BACKGROUND REPORT

AP-42 SECTION 12.18

LEAD-BEARING ORE CRUSHING AND GRINDING

Prepared for

U.S. Environmental Protection Agency
OAQPS/TSD/EIB
Research Triangle Park, NC 27711

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1.0 INTRODUCTION

The document "Compilation of Air Pollutant Emission Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (the EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by the EPA to respond to new emission factor needs of the EPA, state and local air pollution control programs and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of area-wide emissions;
2. Emission estimates for a specific facility; and
3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from process information obtained from industry comment No test reports to support revision of emission factors were obtained because few tests exist.

Including the introduction (Chapter 1), this report contains four chapters. Chapter 2 gives a description of the lead-bearing ore crushing and grinding industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from lead-bearing ore crushing and grinding.

Chapter 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Chapter 4 details criteria and noncriteria pollutant emission factor development. It includes the review of specific data sets and the results of data analysis. Particle size determination and particle size data analysis methodology are described when applicable.

2.0 INDUSTRY DESCRIPTION

2.1 GENERAL

Lead-bearing ore is mined from underground or open pit mines. After extraction, the ore is processed by crushing, screening and milling. Domestic lead mine production for 1991 totaled 480,000 megagrams (530,000 tons) of lead in ore concentrates, a decrease of some 15,000 megagrams (16,500 tons) from 1990 production.

Except for mines in Missouri, lead ore is closely interrelated with zinc and silver. Lead ores from Missouri mines are primarily associated with zinc and copper. Average grades of metal from Missouri mines have been reported as high as 7.2 percent lead, 1 percent zinc, and 0.6 percent copper. Due to ore body formations, lead and zinc ores are normally deep mined (underground), whereas copper ores are mined in open pits. Lead, zinc, copper, and silver are usually found together (in varying percentages) in combination with sulfur and/or oxygen.

2.2 PROCESS DESCRIPTION

In underground mines the ore is disintegrated by percussive drilling machines, processed through a primary crusher, and then conveyed to the surface. In open pit mines ore is loosened and pulverized by explosives, scooped up by mechanical equipment, and transported to the concentrator. A trend toward increased mechanical excavation as a substitute for standard cyclic mine development, such as drill-and-blast and surface shovel-and-truck routines, has surfaced as an element common to most metal mine cost-lowering techniques.

Standard crushers, screens, and rod and ball mills classify and reduce the ore to powders in the 65 to 325 mesh range. The finely divided particles are separated from the gangue and are concentrated in a liquid medium by gravity and/or selective flotation, then cleaned, thickened and filtered. The concentrate is dried prior to shipment to the smelter.

2.3 EMISSIONS AND CONTROLS

Lead emissions from lead ore crushing and grinding processes are largely fugitive and are caused by drilling, loading, conveying, screening, unloading, crushing, and grinding. The primary means of control are good mining techniques and equipment maintenance. These practices include enclosing the truck loading operation, wetting or covering truck loads and stored concentrates, paving the road from mine to concentrator, sprinkling the unloading area, and preventing leaks in the crushing and grinding enclosures. Cyclones and fabric filters can be used in the milling operations.

Particulate and lead emission factors for lead ore crushing and materials handling operations are given in Table 12.18-1 and 12.18-2. Additionally, the VOC/PM Speciation Database (SPECIATE) indicates that several Clean Air Act Amendments (CAA) Title III hazardous air pollutants (HAPs) are associated with crushing and grinding lead ores. These include chromium, manganese, nickel, arsenic, selenium, cadmium, antimony, and mercury, as well as lead in process emissions.

TABLE 2.3-1 (METRIC UNITS)
EMISSION FACTORS FOR LEAD ORE CRUSHING AND GRINDING[a]
All Emission Factors in kg/Mg Feed Processed
Ratings (A-E) Follow Each Factor

Type of ore and lead content (wt%)		Particulate Emission Factor		Lead Emission Factor	
Lead[b]	5.1	0.0195	E	0.001	E
Zinc[c]	0.2	0.0195	E	0.00004	E
Copper[d]	0.2	0.0195	E	0.00004	E
Lead-Zinc[e]	2.0	0.0195	E	0.0004	E
Copper-Lead[f]	2.0	0.0195	E	0.0004	E
Copper-Zinc[g]	0.2	0.0195	E	0.00004	E
Copper-Lead-Zinc[g]	2.0	0.0195	E	0.0004	E

[a] Reference 1. Units are expressed as kg of pollutant/Mg ore processed. SCC = Source Classification Code. PM Emissions Factors are from uncontrolled fines crushing in AP-42 Section 11.19.2. Lead Emissions Factors are the product of the PM Emissions Factors and the wt% lead content of the ore.
[b] Characteristic of some mines in Colorado.
[c] Characteristic of some mines in Alaska, Idaho, and New York.
[d] Characteristic of Arizona mines.
[e] Characteristic of some mines in Missouri, Idaho, Colorado, and Montana.
[f] Characteristic of some mines in Missouri.
[g] Does not appear in ore characterization of the top 25 domestic lead producing mines.

TABLE 2.3-1 (ENGLISH UNITS)
EMISSION FACTORS FOR LEAD ORE CRUSHING AND GRINDING[a]
All Emission Factors in kg/Mg Feed Processed
Ratings (A-E) Follow Each Factor

Type of ore and lead content (wt%)		Particulate Emission Factor		Lead Emission Factor	
Lead[b]	5.1	0.030	E	0.002	E
Zinc[c]	0.2	0.030	E	0.00008	E
Copper[d]	0.2	0.030	E	0.00008	E
Lead-Zinc[e]	2.0	0.030	E	0.0008	E
Copper-Lead[f]	2.0	0.030	E	0.0008	E
Copper-Zinc[g]	0.2	0.030	E	0.00008	E
Copper-Lead-Zinc[g]	2.0	0.030	E	0.0008	E

[a] Reference 1. Units are expressed as lb of pollutant/ton ore processed. SCC = Source Classification Code. PM Emissions Factors are from uncontrolled fines crushing in AP-42 Section 11.19.2. Lead Emissions Factors are the product of the PM Emissions Factors and the wt% lead content of the ore.
Note: The PM factor was corrected from 0.039 to 0.030. The correction was editorial. Note a was corrected to read lb/ton from kg/Mg. No changes were made to the metric table. October 2010 - Ron Myers, EPA.
[b] Characteristic of some mines in Colorado.
[c] Characteristic of some mines in Alaska, Idaho, and New York.
[d] Characteristic of Arizona mines.
[e] Characteristic of some mines in Missouri, Idaho, Colorado, and Montana.
[f] Characteristic of some mines in Missouri.
[g] Does not appear in ore characterization of the top 25 domestic lead producing mines.

2.4 REVIEW OF SPECIFIC DATA SETS

Pacific Environmental Services (PES) contacted the following sources to obtain the most up-to-date information on process descriptions and emissions for this industry:

1) ASARCO Inc. Denver, Colorado.
2) Cominco American, Inc. Ironton, Missouri.
3) Doe Run Company Ironton, Missouri.
4) Green Creek Mine, Admiralty Island, Alaska.
5) New Butte Mining Company, Silver Bow, Montana.

No responses other than telephone conversations with ASARCO Inc., and Cominco American Inc., were received from any of these companies.

A telephone conversation between PES and ASARCO, Inc. (Reference 8) revealed that their company does not have emission test results for crushing or grinding operations on file, simply because they are not required by permitting authorities. Emission tests are performed only when required for quality control. The emissions are generally calculated using material balance methods. They utilize wet scrubbers and dry cyclones to control dust emissions. The information obtained from this company was not used in the update because they had no raw data on their emissions.

A telephone conversation between PES and Cominco American Inc. (Reference 9) related information similar to that which was obtained from ASARCO, Inc. Cominco uses a wet grinding process, resulting in a slurry from which there are essentially no dust emissions. All of the mining, crushing, and grinding takes place underground. Any tests that would be performed would only be for quality control measures. However, for Cominco, this is very unlikely since they do not have an air permit and have no specific requirements with which to comply. For any possible emission controls, they utilize scrubbers. This company did not have any source tests. The information from this company was not used in the update since no raw data on emissions existed for the lead-bearing ore crushing and grinding process.

2.5 REFERENCES FOR CHAPTER 2

1. Control Techniques for Lead Air Emissions. EPA-450/2-77-012A. U.S. Environmental Protection Agency. Research Triangle Park, NC. December 1977.

2. W.E. Davis. Emissions Study of Industrial Sources of Lead Air Pollutants, 1970. EPA Contract No. 68-02-0271. W.E. Davis and Associates, Leawood, KS. April 1973.

3. B.G. Wixson and J.C. Jennett. The New Lead Belt in the Forested Ozarks of Missouri. *Environmental Science and Technology*. 9(13):1128-1133. December 1975.

4. W.D. Woodbury. "Lead." Minerals Yearbook, Volume 1. Metals and Minerals. U.S. Department of the Interior, Bureau of Mines. 1989.

5. Environmental Assessment of the Domestic Primary Copper, Lead, and Zinc Industry. EPA Contract No. 68-02-1321. PEDCO-Environmental Specialists, Inc. Cincinnati, OH. September 1976.

6. A.O. Tanner. Mining and Quarrying Trends in the Metals and Industrial Minerals Industries. *Minerals Yearbook*. U.S. Department of the Interior, Bureau of Mines. 1989.

7. VOC/PM Speciation Data System. Radian Corporation. EPA Contract No. 68-02-4286. November 1990.

8. Telecon between ASARCO, Inc. Denver, Colorado and E. Bowen of Pacific Environmental Services, Research Triangle Park, NC. September 1992.

9. Telecon between Cominco American, Inc., Ironton, MO, and E. Bowen of Pacific Environmental Services, Research Triangle Park, NC. September 1992.

3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

The first step of this investigation involved a search of available literature relating to criteria and noncriteria pollutant emissions associated with lead-bearing ore crushing and grinding. This search included, but was not limited to, the following references:

AP-42 background files maintained in the Emission Factor and Methodologies Section. There was no information on lead-bearing ore crushing in the background files.

PM_{10} "gap filling documents including: "Generalized Particle Size Distributions for Use in Preparing Size Specific Particulate Emission Inventories" (EPA-450/4-86-013), and "PM_{10} Emission Factor Listing Developed by Technology Transfer"(EPA-450/4-89-002). No new information was found from these two references.

"Gap Filling PM_{10} Emission Factors for Selected Open Area Dust Sources" (EPA-450/4-88-003). This document gave no emission factors for this source category.

AIRS Facility Subsystem Source Classification Coeds and Emission Factor Listing for Criteria Air Pollutants (EPA-450/4-90-0003) This document gave specific emission factors for ore crushing, materials handling, raw material crushing, and grinding that were derived using emission factors found in previous versions of AP-42. No new information was revealed.

EPA databases, including: *Clearinghouse for Inventories and Emission Factors (CHIEF), VOC/Particulate Matter (PM) Speciation Database Management System (SPECIATE), and Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF).* No new information was found in these databases.

To reduce the amount of literature collected to a final group of references pertinent to this report, the following general criteria were used:

1. Emissions data must be from a primary reference; i.e., the document must constitute the original source of test data, including raw source data.
2. The referenced study must contain test results based on more than one test run.
3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

If no primary data (raw data such as source tests) were found and the previous update utilized secondary data (i.e., data obtained by means other than source tests, such as literature, industry surveys, etc.), these secondary data were still used and the emission factor rating lowered, if needed. A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria. The final set of reference materials is given in Chapter 4.

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of Pacific Environmental Services' analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration.

1. Test series averages reported in units that cannot be converted to the selected reporting units;
2. Test series representing incompatible test methods (e.g., comparison of the EPA Method 5 front-half with the EPA Method 5 front- and back-half);
3. Test series of controlled emissions for which the control device is not specified;
4. Test series in which the source process is not clearly identified and described; and
5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Data sets that were not excluded were assigned a quality rating. The rating system used was that specified by the OAQPS for the preparation of AP-42 sections. The data were rated as follows:

A

Multiple tests performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in the EPA reference test methods, although these methods were certainly used as a guide for the methodology actually used.

B

Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C

Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D

Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. <u>Source operation</u>. The manner in which the source was operated is well documented In the report. The source was operating within typical parameters during the test.
2. <u>Sampling procedures</u>. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations

are well documented. When this occurred, an evaluation was made of the extent such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report. Many variations can occur unnoticed and without warning during testing. Such variations can induce wide deviations in sampling results. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and were given a lower rating.
4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by the EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated utilizing the following general criteria:

A (Excellent)

Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B (Above average)

Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

C (Average)

Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

D (Below average)

The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E (Poor)

The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always noted.

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer.

3.4 REFERENCES FOR CHAPTER 3

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections. U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, April 1992. [Note: this document is currently being revised at the time of this printing.]

2. AP-42, Supplement A, Appendix C.2, "Generalized Particle Size Distributions." U.S. Environmental Protection Agency, October 1986.

4.0 POLLUTANT EMISSION FACTOR DEVELOPMENT

4.1 CRITERIA POLLUTANT EMISSIONS DATA

Because no processes involving combustion or other chemical changes are used in lead-bearing ore crushing and grinding operations, no data on emissions of nonmethane organics, nitrogen oxides, carbon monoxide, or sulfur dioxide were found nor expected from this industry.

Lead and particulate emissions are the only emissions to be expected from this process. No new data on particulate emissions and lead emissions were found. Conversations with two different companies (ASARCO, Inc. and Cominco American, Inc.) revealed that source tests on lead-bearing ore crushing and grinding are usually only performed if a problem with fugitive emissions has been identified. Therefore, emission testing is limited to facilities that have been identified as emitting substantial quantities of product. Due to the lack of new data, the emission factors have been transferred directly from Section 12.18 of the previous AP-42 into the revised section.

4.2 NONCRITERIA POLLUTANT EMISSION DATA

Hazardous Air Pollutants.

Hazardous Air Pollutants (HAPs) are defined in Title III of the 1990 Clean Air Act (CAA) Amendments. The VOC/PM Speciation Database (SPECIATE) indicates that the following CAA Title III HAPs are associated with crushing and grinding of lead ores: chromium, manganese, nickel, arsenic, selenium, cadmium, antimony, and mercury, as well as lead in process emissions. No data on emissions of any of these pollutants were found for the lead-bearing ore crushing and grinding processes.

Global Warming Gases.

Pollutants such as methane (CH_4), carbon dioxide ($C0_2$), and nitrous oxide (N_2O) have been found to contribute to overall global warming. No data on emissions of these pollutants were found for the lead-bearing ore crushing and grinding process.

Stratospheric Ozone-Depleting Gases.

Chlorofluorocarbons have been found to contribute to ozone depletion. No data on emissions of these pollutants were found for the lead-bearing ore crushing and grinding process.

4.3 REVIEW OF SPECIFIC DATA SETS

None of the emission factors presented in the previous version of AP-42 section 12.18 could be verified. For this reason, along with the fact that no new data could be obtained, the emission factors were not changed. Since PES could not review most of the old references, a determination on whether to downgrade the emission factors cannot be made at this time. Therefore, the emission factor rating of "B" has been retained.

References 1, 2, 3, and 5

These references are the basis for the emission factors presented in the previous version of AP-42 section 12.18. PES could not obtain a copy of Reference 1 (Control Techniques for Lead Air Emissions. EPA-450/2-77-012A) from the EPA library; this particular document could not be located. Reference 2 could not be found in the file and also could not be located by the EPA library. PES was able to locate and review Reference 3. Reference 3 is an article on environmental information on the lead industry, and does not contain any emission information for this process. It could not be used to verify the emission factors in the previous version of AP-42 section 12.18. Reference 5 could not be located in the background file or otherwise obtained.

In 2007, a copy of Reference 1 was located in the EPA Region VII library was scanned and posted to http://www.epa.gov/ttn/chief/old/ap42/ch12/s06/reference/ref14_c12s06_1995.pdf . This document provides no detailed information on the derivation or selection of the PM or Lead emissions factors that were originally in the section. The range of lead emissions factors in this original section are reflected in Table 2-8 of this document.

An examination of the particulate matter emissions factors (6 #/ton)used for lead,zinc, and lead zinc presented in this section previously are identical to the uncontrolled total particulate matter emissions factors for tertiary crushing and screening available in the 1975 version of Stone Quarrying and processing. It is likely that the emissions factors for Reference 1 and for this section were extracted from this AP-42 section. It is unclear why the slightly larger (6.4 #/ton) particulate matter emissions factors for copper, copper-lead, copper-zinc and copper-lead-zinc were used. In 1985, the emissions factors for crushed stone processing were revised to a somewhat lower value (1.85 #/ton) based upon data that ranged from 0.0016 to 2.76 #/ton. In 2004 an emissions factor for fines crushing was added to the factors for crushed stone processing. The uncontrolled emissions factor for fines crushing was selected as the most appropriate for uncontrolled leadbearing ore crushing since the tertiary crushing at crushed stone plants produces material between 3/16 inch and 1 inch. The process used for leadbearing ore crushing appears to produce smaller material.

References 4 and 6

References 4 and 6 are both articles in a widely available non-technical reference document. They contain general information concerning the lead industry. No emission information was contained in either of the articles.

Reference 7

The VOC/PM Speciation Database (SPECIATE) indicated that the following CAA Title III HAPs are associated with the crushing and grinding of lead ores. These include chromium, manganese, nickel, arsenic, selenium, cadmium, antimony, and mercury, as well as lead in process emissions. However, no new information on this process could be obtained using this database.

4.4 DATA GAP ANALYSIS

According to the companies that were contacted, very few source tests exist for this industry. The companies contacted also indicated that it is difficult to quantify such fugitive emissions due to the nature of this process. Source tests are only performed for quality control measures. The best way to control emissions from this process is to use good mining techniques and equipment maintenance. Having the process enclosed with wet sprayers can aid in the control of fugitive emissions. Cyclones and fabric filters can also be used in the milling operations.

Most of the information on lead-bearing ore crushing and grinding processes is general in nature and generally pertains to the production of lead, and not specifically to crushing and grinding. It is the position of several members of the industry that emission testing is not practical or necessary, due to the fugitive nature of the emissions. Another option to control emissions could be to enclose the entire operation. This alternative, in most if not all cases, would appear to be economically unfeasible.

4.5 REFERENCES FOR CHAPTER 4

1. Control Techniques for Lead Air Emissions. EPA-450/2-77-012A. U.S. Environmental Protection Agency. Research Triangle Park, NC. December 1977.

2. W.E. Davis. Emissions Study of Industrial Sources of Lead Air Pollutants, 1970. EPA Contract No. 68-02-0271. W.E. Davis and Associates, Leawood, KS. April 1973.

3. B.G. Wixson and J.C. Jennett. The New Lead Belt in the Forested Ozarks of Missouri. *Environmental Science and Technology*. 9(13):1128-1133. December 1975.

4. W.D. Woodbury. "Lead." Minerals Yearbook, Volume 1. Metals and Minerals. U.S. Department of the Interior, Bureau of Mines. 1989.

5. Environmental Assessment of the Domestic Primary Copper, Lead, and Zinc Industry. EPA Contract No. 68-02-1321. PEDCO-Environmental Specialists, Inc. Cincinnati, OH. September 1976.

6. A.O. Tanner. Mining and Quarrying Trends in the Metals and Industrial Minerals Industries. *Minerals Yearbook*. U.S. Department of the Interior, Bureau of Mines. 1989.

7. VOC/PM Speciation Data System. Radian Corporation. EPA Contract No. 68-02-4286. November 1990.

TABLE 4.5-1

LIST OF CONVERSION FACTORS

Multiply:	**by:**	**To obtain:**
mg/dscm	4.37×10^{-4}	gr/dscf
m^2	10.764	ft^2
M^3	35.31	ft^3
m	3.281	ft
kg	2.205	lb
kPa	1.45×10^{-1}	psia
kg/Mg	2.0	lb/ton
Mg	1.1023	ton

Temperature conversion equations:

Fahrenheit to Celsius:

$$°C = \frac{(°F - 32)}{1.8}$$

Celsius to Fahrenheit:

$$°F = 1.8(°C) + 32$$