of K106 and Certain D009 Wastes," in "Arsenic and Mercury: Workshop on Removal, Recovery, Treatment, and Disposal," August 1992, EPA/600/R-92/105.

[12] Telephone Conversation, A. Dungan, 1998; and Telephone Conversation, Iliam Rosario, EPA, and John Vierow, SAIC, July 1, 1998.

[13] Telephone Conversation, A. Dungan, 1998.

BRS data show that 120 tons of K106 waste were generated in 1995 and described to be managed by onsite retorting. The retort treatment residue (100 tons) is managed by landfilling. For K071 wastes, 642 tons were generated and managed offsite by landfill. The 1995 BRS data also show that 120 tons of D009 were generated, and managed by retorting. This facility also generates approximately 786 tons of D009 waste, which is managed offsite by landfilling.

This facility's K106 retort treatment residue has been delisted (i.e., designated as nonhazardous under the provisions of 40 CFR sections 260.20 and 260.22). As part of their petition, Occidental provided significant characterization and treatment data. This facility's raw waste shows total mercury levels from 2,000 to 5,500 mg/kg, which places this waste in the high mercury subcategory. Total levels of mercury in the retort treatment residue range from 40 to 100 mg/kg, making the residue a low mercury subcategory waste. The NESHAP information verifies that retorting is conducted.

Occidental, Delaware City, DE

BRS data show that 71 tons of K106 retorting treatment residue were generated in 1995. Management of the retort treatment residue is not described. For K071 wastes, 175 tons were generated and managed by stabilization and landfilling. Additional K071/K106 wastewaters are also generated. The NESHAP information confirms that the facility operates a retort. This facility also retorts a small quantity of D009 wastes, and sends the treatment residue offsite to be managed in a landfill.

Olin Chemical, Charleston, TN

BRS data show that 166 tons of K106 waste were generated in 1995. This waste is reported to be managed by "other onsite disposal." No data for K071 waste was provided. This facility also reported generating some D009 waste from retort as well as from miscellaneous sources. This waste was reported to be managed by landfill onsite, although Olin Chemical does ship about 0.22 tons of retort ash waste off-site to be incinerated. The NESHAP information shows this facility to have an onsite retorting system.

Olin, Augusta, GA

BRS data show that 42 tons of K106 waste and 110 tons of K071 waste were generated in 1995. The K106 waste is managed by offsite retorting at Olin's Charleston, TN facility. The K071 waste is managed by offsite landfilling. The 1995 BRS data also show that almost 72 tons of D009 waste were generated at this facility and shipped to Olin's Charleston, TN, facility. There also were 61 tons of D009 waste shipped offsite for management in a landfill.

PPG, Westlake, LA

BRS data show that 134 tons of K106 thermal treatment residue were generated in 1995, and managed by landfill. Additional K106 wastewaters were also generated. PPG also generated some D009 waste, although none of it was retorted and most of it was treated by landfill offsite or by transfer facility storage without any prior treatment. The NESHAP information verifies that the facility has a retort system.

PPG, New Martinsville, WV

This facility does not report the generation of K106 or K071 waste in the 1995 BRS. PPG does report generating D009 waste, shipping most of this waste offsite for incineration or to be landfilled. The NESHAP information reports that the facility's waste is shipped to the PPG Westlake retorting facility, which may be classified as an incinerator for regulatory purposes.

Vulcan, Port Edwards, WI

The NESHAP information shows that this facility operates an onsite retort system. Correspondance with the Chlorine Institute indicates that this facility uses the Hazen Technology fixed hearth furnace (batch process) rather than a rotary kiln.[14] BRS data show that 39 tons of K106 waste and approximately 12,000 tons of K071 waste were generated by this facility. Management data from BRS are incomplete; the K106 waste is reported to be stored offsite while the K071 waste has no onsite or offsite management information. This facility also reported generating a large quantity of D009 wastes, although the BRS data are incomplete here too. While it seems that about 30 tons of D009 waste is shipped offsite for treatment, there is no indication of what happens to the remaining volume of waste. This facility received a delisting of its K071 waste.

2. Chlor-Alkali Facilities That Do Not Use Retort/Roasting

Six of the 14 chlor-alkali facilities do not treat their K106 waste by roasting or retorting:

- ASHTA Chemicals, Ashtabula OH (land disposal)
- B.F. Goodrich, Calvert City KY (wet process)
- Georgia Pacific, Bellingham WA (wet process)
- HoltraChem, Orrington ME (land disposal)
- HoltraChem, Acme NC (land disposal)
- Pioneer, St. Gabriel LA (wet process)

Specifically, these facilities use either the Universal Dynamics REMERC process or they ship the waste to a landfill in Canada. The Universal Dynamics process does not "treat" K106, but rather treats the wastewaters and solids that comprise K106 wastes when filtered. Therefore, K106 waste generated using the Universal Dynamics recovery process has a much lower mercury concentration than conventional K106 wastes, and is typically below the 260 mg/kg total mercury threshold.

ASHTA Chemicals, Ashtabula, OH

BRS data show that 247 tons of K106 waste and 304 tons of K071 waste were generated in 1995. The K071 waste was stabilized at a Chemical Waste Management facility in New York. The K106 waste was also stabilized, but the location of the treatment facility was not identified.

B.F. Goodrich, Calvert City, KY

BRS data show that 60 tons of K106 waste and 0.9 tons of K071 waste were generated in

[14] Conversation between Rita Chow, USEPA, and Art Dungan, Chlorine Institute, November 1998.

1995. The K106 is managed in two ways: 58 tons were managed by offsite stabilization while 2 tons were shipped offsite for retorting to a facility in Canada (Stablex Canada). This may be a coding error because another facility (HoltraChem in Orrington Maine) classifies this Canadian facility as a landfill. This facility also generates approximately 9.3 tons of D009 waste, which it ships to two different retort facilities (Olin Corporation's facility in Tennessee, and a facility in Pennsylvania). Information from the NESHAP office indicates that B.F. Goodrich currently operates the Universal Dynamics REMERC Process. This facility received a delisting of its K071 waste.

Georgia Pacific, Bellingham, WA

BRS data show that approximately 106 tons of K106 waste and 214 tons of K071 waste were generated in 1995. Most of the K106 waste (77 tons) was managed at a landfill in Canada (Stablex Canada). The remaining 29 tons were landfilled at a Chemical Waste Management facility in Oregon. The K071 waste was also reported to be landfilled at the same Oregon facility. The NESHAP information shows that this facility operates the Universal Dynamics REMERC Process, which is expected to result in the generation of K106 waste suitable for landfilling (i.e., <260 ppm mercury).

HoltraChem, Orrington, ME

BRS data show that 762 tons of K106 waste and K071 waste were generated in 1995. The waste is shipped offsite to a landfill in Canada (Stablex Canada). Information from the NESHAP office verifies this management practice.

HoltraChem, Acme, NC

BRS data show that 115 tons of K106 waste were generated in 1995. Most of the waste (99 tons) is shipped offsite to a landfill in Canada (Stablex Canada). The remaining 16 tons were stored at a facility in Ohio (Republic Environmental Systems). Information from the NESHAP office verifies that HoltraChem uses a landfill in Canada.

Pioneer, St. Gabriel, LA

BRS data show that 201 tons of K106 waste were generated in 1995. The waste was described in the BRS to be stabilized at a facility in Canada. Information from the NESHAP office indicates that Pioneer currently operates the Universal Dynamics REMERC Process, which is expected to result in the generation of K106 waste suitable for landfilling (i.e., <260 ppm mercury). Pioneer received a delisting of their K071 waste.

3. Retort Facilities

Overview of Commercial Mercury RMERC Industry and Wastes Codes Accepted

Although the chlor-alkali industry presently treats or manages all of its K106 high mercury subcategory waste without the use of the commercial sector, other characteristic and listed wastes do require the RMERC commercial sector. The commercial mercury recovery sector consists of three types of facilities:

1. Facilities principally accepting a single type of waste, such as fluorescent bulbs or mercury vapor lamps. Such companies will usually have multiple collection or physical processing sites to concentrate the mercury waste, in conjunction with a smaller number of retorting sites for mercury recovery. Based on a review of multiple data sources, at least 12 such facilities conduct RMERC operations on wastes limited to fluorescent bulbs and similar wastes. It is difficult to determine the exact number, as some of these facilities are small, new, or exempt from certain hazardous waste regulations.

2. Facilities recovering mercury from a wide variety of wastes. These facilities have the ability to recover mercury but typically have little to no additional treatment or recovery ability. Facilities specializing in this type of mercury recovery include AERC (Bethlehem, PA), Bethlehem Apparatus (Hellerton, PA and Allentown, PA), Mercury Recycling (Brisbane, CA), and Mercury Refining Company (Albany, NY). It must be emphasized, however, that each facility has its own waste acceptance restrictions.

3. Larger treatment, storage, disposal (TSD) facilities for which mercury retorting likely comprises only a fraction of their operations. These facilities are centralized waste treatment facilities accepting and treating many wastes. For example, the ENSCO (Dalton, GA) facility conducts mercury retorting in conjunction with stabilization, incineration, wastewater treatment, and other treatment and disposal processes.

Note that none of these three types of facilities includes vendors, such as Mercury Recovery Systems (New Brighton, PA), that specialize in providing mobile and temporary mercury treatment or recovery services, such as for soils cleanup.

Table 6 provides a summary of the facilities that may conduct retorting, based on the 1995 BRS and other information. Table 6 shows that D009 wastes are readily accepted by most or all facilities. U151 wastes are accepted by at least two facilities specializing in mercury recovery by retorting (Bethlehem Apparatus and Mercury Recycling) and one centralized waste treater managing many wastes (Burlington Environmental, Kent WA). The P-wastes are potentially accepted by only one centralized waste treater, NSSI (Houston TX), although it is difficult to determine exactly how many facilities accept P wastes and how these wastes are managed, since the wastes are likely to be received infrequently and in small quantities.

Table 6: Retort Facility Information

Site	EPA ID	Waste Codes and Forms Accepted	References
Mercury Waste Recovery Facilities			
AERC 2951 Mitchell Ave Allentown, PA	PAD987367216	D009: Straight and U-shaped fluorescent lamps, HID lamps thermometers, manometers, switches, amalgams, and other items	1, 2, 3
Bethlehem Apparatus Co. Inc. 890 Front Street Hellerton, PA	PAD002390961	D009, U151: Thermometers, glass and steel switches, controls, relays, ignition tubes, high pressure quartz lamps, mercury vapor lamps, mercury dental amalgams, fluorescent lamps, mercury batteries, mercury encapsulated in devices and containers, mercury oil sludges, mercury spill kits, mercury oxide, mercury sulfide, mercury sulfate, mercury iodide, and other mercury containing solids	1, 2, 3, 5
Bethlehem Apparatus Company Inc. Bethlehem, PA	PAD000453084	Similar to Hellerton facility	3
Mercury Recycling Inc. Brisbane, CA		D009, U151: Metallic mercury, mercury compounds, switches, relays, and some solutions	6
Mercury Refining Company, Inc. 1218 Central Ave Albany, NY	NYD048148175	D001-D009, D011, D018, D023-D025, D035: Fluorescent light bulbs, batteries, compounds, contaminated soils, relay switches, wastewater, PCB grease/mercury mixtures, contaminated debris, and other waste types	1, 2, 4, 5
TSD Facilities			
Burlington Environmental Inc. Kent, WA	WAD991281767	D001-D016, D018, D022, D026-D030, D035, D037, D039, F001-F008, F019, F032, F034, F035, U117, U151, P042, K050: Sludges, solvents, batteries, aerosol cans, oil/fuel, antifreezes, photo developers, household wastes, wastewater, oily wastes, aqueous and non-aqueous metal-bearing waste, and PCBs	1
Drug and Laboratory Disposal, Inc. 337 Broad Street Plainwell, MI	MID092947928	D001-D011, D014, D018-D020, D022, D027, D035, F001-F003, F005, P042, P081, U113: Miscellaneous burnables, lab packs, toxic heavy metals, toxic paint filters, toxic acids, toxic oil filters, and other toxic chemical wastes	1
E.I. DuPont de Nemours & Company Orange, TX	TXD008079642	Most D, F, K, P, and U listed wastes: Paint thinner, lab packs, oil filters, fluorescent bulbs, incinerator ash, wastewater, aerosol residue, contaminated trash, and other related wastes	1
ENSCO Dalton, GA	GAD000222083	Variety of wastes, including those amenable to mercury retorting	4
NSSI/ Recovery Services Houston, TX		Authorized for all EPA waste codes: Chemicals, COD vials, acid washing residues, spent lighting phosphors, radioactive residues, and mercury batteries	6

Site	EPA ID	Waste Codes and Forms Accepted	References
Fluorescent Bulb Retorters			
Entergy System & Services Chesterfield, MO	MOP000001768	D009: Lighting fixtures, and lighting tubes	1
Mercury Technologies Corporation Hayward, CA		D009: Straight and U-shaped fluorescent lamps	5
Recyclights, Inc. Tallahassee, FL	FL0000207449	D009: Fluorescent bulbs, wastewater, switches, batteries, electronics, PCB, DEHP, and non-PCB/DEHP ballast recycling	1, 4
Recyclights, Inc. Columbus, OH Lakeland, FL Minneapolis, MN			4
Allied Technology Fremont, CA		Fluorescent lamps	6
Dynex Milwaukee, WI		Fluorescent lamps	6
Global Recycling Stoughton, MA		Fluorescent lamps	6
Lighting Resources Ontario, CA		Fluorescent lamps	6
Lighting Resources/ EPSI Phoenix, AZ		Fluorescent lamps	6
USA Lights Roseville, MN		Fluorescent lamps	6
Unknown Operations			
Green Mountain Power Corporation Colchester, VT	VTD988366654	D001, D009, F003: Fluorescent bulbs, oily debris, waste oil, oily solvent from equipment maintenance	1

References:
1- BRS, 1995
2- TRI, 1995
3- State/Region Contact
4- Facility Information (web page/brochure)
5- Research Triangle Institute, Management of Used Fluorescent Bulbs: Preliminary Risk Assessment. Final Report. June 1992.
6- Kenney and Hansen, State of the Art Mercury Recycling and Remediation of Mercury - Containing Waste, 1995

Facility-Specific Information

AERC, Allentown, PA

AERC uses retorting and a triple distillation process. Additionally, the facility

preprocesses fluorescent lamps by first removing the mercury-containing phosphor powder. It also reports conducting hydrometallurgical processing of aqueous wastes to recover mercury and other metals.[15]

In the 1995 BRS, this facility reported recycling approximately 1,600 tons of D009, principally fluorescent lamps. Other D009 wastes reportedly accepted include lab packs, spent acid, elemental mercury, mercury contained in manufactured articles, contaminated soil, batteries, mercury salts and (unspecified) compounds, spent carbon, and industrial scrap.

Specific characterization data are unavailable. Quantitative data are not generally available, partly because most wastes are discarded objects such as lamps.

AERC reported sending 250 pounds of mercury offsite for recycling in the 1995 TRI. The facility is expected to generate wastewater, activated carbon (from pollution control equipment), and decharacterized waste. Additional treatment residuals unique to the hydrometallurgical process are also expected to be generated. The following are the hazardous wastes the facility generated in 1995, according to the BRS:

- Crushed fluorescent tubes (D009), 51 tons
- Personal protective equipment and other plant scrap (D009 mercury), 22 tons
- Spent acid (D002, D007, D009, D011), 3.5 tons
- Floor sweeps (D009), 3.2 tons
- Spent carbon (D001, D009), 2 tons
- Lab packs (D001, D002, D009), 1.2 tons
- Spent caustic (D002, D009, D011), 1.1 tons
- Organic liquids (D002, D009), 0.02 tons

Bethlehem Apparatus Co. Inc., Hellerton, PA and Bethlehem, PA

Bethlehem Apparatus operates the world's largest commercial recycling facility, processing more than 1000 tons of mercury waste annually.[16] The Hellerton facility accepts mercury-containing waste in drums or similar containers, conducts physical processing (e.g., crushing) if necessary, and then retorts the wastes through a multiple distillation process to achieve a purified mercury product for sale. It has been in operation since the 1970s.[17]

Hellerton's retort operation is a batch process. A drum containing the waste is placed directly inside the stainless steel retort chamber, a high vacuum is created, and the vessel is heated to 1250°F (the normal boiling point of elemental mercury is 675°F, and is lower in a vacuum). The vapors are condensed and further purified in a continuous feed step-wise triple distillation process to produce mercury product. The facility operates 23 retort units to increase its processing rate. Retorting time and temperatures are dependent on the specific waste being processed.[18] The process usually takes up to three days per cycle, although a continuous retort

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15 AERC. Information submitted to Region III in support of its Subpart X permit. 1993.

16 Bethlehem Apparatus information pamphlet.

17 Bethlehem Apparatus Company Incorporated, Hellerton Pennsylvania. Waste Analysis and Recycling Plan for Pennsylvania Department of Environmental Protection Hazardous Waste Recycling Permit Application and the U.S. EPA Smelting, Melting, and Refining Furnace Conditional Exemption. January 1996.

18 Research Triangle Institute. Management of Used Fluorescent Bulbs: Preliminary Risk Assessment. Final Report. June 1992.

system would speed up the process. A continuous retort system is in place at another Bethlehem Apparatus facility in Bethlehem, PA, which allows the waste to be processed faster than with the batch systems.[19]

This facility claims to accept only D009 and U151 wastes.[20] This is supported by BRS data. A total of 600 tons of D009 and U151 waste were accepted in 1995, 590 of which were D009. Table 6 lists the waste forms accepted. This facility will not accept liquid wastes, mercuric chlorides, mercuric cyanides, or organometallic mercury compounds.[21] It also rejects chloride, lithium, arsenic, and any radioactive wastes. Due to a lack of air pollution control equipment, this facility must reject most sulfides because it is not equipped to handle this waste. This facility is also has to reject wastewater treatment sludge due to permit limitations.[22]

The facility accepts a limited number of wastes with a heating value above 5,000 BTU, including activated carbon, wood, paper, protective clothing, sweepings, respiratory cartridge filters, cleanup articles, plastic bags and other contaminated containers, and recoverable levels of mercury contained in soil. It must obtain approval prior to treatment for any other material with such a heating value.[23]

A detailed description of the Hellerton process is presented in the U.S. EPA's Document on Arsenic and Mercury.[24] Treatment residuals produced include the following:

- Approximately 20 tons per year of waste materials (e.g., glass, dirt) from which mercury was removed during the retort operation. Occasionally, this waste will be hazardous due to the presence of other metals.[25] Based on 1995 BRS data, approximately 11 tons of such waste were generated and sent to an offsite hazardous waste landfill. The facility's previous estimate of hazardous waste generation was 0.25 tons.[26]
- Approximately 20 tons per year are sent to scrap metal recycling centers.[27] The facility's TRI report indicates that 250 pounds of mercury were sent offsite for recycling in 1995 but no other metals were reported.
- 20-50 gallons of wastewater are generated per day from the condensing of steam condensate generated from the mercury-containing waste and from noncontact cooling (e.g., for condenser operation). The wastewater is filtered using activated charcoal prior to it being sent to a local sewage treatment plant. BRS data also indicate an unreasonably large quantity of D009 mercury-containing wastewater generated for unspecified offsite management in Maryland.
- 50-100 gallons per year of oil are generated from the retort and vacuum pumps,

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19 Kenney and Hansen, State of the Art in Mercury Recycling and Remediation of Mercury-Containing Waste, 1995.

20 Bethlehem Apparatus, Waste Analysis and Recycling Plan, 1996.

21 Memorandum from ICF to EPA. "Review of Facilities that Reclaim Mercury-Contaminated Wastes." May 29, 1992.

22 Kenney and Hansen, State of the Art in Mercury Recycling and Remediation of Mercury-Containing Waste, 1995.

23 Bethlehem Apparatus, Waste Analysis and Recycling Plan, 1996.

24 U.S. EPA, Arsenic & Mercury: Workshop on Removal, Recovery, Treatment, and Disposal, 1992.

25 Bethlehem Apparatus, Waste Analysis and Recycling Plan, 1996.

26 U.S. EPA, Arsenic & Mercury: Workshop on Removal, Recovery, Treatment, and Disposal, 1992.

27 Ibid.

which are subsequently filtered, treated, and fuel blended.[28]

- Spent activated carbon from air and water pollution control is generated and is returned to the retort for mercury removal.[29]

EPA presents data on treated wastes generated by this facility (i.e., following retorting), such as switches, activated charcoal, and glass.[30] Presumably, these materials represent residual materials managed as nonhazardous wastes. Total levels of mercury in these wastes ranged from 0.6 to 30 mg/kg. TCLP levels of mercury ranged from non-detects to 0.068 mg/L. The facility also indicates that, when receiving a new waste type, it processes the material and analyzes the residual material to determine if mercury removal is effective.[31]

Burlington Environmental Inc., Kent, WA

This site is a commercial hazardous waste management facility, and it accepts many D and F listed wastes, as well as U117, U151, P042, and K050 listed wastes. This facility reported using the retort process to recycle 5.94 tons of mercury waste in 1995. No treatment cost information exists, but there was some information about waste residues. Based on 1995 BRS data, there is no waste disposal at this facility and all residue is sent off-site to be combusted for energy recovery, disposed by incineration, discharged to the King County POTW, sent to another hazardous waste treatment facility for additional treatment, or disposed of in a landfill.

Drug and Laboratory Disposal, Inc., Plainwell, MI

This facility is designed to handle medical, chemical, and lab waste. According to BRS data, this facility recycled approximately 0.02 tons of mercury waste in 1995. No information exists for the method used to recycle the mercury waste, although the reported management method was retorting.

E.I. DuPont de Nemours & Company, Orange, TX

This facility reported recycling 1.17 tons of mercury waste in the BRS data for 1995. Although this facility reportedly conducts retorting, there is little other information available about the process used to recycle mercury at this plant.

Entergy System & Services, Chesterfield, MO

This facility reported retorting 31.2 tons of mercury, according to the 1995 BRS. This facility also reported generating 15.6 tons of D009 wastes from mercury-bearing lighting tubes and fixtures accumulated for recycling. This waste was shipped off-site for further retorting. There was no other information available for the retort process carried out at this facility.

Green Mountain Power Corporation, Colchester, VT

This utility company in southern Vermont produces and treats waste from the maintenance

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28 U.S. EPA, Arsenic & Mercury: Workshop on Removal, Recovery, Treatment, and Disposal, 1992.

29 Ibid.

30 Ibid.

31 Bethlehem Apparatus, Waste Analysis and Recycling Plan, 1996.

of its equipment. Fluorescent bulbs comprised 0.08 tons of mercury waste this facility retorted in the BRS reporting year of 1995. While this facility is listed as a retorter in the BRS data, there is no additional information about how the retort process is carried out at this facility.

Mercury Recycling Inc., Brisbane, CA

This facility, formerly Quicksilver Recycling, operates a crushing and shredding circuit, which is followed by filtration. This processing train allows the facility to handle amenable mercury-contaminated scrap; much of the current feedstock is electrical scrap. The facility accepts D009 and U151 wastes in the form of mercury metallics, mercury compounds, or solutions to produce distilled elemental mercury product.[32] The facility also accepts switches and relays for recycling, although it will not accept batteries.[33]

Mercury Refining Company, Inc., Albany, NY

This retort facility, recently purchased by Mercury Waste Solutions, Incorporated, recovers mercury from various commercial and industrial products. In addition to the waste forms listed in Table 6, this facility also accepts solutions, solids, sludges, lamps, clothing, and certain organometallic mercury compounds.[34] While the facility will make some exceptions, most of the wastes they accept must be in 55-gallon containers, or smaller. This facility is permitted for treatment, storage, and disposal of certain mercury waste and can recover mercury from aqueous solutions and solids. This facility does not accept mercuric chlorides, mercuric cyanides, liquid wastes, halogenated compounds, some organometallic mercury compounds, wastes with greater than 1 percent lead,[35] radioactive wastes, or wastes containing greater than 0.1 percent chloride.[36]

This facility uses a retort unit that is contained in a multicompartment building, and all of the operations are conducted under negative pressure to help control emissions. The unit operates at 1000°F.[37] The facility also uses sealed rooms for the preheating and cooling of the mercury-bearing wastes, and the rooms are equipped with their own carbon adsorption filters to trap mercury vapor.[38] While the company seeks to limit their mercury air emissions to near zero, they reported point source emissions of ten pounds to the air in the 1995 TRI data. They also reported emissions of five pounds of mercury to the water, and another five pounds for offsite recycling. During this BRS reporting period, the facility created a total of 378.48 tons of recycled mercury for reuse. This mercury can be returned to the generator who shipped it, or it can be stored for resale at a future time.

Residues generated from waste treatment reflect some of the treatment processes used by this facility. Residue data are available from 1995 BRS, which does not include the quantity of nonhazardous residue that is generated. A total of 78 tons of hazardous waste residue (D004 to D008 wastes) and 49 tons of debris is managed by offsite stabilization. Other wastes include:

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32 Kenney and Hansen, State of the Art in Mercury Recycling and Remediation, 1995.
33 ICF Memorandum to Jose Labiosa, May 29, 1992.
34 Kenney and Hansen, State of the Art in Mercury Recycling and Remediation, 1995.
35 ICF Memorandum to Jose Labiosa, May 19, 1992.
36 Kenney and Hansen, State of the Art in Mercury Recycling and Remediation, 1995.
37 ICF Memorandum to Jose Labiosa, May 19, 1992.
38 Mercury Refining Company, Facility Information Packet.

- Wastes from the separation of PCB/mercury grease mixtures, prior to retorting. Debris is stabilized offsite (11 tons), grease is incinerated offsite (8 tons), and wastewater is incinerated offsite (23 tons).
- Ion exchange resin (<1 ton) is retorted onsite. Corrosive, mercury-containing solutions are not amenable to retorting and, therefore, the mercury is concentrated using an ion-exchange resin, where the mercury is transferred from a solution to a solid matrix. The solid ion exchange resin, containing mercury, is likely placed in the retort oven.
- Caustic waste drained mercury batteries (2 tons) and characteristic ion exchange resin effluent (5 tons) is sent offsite for unknown treatment.
- For air pollution control, activated carbon is used. Spent material is retorted onsite (<1 ton). Additionally, scrubber water is generated and sent offsite for treatment by precipitation (111 tons). Other nonhazardous scrubber water may also be generated, but was not reported in BRS.
- Liquid organic wastes are generated from the retorting of certain organic-containing mercury wastes (36 tons). These wastes have hazardous waste codes D001, D006, D009, D018, and D035 and are managed by offsite stabilization.

NSSI/Recovery Services, Houston, TX

This facility did not report any retort activity to the BRS database for 1995, although other sources indicate that this facility does conduct retort processes on some wastes. This facility uses a continuous retorting process to treat mercury waste, and is the only domestic recycler of radioactive mercury materials. This facility is authorized to treat all hazardous wastes, and its feedstocks can be pretreated to convert mercury oxides and sulfides by oxidation/reduction. Organometallics can be converted to oxides in a small thermal treatment unit. This facility accepts large volumes of a wide variety of mercury-containing wastes, such as chemicals from industry and research and development facilities, COD vials from analytical processes, acid washing residues from remediation activities, spent lighting phosphors, and radioactive residues from the lighting industry. The facility also accepts mercury and lithium batteries.[39]

Recyclights, Inc., Tallahassee, FL

This facility reported "retorting" in the 1995 BRS. No other Recyclights facility was listed in the BRS. Recyclights reported using the MRT Superior Distiller process at its Minneapolis, Minnesota facility and using distillation in general at their Columbus (Ohio) and at least one of their two Florida facilities.[40] It is likely that Recyclights uses similar or identical MRT systems at all of its locations.

The MRT distillation process is a batch distillation process licensed by MRT Systems AB (Karlskrona, Sweden); MRT sells a variety of models, such as the Superior system, but all use similar technologies. The waste material is heated in a vacuum chamber to temperatures ranging

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[39] Kenney and Hansen, State of the Art in Mercury Recycling and Remediation, 1995.

[40] http://www.recyclights.com/servloc.html

from 750 to 1100°F. The offgas is passed through an afterburner and then through two condensers in series to recover the mercury. The offgas is passed through activated carbon for final mercury recovery.[41]

The Florida facility currently recycles only about 298 tons of mercury a year, although it is capable of recycling about 6,000 tons. In all, Recyclights has recycled about 15 million pounds of mercury waste since operations began in 1992.

4. Restrictive Waste Characteristics

Most facilities are unable to accept all types of mercury-containing D009 waste for retorting. The following is a list of waste characteristics that cause difficulties in retorting or roasting.

- Organic forms of mercury (e.g., mercury fulminate, phenylmercury acetate). Independent of regulatory restrictions, some facilities do not accept any organomercury compounds because the compound does not decompose into elemental mercury. Instead, the compound is carried through the retort and distillation system and results in an impurity in the final mercury product.
- High water content. Large quantities of generated steam interfere with the mercury condensation process. To solve this problem, one facility (AERC) precipitates or concentrates liquid solutions prior to retorting.
- Mercury chloride, polyvinyl chloride, and halogens in general. Mercury chloride and other salts carry over during the retorting and condensation process, forming impurities.[42] Additionally, halogens will form acids in the presence of steam, which are corrosive to equipment. One facility (Mercury Refining Company) pretreats corrosive solutions using ion-exchange to overcome this problem.
- Radioactive wastes. For obvious regulatory and safety reasons most facilities reject radioactive wastes. Only one facility has been identified that accepts radioactive mercury-bearing wastes (NSSI, Houston TX).
- Mercury nitrate/nitrite solutions. This material typically results in an ignitable solution, which is problematic from a permitting perspective.[43]
- Volatile metals. Some retorting facilities restrict certain metals, including lithium, arsenic, and thallium. It is not known why these self-imposed restrictions exist, but arsenic is volatile in the same temperature range as mercury.
- Wastes containing mercuric sulfide. These wastes are difficult to retort - additives are required to scavenge elemental sulfur produced before it can recombine with the mercury.

C. Air Emissions

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41 Research Triangle Institute, for EPA Office of Solid Waste. "Management of Used Fluorescent Bulbs: Preliminary Risk Assessment," Final Report. June 1992. More recent information at MRT's Internet site, www.freeway.fr/MRT/, supports the process description.

42 Ibid.

43 Ibid.

Secondary mercury production is estimated to have accounted for approximately 0.4 Mg of mercury emissions in 1995.[44] Air emissions from retorting or roasting units are generally scrubbed and passed through carbon filters that efficiently capture mercury vapor. When spent, these filters are retorted or roasted along with other wastes to recover the mercury that has been trapped. The units may also incorporate an afterburner prior to any additional air pollution control devices (APCDs) for odor control.

1. Chlor-Alkali facilities

Of the 14 chlor-alkali facilities using the mercury cell process, six conduct onsite retorting or roasting. Table 7 presents air emissions data for these six facilities from the TRI, and two other facilities that do not conduct onsite mercury recovery (these two facilities ship their wastes off-site to other facilities owned by the same parent company). The releases in Table 7 represent all releases. Other sources of mercury emissions at these facilities include fugitive emissions and hydrogen stream purification.[45] As shown in Table 7, the range of airborne mercury releases from facilities with a retort process unit range from 250 to 1,500 pounds for 1995. However, mercury releases from facilities without a retort process unit are comparable to the releases from facilities with retorters, indicating that retort emissions are relatively small compared to the total facility emissions.

Other air emissions data specific to the facilities are not yet available. Specifically, air emissions data from individual facilities was to be collected in summer/fall 1998 as part of an EPA questionnaire mailed to these 14 facilities. A new mercury standard for chlor-alkali facilities is under development, as required by section 112 of the Clean Air Act, and a new standard is expected to be finalized by November 2000.

Of the six facilities with RMERC capacity, four operate a batch process and two operate a continuous (rotary kiln) process. Air pollution control equipment includes a caustic scrubber (at an unknown number of facilities) followed by a carbon adsorption unit (at all facilities). The rotary kiln units also incorporate an afterburner prior to any additional air pollution control equipment.

In regard to the regulatory status of these units, at least one is believed to be permitted as an incinerator (i.e., the PPG rotary kiln unit in Lake Charles, LA). This facility was in the process of obtaining a boiler and industrial furnace (BIF) permit in 1993.[46] In general, mercury recovery facilities can be exempt from BIF provided they meet certain requirements listed in 40 CFR §266.100. It is unknown if the other five facilities have BIF permits or not.

Table 7: Air Emissions Data for Selected Chlor-Alkali Facilities

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44 Mercury Study Report to Congress, USEPA, December 1997, Volume I: Executive Summary, page 3-6.

45 Telephone conversation, Iliam Rosario, EPA, and John Vierow, SAIC, July 1998.

46 Note from Fred Chanania, USEPA, to Sonya Sasseville, USEPA, June 11, 1993.

Site and Retort Process	1995 Mercury Air Releases, Pounds [a]
Facilities With RMERC	
Occidental, Delaware City DE (batch)	492
Occidental, Muscle Shoals AL (batch)	240
Occidental, Deer Park TX (batch)	1,040
Olin, Charleston TN (rotary kiln)	1,533
PPG, Lake Charles LA (rotary kiln)	1,240
Vulcan, Port Edwards WI (rotary kiln)	1,161
Facilities Without Any Onsite Mercury Recovery	
Olin, Augusta GA (no recovery onsite)	1,317
PPG, New Martinsville WV (no recovery onsite)	1,130

[a] Represents combined fugitive and stack releases from 1995 Toxic Release inventory.

2. Commercial Facilities

Table 8 presents data obtained from the TRI for commercial facilities who use RMERC. This table provides mercury emission data to air, water, and offsite recycling sites for the three facilities which reported to TRI. This table is followed by anecdotal data for the three facilities. No other emissions data were available for other facilities.

Table 8: Air Emissions Data for Commercial RMERC Facilities

Site	EPA ID	Location	Mercury Releases
AERC	PAD987367216	Allentown, PA	all offsite recycling (250 lb.). No air releases
Bethlehem Apparatus Co. Inc.	PAD002390961	Hellerton, PA	15 lb. Hg (Air) 250 lb. offsite recycling
Mercury Refining Company, Inc.	NYD048148175	Albany, NY	10 lb. Hg (Air) 5 lb. Hg (Water) 5 lb. offsite recycling

Air emissions data for the three facilities show that releases are low. Stack emissions data were not obtained, but verbal correspondence indicates that measured emissions are also low. For example, the AERC facility measures for mercury at the stack several times per day. A State official believed that these are normally not-detected, and if any mercury is detected the operation

shuts down.[47]

Detailed air pollution control device information is also available for several facilities. Air pollution control at the Bethlehem Apparatus (Hellerton) and the AERC facilities include carbon adsorption with no scrubbers.[48] BRS data indicate that the Albany facility uses carbon absorption and a scrubber.

At the Bethlehem Apparatus facility, all retorting and ancillary operations (e.g., material handling) are conducted indoors.[49] This facility has emission controls for its furnace operation and for the building where the ancillary operations are conducted. The furnace off gas is cooled, then passed through activated carbon and a gas afterburner. Vent gas from the building passes through activated carbon and is emitted to the atmosphere. AERC's second facility's furnace emissions are cooled, passed through a series of activated carbon absorption, and emitted to the atmosphere.[50] The Mercury Refining Company's retort process is contained in a multicompartment building and all of the operations are conducted under negative pressure to help control emissions. The facility also uses sealed rooms for the preheating and cooling of the mercury-bearing wastes, and the rooms are equipped with their own carbon adsorption filters to trap mercury vapor.[51]

Most mercury recovery facilities do not appear to be subject to the mercury NESHAP (40 CFR §61 Subpart E is applicable to mercury ore recovery facilities, chlor-alkali facilities, and incinerators of wastewater treatment plant sludge). It is unknown if facilities are subject to the second criteria regarding PSD permits. With regard to the third criteria of a state permit, at least two facilities do not have State permits, but do operate with some degree of State oversight. Finally, it is possible (but unlikely) that some mercury recovery facilities may be subject to the BIF requirements. Mercury recovery facilities can be exempt from the BIF requirements of 266.100 provided they meet certain feed restriction requirements. The Bethlehem Apparatus and AERC facilities are both known to be exempt from the BIF regulations.

Oversight for air emissions is conducted by the State for both the Bethlehem Apparatus (Hellerton) and AERC facilities. The facilities do not have an air permit for their furnace operation. Instead of a permit, each facility has an "approved minor source determination" for its furnace operations. This is a legal way to operate; the facility had to submit certain information to the State prior to obtaining this approval, but it is less cumbersome than the permit process. The Hellerton facility was issued an air permit for its building vent emissions, with the concern principally for odors.[52]

D. Alternative Technologies for High Mercury Wastes

As discussed in the Best Demonstrated Available Technology (BDAT) Background Document for mercury wastes, retorting is not the only technology that has been used in treating

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47 Telephone Conversation between John Vierow, SAIC, and Luis Pizarro, USEPA Region III, June 1998.
48 Ibid.
49 Bethlehem Apparatus, Waste Analysis and Recycling Plan, 1996.
50 Telephone Conversation between John Vierow, SAIC, and Luis Pizarro, USEPA Region 3, June 1998.
51 Mercury Refining Company, Facility Information Packet.
52 Mercury Refining Company, Facility Information Packet.

high mercury wastes. Alternative treatment technologies included acid leaching, stabilization, and incineration. Additionally, other processes have been developed which are presently used or could potentially be used for treating such wastes.

There are two reasons why alternative technologies presently exist or existed in the past. First, the alternative technology may be simply another competing process to remove mercury from, or fix mercury within, a matrix. Second, the technology may overcome the waste's restrictive waste characteristics that cause difficulty during retorting or roasting. In regard to the latter point, several processes described below are actually "pretreatment" processes to prepare the waste for retorting. These processes remove restrictive characteristics, such as water content, and convert mercury compounds into easier to treat sulfides.

1. Acid/Chemical Leaching

Acid/chemical leaching is applicable for solids, slurries, or aqueous wastes. Acid/chemical leaching is an aqueous process that utilizes acids or other chemicals to solubilize and remove mercury from the waste matrix. Aqueous and solid wastes are mixed with the appropriate chemicals (determined based on waste characterization and treatability studies). In the case of solid wastes or sludges, water may need to be added to form a slurry. If solid wastes contain large pieces, size reduction will frequently be required to maximize contact of treatment chemicals with mercury in the waste. Multiple washes, longer retention times, and more aggressive mixing can be used to improve removal efficiencies. Phase separation (e.g., filtration, centrifugation) is used to separate the aqueous phase containing the inorganic mercury. The solubilized inorganic mercury can then be precipitated as a sulfide and the water recycled through the process. Further information is available in EPA's Analysis of Alternatives to Incineration for Organic-Mercury Wastes report.[53] The presence of large amounts of organomercury or elemental mercury will limit the applicability of this technology, since acid/chemical leaching is used primarily for inorganic mercury compounds.

Universal Dynamics Ltd. Of Vancouver, Canada developed an alternative process to retorting high mercury chlor-alkali wastes. Currently, three chlor-alkali facilities use this process, although each facility has engineered the basic process to best serve its needs. The technology is advertised as a hydrometallurgical process that requires less operating attention, costs less, and has lower air emissions than RMERC.[54]

The Chemtron Corporation facility in Avon, OH, uses a new "cold" recovery process, called the Hydrar-Zn process, to recover and recycle mercury. Detailed information is not available, but the process likely includes leaching or precipitation, based on information available from vendors treating similar wastes. This process is used on the following compounds: mercuric iodide, mercuric bromide, mercuric oxide, mercuric nitrate, mercuric chloride, mercuric cyanide, mercuric sulfate, mercurous chloride, mercuric acetate, phenyl mercuric acetate, and Nessler's Reagent. It is used on debris from mercury spill cleanups, such as sponges, gloves, mercury wipes, broken glassware, thermometers, etc.[65] In addition to the D009 mercury waste, this facility

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53 U.S. EPA, Analysis of Alternatives to Incineration for Organic-Mercury Wastes.

54 Letter from Jack Selby, Universal Dynamics, to Mary Cunningham, USEPA, March 2, 1998.

65 http://www.chemtron-corp.com/chem01/tng080.html

accepts F001, F002, F003, F005 and a variety of U listed wastes in the form of sludge, still bottoms, and fuel blends.

One alternative treatment technology involves the removal of mercury-containing solids through the use of a water and additive based solution. This nonthermal technique was developed for the remediation of the General Electric Superfund site in Puerto Rico. However, it has since been abandoned as a treatment alternative due to higher than expected volume of soil requiring treatment (now 11,000 cubic yards), which considerably increased the costs of the project and increased the difficulties of obtaining the relatively scarce raw material iodine.[66] Process details are provided in a 1992 letter and a 1993 patent.[67] A demonstration scale unit was developed at the site, however, and it is possible that the technology may be used elsewhere. The technique leaches mercury from solids using an iodide solution, followed by recovery of elemental mercury from the solution in an electrolytic cell. Further discussion will not be provided since the technique is only experimental.

2. Pretreatment Prior to Retorting

Three facilities convert difficult-to-treat mercury wastes into forms more amenable to retorting. Other information provided in this section of the report is also applicable to pretreatment, such as the sulfide precipitation step used by USPCI.

USPCI proposed a process to pretreat certain mercury wastes that are difficult to retort. The process uses a sulfide solution to replace the mercury compound species with mercury sulfide, which is acceptable to retorters. The resulting low mercury subcategory wastewaters can be further treated by physical/chemical methods, or incineration.[68]

AERC, a commercial retorting facility, accepts a variety of mercury and mercury-free waste materials. The facility operates a thermal recovery unit for some D009 wastes such as phosphor from fluorescent bulbs. It also operates a hydrometallurgical process to treat aqueous wastes containing mercury, gold, or silver. The metal is removed by electroplating, precipitation, or reduction. Recovered mercury is retorted and/or distilled.[69]

Mercury Recovery Services of Albany New York uses several pretreatment processes, based on BRS information. Corrosive solutions containing mercury are concentrated onto a solid matrix using ion exchange resin. PCB-mercury wastes are pretreated using an unknown technology to separate each component prior to retorting. Finally, mercury-containing batteries are drained of caustic prior to retorting.

3. Solidification/Stabilization (S/S)

S/S processes are nondestructive methods to immobilize the hazardous constituents in a waste while decreasing the waste surface area and permeability.[70] Common S/S agents include

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66 Telephone conversation, Caroline Kwan, EPA Region II, with John Vierow, SAIC, July 6, 1998.

67 Letter from Donald Foust, GE Corporate Research & Development, to Jose Labiosa, EPA, August 21, 1992; and U.S. Patent No. 5,226,545 (July 13, 1993).

68 Frederick J. Manley, USPCI Lab Pack Manager, letter to EPA, July, 2, 1992.

69 AERC, Information submitted to Region III, 1993.

70 U.S. EPA, Technical Resource Document: Solidification/Stabilization and its Application to Waste Materials, EPA/530/R-93/012, June 1993.

Type 1 Portland cement, lime, fly ash, and organic binders such as asphalt. Ex situ S/S can occur in continuous feed or batch systems. The final product can be a monolith of any practical size or a granular material resembling soil.[71]

A much more comprehensive review of S/S processes is presented in the companion paper, "Technologies for Immobilizing High Mercury Subcategory Wastes." Additional references discuss the limitations of immobilizing mercury.[72] Treatment data are available from one facility stabilizing high mercury waste in 1991.[73] Because the letter was sent prior to the June 1992 effective date for D009 LDRs it is not known if this facility still treats mercury waste in this manner. Specific information is confidential and is generally described as oxidation followed by sulfide precipitation, followed by conventional stabilization, applicable to liquids, slurries, and solids. Composition of the raw wastes ranged from less than 100 ppm to greater than 60 percent mercury, with waste forms described as liquids to dry solids, and mercury in the form of "salts," chloride, and nitrate. The commenter also provided general information concerning retorting incompatibility that is consistent with other information presented in the report: wastes with halides and high water content are difficult to retort.

4. Precipitation

Precipitation involves treating aqueous waste streams to change the solubility of the mercury (typically inorganic) and cause it to drop out of solution. In addition to aqueous wastes, this technology is frequently applied in a treatment train with technologies such as acid leaching. The two most common methods are sulfide precipitation and coagulation/co-precipitation. In the former, sodium sulfide, or another sulfide salt, is added to the wastestream to convert soluble mercury to the relatively insoluble mercury sulfide (HgS) form. Typically the pH is adjusted to between 7 and 9, and a flocculent is added to promote gravity settling of the HgS. Coagulation/co-precipitation is used to treat a variety of wastes containing organic and inorganic mercury. Typical coagulants include alum (aluminum sulfate), lime, and iron salts. Iron or aluminum hydroxides are formed which adsorb mercury ions. The coagulated solids are settled gravimetrically. The pH is adjusted to maximize coagulation and mercury ion solubility; final filtration may be required to improve removal efficiencies.[74]

The application of excess sulfide reagent can result in the formation of soluble mercury sulfide species. It may be difficult to simultaneously maximize coagulation and mercury species solubility; the presence of other metals requiring treatment will complicate this process further. Sludges also need to be managed, which results in additional cost and another waste that may require treatment to meet LDR requirements.[75]

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71 U.S. EPA, Engineering Bulletin: Solidification/Stabilization of Organics and Inorganics, EPA/540/S-92/015, February 1993.

72 U.S. EPA, Arsenic & Mercury: Workshop on Removal, Recovery, Treatment, and Disposal - Abstract Proceedings, Alexandria Virginia, EPA/600/R-92/105, August 1992; and U.S. EPA, SITE Technology Capsule: Geosafe Corporation In Situ Vitrification Technology, EPA/540/R-94/520a, November 1994.

73 Public comments from CyanoKEM, December 6, 1991, Advanced Notice of Proposed Rulemaking Regarding Land Disposal Restrictions for Potential Treatment Standards for Newly Identified and Listed Wastes and Contaminated Soil (56 Federal Register 55160). F-91-CSP-00023.

74 U.S. EPA, Capsule Report: Aqueous Mercury Treatment, EPA/625/R-97/004, July 1997.

75 Ibid.

Removal efficiencies of 95 to 99.9 percent are reported for well designed and operated treatment systems in chlor-alkali plants. Effluent concentrations of approximately 65 μg/L have been reported for these plants. Costs at these plants are reported to be $0.79/1,000 gallon (1987 basis), exclusive of sludge management. Final mercury concentrations in aqueous wastes treated by coagulation/co-precipitation have been reported at less than 1 μg/L in some cases, and concentrations of less than 100 μg/L are common.[76]

5. Vitrification

Vitrification uses an electric current to heat and melt soils and wastes at temperatures frequently in excess of 2,000ºC. After treatment, the molten waste cools to form a hard, glass-like monolith that immobilizes thermally stable inorganic compounds. The monolith has very low leaching characteristics. In general, vitrification is probably impractical for wastes with high levels of mercury because all mercury compounds are volatile at elevated temperatures (e.g., mercuric chloride volatilizes at about 300ºC and elemental mercury has a boiling point of 360ºC). The gas generated by this process may contain mercury compounds and will require treatment (e.g., condensation).[77] Therefore, in this case vitrification will not immobilize the mercury in a solid matrix, but instead capture of the vapors for subsequent recovery or treatment will be required.

No independently verified results were found for an ex situ application of vitrification. An in situ process was utilized to treat soils at the Parsons Chemical site. Initial mercury concentrations of 2,220 to 4,760 μg/kg were reduced to less than 40 μg/kg. Toxicity Characteristic Leachate Procedure (TCLP) mercury concentrations were less than 0.2 μg/L before and after treatment.[78] (The totals results demonstrate that mercury volatilization occurs.)

6. Adsorption

Activated carbon or other adsorbents (e.g., treated peanut hulls, xanthate starch, forager sponge) are used to adsorb mercury from aqueous wastes. Granular activated carbon (GAC) is, by far, the most commonly used adsorbent. Fixed or moving bed reactors are utilized; units are typically organized in series, although they may be in parallel or a single unit may be used in a batch mode. When the carbon's capability to achieve required effluent concentration is exceeded (breakthrough), the carbon is backwashed or replaced, depending on the design. Powdered activated carbon (PAC) can be added to aqueous wastes in a reactor where it is mixed for a specified period of time, allowed to settle, and the mercury-loaded carbon discarded. Ethylene diamine triacetic acid (EDTA) can be added to improve removal efficiency. Pretreatment of certain wastes with carbon disulfide can also improve mercury removal. Adjustment of pH is frequently required to maximize removal efficiency.[79]

Mercury present in aqueous wastes can be effectively removed with carbon, especially

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76 Ibid.

77 U.S. EPA, Engineering Bulletin: In Situ Vitrification Treatment, EPA/540/S-94/504, October 1994; and U.S. EPA, SITE Technology Capsule: Geosafe Corporation In Situ Vitrification Technology, EPA/540/R-94/520a, November 1994.

78 U.S. EPA, SITE Technology Capsule: Geosafe Corporation In Situ Vitrification Technology, EPA/540/R-94/520a, November 1994.

79 U.S. EPA, Capsule Report: Aqueous Mercury Treatment, EPA/625/R-97/004, July 1997; and U.S. EPA, Engineering Bulletin: Granular Activated Carbon, EPA/540/2-91/024, October 1991.

granular activated carbon (GAC). Different brands of activated carbon display different performance over a range of pH values. Care must be taken to select the type or brand compatible with the target pH for the treatment process. High levels of suspended solids can block adsorption sites, leading to premature breakthrough and/or reduced removal efficiencies.[80]

Removals of greater than 99.9 percent have been reported with final effluent concentrations of less than 1 μg/L. Additional data are believed to be available from a SITE demonstration of forager sponge.[81]

7. Ion-Exchange

At least one mercury retorting facility uses ion exchange as a way of concentrating mercury in corrosive solution. Ion exchange processes are generally operated as packed columns that operate in batch mode. Aqueous waste passes through columns filled with an ion exchange resin. Ions in the resin are exchanged for mercury ions of similar charge. When effluent concentrations increase to a predetermined level, the influent pipe is closed and the system is backwashed. Backwashing consists of a slow countercurrent flow designed to expand and suspend the resin bed (in water) to remove fine materials that may be clogging the packed bed. The resin is then regenerated with a concentrated solution of the original exchange ion. Finally, the resin bed is rinsed before being placed back in operation.[82] In the case of mercury retort, backflushing may not be conducted because it may be easier to treat the resulting solid by retort, even though the resin is used only once.

Ion exchange is relatively insensitive to variability, can achieve essentially a zero discharge level, and can be highly selective for the contaminant of concern (if the proper resin is selected). Ion exchange is generally not appropriate for wastes with high total solids content.[83]

For drinking water, ion exchange yielded effluent concentrations of less than 1 μg/L. A full-scale ion exchange process consistently removed mercury from levels of 0.2 to 70 mg/L down to levels of 1 to 5 μg/L.[84]

E. Comparison of Air Releases to Other Mercury Producers

When the production of mercury occurs, in many of the different processes used, there is typically some mercury lost to the atmosphere. By comparing the emissions for three different methods of production (the mining of mercury ore, the production of mercury as a byproduct of gold mining, and the recycling of used mercury from other sources), the affect that each process has on the environment can be examined more closely. Comparing each producer's level of mercury emissions proved to be more difficult than previously anticipated, due to the lack of data available. Also, while there is data available for the amount of mercury produced at the six gold

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80 U.S. EPA, Capsule Report: Aqueous Mercury Treatment, EPA/625/R-97/004, July 1997; and U.S. EPA, Engineering Bulletin: Granular Activated Carbon, EPA/540/2-91/024, October 1991.

81 U.S. EPA, Capsule Report: Aqueous Mercury Treatment, EPA/625/R-97/004, July 1997.

82 U.S. EPA, Arsenic & Mercury: Workshop on Removal, Recovery, Treatment, and Disposal - Abstract Proceedings, Alexandria Virginia, EPA/600/R-92/105, August 1992; and U.S. EPA, Capsule Report: Aqueous Mercury Treatment, EPA/625/R-97/004, July 1997.

83 U.S. EPA, Capsule Report: Aqueous Mercury Treatment, EPA/625/R-97/004, July 1997.

84 Ibid.

mines which produced mercury as a byproduct, there was no emissions data for these mines. Lastly, while there was data for mercury retorters (secondary producers), even these data were not particularly solid. By manipulating the available data mercury, emissions for retorters was estimated to be about 0.0013 tons emitted for every ton produced (2.6 lb per ton).

1. Emissions from the Mining of Mercury Ore

Primary mercury production (i.e., the mining of mercury ore) was last practiced in the U.S. in 1990. This was when the last mercury ore mine, the McDermitt Mine in McDermitt, Nevada, dismantled its operation. This was due to a lack of economic viability in mercury production, as the value of mercury fell below 200 dollars. The last available data concerning the emissions of a primary mercury producer come from a report published in 1973, which put the total emissions at 0.342 lb. per ton of mercury produced (0.000171 tons per ton produced). These emissions are determined by stack gas temperature, which is equivalent to mercury saturated air at the given temperature. The cooling stack is the major emission source from a mercury ore processing operation.

2. Emissions from the Mining of Gold Ore

Metallic mercury is produced as a byproduct in gold mines, although this is only done at six mines in the United States. These six mines are the Alligator Ridge Mine (White Pines, NV), the Getchell Mine (Humboldt, NV), the Carlin Mines Complex (Eureka, NV), the McLaughlin Mine (Napa, CA), the Mercury Mine (Tooele, UT), and the Pinson Mine (Humboldt, NV).[85] Mercury emissions to the atmosphere can occur at these mines when furnaces or other high temperature sources are used, or when mercury is removed from the launders[86]. In 1992, these mines reported a total of 70 tons of mercury produced as a byproduct of gold mining.[87] Unfortunately, there is insufficient data for estimating the quantity of emissions to the atmosphere created by this mercury byproduct.

3. Emissions from the Recycling of Used Mercury

Only two retorters (Mercury Refining Company, Inc. and Bethlehem Apparatus Company, Inc.) reported their plant's emissions, and this data was from 1994. Another recycler, D. F. Goldsmith Chemical and Metals Corporation, does not extract the mercury themselves; therefore, they claim they have no mercury emissions from their process, and reported no data on atmospheric emissions. This raises an important issue, as some secondary producers claim to not

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85 Mercury Study Report to Congress, Volume II, December 1997, p. 4-70. This information is also supported by the Application of Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes Regulatory Impact Analysis (April 15, 1997). In this document, on page B-4, there is a chart listing the gold mines which produce mercury as a byproduct, which corroborates the information found in the Mercury Study Report to Congress.

86 Launders is the name for the containers used to collect and condense the gas stream under water to recover mercury.

87 Mercury Study Report to Congress, Volume II, December 1997, p. 4-68.

emit mercury to the atmosphere when they recycle. This variability between retorters is hard to account for. In order to approximate total mercury emissions, the federal government assigned the average of the two plants which had reported data to the other recycling plants, for which data was not available. This led to an estimated total of 0.6 tons of mercury emissions in 1994, as reported in the Mercury Study Report to Congress.[88] By combining 1994 total emission data with 1996 total production information, it is possible to arrive at a number for the amount of mercury lost to the atmosphere per ton produced, but this data can not be considered exact. This manipulated data shows us that mercury retorters release approximately 0.0013 tons of mercury into the atmosphere per ton of mercury produced (2.6 lb per ton). While this data is useful for the purposes of this task, it must be used cautiously because of the manner in which it was derived. Also, a report concerning the chlor-alkali industry described the roasting procedure (also, an RMERC process) they used to recovery mercury. Throughout the duration of this project, 467 pounds of mercury were recovered (66.2% of the total input stream) while mercury emissions to the atmosphere were less than 0.003 lb/hr. This meant that less than 0.006% of the mercury fed to the furnace was being emitted to the atmosphere.[89]

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[88] Ibid., p. 4-48 and 4-49.

[89] U. S. EPA, Arsenic & Mercury Workshop; Abstract Proceedings, August 17-20, 1992, pg. 101.

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