EPA 520/1-83-001

AP42 : 7

Draft

Background Information Document

Proposed Standards for Radionuclides

March 1983

U.S. Environmental Protection Agency
Office of Radiation Programs
Washington, D.C. 20460

Chapter 6: PHOSPHATE INDUSTRY FACILITIES

6.1 Phosphate Rock Processing Plants

6.1.1 General Description

Phosphate rock is the starting material for the production of all phosphate products. Mining of phosphate rock is the fifth largest mining industry in the United States in terms of quantity of material mined (Da68). Phosphate rock mines of significant commercial importance are located in Florida, North Carolina, Tennessee, Idaho, Wyoming, Utah, and Montana (Figure 6.1-1).

The U.S. production of phosphate rock was estimated to be 57.9 million metric tons in 1978 with production increasing an average of about 5 percent per year (EPA79). The industry consists of 20 firms which are currently mining phosphate rock at 31 locations. Another five mines are expected to be operational by 1983, and four others have been planned with indefinite start-up dates. Most firms have mining operations and rock processing plants at the same location, while a few companies mine in several areas and ship the rock to a central processing plant. Table 6.1-1 shows the phosphate rock producing companies, plant locations, 1977 production, and percent of U.S. market.

The southeastern U.S. is the center of the domestic phosphate rock industry, with Florida, North Carolina, and Tennessee having over 90 percent of the domestic rock capacity. Florida, with approximately 78 percent of 1978 domestic capacity, dominates the U.S. industry and is the world's largest phosphate rock producing area. Most of these plants are located around Polk and Hillsborough counties in Central Florida, with expansion taking place in Hardee and Manatee counties. Hamilton County, located in North Florida, is another phosphate rock producing area.

Tennessee's phosphate rock industry, located in the middle of the State, has declined in importance over the last several years and is now the least important rock producing area in the country. The Tennessee Valley Authority and two private corporations have discontinued mining in Tennessee, and no new plant expansion is planned.

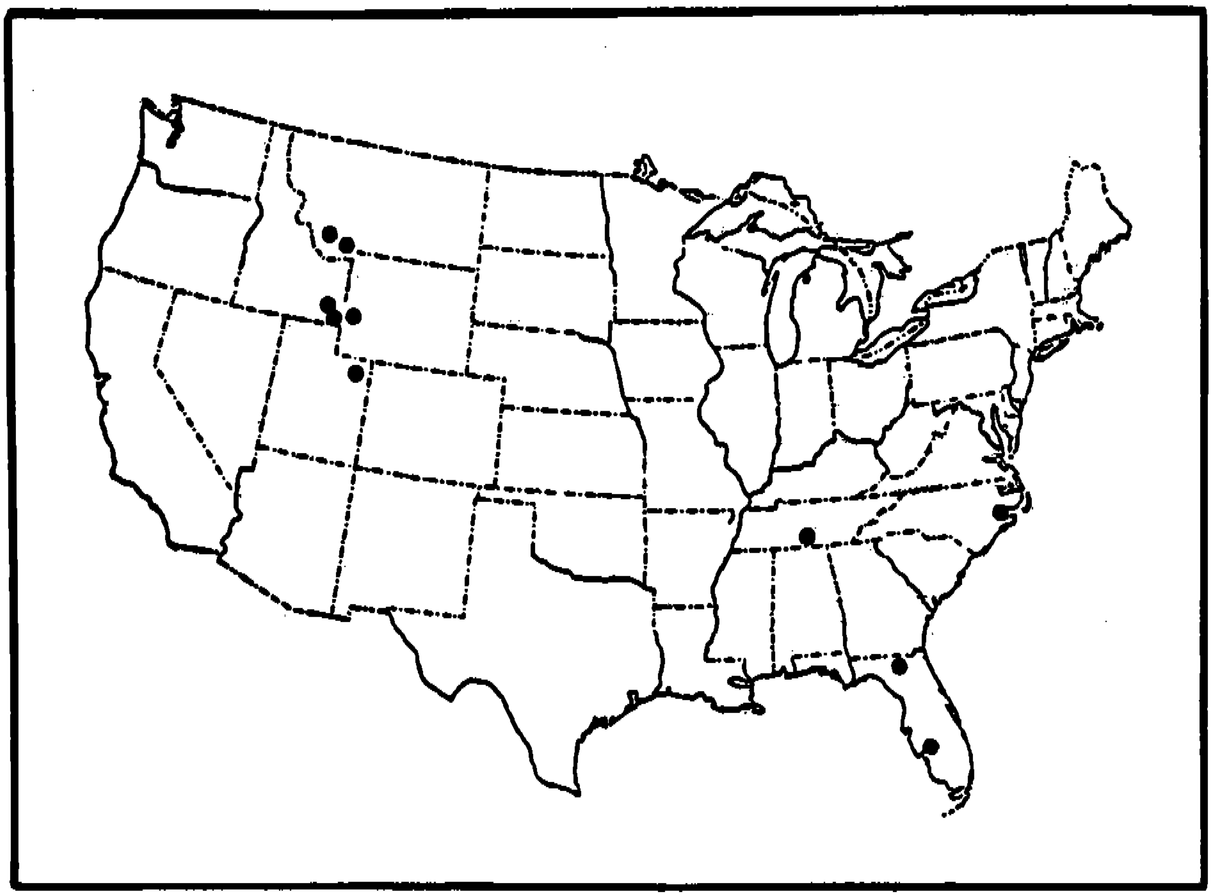

Figure 6.1-1. Geographical location of phosphate rock operations.

Table 6.1-1. Phosphate rock producers and capabilities (EPA79)

Company and location	1977 production (Metric tons) (10^3)	Percent of total
International Minerals and Chemicals Bonnie, Florida Kingsford, Florida Noralyn, Florida	11,340	20.5
Agrico Chemical Co. (Williams) Pierce, Florida Ft. Green, Florida	8,618	15.6
Occidental Agricultural Chemicals White Springs, Florida	2,722	4.9
Mobile Chemical Nichols, Florida Fort Meade, Florida	4,264	7.7
Brewster Phosphate Brewster, Florida Bradley, Florida	3,175	5.7
U.S. Steel-Agri-Chem, Inc. Ft. Meade, Florida	1,814	3.3
Gardinier Ft. Meade, Florida	1,966	3.6
Swift Chemical Bartow, Florida	2,903	5.3
W.R. Grace & Company Hookers Pr., Florida Bonnie Lake, Florida Manatte Co., Florida	4,808	8.7
Borden Chemical Company Teneroc, Florida Big Four, Florida	907	1.6
T-A Minerals Polk City, Florida	454	0.8

Table 6.1-1. Phosphate rock producers and capabilities (EPA79) --continued

Company and location	1977 production (Metric tons) (10^3)	Percent of total
Beker Industries Dry Valley, Idaho	1,089	2.0
J.R. Simplot Ft. Hall, Idaho	1,814	3.3
Cominco-American Garrison, Montana	249	0.5
George Relyea Garrison, Montana	91	0.2
Texasgulf Aurora, North Carolina	4,536	8.2
Stauffer Chemical Company Mt. Pleasant, Tennessee Vernal, Utah Wooley Valley, Utah	1,950	3.5
Hooker Chemical Company Columbia, Tennessee	454	0.8
Presnell Phosphate Columbia, Tennessee	454	0.8
Monsanto Industrial Chemical Co. Columbia, Tennessee Henry, Idaho	1,814	3.3

Summary by Region

Location	Percent of total U.S.
Florida	78.3
North Carolina	7.8
Tennessee	4.1
Western States	9.8

North Carolina possesses a rich phosphate rock deposit in Beaufort County along the Pamlico River. Texasgulf, the only company currently exploiting this resource, recently expanded plant capacity by 43 percent and has plans for further expansion. Another company has announced plans for a large operation in Washington, North Carolina.

The western U.S. phosphate rock industry is located in eastern Idaho, northern Utah, western Wyoming, and southern Montana. This area accounts for almost six million metric tons per year of the U.S. capacity, or about 10 percent. Six companies currently operate seven mines and six processing plants.

The U.S. industry is relatively concentrated as the 10 largest producers control about 84 percent of the capacity. The two largest companies control over 34 percent. In the Florida region, two firms have nearly 44 percent of the State's capacity, while the five largest companies control over 70 percent (EPA79).

The principal ingredient of the phosphate rock that is of economic interest is tricalcium phosphate, $Ca_3(PO_4)_2$. However, phosphate rock also contains appreciable quantities of uranium and its decay products. The uranium concentration of phosphate rock ranges from 20 to 200 ppm which is 10 to 100 times higher than the uranium concentration in natural material rocks and soils (2 ppm). The radionuclides of significance which are present in phosphate rock are: uranium-238, uranium-234, thorium-230, radium-226, radon-222, lead-210, and polonium-210. Because phosphate rock contains elevated concentrations of these radionuclides, handling and processing the rock can release radionuclides into the air either as dust particles, or in the case of radon-222, as a gas.

6.1.2 Process Description

After phosphate rock has been mined and beneficiated, it is usually dried and ground to a uniform particle size to facilitate processing. The drying and grinding operations produce significant quantities of particulate material (phosphate rock dust).

Phosphate rock is dried in direct-fired rotary or fluidized-bed dryers. The rock contains 10-15 percent moisture as it is fed to the dryer and is discharged when the moisture content reaches 1-3 percent. Dryer capacities range from 5 to 350 tons per hour (tph), with 200 tph a representative average.

Crushing and grinding are widely employed in the processing of phosphate rock. Operations range in scope from jaw crushers which reduce 12-inch hard rock to fine pulverizing mills which produce a product the consistency of talcum powder. Crushing is employed in some locations in the western field; however, these operations are used for less than 12 percent of the rock mined in the U.S. Fine pulverizing mills or grinders are used by all manufacturers to produce fertilizer. Roller or ball mills are normally used to process from 15 to 260 tph.

Some phosphate rock must be calcined before it can be processed. The need for calcining is determined primarily by the quantity of organic materials in the beneficiated rock. Since Florida rock is relatively free of organics, it usually is not calcined. Most calcining is done in fluidized-bed units, but rotary calciners are also used. The rock is heated to 1400°-1600° F in the calciner to remove unwanted hydrocarbons. Calciners range in capacity from 20 to 70 tph; a representative average is about 50 tph (EPA79).

6.1.3 Control Technology (TRW82a)

At phosphate rock plants, the normal sequence of operation is: mining, beneficiation, conveying of wet rock to and from storage, drying or calcining, conveying and storage of dry rock, grinding, and conveying and storage of ground rock.

Over 98 percent of the phosphate rock produced in the United States is mined from ground where the moisture content is high enough to preclude particulate emissions during extraction of the ore. In the relatively small amount of mining performed in areas where ground moisture content is not sufficient to prevent emissions, such as the hard rock areas of Utah and Wyoming, some particulates are generated during blasting and handling of the overburden and ore body. These emissions are minimized by wetting the active mining area with water from tank trucks.

Beneficiation is performed in a water slurry. Since the rock is wet, it does not become airborne and presents no particulate problem. Mined rock is normally moved by conveyor belts. Some are open, others closed for weather protection. In all except the relatively small plants in the hard rock areas of Utah and Wyoming, the high moisture content of the rock prevents emission of particulates. Weather-protected conveyors also offer some emission control in arid or windy locations.

Particulates from conveying and storage of ground rock are due primarily to fugitive emissions. Conveying and storage of ground rock usually takes place in totally enclosed systems, where proper maintenance will minimize fugitive losses.

Particulate emissions from dryers, calciners, and grinders could be reduced by applying particulate control equipment to "non-fugitive" emission sources.

Controlled emission levels from dryers and calciners can vary considerably from unit to unit, even with the same control device, due primarily to the effects of feed rock characteristics. Industrial representatives have indicated that feed rock characteristics greatly outweigh the effects of dryer or calciner unit types. Several feed rock characteristics can affect the emission levels and particle size distribution of the exhaust gas streams. Surface properties affect emission levels; rough or pitted surfaces can have greater clay adhesion, resulting in higher emission levels and smaller average particle size.

During beneficiation, the least-washed rock will have more fines, higher emission levels, and smaller average particle size. The residence time during which the rock is dried or calcined may also affect emission levels. Although increasing the residence time may lower particulate concentration per volume of exhaust gas, the total weight of particulate emission per weight of feed rock will increase. Other feed rock characteristics can also cause fluctuations in the particulate emission levels.

Coarse pebble rock from Florida is beneficiated the least and has the longest residence time in the dryer of all Eastern rock. Along with other properties, including hardness and clay adhesion, these properties cause coarse pebble rock to produce the most adverse, or worst-case, control levels for Eastern operations. However, unbeneficiated Western rock has a slightly smaller average particle size than Eastern rock and represents the most adverse of all feed rock control situations.

Dryer and Calciner Controls

Phosphate rock calciners and dryers have similar emission characteristics. Scrubbers are the most common control device used in the operation of phosphate rock dryers and calciners. Probably the most important design parameters for scrubbers are the amount of scrubber water used per unit volume of gas treated (liquid-to-gas ratio) and the intimacy of contact between the liquid and gas phases. The latter parameter is generally related to the pressure drop across the scrubber. Because of the similarities in emissions from dryers and calciners, scrubbers can attain similar reduction efficiencies; up to greater than 99.0 percent for high-energy venturi scrubbers.

Electrostatic precipitators (ESP) can be an economical control technique. Plate (electrode) voltage and the ratio of plate area to the volume of gas to be treated are the most important design parameters of an ESP. Particle resistivity and the ease of cleaning collected dust from the plates also affect ESP performance. Electrostatic precipitation is sometimes an economically attractive control technique in cases where fine dust particles predominate. Removing fine particles with a venturi scrubber requires relatively large power inputs (high pressure drops) to achieve the necessary efficiency. If power cost savings effected by the ESP exceed the increased capital charges, this system can be more economical than the venturi scrubber.

Two phosphate rock dryers now use electrostatic precipitators. One has a conventional dry ESP to control emissions from two rotary dryers. The precipitator was designed for 95 percent efficiency, but typically operates at 93 percent. The other uses a wet ESP to control emissions from two dryers operated in parallel, one a rotary design and the other a fluid bed. The ESP was designed for an efficiency of 90 percent, but is probably operating at a higher efficiency because the gas flow rate is about 60 percent of design capacity. With variation in plate voltage and plate area, ESP's can be designed to achieve reduction efficiencies up to greater than 99 percent. A calciner at one existing operation has a two-stage, dry ESP which operates with an indicated overall efficiency of 99.8 percent.

No fabric filters are known to be in use for phosphate rock dryer and calciner emission control. Many industry members believe that moisture condensation would be a major problem because water droplets could mix with the clay-like dust mat formed on the fabric media and cause a mud cake. Were this condition to occur, it would "blind" the bags. Furthermore, since the dust usually has no economical value, dry recovery for reprocessing is not an attractive incentive to operators. High exhaust gas temperatures associated with calciners are also commonly cited as a major difficulty expected with this type control device. However, manufacturers of these devices believe fabric filters can be effective for this application. They state that successful operation of fabric filters are common in more difficult operations, such as asphalt plants, cement plants, fertilizer dryers, and the clay industry. Under proper operating conditions, fabric filters generally exceed 99 percent efficiency.

Grinder Controls

Dried and calcined rock is ground before it is used for the manufacture of fertilizers. The grinding or milling circuit operates under slightly negative pressure to prevent the escape of gases containing ground rock dust. The system is not airtight; hence, the air that is drawn into the system must be vented. This vent stream usually discharges through a fabric filter or, sometimes, a wet scrubber. Electrostatic precipitators are not used for this operation at existing facilities.

Fabric filters are normally used to control emissions from grinders, probably because the dust collected by a fabric filter can be added directly to the product and thereby increase yields. Also, the low moisture content of 5 percent or less and low temperatures make fabric filtration technically and economically feasible. A well maintained and operated baghouse routinely controls particulate emissions to levels greater than 99 percent.

In some plants higher moisture content of the ground rock dust causes difficulty. At these plants, wet collectors are usually chosen for control. These devices can typically control emissions from 90 to

98 percent depending on the pressure drop. There has been a recent move toward wet grinding of rock for the manufacture of wet-process phosphoric acid (WPPA). The rock is ground in a water slurry, then added to the WPPA reaction tanks without drying. This offers the advantages of lower fuel costs and ability to meet more stringent particulate emission regulations. Two companies are now using the wet grinding process.

6.1.4 Radionuclide Emission Measurements

Phosphate rock dust is a source of particulate radioactivity in the atmosphere because the dust particles have approximately the same specific activity (pCi/g) as in the phosphate rock. Very limited data are available for actual field measurements of radioactivity in dryer/grinder air emissions. Measurements made by EPA (EPA78) are summarized in Table 6.1-2.

Table 6.1-2. Radionuclide stack emissions measured at phosphate rock dryers (EPA78)

Parameter	Dryer 1	Dryers 3 and 4
Total particulates (g/y)	2.2E+7	5.0E+7
Operating time (hr/y)	4114	4338
Stack emissions (Ci/y)		
Uranium-234	7.0E-4	2.6E-3
Uranium-235	3.0E-5	2.4E-4
Uranium-238	6.6E-4	2.7E-3
Thorium-227	5.0E-5	2.0E-4
Thorium-228	1.4E-4	2.3E-4
Thorium-230	9.7E-5	2.5E-3
Thorium-232	3.0E-5	8.0E-5
Radium-226	9.3E-4	2.9E-3

In estimating the radionuclide emissions from phosphate rock processing plants in the following sections, the emissions for the calciner plants are assumed to be similar to those of dryer plants (i.e., the radionuclide concentration of the particulates emitted to air is similar to the concentration in the phosphate rock processed). However, unlike dryer plants, no measurements of radionuclide emissions from calciner plants have been made. Therefore, some uncertainty exists as to the validity of the above assumption with respect to polonium-210 emissions. Because calciners operate at higher temperatures than dryers, polonium-210 may be volatized from the phosphate rock and emitted in larger quantities than the other radionuclides in the uranium-238 decay series. In this case, our assumption that calciner plant emissions are similar to dryer plant emissions would underestimate the polonium-210 emissions. EPA is planning to conduct radionuclide emission studies at calciner plants to resolve this uncertainty.

6.1.5 Reference Plant

Table 6.1-3 describes the parameters of a reference phosphate rock drying and grinding plant which are used to estimate the radioactive emissions to the atmosphere and the resulting health impacts. The radioactive emissions from the reference plant are listed in Table 6.1-4. These emissions are representative of dryers with low energy scrubbers which releases 130 grams of particulates per MT of rock processed and of grinders with medium energy scrubbers which release 25 grams of particulates per MT of rock processed.

Table 6.1-3. Reference phosphate rock drying and grinding plant

Parameter	Dryers	Grinders
Number of units[(a)]	3	4
Phosphate rock processing rate (MT/y)	2.7E+6	1.2E+6
Operating factor (hr/y)	6570	6460
Uranium-238 content of phosphate rock (pCi/g)[(b)]	40	40
Stack parameters		
Height (meters)	20	20
Diameter (meters)	2	2
Exit gas velocity (m/s)	10	10
Exit gas temperature (°C)	60°	60°
Type of control system	Low energy scrubber	Medium energy scrubber
Particulate emission rate (g/MT)	130 (0.26)[(c)]	25 (0.05)[(c)]

(a) Dryer units process 145 MT/hr; grinder units process 45 MT/hr.
(b) Uranium-238 is assumed to be in equilibrium with its daughter products.
(c) Values in lb/ton.

Table 6.1-4. Radionuclide emissions from the reference phosphate rock drying and grinding plant

Radionuclide	Emissions (Ci/y)	
	Dryers	Grinders
Uranium-238	1.4E-2	1.0E-3
Uranium-234	1.4E-2	1.0E-3
Thorium-230	1.4E-2	1.0E-3
Radium-226	1.4E-2	1.0E-3
Lead-210	1.4E-2	1.0E-3
Polonium-210	1.4E-2	1.0E-3

6.1.6 Health Impact Assessment of Reference Plant

The estimated annual radiation doses from radionuclide emissions from the reference phosphate rock drying and grinding plant are listed in Table 6.1-5. These estimates are for a model site in central Florida with a regional population of 1.4E+6. The maximum individual is located 750 meters from the plant.

Table 6.1-6 presents estimates of the maximum individual lifetime risk and the number of fatal cancers per year of operation from these doses.

The lifetime risk to the maximum individual is estimated to be about 3E-5 and the number of fatal cancers per year of operation is estimated to be 3E-3. These risks result primarily from doses to the lung from inhalation of radioactive particulates released from drying operations.

6.1.7 Alternative Control Technology

The annualized costs and risk reductions achieved by adding alternative controls to the reference phosphate rock drying and grinding plant are shown in Table 6.1-7. Two alternative levels of control are evaluated for dryers:

1. Reduction of the particulate emissions to 50 g/MT through the use of medium energy venturi scrubbers or ESP's.

2. Reduction of the particulate emissions to 30 g/MT (level of New Source Performance Standards--NSPS) through the use of high energy venturi scrubbers or high energy ESP's.

For grinders, only one alternative level of control is evaluated; the reduction of the particulate emissions to 6 g/MT (level of NSPS) through the use of fabric filters or high energy venturi scrubbers.

REFERENCES

Da68 Dames and Moore, Airborne Radioactive Emission Control Technology, Report on EPA Contract 68-01-4992, White Plains, New York, Unpublished.

EPA78 Environmental Protection Agency, Radiation Dose Estimates due to Air Particulate Emissions from Selected Phosphate Industry Operations, ORP/EERF-78-1, Office of Radiation Programs, Montgomery, Alabama, 1978.

EPA79 Environmental Protection Agency, Phosphate Rock Plants, Background Information for Proposed Standards, EPA-450/3-79-017, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, 1979.

TRW82 Particulate Emissions and Control Costs of Radionuclide Sources in Phosphate Rock Processing Plants. A report prepared by Butch Smith (TRW) for Office of Radiation Programs, December 1982.