EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 11.21 (Formerly 8.18)
Phosphate Rock Processing

1. INTRODUCTION

The document Compilation of Air Pollutant Emissions 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 8.18, Phosphate Rock Processing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the phosphate rock 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 phosphate rock processing. Section 3 is a review of emission 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 revisions to the existing AP-42 section narrative and pollutant emission factor development. It includes the review of specific data sets and the results of data analysis. Section 5 presents the AP-42 Section 8.18, Phosphate Rock Processing.

2. INDUSTRY DESCRIPTION

The separation of phosphate rock from impurities and nonphosphate materials, for use in fertilizer manufacture, consists of beneficiation, drying or calcining at some operations, and grinding stages. Because the primary use of phosphate rock is in the manufacture of phosphatic fertilizer, only those phosphate rock processing operations associated with fertilizer manufacture are discussed here. Alternative flow diagrams of these operations are shown in Figure 2-1. The Standard Industrial Classification (SIC) code for phosphate rock processing is 1475. The six-digit Source Classification Code (SCC) for phosphate rock processing is 3-05-019.

2.1 CHARACTERIZATION OF THE INDUSTRY[1,2]

There are a total of 35 phosphate rock processing plants in the United States, 23 of which were operational in 1990/91. Table 2-1 lists the plants operating in 1990/91, along with the estimated production capacity for each plant. Florida and North Carolina accounted for 94 percent of the domestic phosphate rock mined and 89 percent of the marketable phosphate rock produced during 1989. Other States in which phosphate rock is mined and processed include Idaho, Montana, Utah, and Tennessee.

2.2 PROCESS DESCRIPTION[3-6]

Phosphate rock from the mines is first sent to beneficiation units to separate sand and clay and to remove impurities. Steps used in beneficiation depend on the type of rock. A typical beneficiation unit for separating phosphate rock mined in Florida begins with wet screening to separate pebble rock, which is larger than 1.43 millimeters (mm) (0.056 inch [in.]), or 14 mesh, and smaller than 6.35 mm (0.25 in.) from the balance of the rock. The pebble rock is shipped as pebble product. The material that is larger than 0.85 mm (0.033 in.), or 20 mesh, and smaller than 14 mesh is separated using hydrocyclones and finer mesh screens and is added to the pebble product. The fraction smaller than 20 mesh is treated by two-stage flotation. The flotation process uses hydrophilic or hydrophobic chemical reagents with aeration to separate suspended particles. Phosphate rock mined in North Carolina does not contain pebble rock. In processing this type of phosphate, 2-mm (0.078 in.) or 10-mesh screens are used. Like Florida rock, the fraction that is less than 10 mesh is treated by two-stage flotation, and the fraction larger than 10 mesh is used for secondary road building.

The two major western phosphate rock ore deposits are located in southeastern Idaho and northeastern Utah, and the beneficiation processes used on materials from these deposits differ greatly. In general, southeastern Idaho deposits require crushing, grinding, and classification. Further processing may include filtration and/or drying, depending on the phosphoric acid plant requirements. Primary size reduction generally is accomplished by crushers(impact) and grinding mills. Some classification of the primary crushed rock may be necessary before secondary grinding (rod milling) takes place. The ground material then passes through hydrocyclones that are oriented in a three-stage countercurrent arrangement. Further processing in the form of chemical flotation may be required. Most of the processes are wet to facilitate material transport and to reduce dust.

Northeastern Utah deposits are lower grade and harder than the southeastern Idaho deposits and require processing similar to the Florida deposits. Extensive crushing and grinding is necessary to liberate phosphate from the material. The primary product is classified with 150- to 200-mesh screens, and the finer material is disposed of with the tailings. The coarser fraction is processed through multiple steps of phosphate flotation and then diluent flotation. Further processing may include

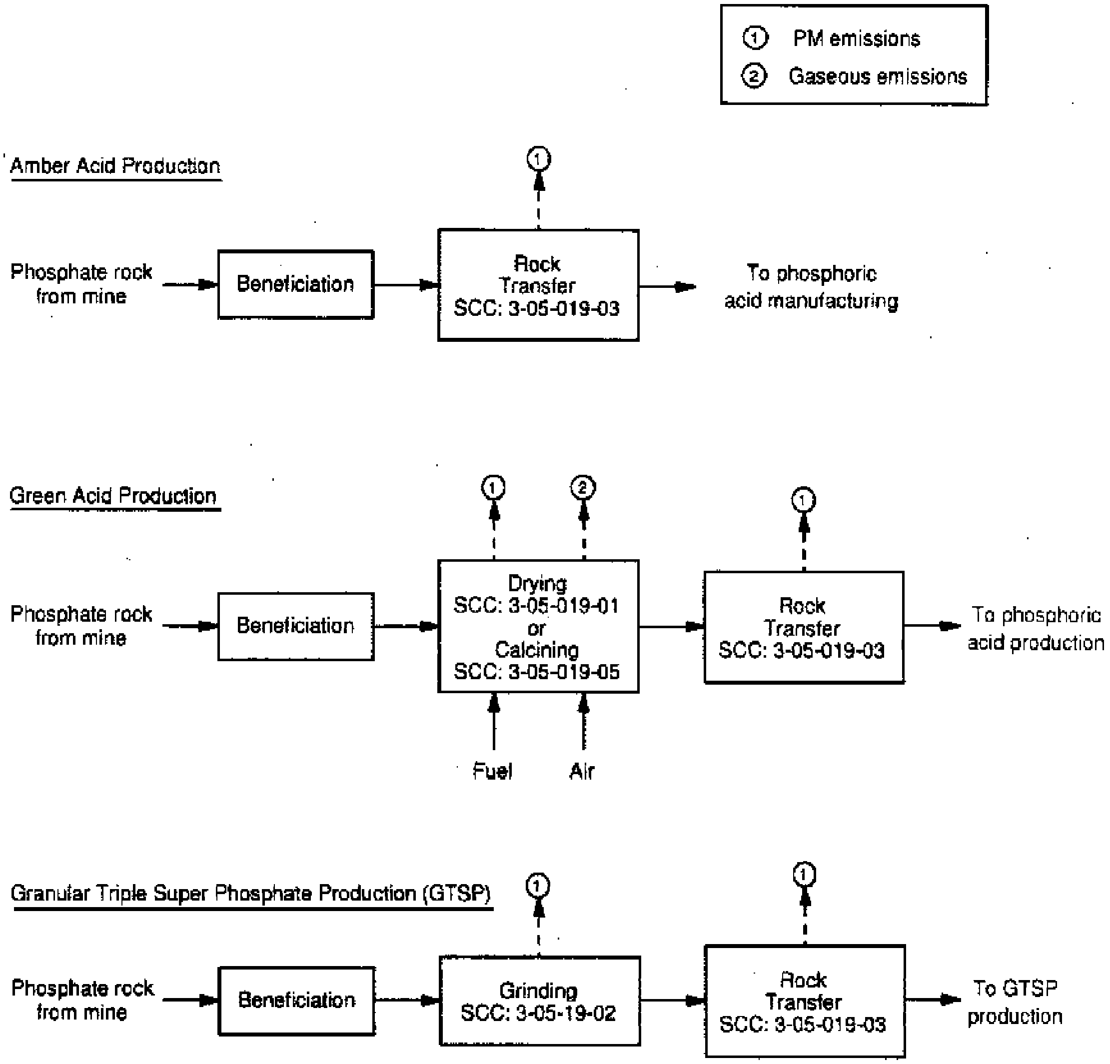

Figure 2-1. Alternate process flow diagrams for phosphate rock processing.[6]

TABLE 2-1. ANNUAL PRODUCTION CAPACITY OF PHOSPHATE ROCK PLANTS OPERATING DURING 1990-1991[1]

Plant name/location	Capacity	
	Mg x 10^3	tons x 10^3
Agrico Chemical (FMRP)		
Fort Green, FL	3,636	4,000
C & G Holdings, Inc.		
Silver City Mine, FL	1,091	1,200
CF Industries, Inc.		
Hardee County, FL	909	1,000
Chevron Chemical Co.		
Vernal, UT	1,182	1,300
Cargill Fertilizer, Inc.		
Fort Meade, FL	2,727	3,000
Cominco		
Garrison, MT	250	275
IMC Fertilizer, Inc.		
Bartow, FL	7,727	8,500
Brewster, FL	4,545	5,000
Four Corners, FL	6,364	7,000
Hopewell, FL	455	500
Mobile Mining & Minerals		
Big Four, FL	2,273	2,500
Nichols, FL	1,364	1,500
Monsanto Co.		
Henry, ID	909	1,000
Nu-Gulf Industries		
Wingate Creek, FL	1,273	1,400
Nu-West Industries		
Dry Valley, ID	1,636	1,800
OxyChem Ag Products, Inc.		
White Springs, FL	5,000	5,500
OxyChem Electrochemicals		
Columbia, TN	455	500
Rhone-Poulenc		
Mt. Pleasant, TN	545	600
Wooley Valley, ID	682	750
Seminole Fertilizer Corp.		
Hooker's Prairie, FL	2,818	3,100
Simplot, J. R., Co.		
Smoky Canyon, WY	1,818	2,000
Texasgulf Chemicals Co.		
Lee Creek, NC	6,000	6,600
US Agri-Chemicals (Sinochem)		
Fort Meade, FL	1,818	2,000
Total United States	55,477	61,025

filtration and/or drying, depending on the phosphoric acid plant requirements. As is the case for southeastern Idaho deposits, most of the processes are wet to facilitate material transport and to reduce dust.

The wet beneficiated phosphate rock may be dried or calcined, depending on its organic content. Florida rock is relatively free of organics and is for the most part no longer dried or calcined. The rock is maintained at about 10 percent moisture and stored at the mine and/or chemical plant in piles for future use. The rock is slurried in water and wet-ground in ball mills or rod mills at the chemical plant. There is no significant emission potential from wet grinding. The small amount of rock that is dried in Florida is dried in direct-fired dryers at about 120°C (250°F); the moisture content of the rock falls from 10 to 15 percent to 1 to 3 percent. Both rotary and fluidized bed dryers are used, but rotary dryers are more common. Most dryers are fired with natural gas or fuel oil (No. 2 or No. 6), with many equipped to burn more than one type of fuel.

Unlike Florida rock, phosphate rock mined from other reserves contains organics and must be heated to 760° to 870°C (1400° to 1600°F) to remove them. Fluidized bed calciners are most commonly used for this purpose, but rotary calciners are also used. After drying, the rock is usually conveyed to storage silos on weather-protected conveyors and, from there, to grinding mills. In North Carolina, a portion of the beneficiated rock is calcined at temperatures generally between 800° and 825°C (1480° and 1520°F) for use in "green" phosphoric acid production, which is used for producing super phosphoric acid and as a raw material for purified phosphoric acid manufacturing. To produce "amber" phosphoric acid, the calcining step is omitted, and the beneficiated rock is transferred directly to the phosphoric acid production processes. Phosphate rock that is to be used for the production of granular triple super phosphate (GTSP) is beneficiated, dried, and ground before being transferred to the GTSP production processes.

Dried or calcined rock is ground in roll or ball mills to a fine powder, typically specified as 60 percent by weight passing a 200-mesh sieve. Rock is fed into the mill by a rotary valve, and ground rock is swept from the mill by a circulating air stream. Product size classification is provided by a "revolving whizzer, which is mounted on top of the ball mill" and by an air classifier. Oversize particles are recycled to the mill, and product-size particles are separated from the carrying air stream by a cyclone.

2.3 EMISSIONS[3-9]

The major emission sources for phosphate rock processing are dryers, calciners, and grinders. These sources emit particulate matter (PM) in the form of fine rock dust and sulfur dioxide (SO_2). Beneficiation has no significant emission potential because the operations involve slurries of rock and water. The majority of mining operations in Florida handle only the beneficiation step at the mine; all wet grinding is done at the chemical processing facility.

Emissions from dryers depend on several factors, including fuel types, air flow rates, product moisture content, speed of rotation, and the type of rock. The pebble portion of Florida rock receives much less washing than the concentrate rock from the flotation processes. It has a higher clay content and generates more emissions when dried. No significant differences have been noted in gas volume or emissions from fluid bed or rotary dryers. A typical dryer processing 230 megagrams per hour (Mg/hr) (250 tons per hour [tons/hr]) of rock will discharge between 31 and 45 dry normal cubic meters per second (dry nm^3/sec) (70,000 and 100,000 dry standard cubic feet per minute [dscfm]) of gas, with a PM loading of 1,100 to 11,000 milligrams per nm^3 (mg/nm^3) (0.5 to 5 grains per dry standard cubic feet [gr/dscf]). Emissions from calciners consist of PM and SO_2 and depend on fuel type (coal or oil), air flow rates, product moisture, and grade of rock.

Phosphate rock contains radionuclides in concentrations that are 10 to 100 times the radionuclide concentration found in most natural material. Most of the radionuclides consist of uranium and its decay products. Some phosphate rock also contains elevated levels of thorium and its daughter products. The specific radionuclides of significance include uranium-238, uranium-234, thorium-230, radium-226, radon-222, lead-210, and polonium-210.

The radioactivity of phosphate rock varies regionally, and within the same region, the radioactivity of the material may vary widely from deposit to deposit. Table 2-2 summarizes data on radionuclide concentrations for domestic deposits of phosphate rock. Materials handling and processing operations can emit radionuclides either as dust, or in the case of radon-222, which is a decay product of uranium-238, as a gas. Phosphate dust particles generally have the same specific activity as the phosphate rock from which the dust originates.

TABLE 2-2. RADIONUCLIDE CONCENTRATIONS OF DOMESTIC PHOSPHATE ROCK[a]

Origin	Typical values, pCi/g
Florida	48 to 143
Tennessee	5.8 to 12.6
South Carolina	267
North Carolina	5.86[b]
Arkansas, Oklahoma	19 to 22
Western States	80 to 123

[a] Reference 8, except where indicated otherwise.
[b] Reference 9.

2.4 CONTROL TECHNOLOGY[3,10]

Scrubbers are most commonly used to control emissions from phosphate rock dryers, but electrostatic precipitators are also used. Fabric filters are not currently being used to control emissions from dryers. Venturi scrubbers with a relatively low pressure loss (3,000 pascals [Pa] [12 in. of water]) may remove 80 to 99 percent of PM 1 to 10 micrometers (µm) in diameter, and 10 to 80 percent of PM less than 1 µm. High-pressure-drop scrubbers (7,500 Pa [30 in. of water]) may have collection efficiencies of 96 to 99.9 percent for PM in the size range of 1 to 10 µm and 80 to 86 percent for particles less than 1 µm. Electrostatic precipitators may remove 90 to 99 percent of total PM. Another control technique for phosphate rock dryers is use of the wet grinding process. In this process, rock is ground in a wet slurry and then added directly to wet process phosphoric acid reactors without drying.

A typical 45 Mg/hr (50 ton/hr) calciner will discharge about 13 to 27 dry nm^3/sec (30,000 to 60,000 dscfm) of exhaust gas, with a PM loading of 0.5 to 5 gr/dscf. The size distribution of the uncontrolled calciner emissions is similar to that of the dryer emissions. As with dryers, scrubbers are the most common control devices used for calciners. At least one operating calciner is equipped with a precipitator. Fabric filters could also be applied.

Oil-fired dryers and calciners have a potential to emit sulfur oxides when high-sulfur residual fuel oils are burned. However, phosphate rock typically contains about 55 percent lime (CaO), which reacts with the SO_2 to form calcium sulfites and sulfates and thus reduces SO_2 emissions. Dryers and calciners also emit fluorides.

A typical grinder of 45 Mg/hr (50 ton/hr) capacity will discharge about 1.6 to 2.5 dry nm^3/sec (3,500 to 5,500 dscfm) of air containing 0.5 to 5.0 gr/dscf of PM. The air discharged is "tramp air," which infiltrates the circulating streams. To avoid fugitive emissions of rock dust, these grinding processes are operated at negative pressure. Fabric filters, and sometimes scrubbers, are used to control grinder emissions. Substituting wet grinding for conventional grinding reduces the potential for PM emissions.

Emissions from material handling systems are difficult to quantify, because several different systems are used to convey rock. Moreover, a large portion of the PM from materials handling operations is generated as fugitive emissions. Conveyor belts moving dried rock are usually covered and sometimes enclosed. Transfer points are sometimes hooded and evacuated. Bucket elevators are usually enclosed and evacuated to a control device, and ground rock is generally conveyed in totally enclosed systems with well-defined and easily controlled discharge points. Dry rock is normally stored in enclosed bins or silos, which are vented to the atmosphere, with fabric filters frequently used to control emissions.

The new source performance standard (NSPS) for phosphate rock plants was promulgated in April 1982 (40 CFR 60 Subpart NN). This standard limits PM emissions and opacity for phosphate rock calciners, dryers, and grinders and limits opacity for handling and transfer operations.

REFERENCES FOR SECTION 2

1. North American Fertilizer Capacity Data, TVA/NFERC-91/14, Circular Z-305, Tennessee Valley Authority, Muscle Shoals, AL, December 1991.

2. Minerals Yearbook, Volume I, Metals and Minerals, Bureau of Mines, U.S. Department of the Interior, Washington D.C., 1991.

3. Background Information: Proposed Standards for Phosphate Rock Plants (Draft), EPA-450/3-79-017, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1979.

4. Written communication from M. S. Batts, Florida Phosphate Council, to R. Myers, Emission Inventory Branch, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 12, 1992.

5. Written communication from K. T. Johnson, The Fertilizer Institute, to R. Myers, Emission Inventory Branch, U. S. Environmental Protection Agency, Research Triangle Park, NC, April 30, 1992.

6. Written communication from K. T. Johnson, The Fertilizer Institute, to R. Myers, Emission Inventory Branch, U. S. Environmental Protection Agency, Research Triangle Park, NC, February 12, 1993.

7. Background Information Document: Proposed Standards for Radionuclides, EPA 520/1-83-001, U. S. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C., March 1983.

8. R. T. Stula, et al., Control Technology Alternatives and Costs for Compliance--Elemental Phosphorus Plants, Final Report, EPA Contract No. 68-01-6429, Energy Systems Group, Science Applications, Incorporated, La Jolla, CA, December 1, 1983.

9. Telephone communication from B. Peacock, Texasgulf, Incorporated, to R. Marinshaw, Midwest Research Institute, Cary, NC, April 4, 1993.

10. "Sources of Air Pollution and Their Control," Air Pollution, Volume III, 2nd Ed., Arthur Stern, ed., New York, Academic Press, 1968, pp. 221-222.

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 AP-42 Background Files located in the Emission Inventory Branch (EIB) were 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, Census of Minerals, and other sources. 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 Method Storage and Retrieval (TSAR) data base was conducted to identify test reports for sources within the phosphate rock 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 Minerals, 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 phosphate rock processing industry. In addition, representative trade associations, including the American Mining Congress, the Fertilizer Institute, the Potash and Phosphate Institute, and the Florida Phosphate Council, 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. An exception to this criterion was made for background information documents (BID's) for proposed standards, provided run-by-run emission and production rate data were included in the document.

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).

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[1]

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 are 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[1]

The quality of the emission factors developed from analyzing the test data was rated using 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. 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 upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Chapter 4 of this report.

REFERENCE 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 REVISION OF SECTION NARRATIVE

Based on comments received from two trade associations, the narrative to Section 8.18 was revised to reflect current practices in the phosphate rock processing industry. The majority of the revisions provide details on differences in the processing of phosphate rock mined from the various regions of the country. Additional information on emissions has also been incorporated into the draft section narrative.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

A total of 20 emission test reports were documented and reviewed in the process of developing the section on phosphate rock mining and beneficiation. Three of the tests (References 1, 2, and 3) were conducted as part of emission test programs to develop background information for the phosphate rock NSPS, and three of the tests (References 5, 8, and 9) were conducted as part of the test program for an NSPS for elemental phosphorus plants. These tests were sponsored by EPA. Two of the tests (References 10 and 11) were conducted to obtain data for the development of a national emission standard for hazardous air pollutants (NESHAP) to limit emissions of radionuclides from the elemental phosphorus industry. These tests were also sponsored by EPA. The other 12 test reports reviewed were industry-sponsored compliance tests (References 4, 6, 7 and 12 to 20). Seven of the 20 references could not be used for developing emission factors. References 5, 8, and 9 were rejected because the process tested, elemental phosphorus furnace slag tapping, is not included in the scope of AP-42 Section 8.18, which addresses phosphate rock beneficiation processes. In addition, the production rates were not provided in these three test reports. References 6, 7, 10, and 11 were rejected because production rates were not included in the reports. For two of these (References 10 and 11), the process data are considered confidential business information (CBI) and were not available. Table 4-1 lists the reasons for rejecting these references.

Information obtained from two other documents (References 12 and 13) was used to develop radionuclide emission factors for some phosphate rock processing operations based on the radioactivity of the rock. In addition, the test data presented in Appendix C of the BID for the phosphate rock plant NSPS (Reference 14) was also used to develop emission factors.

4.2.1 Review of Specific Data Sets

4.2.1.1 Reference 1. The International Minerals And Chemical Corporation, Kingsford, Florida, test was sponsored by EPA. The test was conducted as part of the emission test program for the development of an NSPS for the phosphate rock industry.

Uncontrolled and controlled emissions from a phosphate rock fluidized bed dryer were tested. The dryer was fueled with natural gas. A vertical spray chamber scrubber was used to control emissions from the dryer. Filterable and condensible inorganic PM, total fluoride, water-soluble fluoride, carbon monoxide (CO), and carbon dioxide (CO_2) emissions were quantified. The test methods for PM and fluorides were EPA Method 5 and draft EPA Method 13, respectively. The back half of the Method 5 sampling train was analyzed by rinsing the filter holder, impingers, and connectors first with distilled water and then with acetone. For sources that emit significant levels of SO_2, this can result in the formation of sulfates, which would result in an overestimate of condensible PM emissions. However, because the dryer was gas-fired, SO_2 emissions are likely to have been

TABLE 4-1. TEST REPORTS REJECTED FOR EMISSION FACTOR DEVELOPMENT

Reference No.	Facility name	Reason for rejection
5	Stauffer Chemical Co.	Not phosphate rock beneficiation; no feed or production rates provided
6	J.R. Simplot Company	No feed or production rates provided
7	J.R. Simplot Company	No feed or production rates provided
8	Stauffer Chemical Co.	Not phosphate rock beneficiation; no feed or production rates provided
9	Monsanto Chemical Co.	Not phosphate rock beneficiation; only one test run has a production rate
10	Monsanto Elemental Phosphorus Plant	Process data is CBI; not included in report
11	FMC	Process data is CBI; not included in report

negligible. Carbon dioxide and CO were measured from a flue gas sample that was collected in a Mylar bag during the PM test. Three test runs were conducted at both the inlet and outlet of the scrubber.

A rating of A was assigned to the test data. The report included adequate detail, the methodology appeared to be sound, and no problems were reported during the valid test runs.

4.2.1.2 Reference 2. The Occidental Chemical Company, White Springs, Florida, test was also sponsored by EPA. The purpose of the test was to obtain data for the Industrial Studies Branch of EPA to use for evaluating the phosphate rock industry. Uncontrolled and controlled emissions from a gas-fired, fluidized-bed dryer and from a phosphate rock grinder were tested. Emissions from the dryer were controlled with a cyclone (for product recovery) followed by a cyclonic wet scrubber. Emissions from the grinding process were ducted to a cyclone for product recovery and then to a fabric filter, which operated at a temperature of 43° to 49°C (110° to 120°F). Filterable and condensible inorganic PM, total fluoride, water-soluble fluoride, and CO_2 emissions were quantified. Filterable PM emissions also were measured from the grinding process. The test methods for PM and fluorides were EPA Method 5 and draft EPA Method 13, respectively. The back half of the Method 5 sampling train was analyzed by rinsing the filter holder, impingers, and connectors first with distilled water and then with acetone. For sources that emit significant levels of SO_2, this can result in the formation of sulfates, which would result in an overestimate of condensible PM emissions. However, because the dryer was gas-fired, SO_2 emissions are likely to have been negligible. Carbon dioxide from a flue gas sample was measured using an Orsat analyzer.

Three test runs were conducted at the inlet to the dryer scrubber. The fluoride test runs at the scrubber inlet were not valid. Three test runs for filterable PM, condensible PM, and fluorides were conducted at the scrubber outlet. The impinger from the third test run for total PM was broken, leaving two valid data sets from which to calculate condensible PM emission factors. Carbon dioxide samples were taken during each test run.

Emissions from the grinder were controlled by fabric filters. Three test runs for filterable and condensible PM were conducted at the inlet and outlet to the grinder fabric filters. The inlet tests were invalid due to isokinetic testing conditions.

A rating of A was assigned to the test data. The report included adequate detail, the methodology appeared to be sound, and no problems were reported during the valid test runs.

4.2.1.3 Reference 3. The International Minerals and Chemical Corporation, Noralyn, Florida, test was sponsored by EPA. The test was conducted as part of the emission test program for the development of an NSPS for the phosphate rock industry.

Uncontrolled and controlled emissions from a phosphate rock grinder were tested. Emissions from the grinder were controlled with a fabric filter. Filterable and condensible inorganic PM emissions were quantified. The test method for PM was EPA Method 5. The back half of the Method 5 sampling train was analyzed by rinsing the filter holder, impingers, and connectors first with distilled water and then with acetone. For sources that emit significant levels of SO_2, this can result in the formation of sulfates, which would result in an overestimate of condensible PM emissions. However, because combustion is required for the grinding process, SO_2 emissions are likely to have been negligible. Three test runs were conducted at both the inlet and outlet of the fabric filter. The second inlet test run was not valid due to isokinetic testing conditions.

A rating of A was assigned to the test data. The report included adequate detail, the methodology appeared to be sound, and no problems were reported during the valid test runs.

4.2.1.4 References 4 and 12-20. These reports document 10 emission tests on 6 phosphate rock calciners located at the same facility. The calciners are fired with a mixture of coal and coke. The tests included measurements of emissions of filterable PM, condensible inorganic PM, condensible organic PM, SO_2, and CO_2. Table 4-2 lists the tests conducted on each of the calciners. The purpose of the emission tests was to demonstrate compliance with State regulations; the tests were conducted during 1990, 1991 and 1992. Process rates were provided on a raw material dry feed basis.

Emissions from each calciner are controlled with a separate venturi scrubber. However, details on the control devices were not provided in the test reports.

Filterable PM emissions were measured using Method 5; condensible PM emissions were measured using Method 202; SO_2 emissions were measured using Method 6; and CO_2 concentrations in the exhaust streams were measured by Orsat. For each of the tests, three runs were conducted. Emission factors were developed for controlled filterable PM, condensible inorganic PM, condensible organic PM, SO_2, and CO_2 emissions from the calciners.

The emission data are rated B. The test methodologies were sound and no problems were reported, but the report lacked adequate documentation for higher emission data ratings.

4.2.1.5 References 21 and 22. These two documents provided information on the radioactivity of various deposits of phosphate rock and indicated that the specific activity of PM is the

TABLE 4-2. TESTS CONDUCTED ON PHOSPHATE ROCK CALCINERS[a]

Calciner No.	Pollutant	No. of tests	References
1	PM	1	15
1	SO_2	1	4
1	CO_2	1	15
2	PM	2	16, 20
2	CO_2	2	16, 20
3	PM	1	19
3	CO_2	1	19
4	PM	2	12, 14
4	CO_2	2	12, 14
5	PM	1	17
5	CO_2	1	17
6	PM	2	13, 18
6	CO_2	2	13, 18

[a] All tests conducted at the same facility. PM tests include measurements of filterable PM, condensible inorganic PM, and condensible organic PM.

same as that of the rock. Based on this information, order of magnitude emission factors were developed for radionuclide emissions from phosphate rock grinding as the product of the PM emission rate and the specific activity of the rock. These are expressed as follows:

$$EF_r = EF_p \times R$$

where:

EF_r is the radionuclide emission factor in units of picocuries (pCi) per unit mass;
EF_p is the PM emission factor (combined filterable and condensible inorganic); and
R is the specific activity of the phosphate rock in units of picocuries per gram (pCi/g).

This results in the following emission factors for radionuclide emissions from phosphate rock grinding:

800R	(uncontrolled emissions in units of pCi/Mg);
730R	(uncontrolled emissions in units of pCi/ton);
5.2R	(fabric filter controlled emissions in units of pCi/Mg); and
4.7R	(fabric filter controlled emissions in units of pCi/ton).

4.2.2 Review of XATEF and SPECIATE Data Base Emission Factors

The SPECIATE data base includes emission factors for a number of speciated inorganic and volatile organic compounds (VOC's) from phosphate rock drying, grinding, transfer/storage, open storage, and calcining. However, the emission factors are all surrogates, which are based on averages for the mineral products industry as a whole.

The XATEF data base includes emission factors for radionuclides from phosphate rock processing. The reference cited for this information (Background Information Document, Proposed Standards for Radionuclides, EPA 520/1-83-001, Office of Radiation Programs, Washington, D.C., March 1983), which provides emission factors for five radionuclides, is a secondary reference. The primary reference for the emission data (Radiation Dose Estimates Due to Air Particulate Emissions From Selected Phosphate Industry Operations, ORP/EERF-78-1, Office of Radiation Programs, Montgomery, Alabama, 1978), could not be obtained in time for this review. For that reason, those emission factors have not been incorporated into the draft revision to the section described here.

4.2.3 Review of Test Data in AP-42 Background File

The current version of Section 8.18 includes uncontrolled PM emission factors for phosphate rock drying, calcining, grinding, transfer and storage, and open storage pile emissions. The emission factors for drying, calcining, and grinding are referenced to the BID for proposed standards for phosphate rock plants (Reference 23). This reference includes run-by-run data on tests conducted at eight plants. However, only the controlled emission data are reported. With the exception of two plants (Plants D and E), the primary references (i.e., the test reports) for these tests could not be obtained. Therefore, only the controlled emissions data, as reported in the background information document, could be used for developing new emission factors. The data for Plants D and E in the phosphate rock BID are accounted for in References 2 and 3, respectively. Because the information contained in the BID lacks adequate detail for adequate validation, these data are assigned a rating of B.

The current version of Section 8.18 also includes average particle size data for phosphate rock dryer and calciner emissions, which are referenced to the phosphate rock NSPS BID. These data are taken directly from Table 4-2 of the phosphate rock BID; run-by-run data for the tests upon which the data are based are not provided in Appendix C of the BID. Although not stated explicitly in the BID, it is assumed that these particle size data are for uncontrolled emissions. Because the primary references for these data could not be located for this review, the data could not be verified. These data are rated C.

The emission factor for transfer and storage is referenced to unpublished test data from 1970. The reference is not found in the background file. Because of the lack of documentation and the age of the test data, the test method and representativeness of the emission data are highly suspect. For this reason, the emission factor for transfer and storage has been rated E.

The emission factor for open storage piles is referenced to a document (Control Techniques for Fluoride Emissions, Internal Document, Office of Air Quality Planning and Standards, September 1970) that provides unreferenced estimates for PM emissions from phosphate rock storage piles. Because of the lack of documentation for the basis of this estimate, which appears to have been based on engineering judgment, this emission factor has been excluded from the draft section. Instead, the draft section refers the reader to Section 11.3, which includes equations for developing emission factors for handling, transfer, and storage.

4.2.4 Results of Data Analysis

Emission factors for controlled filterable and condensible inorganic PM emissions were developed for phosphate rock dryers and grinders. Uncontrolled and controlled emission factors for total and water-soluble fluoride emissions also were developed for phosphate rock dryers and grinders. Emission factors for uncontrolled CO_2 and CO emissions from phosphate rock dryers were developed. For phosphate rock calciners, emission factors were developed for emissions of controlled filterable PM, condensible inorganic PM, condensible organic PM, SO_2, and CO_2. Order of magnitude emission factors for uncontrolled and controlled radionuclide emissions from phosphate rock grinders also were developed, as described above.

The emission factors first were determined on a run-by-run basis and then averaged. In the case of the calciner emission test data, which are all from the same facility, emission factors for separate tests on the same calciner were averaged together and treated as a single data point in the determination of average emission factors for calciners.

The emission factors developed from the phosphate rock plant BID (Reference 23) were averaged with the emission factors developed from test reports. The two exceptions were the data reported for tests at Plants D and E in Reference 23. These tests correspond to those described in References 2 and 3 and thus already had been taken into account.

With the exception of the radionuclide emission factors, the emission factors discussed above for phosphate rock drying and grinding have been developed from A- or B-rated test data, but most of the factors were developed from only one or two emission tests. Because of the relatively large number of phosphate rock processing plants (35), it is likely that these emission factors may not be representative of the industry. For this reason, these emission factors are assigned a rating of D. The radionuclide emission factors are assigned a rating of E and can be used for order of magnitude estimates only because they are not based on direct measurements of radionuclide emissions.

For filterable PM emissions from calcining, the emission factors developed from new test data (eight tests on six calciners at the same facility) were combined with the emission factors from the phosphate rock BID (four tests on two calciners at two facilities) to produce an average emission factor. This emission factor was developed entirely from B-rated data and is assigned a rating of C because it is based on emission tests on a relatively large number of calciners. The average emission factor for condensible inorganic PM emissions from calciners also is based on the new test data (eight tests on six calciners at the same facility) and the phosphate rock BID (two tests on the same calciner) and also is rated C. The average emission factor for condensible organic PM emissions from calciners is based only on the new test data (eight tests on six calciners at the same facility). This emission factor is rated D because the data are taken from a single facility.

Average emission factors for SO_2 and CO_2 emission factors from phosphate rock calciners were developed from the new test data. The SO_2 emission factor is based on two tests on two calciners at the same facility and is rated D. The emission factor for CO_2 emissions is based on nine tests on six calciners at the same facility. This emission factor also is rated D. Although the number of calciners upon which the emission factor is based is relatively large, the data are all from the same facility.

The new emission factors for uncontrolled PM emissions from drying, grinding, and calcining that were developed from References 1, 2, and 3 are comparable to the uncontrolled PM emission factors in the current version of AP-42. Because the emission factors presented in the current version are based on more emission tests than the new factors developed for this review, no changes are proposed to the existing uncontrolled PM emission factors for phosphate rock processing. However, these emission factors are presented as uncontrolled "filterable PM" emission factors, rather than as simply uncontrolled "PM" emission factors in the revised AP-42 Section. Currently, these emission factors are rated B. However, because they are based on tests at a small number of plants, the emission factors for drying and calcining (based on two plants) are downrated to D, and the emission factors for grinding (based on four plants) are downrated to C in the proposed revision.

The particle size distribution data for dryers and calciners from the current version of Section 8.18 also have been retained in the revised version of the section. Because the data have been assigned a rating of C, the particle size distribution presented in the revised section, and size-specific emission factors based on that data, are assigned a rating of E. These data were used develop uncontrolled PM-10 emission factors for phosphate rocks dryers and calciners. These PM-10 emission factors also are rated E.

Table 4-3 summarizes the emission data for filterable PM, condensible inorganic PM, water-soluble fluoride, total fluoride, CO_2, and CO from dryers. Table 4-4 summarizes the emission data for filterable and condensible PM from grinders. Table 4-5 summarizes the emission factors for filterable PM, condensible inorganic PM, condensible organic PM, SO_2 and CO_2 emissions from phosphate rock calciners. Table 4-6 provides a summary of the new emission factors developed from the phosphate rock plant BID. Table 4-7 provides a summary of emission factors developed for phosphate rock processing. The table includes the number of tests upon which the emission factors are based, identifies the references for the test data, and indicates the emission factor ratings. Table 4-7 does not include the emission factors for uncontrolled PM emissions from phosphate rock drying, grinding, calcining, transfer, and storage and particle size distribution, which, with the exception of the emission factor for open storage piles, are retained from the current version of Section 8.18.

REFERENCES FOR SECTION 4

1. Emission Test Report: International Minerals and Chemical Corporation, Kingsford, Florida, EMB Report 73-ROC-1, U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1973.

2. Emission Test Report: Occidental Chemical Company, White Springs, Florida, EMB Report 73-ROC-3, U. S. Environmental Protection Agency, Research Triangle Park, NC, January 1973.

3. Emission Test Report: International Minerals and Chemical Corporation, Noralyn, Florida, EMB Report 73-ROC-2, U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1973.

4. Sulfur Dioxide Emission Rate Test, No. 1 Calciner, Texasgulf Incorporated, Aurora, North Carolina, Texasgulf Environmental Section, Aurora, NC, May 1990.

TABLE 4-3. SUMMARY OF TEST DATA FOR PHOSPHATE ROCK DRYERS

Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
				Range, kg/mg (lb/ton)	Average, kg/Mg (lb/ton)	
None	Filterable PM	3	A	1.2-1.6 (2.3-3.3)	1.4 (2.7)	1
None	Condensible inorganic PM	3	A	0.021-0.055 (0.041-0.11)	0.034 (0.068)	1
None	Fluoride, H_2O-soluble	3	A	0.00055-0.0013 (0.0011-0.0025)	0.00085 (0.0017)	1
None	Fluoride, total	3	A	0.033-0.042 (0.065-0.084)	0.037 (0.073)	1
None	CO_2	6	A	21-31 (42-62)	26 (51)	1
None	CO	6	A	0-0.28 (0.056)	0.020 (0.041)	1
Scrubber	Filterable PM	3	A	0.025-0.06 (0.049-0.12)	0.038 (0.076)	1
Scrubber	Condensible inorganic PM	3	A	0.009-0.018 (0.017-0.035)	0.013 (0.026)	1
Scrubber	Fluoride, H_2O-soluble	3	A	0.0003-0.0009 (0.0006-0.0018)	0.00068 (0.0014)	1
Scrubber	Fluoride, total	3	A	0.0009-0.010 (0.0018-0.019)	0.0038 (0.0076)	1
None	Filterable PM	3	A	0.24-0.50 (0.47-1.0)	0.40 (0.80)	2
None	Condensible inorganic PM	3	A	0.014-0.032 (0.027-0.063)	0.026 (0.051)	2
None	CO_2	9	A	28-90 (55-180)	52 (100)	2
Scrubber	Filterable PM	3	A	0.022-0.08 (0.043-0.16)	0.047 (0.094)	2
Scrubber	Condensible inorganic PM	2	A	0.007-0.027 (0.014-0.054)	0.017 (0.034)	2
Scrubber	Fluoride, H_2O-soluble	3	A	0.00015-0.00046 (0.0003-0.00091)	0.00027 (0.00053)	2
Scrubber	Fluoride, total	3	A	0.0003-0.00048 (0.0006-0.00096)	0.00040 (0.00079)	2

TABLE 4-4. SUMMARY OF TEST DATA FOR PHOSPHATE ROCK GRINDING[a]

Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
				Range, kg/mg (lb/ton)	Average, kg/Mg (lb/ton)	
None	Filterable PM	2	A	1.1-1.3 (2.2-2.6)	1.2 (2.4)	3
None	Condensible inorganic PM	2	A	0.0026-0.0038 (0.0051-0.0076)	0.0032 (0.0064)	3
Fabric filter	Filterable PM	3	A	0.0036-0.0049 (0.0072-0.0097)	0.0044 (0.0088)	2
Fabric filter	Condensible inorganic PM	3	A	0.0010-0.0017 (0.0020-0.0033)	0.0014 (0.0027)	2
Fabric filter	Filterable PM	3	A	0.0016-0.0023 (0.0031-0.0055)	0.0021 (0.0042)	3
Fabric filter	Condensible inorganic PM	3	A	0.0013-0.0036 (0.0026-0.0072)	0.0023 (0.0046)	3

[a] Dry grinding process only.

TABLE 4-5. SUMMARY OF TEST DATA FOR PHOSPHATE ROCK CALCINERS[a]

Pollutant	No. runs	Emission factor, kg/Mg			Emission factor, lb/ton			Ref. No.
		Minimum	Maximum	Average	Minimum	Maximum	Average	
SO_2	3	0.0028	0.0043	0.0034	0.0055	0.0086	0.0068	4
Filterable PM	3	0.079	0.084	0.082	0.16	0.17	0.16	12
Condensible inorganic PM	3	0.0026	0.0055	0.0043	0.0052	0.011	0.0085	12
Condensible organic PM	3	0.0099	0.018	0.014	0.020	0.035	0.027	12
CO_2	3	130	130	130	270	270	270	12
SO_2	3	0.0033	0.0036	0.0035	0.0067	0.0072	0.0069	13
CO_2	3	100	110	110	200	220	210	13
Filterable PM	3	0.074	0.087	0.081	0.15	0.17	0.16	14
Condensible inorganic PM	3	0.0010	0.013	0.0073	0.0020	0.027	0.015	14
Condensible organic PM	3	0.021	0.059	0.044	0.041	0.12	0.088	14
CO_2	3	52	60	57	110	120	110	14
Filterable PM	3	0.15	0.34	0.21	0.30	0.68	0.43	15
Condensible inorganic PM	3	0.0041	0.0071	0.0060	0.0082	0.014	0.012	15
Condensible organic PM	3	0.014	0.067	0.037	0.027	0.13	0.073	15
CO_2	3	130	130	130	250	260	260	15
Filterable PM	3	0.11	0.12	0.12	0.22	0.24	0.23	16
Condensible inorganic PM	3	0.0012	0.0037	0.0021	0.0024	0.0074	0.0042	16
Condensible organic PM	3	0.016	0.023	0.021	0.033	0.046	0.042	16
CO_2	3	110	110	110	220	220	220	16
Filterable PM	3	0.10	0.11	0.10	0.20	0.22	0.21	17
Condensible inorganic PM	3	0.014	0.029	0.023	0.029	0.057	0.046	17
Condensible organic PM	3	0.0088	0.018	0.013	0.018	0.035	0.027	17
CO_2	3	150	150	150	290	290	290	17
Filterable PM	3	0.071	0.096	0.084	0.14	0.19	0.17	18

TABLE 4-5. (continued)

Pollutant	No. runs	Emission factor, kg/Mg			Emission factor, lb/ton			Ref. No.
		Minimum	Maximum	Average	Minimum	Maximum	Average	
Condensible inorganic PM	3	0.0035	0.0097	0.0057	0.0071	0.019	0.011	18
Condensible organic PM	3	0.045	0.076	0.062	0.090	0.15	0.12	18
CO_2	3	96	98	97	190	200	190	18
Filterable PM	3	0.089	0.10	0.095	0.18	0.20	0.19	19
Condensible inorganic PM	2	0.0022	0.0041	0.0032	0.0044	0.0083	0.0063	19
Condensible organic PM	3	0.060	0.15	0.10	0.12	0.31	0.21	19
CO_2	3	91	95	94	180	190	190	19
Filterable PM	3	0.077	0.095	0.084	0.15	0.19	0.17	20
Condensible inorganic PM	3	8.1×10^{-5}	0.0023	0.0013	0.00016	0.0046	0.0026	20
Condensible organic PM	3	0.015	0.028	0.020	0.030	0.057	0.040	20
CO_2	3	120	130	120	240	250	240	20

[a] All calciners controlled with venturi scrubbers; all data rated B; all tests conducted at same facility.

TABLE 4-6. SUMMARY OF TEST DATA FOR PHOSPHATE ROCK BID, APPENDIX C[23]

Process	Type of control	Pollutant	No. of test runs	Emission factor		Plant
				Range, kg/mg (lb/ton)	Average, kg/Mg (lb/ton)	
Dryer	Scrubber	Filterable PM	5	0.017-0.024 (0.034-0.047)	0.019 (0.039)	A
		Condensible inorganic PM	5	0.012-0.055 (0.024-0.11)	0.031 (0.061)	
Dryer	ESP	Filterable PM	3	0.012-0.019 (0.023-0.038)	0.016 (0.033)	B
		Condensible inorganic PM	3	0.004-0.005 (0.007-0.009)	0.004 (0.008)	
Calciner	Scrubber	Filterable PM	11	0.05-0.16 (0.10-0.31)	0.085 (0.17)	C
		Condensible inorganic PM	6	0.005-0.02 (0.01-0.04)	0.01 (0.02)	
Calciner	Scrubber	Filterable PM	3	0.041-0.054 (0.082-0.107)	0.047 (0.095)	K
Calciner	Scrubber	Fluoride, total	6	0.0003-0.0015 (0.0006-0.0030)	0.00081 (0.0016)	C
Grinder	Fabric filter	Filterable PM	3	0.00060-0.00075 (0.0012-0.0015)	0.00067 (0.0013)	F
		Condensible inorganic PM	3	0.0002-0.0004 (0.0003-0.0008)	0.0003 (0.0006)	
Grinder	Fabric filter	Filterable PM	6	0.0003-0.0030 (0.0006-0.0060)	0.0014 (0.0027)	G
		Condensible inorganic PM	3	0.0000-0.0005 (0.0000-0.0009)	0.0002 (0.0004)	

TABLE 4-7. SUMMARY OF NEW EMISSION FACTORS DEVELOPED FOR PHOSPHATE ROCK PROCESSING

Process	Type of control	Pollutant	No. of tests	Average emission factor, kg/Mg (lb/ton)	Emission factor rating	Ref. No.
Dryer	None	PM-10	Not specified	2.4 (4.8)	E	23
Dryer	None	Fluoride, H_2O-soluble	1	0.00085 (0.0017)	D	1
Dryer	None	Fluoride, total	1	0.037 (0.073)	D	1
Dryer	None	CO_2	2	43 (86)	D	1,2
Dryer	None	CO	1	0.17 (0.34)	D	1
Dryer	Scrubber	Filterable PM	3	0.035 (0.070)	D	1,2,23
Dryer	Scrubber	Condensible inorganic PM	2	0.015 (0.030)	D	1,2,23
Dryer	Scrubber	Fluoride, H_2O-soluble	2	0.00048 (0.00095)	D	1,2
Dryer	Scrubber	Fluoride, total	2	0.0048 (0.0096)	D	1,2
Dryer	ESP	Filterable PM	1	0.016 (0.033)	D	23
Dryer	ESP	Condensible inorganic PM	1	0.004 (0.008)	D	23
Grinder[a]	Fabric filter	Filterable PM	2	0.0022 (0.0043)	D	2,3
Grinder[a]	Fabric filter	Condensible inorganic PM	4	0.0011 (0.0021)	D	2,3,23
Grinder[a]	None	Radionuclides	--	800R (730R)[b]	E	21,22
Grinder[a]	Fabric filter	Radionuclides	--	5.2R (4.7R)[b]	E	21,22
Calciner	None	PM-10	Not specified	7.4 (15)	E	23
Calciner	Scrubber	Filterable PM	12	0.010 (0.20)	C	12-20-23
Calciner	Scrubber	Condensible inorganic PM	10	0.0079 (0.016)	C	12-20,23
Calciner	Scrubber	Considerable organic PM	8	0.044 (0.088)	D	12-20
Calciner	Scrubber[c]	CO_2	9	115 (230)	D	12-20
Calciner	Scrubber	Fluoride, total	1	0.00081 (0.0016)	D	23
Calciner	Scrubber	SO_2	2	0.0034 (0.0069)	D	4,13

[a] Dry grinding process only.
[b] In units of pci/Mg (pCi/ton), where R is the specific activity of phosphate rock in units of pCi/g.
[c] Scrubbers achieve only incidental control of CO_2.

5. Emission Test Report: Stauffer Chemical Company, Mt. Pleasant, Tennessee, EMB Report 72-MM-04, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1972.

6. Stack Test Report, J.R. Simplot Company, Don Plant, No. 2 Mill, Pocatello, Idaho, J.R. Simplot Company, Pocatello, ID, May 1990.

7. Stack Test Report, J.R. Simplot Company, No. 300 Calciner, Pocatello, Idaho, J.R. Simplot Company, Pocatello, ID, May 1990.

8. Emission Test Report: Stauffer Chemical Company, Tarpon Springs, Florida, EMB Report 72-MM-05, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1972.

9. Emission Test Report: Monsanto Chemical Company, Soda Springs, Idaho, EMB Report 72-MM-27, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1972.

10. Emission Test Report: Monsanto Elemental Phosphorus Plant, Soda Springs, Idaho, EMB Report 88-EPP-01, U. S. Environmental Protection Agency, Research Triangle Park, NC, January 1989.

11. Emission Test Report: FMC, Pocatello, Idaho, EMB Report 88-EPP-02, U. S. Environmental Protection Agency, Research Triangle Park, NC, January 1989.

12. Source Performance Test, Calciner Number 4, Texasgulf, Inc., Phosphate Operations, Aurora, NC, August 28, 1991, Texasgulf, Incorporated, Aurora, NC, September 25, 1991.

13. Source Performance Test, Calciner Number 6, Texasgulf, Inc., Phosphate Operations, Aurora, NC, August 5 and 6, 1992, Texasgulf, Incorporated, Aurora, NC, September 17, 1992.

14. Source Performance Test, Calciner Number 4, Texasgulf, Inc., Phosphate Operations, Aurora, NC, June 30, 1992, Texasgulf, Incorporated, Aurora, NC, July 16, 1992.

15. Source Performance Test, Calciner Number 1, Texasgulf, Inc., Phosphate Operations, Aurora, NC, June 10, 1992, Texasgulf, Incorporated, Aurora, NC, July 8, 1992.

16. Source Performance Test, Calciner Number 2, Texasgulf, Inc., Phosphate Operations, Aurora, NC, July 7, 1992, Texasgulf, Incorporated, Aurora, NC, July 16, 1992.

17. Source Performance Test, Calciner Number 5, Texasgulf, Inc., Phosphate Operations, Aurora, NC, June 16, 1992, Texasgulf, Incorporated, Aurora, NC, July 8, 1992.

18. Source Performance Test, Calciner Number 6, Texasgulf, Inc., Phosphate Operations, Aurora, NC, August 4 and 5, 1992, Texasgulf, Incorporated, Aurora, NC, September 21, 1992.

19. Source Performance Test, Calciner Number 3, Texasgulf, Inc., Phosphate Operations, Aurora, NC, August 27, 1992, Texasgulf, Incorporated, Aurora, NC, September 21, 1992.

20. Source Performance Test, Calciner Number 2, Texasgulf, Inc., Phosphate Operations, Aurora, NC, August 21 and 22, 1992, Texasgulf, Incorporated, Aurora, NC, September 20, 1992.

21. R. T. Stula et al., Control Technology Alternatives and Costs for Compliance--Elemental Phosphorus Plants, Final Report, EPA Contract No. 68-01-6429, Energy Systems Group, Science Applications, Incorporated, La Jolla, CA, December 1, 1983.

22. Background Information Document, Proposed Standards for Radionuclides, EPA 520/1-83-001, U. S. Environmental Protection Agency, Washington, D.C., March 1983.

23. Background Information: Proposed Standards for Phosphate Rock Plants (Draft), EPA 450/3-79-017, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1979.