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Review and Update of Mineral Products Industry and Metallurgical Sections of Chapters 11 and 12 of AP-42
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INTRODUCTION

This memorandum presents the background information that was used to develop the proposed AP-42 Section 11.28 on vermiculite processing. A description of the industry is presented first. A process description followed by a discussion of emissions and controls is then presented. Following these sections, a description of the references that were used to develop the draft section and the results of the data analysis are presented. Finally, the reference list is provided. The draft AP-42 section is provided as the attachment.

1. DESCRIPTION OF THE INDUSTRY[1-5]

Vermiculite is the geological name given to a group of hydrated laminar minerals that are aluminum-iron-magnesium silicates and that resemble mica in appearance. The chemical formula for vermiculite is:

$$(Mg,Ca,K,Fe^{+2})_3\ (Si,Al,Fe^{+3})\ _4O_{10}(OH)_2{\cdot}4H_2O.$$

When subjected to heat, vermiculite has the unusual property of exfoliating, or expanding, due to the interlaminar generation of steam. The Standard Industrial Classification (SIC) code for vermiculite mining is 1499, miscellaneous nonmetallic minerals, except fuels. For vermiculite processing, the SIC Code is 3295, minerals and earths, ground or otherwise treated. The six-digit Source Classification Code (SCC) for vermiculite processing is 3-05-033.

The world's largest deposit of vermiculite, which is located near Libby, Montana, is no longer in operation. Other major vermiculite deposits are located near Enoree, South Carolina, and in the Republic of South Africa. Vermiculite is also mined and beneficiated at a mine in Louisa County, Virginia. Deposits of economic significance contain 25 to 95 percent vermiculite.

Estimated world production of crude vermiculite in 1991 was 523,000 megagrams (Mg) (576,000 tons), more than 80 percent of which came from five mines. The United States and Republic of South Africa account for most of the world production. Estimated U.S. production of crude vermiculite sold or used by producers in 1991 was 168,000 Mg (185,000 tons), of which approximately 136,000 Mg (150,000 tons) were exfoliated.

Vermiculite ore is mined using open-pit methods. Beneficiation includes screening, flotation, drying in rotary or fluidized bed dryers, and expansion by exposure to high heat. All mined vermiculite is dried and sized at the mine site prior to exfoliation. Uses of unexpanded vermiculite include muds for oil-well drilling and fillers in fire-resistant wallboard.

Vermiculite is commercially exfoliated by heating the presized crude vermiculite in a furnace chamber. The bulk volume of commercial grades increases 8- to 12-fold, but individual vermiculite particles may expand as much as 30-fold compared to the raw ore. The bulk density of exfoliated vermiculite ranges from 64 to 160 kilograms per cubic meter (kg/m^3) (4 to 10 pounds per cubic foot [lb/ft^3]). The chemical constituents of a typical sample of vermiculite are summarized in Table 1.

TABLE 1. CHEMICAL CONSTITUENTS OF VERMICULITE[a]

Compound	Weight percent
SiO_2	38 to 46
Al_2O_3	10 to 16
MgO	16 to 35
CaO	1 to 5
K_2O	1 to 6
Fe_2O_3	6 to 13
TiO_2	1 to 3
H_2O	8 to 16
Other[b]	0.2 to 1.2

[a]References 4-5.

Exfoliated vermiculite was produced at 35 plants in 27 States in 1989. The principal producing States were, in order of decreasing exfoliated vermiculite output, Ohio, California, South Carolina, Florida, New Jersey, Illinois, Texas, and Arkansas. The main uses of exfoliated vermiculite in 1990 were fertilizer carriers (22 percent), concrete aggregate (19 percent), horticultural uses (13 percent), premixes

(12 percent), block insulation (12 percent), loose fill insulation (9 percent), soil conditioners (5 percent), and plaster aggregates (1 percent).

2. PROCESS DESCRIPTION[1,3-8,11-13]

a. Crude Ore Processing

is a process flow diagram for vermiculite processing. Crude ore from open-pit mines is brought to the mill by truck and loaded onto outdoor stockpiles. Primary processing consists of screening the raw material to remove the waste rock greater than 1.6 centimeters (cm) (5/8 inch [in.]) and returning the raw ore to other stockpiles. Blending is accomplished as material is removed from stockpiles and conveyed to the mill feed bin. The blended ore is fed to the mill, where it is separated into fractions by wet screening and concentrated by gravity. All concentrates are collected, dewatered, and dried in a fluidized bed or rotary dryer. Drying reduces the moisture content of the vermiculite concentrate from approximately 15 to 20 percent to approximately 2 to 6 percent. At least one facility uses a hammermill to crush the material exiting the dryer. However, at most facilities, the dryer products are transported by bucket elevators to vibrating screens, where the material is classified. The dryer exhaust generally is ducted to a cyclone for recovering the finer grades of vermiculite concentrate. The classified concentrate then is stored in bins or silos for later shipment or exfoliation.

The rotary dryer is the most common dryer type used in the industry, although fluidized bed dryers also are used. Drying temperatures range from 120° to 480°C (250° to 900°F), and fuel oil is the most commonly used fuel. Natural gas and propane also are used to fuel dryers.

b. Exfoliation

After being transported to the exfoliation plant, the vermiculite concentrate is stored. The concentrate then is conveyed by bucket elevator or other means and dropped continuously through a gas- or oil-fired vertical furnace. Exfoliation occurs after a residence time of less than 8 seconds in the furnace, and immediate removal of the expanded material from the furnace prevents damage to the structure of the vermiculite particle. Flame temperatures of more than 540°C (1000°F) are used for exfoliation. Proper exfoliation requires a high rate of heat transfer and rapid generation of steam within the vermiculite particles. The expanded product falls through the furnace and is air-conveyed to a classifier system, which collects the vermiculite product and removes excessive fines. The furnace exhaust generally is ducted through a product recovery cyclone, followed by an emission control device. At some facilities, the exfoliated material is ground in a pulverizer prior to being classified. Finally, the material is packaged and stored for shipment.

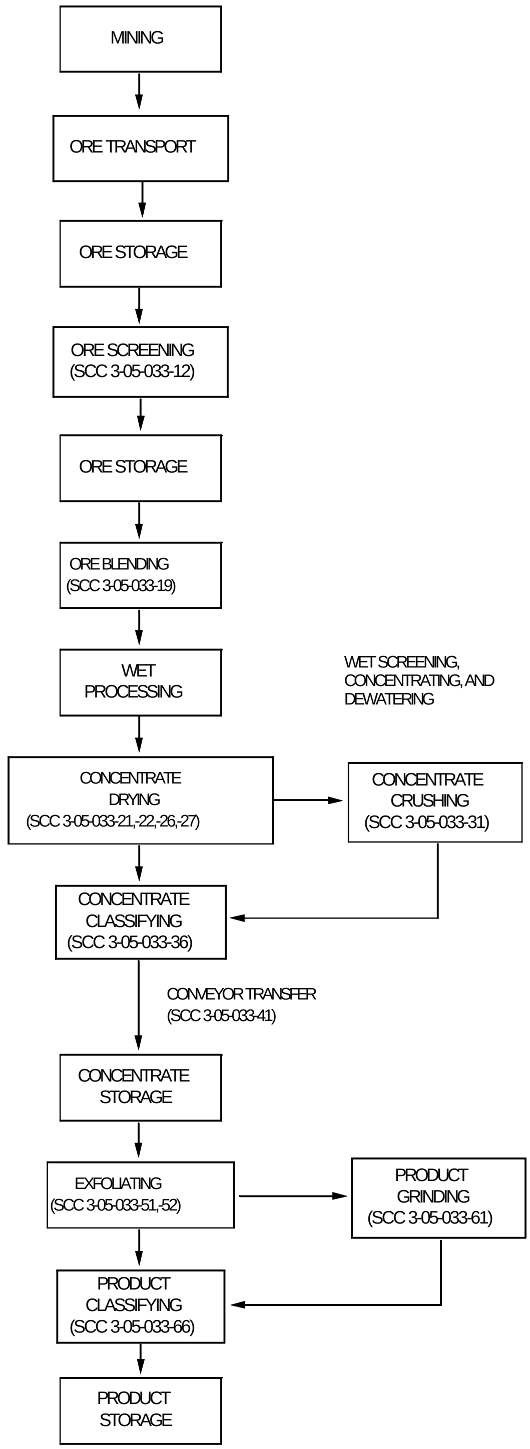

Figure 1. Flow diagram for vermiculite processing.
(Source Classification Codes in parentheses.)

3. EMISSIONS AND CONTROLS[1,6-9,11-13]

The primary pollutants of concern in vermiculite processing are particulate matter (PM) and PM less than 10 micrometers
ndling and transfer
operations. In addition, vermiculite ore may contain asbestos. However, other than vermiculite mined from the Libby, Montana, deposit, which is no longer in operation, the amount of asbestos found in vermiculite deposits is considered to be negligible. Emissions from rotary dryers and expansion furnaces include products of combustion, such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur oxides (SO_x), in addition to filterable and condensible PM and PM-10.

Wet scrubbers are used to control dryer emissions. The majority of expansion furnaces are ducted to fabric filters for emission control. However, wet scrubbers also are used to control the furnace emissions. Cyclones and fabric filters also are used to control emissions from screening, milling, and materials handling and transfer operations.

4. DESCRIPTION OF REFERENCES

This section describes the primary references that contained data on emissions from vermiculite processing that were used to develop the draft AP-42 section. Reference 1 is not described because it is a secondary reference, and the vermiculite processing emission data in Reference 1 are taken from Reference 6, which is the primary reference for the data. References 2 to 8 and 10 also are not described because they do not contain emission data. However, References 5 and 14 contain the process operating rates for the emission tests documented in Reference 12 and 13.

a. <u>Reference 9</u>

This report documents measurements of filterable PM and CO_2 from an oil-fired rotary dryer. The purpose of the emission test was to demonstrate compliance with State regulations. The test was conducted in 1979. Process rates were provided on the basis of raw material feed. The dryer emissions are controlled with a low-energy spray tower with a design pressure drop of 1.2 kilopascals (5-in. water column).

Particulate matter emissions were measured during three Method 5 test runs. The method used to measure CO_2 concentrations in the exhaust was not specified in the report. Emission factors were developed for filterable PM and CO_2.

The emission data for filterable PM are rated B. The test methodology was sound, and no problems were reported, but the report lacked adequate documentation for a higher rating. The CO_2 data are rated C because the test method was not specified.

B. <u>Reference 11</u>

This report documents measurements of filterable PM emissions from an exfoliated vermiculite grinder. Emissions from the grinder were controlled with a fabric filter. The test was conducted in August 1989 to demonstrate compliance with State regulations.

Filterable PM emissions were measured using Method 5, and three test runs were conducted. Emission factors were developed for emissions of filterable PM from the grinder. The emission data are rated A. The test methodology was sound, no problems were reported, and the results were adequately documented.

C. Reference 12

This report documents measurements of filterable PM emissions from three gas-fired exfoliation furnaces. In addition, condensible organic PM emissions from two of the three exfoliation furnaces were quantified. Emissions from each furnace were ducted to separate fabric filters. Typical process rates for the furnaces tested were provided in Reference 5 on the basis of exfoliated vermiculite production. The tests were conducted in April 1990 to demonstrate compliance with State regulations.

Emissions of condensible organic PM were quantified in order to evaluate how well two of the three furnaces combusted the residual oil that was used in the process of beneficiating the vermiculite ore. There was no evidence that the third furnace, which was a newer piece of equipment, was emitting uncombusted oil, and the stack for that furnace was not tested for condensible PM.

Filterable PM emissions were measured using Method 5. The report states that condensible organic PM emissions were quantified by means of a methylene chloride extraction of the Method 5 impinger contents, but no other details are provided on the analytical procedures. Three test runs were conducted.

Emission factors were developed for emissions of filterable PM from all three furnaces and condensible organic PM from two of the three furnaces. The emission data are rated B. The test methodology was sound, and no problems were reported. However, the report lacked adequate documentation for a higher rating.

D. Reference 13

This report documents measurements of filterable PM emissions from a natural gas-fired rotary dryer, a screening operation, and a concentrate conveyor transfer operation. Emissions from the dryer were ducted to a wet scrubber and cyclones were used to control emissions from the screening and conveyor transfer operations. Process rates for the dryer were provided on the basis of production. However, using the moisture contents of the dryer feed and product, feed rates were determined. The tests were conducted in August 1991 to demonstrate compliance with State regulations.

Filterable PM emissions were measured using Method 5, and three test runs were conducted. Emission factors were developed for emissions of filterable PM from all four sources. The emission data are rated B. The test methodology was sound, and no problems were reported. However, the report lacked adequate documentation for a higher rating.

TABLE 2. SUMMARY OF TEST DATA FOR VERMICULITE PROCESSING.

Source	APCD	Pollutant	No. of runs	Data rating	Emission factor						Ref. No.
					kg/Mg			lb/ton			
					Min.	Max.	Ave.	Min.	Max.	Ave.	
Rotary dryer	ST	Filterable PM	3	B	0.078	0.11	0.095	0.16	0.22	0.19	9
Rotary dryer	ST	CO_2	3	C	45	62	50	91	130	100	9
Product grinder	FF	Filterable PM	3	A	0.17	0.19	0.18	0.35	0.37	0.36	11
Exfoliation furnace	FF	Filterable PM	3	B	0.31	0.55	0.45	0.63	1.1	0.89	12
Exfoliation furnace	FF	Cond. org. PM	3	B	0.10	0.17	0.12	0.19	0.35	0.25	12
Exfoliation furnace	FF	Filterable PM	3	B	0.10	0.83	0.38	0.20	1.7	0.75	12
Exfoliation furnace	FF	Cond. org. PM	3	B	0.15	0.36	0.24	0.30	0.72	0.48	12
Exfoliation furnace	FF	Filterable PM	3	B	0.11	0.14	0.12	0.21	0.28	0.24	12
Rotary dryer	WS	Filterable PM	3	B	0.39	0.56	0.48	0.78	1.1	0.95	13
Screening operation	C	Filterable PM	3	B	0.26	0.36	0.30	0.52	0.72	0.61	13
Concentrate transfer	C	Filterable PM	3	B	0.0085	0.018	0.013	0.017	0.035	0.025	13

APCD = air pollution control device; ST = spray tower; WS = wet scrubber; FF = fabric filter; C = cyclone.

VI.RESULTS OF DATA ANALYSIS

Table 2 summarizes the emission data from the four test reports reviewed. These data were used to develop the candidate emission factors, which are listed in Table 3, for AP-42 Section 11.28. The following paragraphs describe how the data in Table 2 were used to develop the emission factors presented in the draft AP-42 section. The ratings assigned to each emission factor are based on the guidance provided in Reference 15.

TABLE 3. SUMMARY OF EMISSION FACTORS FOR VERMICULITE PROCESSING.

Source	Control	Pollutant	No. of tests	Emission factor			References
				kg/Mg	lb/ton	Rating	
Ore drying	Wet collector	Filterable PM	2	0.29	0.57	D	9,13
Ore drying	None	CO_2	1	50	100	E	9
Concentrate screening	Cyclone	Filterable PM	1	0.30	0.61	D	13
Concentrate conveyor transfer	Cyclone	Filterable PM	1	0.013	0.025	D	13
Exfoliating	Fabric filter	Filterable PM	3	0.32	0.63	D	12
Exfoliating	Fabric filter	Cond. org. PM	2	0.18	0.37	D	12
Product grinding	Fabric filter	Filterable PM	1	0.18	0.37	D	11

For vermiculite ore rotary dryers, filterable PM data were available from two B-rated emission tests. The data from Reference 9 for a spray tower-controlled dryer averaged 0.095 kilograms per megagram (kg/Mg) (0.19 pounds per ton [lb/ton]), and the data from Reference 13 for a dryer controlled with a wet scrubber averaged 0.48 kg/Mg (0.95 lb/ton). The test reports do not include adequate information on the dryers and control devices to help explain the difference between the two emission rates. Therefore, the data for both tests were averaged to yield an average emission factor of 0.29 kg/Mg (0.57 lb/ton) of ore feed for filterable PM emissions from vermiculite ore drying controlled with a generic wet collector. This emission factor is rated D because it is based on B-rated data from tests on a relatively small number of sources, and it is likely that the facilities do not represent a random sample of the industry.

For CO_2 emissions from vermiculite dryers, C-rated data from a single emission test were available. Although the dryer exhaust was equipped with a spray tower, the emission factor is considered to represent uncontrolled emissions because spray towers are assumed to have negligible effects on CO_2 emissions. Because it is based entirely on C-rated data, this emission factor (50 kg/mg [100 lb/ton] of ore feed) is rated E.

For dried vermiculite concentrate screening, data were available from one B-rated emission test (Reference 13) on screening operations controlled with a cyclone. The results of the test averaged 0.30 kg/Mg (0.61 lb/ton) for filterable PM emissions from dried vermiculite concentrate screening controlled with a cyclone. This emission factor is rated D because it is based on B-rated data from one test.

For dried vermiculite concentrate conveyor transfer, data were available from one B-rated emission test of filterable PM emissions controlled with a cyclone. The emission factor based on these data (0.013 kg/Mg [0.025 lb/ton]) is assigned a rating of D.

For vermiculite exfoliating, B-rated data were available from Reference 12 for fabric filter-controlled filterable PM emissions from three natural gas-fired furnaces and for condensible organic PM emissions from two natural gas-fired furnaces. The results of these tests averaged 0.45 kg/Mg (0.89 lb/ton), 0.38 kg/Mg (0.75 lb/ton), and 0.12 kg/Mg (0.24 lb/ton) of exfoliated vermiculite produced for filterable PM, and 0.12 kg/Mg (0.25 lb/ton) and 0.24 kg/Mg (0.48 lb/ton) of exfoliated vermiculite produced for condensible organic PM. These groups of data were combined to yield average emission factors of 0.32 kg/Mg (0.63 lb/ton) for filterable PM, and 0.18 kg/Mg (0.37 lb/ton) for condensible organic PM. These emission factors also are rated D.

For exfoliated vermiculite grinding, A-rated data were available from one emission test (Reference 11). The emission factor developed from this data, 0.18 kg/Mg (0.37 lb/ton) of ground material produced, is also rated D.

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