AP42 Section:	11.25
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EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 8.32
Clay Processing

1. INTRODUCTION

The document "Compilation of Air Pollutant Emission Factors" (AP-42) has been published by the U. S. Environmental Protection Agency (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 EPA to respond to new emission factor needs of 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 areawide emissions;

2. Estimates of emissions 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 test reports and other information to support preparation of AP-42 Section 8.32, Clay Processing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the clay processing 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 clay processing. Section 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. Section 4 details the development of pollutant emission factors for the draft AP-42 section. It includes the review of specific data sets and the results of data analysis. Section 5 presents the draft AP-42 Section 8.32, Clay Processing.

2. INDUSTRY DESCRIPTION[1,2]

Clay is defined as a natural, earthy, fine-grained material composed largely of a group of crystalline hydrous silicate minerals, known as clay minerals. Clay minerals are composed mainly of silica, alumina, and water, but may also contain appreciable quantities of iron, alkalies, and alkaline earths. Clay is formed by the mechanical and chemical breakdown of rocks. Clays are categorized into six groups by the U.S. Bureau of Mines. The categories are kaolin, ball clay, fire clay, bentonite, fuller's earth, and common clay and shale.

This section addresses emissions that result from the basic processing of clays that takes place between the mining of the raw material and the production of the finished clay product. Emissions from finished clay products are addressed under other AP-42 sections, including Section 8.3, Bricks and Related Clay Products; Section 8.5, Refractory Manufacturing; Section 8.6, Portland Cement Manufacturing, Section 8.7, Ceramic Clay Manufacturing; and Section 8.25, Lightweight Aggregate Manufacturing. Clay sintering, which is no longer practiced in the United States, is addressed in Section 8.9, Clay and Fly Ash Sintering.

The Standard Industrial Classification (SIC) code for mining, milling, and processing kaolin and ball clay is 1455, Kaolin and Ball Clay; the SIC code for mining, milling, and processing fire clay, bentonite, fuller's earth, and common clay and shale is 1459, Clay, Ceramic, and Refractory Materials, Not Elsewhere Classified. There currently are no general Source Classification Codes (SCC's) for clay processing. However, the six-digit SCC for processing the raw material (common clay and shale) used in brick manufacturing is 3-05-003; the six-digit SCC for processing the raw material (generally, fire clay) used in refractory manufacturing is 3-05-005; and the six-digit SCC for processing raw material (generally, ball clay or kaolin) used in ceramic manufacturing is 3-05-008.

2.1 CHARACTERIZATION OF THE INDUSTRY[1-3]

Approximately 44 million megagrams (Mg) of clay were sold or used by domestic producers in 1991. An estimated 319 companies operating more than 1,000 clay pits or mines in 44 States and Puerto Rico reported clay production. Approximately 100 companies, most of which operate more than one plant, accounted for approximately 66 percent of the tonnage and 75 percent of the value for all types of clay produced and sold or used. Common clays and shale accounted for 62 percent of the tonnage, and kaolin accounted for 61 percent of the value of clays produced in 1991. The seven leading clay producing States, in descending order, were Georgia, Wyoming, Texas, Ohio, Alabama, California, North Carolina, Michigan, Missouri, and South Carolina. Table 2-1 summarizes 1991 domestic clay production by State. The primary end uses of domestically produced clay are listed in Table 2-2. The following paragraphs discusses the clay industry in more detail by clay type.

2.1.1 Kaolin.

Kaolin, or china clay, is defined as a white, claylike material composed mainly of kaolinite, which is a hydrated aluminum silicate ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$), and other kaolin-group minerals. Kaolin is chemically inert over a relatively wide pH range and is white in color. Kaolin is an effective covering agent when used as a pigment or extender in coated films and filling applications. In addition, kaolin is soft, nonabrasive, and has a low conductivity of heat and electricity. As a result, kaolin has wide variety of industrial applications.

Total domestic production of kaolin in 1991 amounted to 9,575,000 Mg. Forty-two firms operated 141 kaolin mines in 14 States, and three large, diversified firms accounted for about 60 percent of total domestic kaolin output. Most large kaolin producers have operations in Georgia, which accounted for 79 percent of the kaolin production. The second leading kaolin producing State is South Carolina, which accounted for 6 percent of total production in 1991. Most kaolin plants are highly integrated operations that are capable of mining, processing, packaging, and shipping the finished product. Major end uses of kaolin sold or used in the U.S. in 1991 were paper-coating (34 percent), refractories (21 percent), paper-filling (14 percent), fiberglass and insulation (5 percent), face brick (3 percent), rubber (3 percent), and paint and chemicals (3 percent).

2.1.2 Ball clay.

Ball clay is a plastic, white-firing clay used mainly for bonding in ceramic ware, primarily dinnerware, floor and wall tile, pottery, and sanitary ware. The principal component of ball clay is kaolinite, which constitutes at least 70 percent of the material. Organic matter is also common in most ball clays, and ball clays usually are much finer grained than kaolins. The most important properties of ball clays are high plasticity, high wet and dry strength, high shrinkage due to drying and firing, and a wide vitrification range.

In 1991, 6 producers operated 36 mines in 5 States. Total domestic production of ball clay in 1991 amounted to 784,000 Mg. Tennessee ball clay production accounted for approximately 66 percent of the total output. Other major producing States, in descending order of production, were Kentucky, Mississippi, Texas, and Indiana. Major end uses of ball clay in 1991 were sanitary ware (20 percent); floor and wall tile (20 percent); fillers, extenders, and binders (15 percent); and dinnerware (15 percent).

2.1.3 Fire clay.

Fire clays are composed primarily of kaolinite, but also may contain several other materials including diaspore, burley, burley-flint, ball clay, and bauxitic clay and shale. Due to their ability to withstand temperatures of 1500 °C (2700°F) or higher, fire clays generally are used for refractories or to raise vitrification temperatures in heavy clay products. Fire clay producers generally are refractory manufacturers that use the clays to produce firebrick and other refractory materials.

In 1991, 78 fire clay mines were operated by 19 firms in 7 States. Total domestic production of fire clay sold in 1991 amounted to 474,000 Mg. The leading fire clay producing States, in descending order of production, in 1991 were Missouri, Ohio, Alabama, New Jersey, Pennsylvania, and New Mexico.

2.1.4 Bentonite.

Bentonite is a clay composed primarily of smectite minerals, usually montmorillonite. Bentonite can be classified as swelling or nonswelling, based on how much the material swells when wet. The swelling type of bentonite has a high-sodium ion concentration, and its volume increases 15 to 20 times its dry volume when wetted with water. Nonswelling bentonites usually are high in calcium and swell slightly more than common clay. The swelling types of bentonite are used largely in drilling muds, in foundry sands, and in pelletizing taconite iron ores. The nonswelling types of bentonite are used mostly in conjunction with the swelling bentonites in foundry sand mixes. In addition, nonswelling bentonites are used in decolorizing and purifying mineral, vegetable, and animal oils.

Firms producing bentonite operated 144 mines in 11 States. Wyoming was the leading State, accounting for 73 percent of the total output. Total domestic production of bentonite in 1991 amounted to 3,400,000 Mg. The swelling-type bentonite is produced mainly in Wyoming and Montana, and the nonswelling-type bentonite is produced in Mississippi and Texas. The United States is the world's largest producer and exporter of bentonite. Major end uses of bentonite in 1991 were drilling mud (23 percent), foundry sand (25 percent), iron ore pelletizing (21 percent), absorbents (9 percent), and waterproofing and sealing (6 percent).

2.1.5 Fuller's earth.

Fuller's earth is defined as a nonplastic clay or claylike material that typically is high in magnesia and has specialized decolorizing and purifying properties. Fuller's earth and bentonite are closely related, and much of the clay sold as fuller's earth is actually bentonite. The two major end uses of fuller's earth are pet waste and oil and grease absorbents.

Domestic fuller's earth production totalled 2.74 million Mg in 1991. Nineteen companies produced fuller's earth from 37 mines in 10 States. Eleven of the mines were located in Florida and Georgia. These two States accounted for almost one-half of total domestic production of fuller's earth. The United States is the world's largest producer and user of fuller's earth. Major end uses of fuller's earth in 1991 were pet waste absorbents (65 percent), oil and grease absorbents (13 percent), and pesticides and related products (7 percent).

2.1.6 Common clay and shale.

Common clay is defined as a plastic clay or claylike material with a vitrification point below 1,100° C. Shale is a laminated sedimentary rock that is formed by the consolidation of clay, mud, or silt. Common clay and shale are composed mainly of illite or chlorite, but also may contain kaolin and montmorillonite. Common clay and shale deposits are found throughout the United States and are used primarily to manufacture structural clay products such as brick, drain tile, portland cement clinker, and lightweight aggregate. Domestic clay and shale generally are mined and used onsite to fabricate or manufacture products.

Common clay and shale were mined commercially in 44 States and Puerto Rico in 1991. Total domestic production of common clay and shale amounted to 27.2 million Mg in 1991 and accounted for 62 percent of total domestic clay production. Domestic resources are almost unlimited, but relatively few deposits are suitable for manufacturing lightweight aggregate. Major end uses of common clay and shale in 1991 were brick (43 percent), portland and other cements (37 percent), and lightweight aggregate (13 percent).

2.2 PROCESS DESCRIPTION[1-4]

Most domestic clay is mined by open-pit methods using various types of equipment, including draglines, power shovels, front-end loaders, backhoes, scraper-loaders, and shale planers. In addition, some kaolin is extracted by hydraulic mining and dredging. Most underground clay mines are located in Pennsylvania, Ohio, and West Virginia, where the clays are associated with coal deposits. A higher percentage of fire clay is mined underground than the percentage of other clays mined underground because the higher quality fire clay deposits are found at depths that make open-pit mining less profitable.

Clays usually are transported by truck from the mine to the processing plants, many of which are located at or near the mine. For most applications, clays are processed by mechanical methods, such as crushing, grinding, and screening, that do not appreciably alter the chemical or mineralogical properties of the material. However, because clays are used in such a wide range of applications, it is often necessary to use other mechanical and chemical processes, such as drying, calcining, bleaching, blunging, and extruding to prepare the material for use.

Primary crushing reduces material size from as much as one meter to a few centimeters in diameter and typically is accomplished using jaw or gyratory crushers. Rotating pan crushers, cone crushers, smooth roll crushers, toothed roll crushers, and hammer mills are used for secondary crushing, which further reduces particle size to 3 mm (0.1 in.) or less. For some applications, tertiary size reduction is necessary and is accomplished by means of ball, rod, or pebble mills, which are often combined with air separators. Screening typically is carried out by means of two or more multi-deck sloping screens that are mechanically or electromagnetically vibrated. Pug mills are used for blunging, and rotary, fluid bed, and vibrating grate dryers are used for drying clay materials. At most plants that calcine clay, rotary or flash calciners are used. However, multiple hearth furnaces often are used to calcine kaolin.

Material losses due to basic mechanical processing generally are insignificant. However, material losses for processes such as washing and sizing can reach 30 to 40 percent. The most significant processing losses occur in the processing of kaolin and fuller's earth.

The following paragraphs describe the steps used to process each of the six categories of clay. Table 2-3 summarizes these processes by clay type.

2.2.1 Kaolin.

Kaolin is both dry- and wet-processed. The dry process is simpler and produces a lower quality product than is produced by the wet process. Dry-processed kaolin is used mainly in the rubber industry, and to a lesser extent, for paper filling and to produce fiberglass and sanitary ware. Wet-processed kaolin is used extensively in the paper manufacturing industry.

In the dry process, the raw material is crushed to the desired size, dried in rotary dryers, pulverized and air-floated to remove most of the coarse grit. Wet processing of kaolin begins with blunging to produce a slurry, which then is fractionated into coarse and fine fractions using centrifuges, hydrocyclones, or hydroseparators. At this step in the process, various chemical methods, such as bleaching, and physical and magnetic methods may be used to refine the material. Chemical processing includes leaching with sulfuric acid, followed by the addition of a strong reducing agent such as hydrosulfite. Prior to drying, the slurry is filtered and dewatered by means of a filter press, centrifuge, rotary vacuum filter, or tube filter. The filtered dewatered slurry material may be shipped or further processed by drying in apron, rotary, or spray dryers. Following the drying step, the kaolin may be calcined for use as filler or refractory material. Multiple hearth furnaces are most often used to calcine kaolin. Flash and rotary calciners also are used.

2.2.2 Ball Clay.

Mined ball clay, which typically has a moisture content of approximately 28 percent, first is stored in drying sheds until the moisture content decreases to 20 to 24 percent. The clay then is shredded in a disintegrator into small pieces 1.3 to 2.5 centimeters (cm) (0.5 to 1 in.) in thickness. The shredded material then is either dried or ground in a hammer mill. Material exiting the hammer mill is mixed with water and bulk loaded as a slurry for shipping.

Indirect rotary or vibrating grate dryers are used to dry ball clay. Combustion gases from the firebox pass through an air-to-air heat exchanger to heat the drying air to a temperature of approximately 300°C (570°F). The clay is dried to a moisture content of 8 to 10 percent. Following drying, the material is ground in a roller mill and shipped. The ground ball clay may also be mixed with water and bulk loaded as a slurry for shipping.

2.2.3 Fire Clay.

Mined fire clay first is transported to the processing plant and stockpiled. In some cases, the crude clay is weathered for 6 to 12 months, depending on the type of fire clay. Freezing and thawing breaks the material up, resulting in smaller particles and improved plasticity. The material then is crushed and ground. At this stage in the process, the clay has a moisture content of 10 to 15 percent. For certain applications, the clay is dried in mechanical dryers to reduce the moisture content of the material to 0 to 7 percent. Typically, rotary and vibrating grate dryers fired with natural gas or fuel oil are used for drying fire clay.

To increase the refractoriness of the material, fire clay often is calcined. Calcining eliminates moisture and organic material and causes a chemical reaction to occur between the alumina and silica in the clay, rendering a material (mullite) that is harder, denser, and more easily crushed than uncalcined fire clay. After the clay is dried and/or calcined, the material is crushed, ground, and screened. After screening, the processed fire clay may be blended with other materials, such as organic binders, prior to being formed in the desired shapes and fired.

2.2.4 Bentonite.

Mined bentonite first is transported to the processing plant and stockpiled. If the raw clay has a relatively high moisture content (30 to 35 percent), the stockpiled material may be plowed to facilitate air drying to a moisture content of 16 to 18 percent. Stockpiled bentonite may also be blended with other grades of bentonite to produce a uniform material. The material then is passed through a grizzly and crusher to reduce the clay to less than 2.5 cm (1 in.). Next, the crushed bentonite is dried in rotary or fluid bed dryers fired with natural gas, oil, or coal, to reduce the moisture content to 7 to 8 percent. The temperatures in bentonite dryers generally range from 800°C (1470°F) at the inlet to 100° to 200°C (210° to 390°F) at the outlet. The dried material then is ground by means of roller or hammer mills and screened. Soda ash may be added to the processed material to improve the swelling properties of the clay.

2.2.5 Fuller's Earth.

After being mined, fuller's earth is transported to the processing plant, crushed, ground, and stockpiled. Prior to drying, fuller's earth is fed into secondary grinders to further to reduce the size of the material. At some plants, the crushed material is fed into a pug mill, mixed with water, and extruded to improve the properties needed for certain end products. The material then is dried in rotary or fluid bed dryers fired with natural gas or fuel oil. Drying reduces the moisture content to 0 to 10 percent from its initial moisture content of 40 to 50 percent. The temperatures in fuller's earth dryers depend on the end used of the product. For colloidal grades of fuller's earth, drying temperatures of approximately 150°C (300°F) are used; for absorbent grades, drying temperatures of 650°C (1200°F) are typical. In some plants, fuller's earth is calcined rather than dried. In these cases, an operating temperature of approximately 675°C (1250°F) is used. The dried or calcined material then is ground by means of roller or hammer mills and screened.

2.2.6 Common Clay and Shale.

Common clay and shale generally are mined, processed, formed, and fired at the same site to produce the final end product. Processing generally begins with primary crushing and stockpiling. The material then is ground and screened. Oversize material may be further ground to produce particles of the desired size. For some applications, common clay and shale are dried to reduce the moisture content to desired levels. Further processing may include blunging or mixing with water in a pug mill, extruding, and firing in a kiln, depending on the type of end product.

2.3 EMISSIONS[3]

The primary pollutants of concern in clay processing operations are particulate matter (PM) and PM less than 10 micrometers (PM-10). Particulate matter is emitted from all dry mechanical processes, such as crushing, screening, grinding, and materials handling and transfer operations. The emissions from dryers and calciners 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. Volatile organic compounds associated with the raw materials and the fuel also may be emitted from drying and calcining.

2.4 CONTROL TECHNOLOGY[3]

Cyclones, wet scrubbers, and fabric filters are the most commonly used devices to control PM emissions from most clay processing operations. Cyclones often are used for product recovery from mechanical processes. In such cases, the cyclones are not considered to be an air pollution control device. Electrostatic precipitators also are used at some facilities to control PM emissions.

REFERENCES FOR SECTION 2

1. S. H. Patterson and H. H. Murray, "Clays", Industrial Minerals and Rocks, Volume 1, Society of Mining Engineers, New York, NY, 1983.

2. R. L. Virta, Annual Report 1991: Clays (Draft), Bureau of Mines, U.S. Department of the Interior, Washington, D.C., September 1992.

3. Calciners and Dryers in Mineral Industries-Background Information for Proposed Standards, EPA-450/3-85-025a, U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1985.

4. J. T. Jones and M. F. Berard, Ceramics, Industrial Processing and Testing, Iowa State University Press, Ames, IO, 1972.

TABLE 2-1. CLAYS SOLD OR USED BY PRODUCERS IN THE U.S. IN 1991[a]

State	Kaolin	Ball clay	Fire clay	Bentonite	Fuller's earth	Common clay and shale	Total[b]
Alabama	W		81	W		2,044	2,124
Arizona				35		193	3,830
Arkansas	212		W			645	8,048
California	113			147	W	1,815	27,463
Colorado			3	W		261	1,964
Connecticut						W	W
Florida	31				332	W	39,150
Georgia	7,519				617	1,382	949,737
Idaho	1					W	W
Illinois					421	514	38,877
Indiana		W				930	3,516
Iowa						530	2,226
Kansas						607	2,828
Kentucky		W				708	2,942
Louisiana						360	3,646
Maine						W	W
Maryland						259	1,141
Massachusetts						W	W
Michigan						2,062	8,770
Minnesota	W					W	W
Mississippi	W	W		211	313	648	34,382
Missouri			251		W	1,751	11,059
Montana				320		42	11,332
Nebraska						198	909
Nevada	W			16	W		3,204
New Hampshire						W	W

State	Kaolin	Ball clay	Fire clay	Ben-tonite	Fuller's earth	Common clay and shale	Total[b]
Alabama	W		81	W		2,044	2,124
New Jersey			W			W	W
New Mexico			W			28	74
New York						421	2,417
North Carolina	W					2,064	9,015
North Dakota						28	W
Ohio			89			2,116	11,016
Oklahoma						824	4,178
Oregon				19		194	1,086
Pennsylvania	W		W			701	2,890
Puerto Rico						145	335
South Carolina	555					1,154	25,663
South Dakota						W	W
Tennessee	W	514			314	W	44,573
Texas	W	W		W	W	2,266	13,247
Utah				W		210	1,028
Virginia					W	723	3,248
Washington						263	2,633
West Virginia						134	322
Wyoming				2,496		W	81,573
Undistributed	1,144	270	51	187	743	1,010	124,996
Total[a]	9,575	784	474	3,432	2,740	27,233	1,505,423

W = withheld to avoid disclosing company proprietary data; included in totals and/or undistributed.

[a] Reference 1; units of Mg.

[b] Data may not add to totals due to independent rounding.

TABLE 2-2. END USES OF CLAY PRODUCED OR SOLD IN THE U.S. IN 1991[a]

Use	Kaolin	Ball clay	Fire clay	Bentonite	Fuller's earth	Common clay and shale	Total
Absorbents				298	2,419		2,717
Ceramics and glass	919	302	21	32	15	242	1,328
Chemical manufacturing	170						170
Civil engineering and sealing	44	12		177		84	317
Drilling mud				693	32		724
Fillers, extenders, and binders	4,415	135		141	369	80	5,141
Filtering, clarifying, and decolorizing				5	20		26
Floor and wall tile		168				429	497
Heavy clay products	455		21	5	26	22,587	23,094
Lightweight aggregate						3,599	3,599
Pelletizing iron ore				717			717
Refractories	1,790	17	412	828		98	3,146
Other	65	51	14	96	27	197	450
Exports	1,931	90	4	438	129	7	2,599
Total	9,575	784	474	3,432	2,740	27,233	44,237

[a] Reference 1; all figures in units of thousands of Mg; data may not add to totals due to independent rounding.

TABLE 2-3. CLAY PROCESSING OPERATIONS

Process	Kaolin	Ball clay	Fire clay	Bentonite	Fuller's earth	Common clay and shale
Mining	X	X	X	X	X	X
Stockpiling	X	X	X	X	X	X
Crushing	X	X	X	X	X	X
Grinding	X	X	X	X	X	X
Screening	X		X		X	X
Mixing	X	X				X
Blunging	X				X	X
Air flotation	X	X				
Slurrying	X	X				
Extruding					X	X
Drying	X		X	X	X	X
Calcining	X		X			
Packaging	X	X	X	X	X	
Other	water fractionation, magnetic separation, acid treatment, bleaching	shredding, pulverizing	weathering, blending	cation exchange, granulation, air classifying	dispersing	

3. GENERAL DATA REVIEW AND ANALYSIS

3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The docket for the development of new source performance standards (NSPS) for calciners and dryers in the mineral industries was reviewed for information on the industry, processes, and emissions. The Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF) and VOC/PM Speciation Data Base Management System (SPECIATE) data bases were searched by SCC for identification of the potential pollutants emitted and emission factors for those pollutants. A general search of the Air CHIEF CD-ROM also was conducted to supplement the information from these two data bases.

Information on the industry , including number of plants, plant location, and annual production capacities, was obtained from the Minerals Yearbook and Census of Manufactures. The Aerometric Information Retrieval System (AIRS) data base also was searched for data on the number of plants, plant location, and estimated annual emissions of criteria pollutants.

A number of sources of information were investigated specifically for emission test reports and data. A search of the Test Methods Storage and Retrieval (TSAR) data base was conducted to identify test reports for sources within the sand and gravel processing industry. Copies of these test reports were obtained from the files of the Emission Measurement Branch (EMB). The EPA library was searched for additional test reports. A list of plants that have been tested within the past 5 years was compiled from the AIRS data base. Using this information and information obtained on plant location from the Minerals Yearbook and Census of Manufactures, State and Regional offices were contacted about the availability of test reports. However, the information obtained from these offices was limited. Publications lists from the Office of Research and Development (ORD) and Control Technology Center (CTC) were also searched for reports on emissions from the sand and gravel processing industry. In addition, representative trade associations were contacted for assistance in obtaining information about the industry and emissions.

To reduce the amount of literature collected to a final group of references from which emission factors could be developed, the following general criteria were used:

1. Emission data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

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.

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of the 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 (i.e., comparison of EPA Method 5 front half with 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.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EIB for preparing AP-42 sections. The data were rated as follows:

A--Multiple tests that were 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 EPA reference test methods, although these methods were 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. Source operation. 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. Sampling procedures. 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 to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. 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 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 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 industry. 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. In addition, 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. Details of the rating of each candidate emission factor are provided in Section 4 of this report.

REFERENCES FOR SECTION 3

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections (Draft), Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 6, 1992.

4. AP-42 SECTION DEVELOPMENT

4.1 POLLUTANT EMISSION FACTOR DEVELOPMENT

For the subcategory addressing kaolin processing, one summary document and four test reports documenting emission tests at kaolin processing plants were reviewed. Data from the emission tests documented in References 1 and 2 were used for emission factor development. The emission test presented in Reference 3 provided an evaluation of visible emissions only and could not be used for emission factor development. Process rates recorded during the emission test documented in Reference 4 are currently considered confidential; therefore the use of the data from this reference is contingent upon release of the process operating rates by the facility tested. The plant has been contacted, and this issue will be resolved as quickly as possible. Presently, space is left in the Section 4 tables for data from Reference 4, but no data associated with the process rates are shown. Reference 7, which is the background information document for the NSPS for calciners and dryers, contains summary data from emission tests at four kaolin processing plants, including summaries of the emission tests documented in References 1 and 3. The four tests summarize results from tests at four different plants (Plants J1, J2, J3, and J4). Data from the two tests (Plants J2 and J4) that are not documented in References 1 and 3 are discussed in Section 4.2.1, Review of Specific Data Sets.

For the subcategory addressing ball clay processing, data from one emission test (summarized in Reference 7) were used for emission factor development. For the subcategories addressing bentonite and fuller's earth, Reference 7 contains summary data for emission tests conducted at two bentonite and one fuller's earth processing facilities. In addition, two emission test reports (References 5 and 6) from a fuller's earth processing facility were used for developing emission factors.

4.1.1 Review of Specific Data Sets

4.1.1.1 Reference 1. This reference documents an emission test conducted at the American Industrial Clay Company in Sandersville, Georgia in September, 1974. Filterable particulate matter (PM) and carbon dioxide (CO_2) emissions were measured at the outlet of a fabric filter controlling emissions from a kaolin spray dryer. Filterable PM emissions were quantified using EPA Method 5 (3 test runs), and CO_2 emissions were determined by Orsat analysis. The dryer operated at 83 percent of design capacity during the tests. Production rates were calculated using the slurry feed rates shown in the report in conjunction with the estimated slurry and finished product moisture contents. The slurry was approximately 60 percent kaolin and 40 percent water, and the finished product contained less than one percent moisture.

The data from this report were assigned a B rating. The testing methodology was sound, adequate detail was provided, and no problems were reported during the valid test runs. However, the production rates may be slightly in error because the material moisture contents were estimated.

4.1.1.2 Reference 2. This reference documents an emission test conducted at the American Industrial Clay Company in Sandersville, Georgia in August and September, 1974. Uncontrolled filterable PM and CO_2 emissions were measured at the outlet of three exhaust stack from an kaolin apron dryer. Filterable PM emissions were quantified using EPA Method 5, and CO_2 emissions were measured by Orsat analysis. Three test runs were performed on each stack. Production rates were calculated using the slurry feed rates shown in the report in conjunction with the estimated slurry and finished product moisture contents. The slurry was approximately 60 percent kaolin and 40 percent water, and the finished product contained about six percent water.

The data from this report were assigned a B rating. The testing methodology was sound, adequate detail was provided, and no problems were reported during the valid test runs. However, the production rates may be slightly in error because the material moisture contents were estimated.

4.1.1.3 Reference 3. This reference documents an emission test conducted at Thiele Kaolin in Sandersonville, Georgia on December 6 and 7, 1978. The test program included only a visible emission evaluation, and the report includes no data suitable for inclusion in AP-42.

4.1.1.4 Reference 4. This reference documents an emission test conducted at a kaolin processing plant in 1983. The sources tested include the inlet and outlet of a venturi scrubber controlling emissions from a multiple hearth furnace, the inlet and outlet of a fabric filter controlling emissions from a kaolin cooling conveyor, and the inlet and outlet of a fabric filter controlling emissions from a flash calciner. Pollutants measured include filterable PM and CO_2, and particle size analyses were performed at the inlet and outlet of each fabric filter.

The process rates for these tests currently are claimed as confidential by the facility. The facility has been contacted regarding release of the process data, and a decision is pending. Emission factors cannot be developed from the test data unless the process data ~~is~~ are released by the facility.

4.1.1.5 Reference 5. This reference documents an industry sponsored emission test conducted at the Waverly Mineral Products Company (fuller's earth processing plant) in Meigs, Georgia on February 1, 1979. The type of raw material processed was not specified in the report, but the cover of the report was labeled as "Fuller's Earth" and was assumed to be accurate. Filterable PM and CO_2 emissions were measured at the outlet of a wet scrubber operating at a pressure drop of 3.7 kilopascals (kPa) (15 inches of water column [in. w.c.]) controlling emissions from several sources, including screenhouses Nos. 1 and 2, rotary kiln No. 2, and rotary cooler No. 2. A multicyclone (for PM removal) was located prior to the scrubber. Filterable PM emissions were quantified using EPA Method 5 (3 test runs), and CO_2 emissions were measured by Orsat analysis. However, CO_2 was not detected during any of the test runs.

The data from this report were assigned an A rating. The testing methodology was sound, adequate detail was provided, and no problems were reported during the valid test runs.

4.1.1.6 Reference 6. This reference documents an industry sponsored emission test conducted at the same fuller's earth processing plant for which emission data were documented in Reference 5. The test was conducted on September 13, 1978. The type of raw material processed was not specified in the report, but the cover of the report was labeled as "Fuller's Earth" and was assumed to be accurate. Filterable PM and CO_2 emissions were measured at the outlet of a wet scrubber operating at a pressure drop of 3.7 kPa (15 in. w.c.) controlling emissions from rotary kiln No. 1 and rotary cooler No. 1. A multicyclone (for PM removal) was located prior to the scrubber. Filterable PM emissions were quantified using EPA Method 5 (3 test runs), and CO_2 emissions were measured by Orsat analysis.

The data from this report were assigned an A rating. The testing methodology was sound, adequate detail was provided, and no problems were reported during the valid test runs.

4.1.1.7 Reference 7. This reference includes descriptions and summaries of results of emission tests conducted at four kaolin processing plants (Plants J1, J2, J3, and J4), one ball clay processing plant (Plant B1), several fire clay processing plants, two bentonite processing plants (Plants C1 and C3), and one fuller's earth processing plant (Plant G1).

The emission data for the tests conducted on fire clay processing plants are addressed in AP-42 Section 8.5, Refractory Manufacturing. The emission tests conducted at Plants J1 and J3 are the same tests documented in References 4 and 1, respectively. Plants J2, J4, B1, C1, C3, and G1 and the emission tests conducted at these plants are described below.

The industry-sponsored test at Plant J2 included filterable PM measurements at the outlet of a shaker fabric filter controlling emissions from a spray dryer and at the outlet of a venturi scrubber (pressure drop of 4.5 to 5.3 kPa [18 to 21 in. w.c.]) controlling emissions from a multiple hearth furnace. Both the spray dryer and the furnace were fired by natural gas, and the raw material processed was kaolin.

The industry-sponsored test at Plant J4 included filterable PM measurements at the outlet of a shaker fabric filter controlling emissions from a natural gas-fired spray dryer. The dryer operated at 104 percent of maximum capacity during the tests. The raw material processed was kaolin.

The industry-sponsored test at Plant B1 included filterable PM measurements at the outlet of a pulse-jet fabric filter controlling emissions from a vibrating-grate dryer. The raw material processed was a mixture of two types of ball clay.

The EPA-sponsored test at Plant C1 included simultaneous filterable PM and particle size tests performed on a coal-fired rotary dryer that was processing bentonite. Uncontrolled emissions were measured at the cyclone inlet, and controlled emissions were measured at the outlet of the fabric filter. The particle size analysis indicated that approximately 7 percent of the uncontrolled filterable PM was PM-10, and about 74 percent of the filterable PM measured at the fabric filter outlet was PM-10.

The industry-sponsored test at Plant C3 included filterable PM measurements at the outlet of a electrostatic precipitator (ESP) controlling emissions from a rotary dryer processing bentonite. Four test runs were performed because the degree of isokinetic variation during Run 1 did not conform with EPA requirements. Data from Run 1 were not used for emission factor development.

The industry-sponsored test at Plant G1 included filterable PM measurements at the outlet of a wet scrubber (pressure drop of 2.5 kPa [10 in. w.c.) controlling emissions from a rotary dryer. The raw material processed was fuller's earth. Data from Run 1 were not used for emission factor development because of problems encountered with the scrubber during the run.

The data from the all of the emission tests except for Plant G1 were assigned a B rating. The test methodologies are assumed to be sound, adequate detail was provided, and no problems were reported during the valid test runs. The data were downrated to B because the reference is a secondary source of data, and the original test reports were not available for review. The data from the test at Plant G1 were assigned a C rating because only 2 valid test runs were performed.

4.1.2 Review of XATEF and SPECIATE Data Base Emission Factors

The XATEF and SPECIATE data bases were searched for emission factors relevant to the clay processing industry. No pertinent information was found.

4.1.3 Results of Data Analysis

Emission factors were developed using the data from References 1, 2, and 4 to 7 for several clay processing operations. Uncontrolled emission factors were developed for filterable PM and CO_2 emissions from apron dryers (kaolin), CO_2 emissions from spray dryers (kaolin) and rotary kiln/coolers (fuller's earth), and filterable PM and PM-10 emissions from rotary dryers (bentonite). Controlled emission factors were developed for filterable PM emissions from spray dryers with fabric filters (kaolin), vibrating-grate dryers with fabric filters (ball clay), rotary dryers with fabric filters or ESP's (bentonite), and combined sources controlled with wet scrubbers (fuller's earth). Controlled PM-10 emission factors were developed for rotary dryers with fabric filters (bentonite). Data for additional source/control combinations are currently considered confidential, but will be included if the plants releases the process data.

Tables 4-1, 4-2, 4-3, and 4-4 present the data used for emission factor development. Table 4-5 presents the emission factors developed using the data gathered. Most of the emission factors were developed from data from a single test, and were assigned a D rating for this reason. The emission factor for spray dryers with fabric filters (kaolin) was developed from data from three tests, but was also assigned a D rating because of the relatively large number of kaolin processing plants in comparison to the number of tests used.

TABLE 4-1. SUMMARY OF EMISSION DATA FOR KAOLIN PROCESSING[a]
(factors represent uncontrolled emissions unless noted)

Source	Pollutant	No. of runs	Data rating	Emission factor, kg/Mg (lb/ton)			Ref. No.
				Minimum	Maximum	Average	
Spray dryer with fabric filter	Filterable PM	3	B	0.15 (0.29)	0.38 (0.75)	0.29 (0.58)	1
Spray dryer with fabric filter	CO_2	3	B	75 (150)	87 (173)	81 (161)	1
Apron dryer	Filterable PM	3	B	0.58 (1.2)	0.69 (1.4)	0.62 (1.2)	2
Apron dryer	CO_2	3	B	36 (71)	200 (400)	140 (280)	2
Kaolin cooling conveyor	Filterable PM	3	A	b	b	b	4
Kaolin cooling conveyor	PM-10	3	A	b	b	b	4
Kaolin cooling conveyor with fabric filter	Filterable PM	3	A	b	b	b	4
Kaolin cooling conveyor with fabric filter	PM-10	3	A	b	b	b	4
Multiple hearth furnace	Filterable PM	3	A	b	b	b	4
Multiple hearth furnace	CO_2	3	A	b	b	b	4
Multiple hearth furnace with venturi scrubber	Filterable PM	3	A	b	b	b	4
Multiple hearth furnace with venturi scrubber	CO_2	3	A	b	b	b	4
Flash calciner	Filterable PM	3	A	b	b	b	4
Flash calciner	CO_2	3	A	b	b	b	4
Flash calciner	PM-10	3	A	b	b	b	4

Flash calciner with fabric filter	Filterable PM	2	B	b	b	b	4
Flash calciner with fabric filter	CO_2	2	B	b	b	b	4
Flash calciner with fabric filter	PM-10	2	B	b	b	b	4
Multiple hearth furnace with venturi scrubber	Filterable PM	3	B	b	b	b	7[c]
Spray dryer with fabric filter	Filterable PM	3	B	b	b	b	7[c]
Spray dryer with fabric filter	Filterable PM	3	B	0.013 (0.026)	0.024 (0.047)	0.018 (0.037)	7[d]

[a] Emission factor in kg/Mg (lb/ton) of product.

[b] Process rates are confidential.

[c] Plant J2.

[d] Plant J4.

TABLE 4-2. SUMMARY OF EMISSION DATA FOR BALL CLAY PROCESSING[a]
(factors represent uncontrolled emissions unless noted)

Source	Pollutant	No. of runs	Data rating	Emission factor, kg/Mg (lb/ton)			Ref. No.
				Minimum	Maximum	Average	
Vibrating grate dryer with fabric filter	Filterable PM	3	B	0.026 (0.051)	0.11 (0.22)	0.071 (0.14)	7[b]

[a] Emission factor in kg/Mg (lb/ton) of product.

[b] Plant B1.

TABLE 4-3. SUMMARY OF EMISSION DATA FOR BENTONITE PROCESSING[a]
(factors represent uncontrolled emissions unless noted)

Source	Pollutant	No. of runs	Data rating	Emission factor, kg/Mg (lb/ton)			Ref. No.
				Minimum	Maximum	Average	
Rotary dryer	Filterable PM	3	B	130 (270)	150 (300)	140 (290)	7[b]
Rotary dryer	PM-10	12	B	9.1 (19)	11 (21)	9.8 (20)	7[b]
Rotary dryer with fabric filter	Filterable PM	3	B	0.032 (0.064)	0.068 (0.14)	0.050 (0.10)	7[b]
Rotary dryer with fabric filter	PM-10	3	B	0.024 (0.047)	0.050 (0.10)	0.037 (0.074)	7[b]
Rotary dryer with ESP	Filterable PM	3	B	0.010 (0.020)	0.078 (0.016)	0.016 (0.033)	7[c]

[a] Emission factor in kg/Mg (lb/ton) of product.

[b] Plant C1. Uncontrolled PM-10 is 7% of uncontrolled filterable PM. Controlled PM-10 is 74% of controlled filterable PM.

[c] Plant C3.

TABLE 4-4. SUMMARY OF EMISSION DATA FOR FULLER'S EARTH PROCESSING[a]
(factors represent uncontrolled emissions unless noted)

Source	Pollutant	No. of runs	Data rating	Emission factor, kg/Mg (lb/ton)			Ref. No.
				Minimum	Maximum	Average	
Kiln, cooler, and screenhouses with multiclone and wet scrubber	Filterable PM	3	A	0.28 (0.56)	0.35 (0.69)	0.32 (0.63)	5
Kiln and cooler with multiclone and wet scrubber	Filterable PM	3	A	0.61 (1.2)	0.68 (1.4)	0.65 (1.3)	6
Kiln and cooler with multiclone and wet scrubber	CO_2	3	A	280 (550)	290 (580)	280 (560)	6
Rotary dryer with wet scrubber	Filterable PM	2	C	b	b	b	7[c]

[a] Emission factor in kg/Mg (lb/ton) of product.
[b] Process rates are confidential.
[c] Plant G1.

TABLE 4-5. SUMMARY OF EMISSION FACTORS FOR CLAY PROCESSING[a]

Raw material type	Source	Pollutant	No. of tests	Emission factor rating	Emission factor, kg/Mg (lb/ton)	Ref. Nos.
Kaolin	Spray dryer with fabric filter	Filterable PM	3	D	0.12 (0.23)	1,7
	Spray dryer with fabric filter	CO_2	1	D	81 (161)	1
	Apron dryer	Filterable PM	1	D	0.62 (1.2)	2
	Apron dryer	CO_2	1	D	140 (280)	2
	Kaolin cooling conveyor	Filterable PM	1	D	b	4
	Kaolin cooling conveyor	PM-10	1	D	b	4
	Kaolin cooling conveyor with fabric filter	Filterable PM	1	D	b	4
	Kaolin cooling conveyor with fabric filter	PM-10	1	D	b	4
	Multiple hearth furnace	Filterable PM	1	D	b	4
	Multiple hearth furnace[c]	CO_2	2	D	b	4
	Multiple hearth furnace with venturi scrubber	Filterable PM	2	D	b	4,7
	Flash calciner	Filterable PM	1	D	b	4
	Flash calciner[c]	CO_2	2	D	b	4
	Flash calciner	PM-10	1	D	b	4
	Flash calciner with fabric filter	Filterable PM	1	D	b	4
	Flash calciner with fabric filter	PM-10	1	D	b	4
Ball clay	Vibrating grate dryer with fabric filter	Filterable PM	1	D	0.071 (0.14)	7
Bentonite	Rotary dryer	Filterable PM	1	D	140 (290)	7
	Rotary dryer	PM-10	1	D	9.8 (20)	7

	Rotary dryer with fabric filter	Filterable PM	1	D	0.050 (0.10)	7
	Rotary dryer with fabric filter	PM-10	1	D	0.037 (0.074)	7
	Rotary dryer with ESP	Filterable PM	1	D	0.016 (0.033)	7
Fuller's earth	Kiln, cooler, and screenhouses with multiclone and wet scrubber	Filterable PM	1	D	0.32 (0.63)	5
	Kiln and cooler with multiclone and wet scrubber	Filterable PM	1	D	0.65 (1.3)	6
	Kiln and cooler with multiclone and wet scrubber	CO_2	1	D	280 (560)	6
	Rotary dryer with wet scrubber	Filterable PM	1	E	[b]	7

[a] Emission factors in kg/Mg (lb/ton) of product.

[b] Process rates are considered confidential.

[c] Combination of uncontrolled sources and sources controlled by fabric filters or venturi scrubbers, which achieve only incidental control of CO_2 emissions.

REFERENCES FOR SECTION 4

1. Report on Particulate Emissions From No. 3 Spray Dryer, American Industrial Clay Company, Sandersonville, Georgia, July 21, 1975.

2. Report on Particulate Emissions From Apron Dryer, American Industrial Clay Company, Sandersonville, Georgia, July 21, 1975.

3. Emission Test Report: Thiele Kaolin, Sandersonville, Georgia, EMB-78-NMM-7, U. S. Environmental Protection Agency, Research Triangle Park, NC, March, 1979.

4. Emission Test Report: Burgess Pigment Company, Sandersonville, Georgia, EMB-83-CDR-12, U. S. Environmental Protection Agency, Research Triangle Park, NC, October, 1983.

5. Source Test Report, Waverly Mineral Products, Meigs, Georgia, Kiln Number 2 Outlet, Technical Services, Inc., Jacksonville, FL, February, 1979.

6. Source Test Report, Waverly Mineral Products, Meigs, Georgia, Number 1 Kiln Outlet. Particulate Emissions, Technical Services, Inc., Jacksonville, FL, February, 1979.

7. Calciners and Dryers in Mineral Industries-Background Information for Proposed Standards, EPA-450/3-85-025a, U. S. Environmental Protection Agency, Research Triangle Park, NC, October, 1985.

5. DRAFT AP-42 SECTION 8.32

8.32 CLAY PROCESSING

8.32.1 Process Description

Clay is defined as a natural, earthy, fine-grained material composed largely of a group of crystalline hydrous silicate minerals, known as clay minerals. Clay minerals are composed mainly of silica, alumina, and water, but may also contain appreciable quantities of iron, alkalies, and alkaline earths. Clay is formed by the mechanical and chemical breakdown of rocks.

The Standard Industrial Classification (SIC) code for mining, milling, and processing kaolin and ball clay is 1455, Kaolin and Ball Clay; the SIC code for mining, milling, and processing fire clay, bentonite, fuller's earth, and common clay and shale is 1459, Clay, Ceramic, and Refractory Materials, Not Elsewhere Classified. There currently are no general Source Classification Codes (SCC's) for clay processing. However, the six-digit SCC for processing the raw material (common clay and shale) used in brick manufacturing is 3-05-003; the six-digit SCC for processing the raw material (generally, fire clay) used in refractory manufacturing is 3-05-005; and the six-digit SCC for processing raw material (generally, ball clay or kaolin) used in ceramic manufacturing is 3-05-008.

Clays are categorized into six groups by the U.S. Bureau of Mines. The categories are kaolin, ball clay, fire clay, bentonite, fuller's earth, and common clay and shale. Kaolin, or china clay, is defined as a white, claylike material composed mainly of kaolinite, which is a hydrated aluminum silicate ($Al_2O_3 \bullet 2SiO_2 \bullet 2H_2O$), and other kaolin-group minerals. Kaolin has a wide variety of industrial applications including paper coating and filing, refractories, fiberglass and insulation rubber, paint, ceramics, and chemicals. Ball clay is a plastic, white-firing clay that is composed primarily of kaolinite and is used mainly for bonding in ceramic ware, primarily dinnerware, floor and wall tile, pottery, and sanitary ware. Fire clays are composed primarily of kaolinite, but also may contain several other materials including diaspore, burley, burley-flint, ball clay, and bauxitic clay and shale. Due to their ability to withstand temperatures of 1500 °C (2700°F) or higher, fire clays generally are used for refractories or to raise vitrification temperatures in heavy clay products. Bentonite is a clay composed primarily of smectite minerals, usually montmorillonite and is used largely in drilling muds, in foundry sands, and in pelletizing taconite iron ores. Fuller's earth is defined as a nonplastic clay or claylike material that typically is high in magnesia and has specialized decolorizing and purifying properties. Fuller's earth, which is very similar to bentonite, is used mainly as pet waste and oil and grease absorbents. Common clay is defined as a plastic clay or claylike material with a vitrification point below 1,100° C. Shale is a laminated sedimentary rock that is formed by the consolidation of clay, mud, or silt. Common clay and shale are composed mainly of illite or chlorite, but also may contain kaolin and montmorillonite.

Most domestic clay is mined by open-pit methods using various types of equipment, including draglines, power shovels, front-end loaders, backhoes, scraper-loaders, and shale planers. In addition, some kaolin is extracted by hydraulic mining and dredging. Most underground clay mines are located in Pennsylvania, Ohio, and West Virginia, where the clays are associated with coal deposits. A higher percentage of fire clay is mined underground than the percentage of other clays mined underground because the higher quality fire clay deposits are found at depths that make open-pit mining less profitable.

Clays usually are transported by truck from the mine to the processing plants, many of which are located at or near the mine. For most applications, clays are processed by mechanical methods, such as crushing, grinding, and screening, that do not appreciably alter the chemical or mineralogical properties of the material. However, because clays are used in such a wide range of applications, it is often necessary to use other mechanical and chemical processes, such as drying, calcining, bleaching, blunging, and extruding to prepare the material for use.

Primary crushing reduces material size from as much as one meter to a few centimeters in diameter and typically is accomplished using jaw or gyratory crushers. Rotating pan crushers, cone crushers, smooth roll crushers, toothed roll crushers, and hammer mills are used for secondary crushing, which further reduces particle size to 3 mm (0.1 in.) or less. For some applications, tertiary size reduction is necessary and is accomplished by means of ball, rod, or pebble mills, which are often combined with air separators. Screening typically is carried out by means of two or more multi-deck sloping screens that are mechanically or electromagnetically vibrated. Pug mills are used for blunging, and rotary, fluid bed, and vibrating grate dryers are used for drying clay materials. At most plants that calcine clay, rotary or flash calciners are used. However, multiple hearth furnaces often are used to calcine kaolin.

Material losses due to basic mechanical processing generally are insignificant. However, material losses for processes such as washing and sizing can reach 30 to 40 percent. The most significant processing losses occur in the processing of kaolin and fuller's earth. The following paragraphs describe the steps used to process each of the six categories of clay. Table 8.32-1 summarizes these processes by clay type.

Kaolin. Kaolin is both dry- and wet-processed. The dry process is simpler and produces a lower quality product than is produced by the wet process. Dry-processed kaolin is used mainly in the rubber industry, and to a lesser extent, for paper filling and to produce fiberglass and sanitary ware. Wet-processed kaolin is used extensively in the paper manufacturing industry.

In the dry process, the raw material is crushed to the desired size, dried in rotary dryers, pulverized and air-floated to remove most of the coarse grit. Wet processing of kaolin begins with blunging to produce a slurry, which then is fractionated into coarse and fine fractions using centrifuges, hydrocyclones, or hydroseparators. At this step in the process, various chemical methods, such as bleaching, and physical and magnetic methods may be used to refine the material. Chemical processing includes leaching with sulfuric acid, followed by the addition of a strong reducing agent such as hydrosulfite. Prior to drying, the slurry is filtered and dewatered by means of a filter press, centrifuge, rotary vacuum filter, or tube filter. The filtered dewatered slurry material may be shipped or further processed by drying in apron, rotary, or spray dryers. Following the drying step, the kaolin may be calcined for use as filler or refractory material. Multiple hearth furnaces are most often used to calcine kaolin. Flash and rotary calciners also are used.

Ball Clay. Mined ball clay, which typically has a moisture content of approximately 28 percent, first is stored in drying sheds until the moisture content decreases to 20 to 24 percent. The clay then is shredded in a disintegrator into small pieces 1.3 to 2.5 centimeters (cm) (0.5 to 1 in.) in thickness. The shredded material then is either dried or ground in a hammer mill. Material exiting the hammer mill is mixed with water and bulk loaded as a slurry for shipping.

Indirect rotary or vibrating grate dryers are used to dry ball clay. Combustion gases from the firebox pass through an air-to-air heat exchanger to heat the drying air to a temperature of approximately 300°C (570°F). The clay is dried to a moisture content of 8 to 10 percent. Following drying, the material is ground in a roller mill and shipped. The ground ball clay may also be mixed with water and bulk loaded as a slurry for shipping.

Fire Clay. Mined fire clay first is transported to the processing plant and stockpiled. In some cases, the crude clay is weathered for 6 to 12 months, depending on the type of fire clay. Freezing and thawing breaks the material up, resulting in smaller particles and improved plasticity. The material then is crushed and ground. At this stage in the process, the clay has a moisture content of 10 to 15 percent. For certain applications, the clay is dried in mechanical dryers to reduce the moisture content of the material to 0 to 7 percent. Typically, rotary and vibrating grate dryers fired with natural gas or fuel oil are used for drying fire clay.

To increase the refractoriness of the material, fire clay often is calcined. Calcining eliminates moisture and organic material and causes a chemical reaction to occur between the alumina and silica in the clay, rendering a material (mullite) that is harder, denser, and more easily crushed than uncalcined fire clay. After the clay is dried and/or calcined, the material is crushed, ground, and screened. After screening, the processed fire clay may be blended with other materials, such as organic binders, prior to being formed in the desired shapes and fired.

Bentonite. Mined bentonite first is transported to the processing plant and stockpiled. If the raw clay has a relatively high moisture content (30 to 35 percent), the stockpiled material may be plowed to facilitate air drying to a moisture content of 16 to 18 percent. Stockpiled bentonite may also be blended with other grades of bentonite to produce a uniform material. The material then is passed through a grizzly and crusher to reduce the clay to less than 2.5 cm (1 in.). Next, the crushed bentonite is dried in rotary or fluid bed dryers fired with natural gas, oil, or coal, to reduce the moisture content to 7 to 8 percent. The temperatures in bentonite dryers generally range from 800°C (1470°F) at the inlet to 100° to 200°C (210° to 390°F) at the outlet. The dried material then is ground by means of roller or hammer mills and screened. Soda ash may be added to the processed material to improve the swelling properties of the clay.

Fuller's Earth. After being mined, fuller's earth is transported to the processing plant, crushed, ground, and stockpiled. Prior to drying, fuller's earth is fed into secondary grinders to further to reduce the size of the material. At some plants, the crushed material is fed into a pug mill, mixed with water, and extruded to improve the properties needed for certain end products. The material then is dried in rotary or fluid bed dryers fired with natural gas or fuel oil. Drying reduces the moisture content to 0 to 10 percent from its initial moisture content of 40 to 50 percent. The temperatures in fuller's earth dryers depend on the end used of the product. For colloidal grades of fuller's earth, drying temperatures of approximately 150°C (300°F) are used; for absorbent grades, drying temperatures of 650°C (1200°F) are typical. In some plants, fuller's earth is calcined rather than dried. In these cases, an operating temperature of approximately 675°C (1250°F) is used. The dried or calcined material then is ground by means of roller or hammer mills and screened.

Common Clay and Shale. Common clay and shale generally are mined, processed, formed, and fired at the same site to produce the final end product. Processing generally begins with primary crushing and stockpiling. The material then is ground and screened. Oversize material may be further ground to produce particles of the desired size. For some applications, common clay and shale are dried to reduce the moisture content to desired levels. Further processing may include blunging or mixing with water in a pug mill, extruding, and firing in a kiln, depending on the type of end product.

8.32.2 Emissions and Controls

The primary pollutants of concern in clay processing operations are particulate matter (PM) and PM less than 10 micrometers (PM-10). Particulate matter is emitted from all dry mechanical processes, such as crushing, screening, grinding, and materials handling and transfer operations. The emissions from dryers and calciners 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. Volatile organic compounds associated with the raw materials and the fuel also may be emitted from drying and calcining.

Cyclones, wet scrubbers, and fabric filters are the most commonly used devices to control PM emissions from most clay processing operations. Cyclones often are used for product recovery from mechanical processes. In such cases, the cyclones are not considered to be an air pollution control device. Electrostatic precipitators also are used at some facilities to control PM emissions.

REFERENCES FOR SECTION 8.32

1. S. H. Patterson and H. H. Murray, "Clays", Industrial Minerals and Rocks, Volume 1, Society of Mining Engineers, New York, NY, 1983.

2. R. L. Virta, Annual Report 1991: Clays (Draft), Bureau of Mines, U.S. Department of the Interior, Washington, D.C., September 1992.

3. Calciners and Dryers in Mineral Industries-Background Information for Proposed Standards, EPA-450/3-85-025a, U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1985.

4. J. T. Jones and M. F. Berard, Ceramics, Industrial Processing and Testing, Iowa State University Press, Ames, IO, 1972.

TABLE 8.32.1 CLAY PROCESSING OPERATIONS

Process	Kaolin	Ball clay	Fire clay	Bentonite	Fuller's earth	Common clay and shale
Mining	X	X	X	X	X	X
Stockpiling	X	X	X	X	X	X
Crushing	X	X	X	X	X	X
Grinding	X	X	X	X	X	X
Screening	X		X		X	X
Mixing	X	X				X
Blunging	X				X	X
Air flotation	X	X				
Slurrying	X	X				
Extruding					X	X
Drying	X		X	X	X	X
Calcining	X		X			
Packaging	X	X	X	X	X	
Other	water fractionation, magnetic separation, acid treatment, bleaching	shredding, pulverizing	weathering, blending	cation exchange, granulation, air classifying	dispersing	

Table 8.32-2 (METRIC UNITS)
EMISSION FACTORS FOR KAOLIN PROCESSING[a]

All Emission Factors in kg/Mg Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	Filterable PM[b]		PM-10	
Spray dryer with fabric filter[c] (3-05-___-__)	0.12	D	ND	
Apron dryer[d] (3-05-___-__)	0.62	D	ND	
Kaolin cooling conveyor (3-05-___-__)	e		e	
Kaolin cooling conveyor with fabric filter (3-05-___-__)	e		e	
Multiple hearth furnace (3-05-___-__)	e		ND	
Multiple hearth furnace with venturi scrubber (3-05-___-__)	f		ND	
Flash calciner (3-05-___-__)	e		e	
Flash calciner with fabric filter (3-05-___-__)	e		e	

ND = No data available

[a] Factors represent uncontrolled emissions unless noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

[c] References 3 and 5.

[d] Reference 6.

[e] Reference 8. Process rates are confidential.

[f] References 3 and 8. Process rates are confidential.

Table 8.32-2 (ENGLISH UNITS)
EMISSION FACTORS FOR KAOLIN PROCESSING[a]

All Emission Factors in lb/ton Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	Filterable PM[b]		PM-10	
Spray dryer with fabric filter[c] (3-05-___-__)	0.23	D	ND	
Apron dryer[d] (3-05-___-__)	1.2	D	ND	
Kaolin cooling conveyor (3-05-___-__)	e		e	
Kaolin cooling conveyor with fabric filter (3-05-___-__)	e		e	
Multiple hearth furnace (3-05-___-__)	e		ND	
Multiple hearth furnace with venturi scrubber (3-05-___-__)	f		ND	
Flash calciner (3-05-___-__)	e		e	
Flash calciner with fabric filter (3-05-___-__)	e		e	

ND = No data available

[a] Factors represent uncontrolled emissions unless noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

[c] References 3 and 5.

[d] Reference 6.

[e] Reference 8. Process rates are confidential.

[f] References 3 and 8. Process rates are confidential.

Table 8.32-3 (METRIC UNITS)
EMISSION FACTORS FOR BALL CLAY PROCESSING[a]

All Emission Factors in kg/Mg Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	Filterable PM[b]	
Vibrating grate dryer with fabric filter (3-05-___-__)	0.071	D

[a] Reference 3. Factors represent uncontrolled emissions unless noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

Table 8.32-3 (ENGLISH UNITS)
EMISSION FACTORS FOR BALL CLAY PROCESSING[a]

All Emission Factors in lb/ton Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	Filterable PM[b]	
Vibrating grate dryer with fabric filter (3-05-___-__)	0.14	D

[a] Reference 3. Factors represent uncontrolled emissions unless noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

Table 8.32-4 (METRIC UNITS)
EMISSION FACTORS FOR BENTONITE PROCESSING[a]

All Emission Factors in kg/Mg Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	Filterable PM[b]		PM-10	
Rotary dryer (3-05-___-__)	140	D	9.8	D
Rotary dryer with fabric filter (3-05-___-__)	0.050	D	0.037	D
Rotary dryer with ESP (3-05-___-__)	0.016	D	ND	

ND = No data available

[a] Reference 3. Factors represent uncontrolled emissions unless noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

Table 8.32-4 (ENGLISH UNITS)
EMISSION FACTORS FOR BENTONITE PROCESSING[a]

All Emission Factors in lb/ton Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	Filterable PM[b]		PM-10	
Rotary dryer (3-05-___-__)	290	D	20	D
Rotary dryer with fabric filter (3-05-___-__)	0.10	D	0.074	D
Rotary dryer with ESP (3-05-___-__)	0.033	D	ND	

ND = No data available

[a] Reference 3. Factors represent uncontrolled emissions unless noted.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

Table 8.32-5 (METRIC UNITS)
EMISSION FACTORS FOR FULLER'S EARTH PROCESSING[a]

All Emission Factors in kg/Mg Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	Filterable PM[b]	
Kiln, cooler, and screenhouses with multiclone and wet scrubber[c] (3-05-___-__)	0.32	D
Kiln and cooler with multiclone and wet scrubber[d] (3-05-___-__)	0.65	D
Rotary dryer with wet scrubber (3-05-___-__)	e	

[a] Factors represent uncontrolled emissions unless noted.
[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.
[c] Reference 9.
[d] Reference 10.
[e] Reference 3. Process rates are confidential.

Table 8.32-5 (ENGLISH UNITS)
EMISSION FACTORS FOR FULLER'S EARTH PROCESSING[a]

All Emission Factors in lb/ton Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	Filterable PM[b]	
Kiln, cooler, and screenhouses with multiclone and wet scrubber[c] (3-05-___-__)	0.63	D
Kiln and cooler with multiclone and wet scrubber[d] (3-05-___-__)	1.3	D
Rotary dryer with wet scrubber (3-05-___-__)	e	

[a] Factors represent uncontrolled emissions unless noted.
[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.
[c] Reference 9.
[d] Reference 10.
[e] Reference 3. Process rates are confidential.

Table 8.32-6 (METRIC UNITS)
EMISSION FACTORS FOR KAOLIN PROCESSING[a]

All Emission Factors in kg/Mg Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	CO_2	
Spray dryer with fabric filter[b] (3-05-___-__)	81	D
Apron dryer[c] (3-05-___-__)	140	D
Multiple hearth furnace (3-05-___-__)	d	
Flash calciner (3-05-___-__)	d	

[a] Factors represent uncontrolled emissions unless noted.
[b] Reference 5.
[c] Reference 6.
[d] Reference 8. Process rates are confidential.

Table 8.32-6 (ENGLISH UNITS)
EMISSION FACTORS FOR KAOLIN PROCESSING[a]

All Emission Factors in lb/ton Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	CO_2	
Spray dryer with fabric filter[b] (3-05-___-__)	161	D
Apron dryer[c] (3-05-___-__)	280	D
Multiple hearth furnace (3-05-___-__)	d	
Flash calciner (3-05-___-__)	d	

[a] Factors represent uncontrolled emissions unless noted.
[b] Reference 5.
[c] Reference 6.
[d] Reference 8. Process rates are confidential.

Table 8.32-7 (METRIC UNITS)
EMISSION FACTORS FOR FULLER'S EARTH PROCESSING[a]

All Emission Factors in kg/Mg Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	CO_2	
Kiln and cooler (3-05-___-__)	280	D

[a] Reference 10. Factors represent uncontrolled emissions unless noted.

Table 8.32-7 (ENGLISH UNITS)
EMISSION FACTORS FOR FULLER'S EARTH PROCESSING[a]

All Emission Factors in lb/ton Produced Unless Noted
Ratings (A-E) Follow Each Emission Factor

Source (SCC)	CO_2	
Kiln and cooler (3-05-___-__)	560	D

[a] Reference 10. Factors represent uncontrolled emissions unless noted.