11.21 Phosphate Rock Processing

11.21.1 Process Description[1-5]

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. The Standard Industrial Classification (SIC) code for phosphate rock processing is 1475. The 6-digit Source Classification Code (SCC) for phosphate rock processing is 3-05-019.

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. 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. Alternative flow diagrams of these operations are shown in Figure 11.21-1.

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 that 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 2-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, 10-mesh screens are used. Like Florida rock, the fraction that is less than 10 mesh is treated by 2-stage flotation, and the fraction larger than 10 mesh is used for secondary road building.

The 2 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 3-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 a lower grade and harder than the southeastern Idaho deposits and require processing similar to that of 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 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.

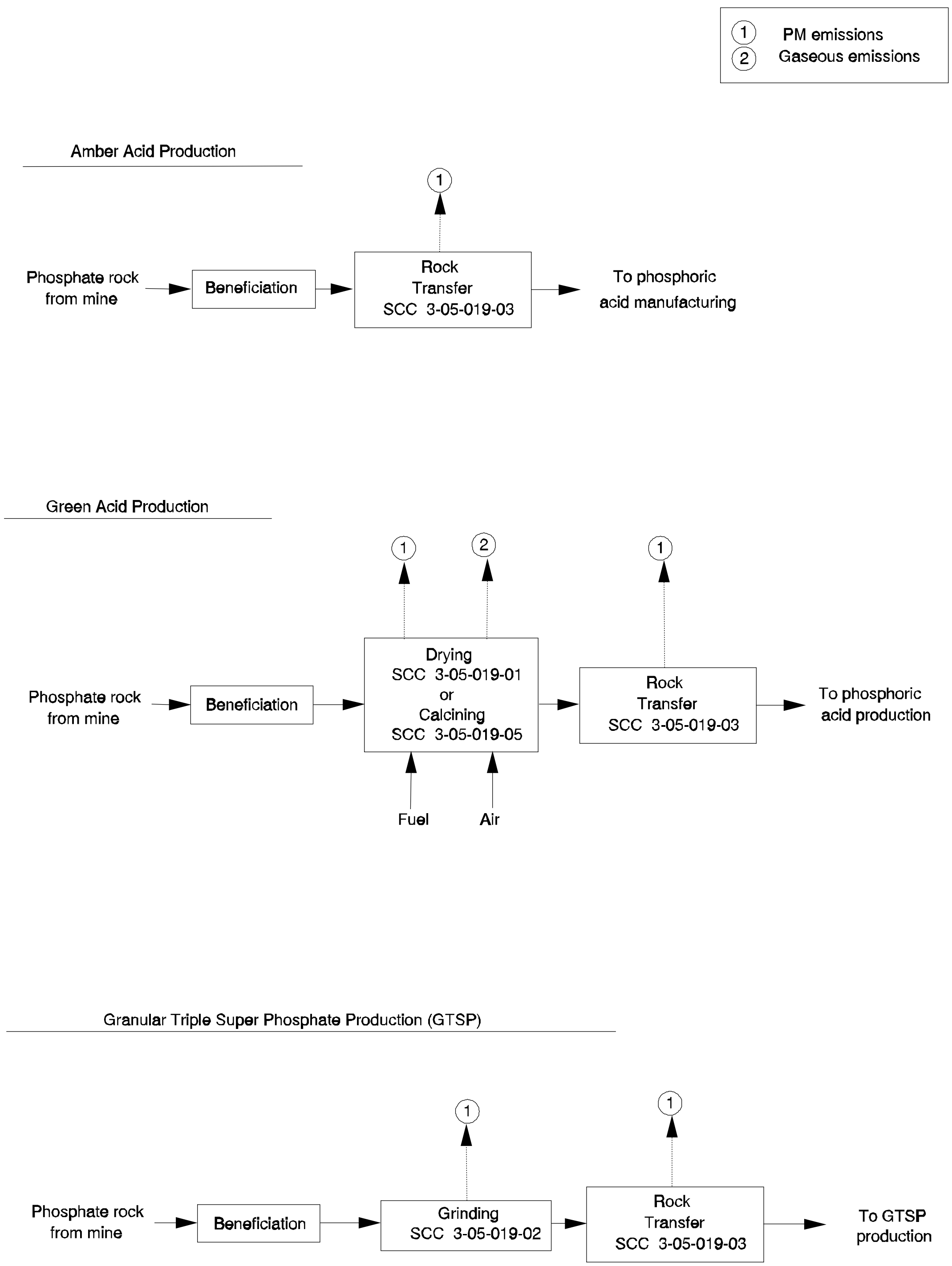

Figure 11.21-1. Alternative process flow diagrams for phosphate rock processing.

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 is stored in piles at the mine and/or chemical plant for future use. The rock is slurried in water and wet-ground in ball mills or rod mills at the chemical plant. Consequently, 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), where 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 1 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.

11.21.2 Emissions And Controls[1,3-9]

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 [ton/hr]) of rock will discharge between 31 and 45 dry normal cubic meters per second (dry normal m^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 dry normal cubic meters (mg/nm^3) (0.5 to 5 grains per dry standard cubic foot [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 11.21-1 summarizes data on radionuclide concentrations (specific activities) for domestic deposits of phosphate rock in picocuries per gram (pCi/g). 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 11.21-1. RADIONUCLIDE CONCENTRATIONS OF DOMESTIC PHOSPHATE ROCK[a]

Origin	Typical Concentration 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. Specific activities in units of picocuries per gram.
[b] Reference 9.

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 all 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 normal m^3/sec (30,000 to 60,000 dscfm) of exhaust gas, with a PM loading of 0.5 to 5 gr/dscf. 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 normal m^3/sec (3,500 to 5,500 dscfm) of air containing 1.14 to 11.4 g/dry normal m^3 (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 would reduce 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 part of the emission potential for these operations is fugitives. 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.

Table 11.21-2 summarizes emission factors for controlled emissions of SO_2 from phosphate rock calciners and for uncontrolled emissions of CO and CO_2 from phosphate rock dryers and calciners. Emission factors for PM emissions from phosphate rock dryers, grinders, and calciners are presented in Tables 11.21-3 and 11.21-4. Particle size distribution for uncontrolled filterable PM emissions from phosphate rock dryers and calciners are presented in Table 11.21-5, which shows that the size distribution of the uncontrolled calciner emissions is very similar to that of the dryer emissions. Tables 11.21-6 and 11.21-7 summarize emission factors for emissions of water-soluble and total fluorides from phosphate rock dryers and calciners. Emission factors for controlled and uncontrolled radionuclide emissions from phosphate rock grinders also are presented in Tables 11.21-6 and 11.21-7. Emission factors for PM emissions from phosphate rock ore storage, handling, and transfer can be developed using the equations presented in Section 13.2.4.

Table 11.21-2 (Metric And English Units). EMISSION FACTORS FOR PHOSPHATE ROCK PROCESSING[a]

EMISSIONS FACTOR RATING: D

Process	SO_2		CO_2		CO	
	kg/Mg Of Total Feed	lb/ton Of Total Feed	kg/Mg Of Total Feed	lb/ton Of Total Feed	kg/Mg Of Total Feed	lb/ton Of Total Feed
Dryer (SCC 3-05-019-01)	ND	ND	43[b]	86[b]	0.17[c]	0.34[c]
Calciner with scrubber (SCC 3-05-019-05)	0.0034[d]	0.0069	115[e]	230[e]	ND	ND

[a] Factors represent uncontrolled emissions unless otherwise noted. SCC = Source Classification Code. ND = no data.
[b] References 10,11.
[c] Reference 10.
[d] References 13,15.
[e] References 14-22.

Table 11.21-3 (Metric Units). EMISSION FACTORS FOR PHOSPHATE ROCK PROCESSING[a]

Process	Filterable PM[b]				Condensable PM[c]			
	PM		PM-10		Inorganic		Organic	
	kg/Mg Of Total Feed	EMISSION FACTOR RATING	kg/Mg Of Total Feed	EMISSION FACTOR RATING	kg/Mg Of Total Feed	EMISSION FACTOR RATING	kg/Mg Of Total Feed	EMISSION FACTOR RATING
Dryer (SCC 3-05-019-01)[d]	2.9	D	2.4	E	ND		ND	
Dryer with scrubber (SCC 3-05-019-01)[e]	0.035	D	ND		0.015	D	ND	
Dryer with ESP (SCC 3-05-019-01)[d]	0.016	D	ND		0.004	D	ND	
Grinder (SCC 3-05-019-02)[d]	0.8	C	ND		ND		ND	
Grinder with fabric filter (SCC 3-05-019-02)[f]	0.0022	D	ND		0.0011	D	ND	
Calciner (SCC 3-05-019-05)[d]	7.7	D	7.4	E	ND		ND	
Calciner with scrubber (SCC 3-05-019-05)	0.10[g]	C	ND		0.0079[g]	C	0.044[h]	D
Transfer and storage (SCC 3-05-019-__)[d]	2	E	ND		ND		ND	

[a] Factors represent uncontrolled emissions unless otherwise noted. SCC = Source Classification Code. ND = no data.
[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.
[c] Condensable PM is that PM collected in the impinger portion of a PM sampling train.
[d] Reference 1.
[e] References 1,10-11.
[f] References 1,11-12.
[g] References 1,14-22.
[h] References 14-22.

Table 11.21-4 (English Units). EMISSION FACTORS FOR PHOSPHATE ROCK PROCESSING[a]

Process	Filterable PM[b]				Condensable PM[c]			
	PM		PM-10		Inorganic		Organic	
	lb/ton Of Total Feed	EMISSION FACTOR RATING	lb/ton Of Total Feed	EMISSION FACTOR RATING	lb/ton Of Total Feed	EMISSION FACTOR RATING	lb/ton Of Total Feed	EMISSION FACTOR RATING
Dryer (SCC 3-05-019-01)[d]	5.7	D	4.8	E	ND		ND	
Dryer with scrubber (SCC 3-05-019-01)[e]	0.070	D	ND		0.030	D	ND	
Dryer with ESP (SCC 3-05-019-01)[d]	0.033	D	ND		0.008	D	ND	
Grinder (SCC 3-05-0190-2)[d]	1.5	C	ND		ND		ND	
Grinder with fabric filter (SCC 3-05-019-02)[f]	0.0043	D	ND		0.0021	D	ND	
Calciner (SCC 3-05-019-05)[d]	15	D	15	E	ND		ND	
Calciner with scrubber (SCC 3-05-019-05)	0.20[g]	C	ND		0.16[g]	C	0.088[h]	D
Transfer and storage (SCC 3-05-019-__)[d]	1	E	ND		ND		ND	

[a] Factors represent uncontrolled emissions unless otherwise noted. SCC = Source Classification Code. ND = no data.
[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.
[c] Condensable PM is that PM collected in the impinger portion of a PM sampling train.
[d] Reference 1.
[e] References 8,10-11.
[f] References 1,11-12.
[g] References 1,14-22.
[h] References 14-22.

Table 11.21-5. PARTICLE SIZE DISTRIBUTION OF FILTERABLE PARTICULATE EMISSIONS FROM PHOSPHATE ROCK DRYERS AND CALCINERS[a]

EMISSION FACTOR RATING: E

Diameter, µm	Percent Less Than Size	
	Dryers	Calciners
10	82	96
5	60	81
2	27	52
1	11	26
0.8	7	10
0.5	3	5

[a] Reference 1.

Table 11.21-6 (Metric Units). EMISSION FACTORS FOR PHOSPHATE ROCK PROCESSING[a]

Process	Fluoride, H_2O-Soluble		Fluoride, Total		Radionuclides[b]	
	kg/Mg Of Total Feed	EMISSION FACTOR RATING	kg/Mg Of Total Feed	EMISSION FACTOR RATING	pCi/Mg Of Total Feed	EMISSION FACTOR RATING
Dryer (SCC 3-05-019-01)[c]	0.00085	D	0.037	D	ND	
Dryer with scrubber (SCC 3-05-019-01)[d]	0.00048	D	0.0048	D	ND	
Grinder (SCC 3-05-019-02)[e]	ND		ND		800R	E
Grinder with fabric filter (SCC 3-05-019-02)[e]	ND		ND		5.2R	E
Calciner with scrubber (SCC 3-05-019-05)[f]	ND		0.00081	D	ND	

[a] Factors represent uncontrolled emissions unless otherwise noted. SCC = Source Classification Code. ND = no data.
[b] R is the radionuclide concentration (specific activity) of the phosphate rock. In units of pCi/Mg of feed.
[c] Reference 10.
[d] References 10-11.
[e] References 7-8.
[f] Reference 1.

Table 11.21-7 (English Units). EMISSION FACTORS FOR PHOSPHATE ROCK PROCESSING[a]

Process	Fluoride, H_2O-Soluble		Fluoride, Total		Radionuclides[b]	
	lb/ton Of Total Feed	EMISSION FACTOR RATING	lb/ton Of Total Feed	EMISSION FACTOR RATING	pCi/ton Of Total Feed	EMISSION FACTOR RATING
Dryer (SCC 3-05-019-01)[c]	0.0017	D	0.073	D	ND	
Dryer with scrubber (SCC 3-05-019-01)[d]	0.00095	D	0.0096	D	ND	
Grinder (SCC 3-05-019-02)[e]	ND		ND		730R	E
Grinder with fabric filter (SCC 3-05-019-02)[e]	ND		ND		4.7R	E
Calciner with scrubber (SCC 3-05-019-05)[f]	ND		0.0016	D	ND	

[a] Factors represent uncontrolled emissions unless otherwise noted. SCC = Source Classification Code. ND = no data.
[b] R is the radionuclide concentration (specific activity) of the phosphate rock. In units of pCi/Mg of feed.
[c] Reference 10.
[d] References 10-11.
[e] References 7-8.
[f] Reference 1.

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. The national emission standard for radionuclide emissions from elemental phosphorus plants was promulgated in December 1989 (40 CFR 61 Subpart K). This standard limits emissions of polonium-210 from phosphate rock calciners and nodulizing kilns at elemental phosphorus plants and requires annual compliance tests.

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