Chapter 11. Mineral Products Industry

11.1 Characterization of Source Emissions

This chapter of the handbook addresses fugitive dust emissions from mineral products industries that involve the production and processing of various ores, as discussed in Chapter 11 of AP-42 [1] In the mineral products industry, there are two major categories of emissions: ducted sources (those vented to the atmosphere through some type of stack, vent, or pipe), and fugitive sources (those not confined to ducts and vents but emitted directly from the source to the ambient air). Ducted emissions are usually collected and transported by an industrial ventilation system having one or more fans or air movers, eventually to be emitted to the atmosphere through some type of stack.

Many operations and processes are common to all mineral products industries, including extraction of aggregate materials from the earth, loading, unloading, conveying, crushing, screening, loadout, and storage. Other operations are restricted to specific industries. These include wet and dry fine milling or grinding, air classification, drying, calcining, mixing, and bagging. Sand and gravel is typically mined in a moist or wet condition such that negligible particulate emissions occur during the mining operation. Construction aggregate processing can produce large amounts of fugitive dust, which due to its generally larger particle sizes tends to settle out within the plant. Some of the individual operations such as wet crushing and grinding, washing, screening, and dredging take place with high moisture content (>4% by weight). Such wet processes do not generate appreciable particulate emissions. For those processing and manufacturing operations that are housed in enclosed buildings with the dust captured by a control device (e.g., product recovery cyclones, fabric filters, and wet scrubber/suppression systems), no uncontrolled fugitive dust emissions are emitted directly into the outdoor air.

The operations at a typical western surface coal mine include drilling and blasting, removal of the overburden with a dragline or shovel, loading trucks, bulldozing and grading, crushing, vehicle traffic, and storage of coal in active storage piles that are subject to wind erosion. All operations that involve movement of soil or coal, or exposure of erodible surfaces, generate some amount of fugitive dust. During mine reclamation, which proceeds continuously throughout the life of the mine, overburden spoils piles are smoothed and contoured by bulldozers. Topsoil is placed on the graded spoils, and the land is prepared for revegetation by furrowing and mulching. From the time an area is disturbed until the new vegetation emerges, all disturbed areas are subject to wind erosion.

11.2 Emission Estimation Methodology

This section was adapted from *EPA's documentation of methods used for the National Emission Inventory (NEI*.[2] and from Section 11, Mineral Products Industry, of EPA's *Compilation of Air Pollutant Emission Factors (AP-42)*.[1] Many of the categories addressed in AP-42 have not been updated by the EPA since the mid to late 1990's.

This section addresses three different mineral categories: (a) metallic ores (b) non-metallic ores and rock, and (c) coal. Fugitive dust emission factors for mining and quarrying activities are based on EPA's methodology used for the annual National Emission Inventory that includes emissions from extraction of the ore or rock from the earth but not processing activities.[2] Fugitive dust emission factors for processing activities are taken from AP-42 and represent average values based on a number of tests made under a variety of conditions such as material silt content, moisture content, and wind speed. As such, the actual uncontrolled emission factors will vary depending upon actual site conditions.

The EPA methodology used to develop the annual National Emission Inventory (NEI) for fugitive PM10 dust emissions from mining and quarrying operations utilizes the sum of the emissions from the mining of metallic and nonmetallic ores and coal as well as rock quarrying, as follows:

$$E = E_m + E_n + E_c \tag{1}$$

where, E = PM10 emissions from mining and quarrying operations
E_m = PM10 emissions from metallic ore mining operations
E_n = PM10 emissions from non-metallic ore mining and rock quarrying operations
E_c = PM10 emissions from coal mining operations

The NEI PM10 emissions estimate for mining and rock quarrying operations involving extraction of ore or rock from the earth include three specific activities: (1) overburden removal, (2) drilling and blasting, and (3) loading and unloading. Ore processing activities that involve transfer and conveyance operations, crushing and screening operations, storage, and travel on haul roads are not included in the NEI emissions estimate since EPA assumes that the dust emissions from these activities are well controlled. Uncontrolled particulate emission factors for ore processing activities are presented in the subsections below for estimating fugitive dust emissions from these sources. Fugitive dust emissions from materials handling, travel on unpaved roads, and wind erosion of storage piles are addressed in Chapters 4, 6 and 9 of this handbook, respectively.

The NEI emissions estimation methodology assumes that the TSP emission factors developed for copper ore mining apply to the three activities listed above for all metallic ore mining. PM10 emission factors for each of these three activities for metallic ore mining are based on the following PM10/TSP ratios: 0.35 for overburden removal, 0.81 for drilling and blasting, and 0.43 for loading/unloading operations.[3]

In the NEI emission estimation methodology, non-metallic ore mining emissions are calculated by assuming that the PM10 emission factors for western surface coal mining apply to mining of all non-metallic ores. The PM10/TSP ratio for western surface coal mining is 0.40.[4]

Coal mining includes two additional sources of PM10 emissions compared to the sources considered for metallic and non-metallic ores, namely overburden replacement and truck loading and unloading of that overburden. EPA assumes that the amount of overburden material handled equals ten times the amount of coal mined.[5]

EPA Method 5 (or equivalent) source tests used to generate particulate emission factors include a filterable PM fraction that is captured on or prior to a filter and a condensable PM fraction that is collected in the impinger portion of the sampling train. PM emission factors presented below include the sum of the filterable and condensable PM fractions for those cases where information exists for both fractions. For those cases where information only exists for the filterable PM fraction, this is clearly identified in the text below.

Previous NEI PM emission inventories for fugitive dust from mineral products industries assumed a PM2.5/PM10 ratio of 0.29.[2] In July 2006 EPA adopted revised PM2.5/PM10 ratios for several fugitive dust source categories, including a ratio of 0.1 for heavy vehicle traffic on unpaved surfaces around aggregate storage piles and a ratio of 0.15 for transfer of aggregate associated with buckets or conveyors based on the recent findings of MRI.[6] Thus, the PM2.5/PM10 ratio for fugitive dust from mineral products industries lies somewhere between 0.1 and 0.15.

Estimates of the amount of metallic and non-metallic ores handled at surface mines are available from the U.S. Geological Survey. Production figures for coal mining operations are available from the Energy Information Administration (EIA) in the U.S. Department of Energy.

11.2.1 Metallic Ores

EPA uses the following equation to calculate PM10 emissions from overburden removal, drilling and blasting, and loading and unloading from metallic ore mining operations:

$$E_m = A_m\,[EF_o + (B \times EF_b) + EF_l + EF_d] \qquad (2)$$

where, A_m = metallic crude ore handled at surface mines (tons)
EF_o = PM10 open pit overburden removal emission factor for copper ore (lbs/ton)
B = fraction of total ore production that is obtained by blasting at metallic ore mines
EF_b = PM10 drilling/blasting emission factor for copper ore (lbs/ton)
EF_l = PM10 loading emission factor for copper ore (lbs/ton)
EF_d = PM10 truck dumping emission factor for copper ore (lbs/ton)

Utilizing the TSP emission factors and PM10/TSP ratios developed for copper ore mining operations, PM10 emissions from metallic ore mining operations are calculated as follows:

$$E_m = A_m\,[0.0003 + (0.57625 \times 0.0008) + 0.022 + 0.032] = 0.0548\,A_m \qquad (3)$$

Based on NEI's emission estimation methodology that excludes fugitive dust emissions from haul truck traffic on unpaved surfaces, PM10 emissions from loading and truck dumping account for 40% and 58%, respectively, of the total PM10 emissions from metallic ore mining operations.

Uncontrolled filterable TSP and PM10 emission factors for metallic ore processing operations are presented in Table 11-1. These emission factors are for emissions after product recovery cyclones. Uncontrolled PM emission factors for taconite ore processing are presented in Table 11-2.

Table 11-1. Filterable TSP and PM10 Emission Factors for Metallic Ore Processing[a]

Source	TSP (lb/ton)	PM10 (lb/ton)
Low-moisture ores[b]		
Primary crushing	0.5	0.05
Secondary crushing	1.2	ND
Tertiary crushing	2.7	0.16
Material handling and transfer – all minerals except bauxite	0.12	0.06
Material handling and transfer – bauxite/alumina	1.1	ND
High-moisture ores[b]		
Primary crushing	0.02	0.009
Secondary crushing	0.05	0.02
Tertiary crushing	0.06	0.02
Material handling and transfer – all minerals except bauxite	0.01	0.004
Material handling and transfer – bauxite/alumina	ND	ND
Both low- and high-moisture ores[b]		
Wet grinding	Neg	Neg
Dry grinding with air conveying and/or air classification	28.8	26
Dry grinding without air conveying and/or air classification	2.4	0.31
Drying – all minerals except titanium/zirconium sands	19.7	12

[a] Emission factors in units of lb/ton of material processed. One lb/ton is equivalent to 0.5 kg/Mg. Neg = negligible. ND = no data.
[b] Low-moisture ore has a moisture content of less than 4% by weight; high-moisture ore has a moisture content of at least 4% by weight.

Table 11-2. TSP and PM10 Emission Factors for Taconite Ore Processing[a]

Source	TSP (lb/ton)	PM10 (lb/ton)
Natural gas-fired grate/kiln	7.4	0.65
Gas-fired vertical shaft top gas stack	16	ND
Oil-fired straight grate	1.2	ND

[a] Applicable to both acid pellets and flux pellets. Emission factors in units of lb/ton of fired pellets produced. One lb/ton is equivalent to 0.5 kg/Mg. ND = no data.

11.2.2 Non-metallic Ores

EPA uses the following equation to calculate the PM10 emissions from overburden removal, drilling and blasting, and loading and unloading from non-metallic ore mining and rock quarrying operations:

$$E_n = A_n [EF_v + (D \times EF_r) + EF_a + 0.5 (EF_e + EF_t)] \quad (4)$$

where, A_n = non-metallic crude ore handled at surface mines (tons)
EF_v = PM10 open pit overburden removal emission factor at western surface coal mining operations (lbs/ton)
D = fraction of total ore production that is obtained by blasting at non-metallic ore mines
EF_r = PM10 drilling/blasting emission factor at western surface coal mining operations (lbs/ton)

EF_a = PM10 loading emission factor at western surface coal mining operations (lbs/ton)
EF_e = PM-10 truck unloading: end dump-coal emission factor at western surface coal mining operations (lbs/ton)
EF_t = PM10 truck unloading: bottom dump-coal emission factor at western surface coal mining operations (lbs/ton)

Utilizing the PM10 factors developed for western surface coal mining operations, PM10 emissions from non-metallic ore mining and rock quarrying operations are calculated as follows:

$$E_n = A_n\,[0.225 + (0.61542 \times 0.00005) + 0.05 + 0.5\,(0.0035 + 0.033)] = 0.293\,A_n \qquad (5)$$

PM10 emissions from overburden removal account for 77% of the total PM10 emissions from non-metallic ore mining and rock quarrying operations.

Uncontrolled TSP and PM10 emission factors for non-metallic ore processing operations are presented in Table 11-3. The emission factors for mixer loading and truck loading for concrete batching operations were updated in June 2006.[7] These new AP-42 emission factors are approximately double the previous emission factors. Excluding road dust and windblown dust, the plant wide PM10 emission factors per yard of concrete for an average concrete batch formulation at a typical facility are 0.058 lb/yd^3 for truck mix concrete and 0.037 lb/yd^3 for central mix concrete.

Table 11-3. TSP and PM10 Emission Factors for Non-metallic Ore Processing Operations [a]

Industry	Source	TSP (lb/ton)	PM10 (lb/ton)
Sand and Gravel	Sand Dryer	2.0	ND
Crushed Stone	Tertiary crushing[b]	0.0054	0.0024
	Fines crushing	0.039	0.0150
	Screening	0.025	0.0087
	Fines screening	0.30	0.072
	Conveyor transfer point	0.0030	0.0011
	Wet drilling – unfragmented stone	ND	8.0×10^{-5}
	Truck unloading – fragmented stone	ND	1.6×10^{-5}
	Truck unloading – conveyor, crushed stone	ND	1.0×10^{-4}
Lightweight Aggregate	Rotary Kiln	131	ND
Concrete Batching	Aggregate transfer	0.0069	0.0033
	Sand transfer	0.0021	0.00099
	Cement unloading to storage silo	0.72	0.46
	Cement supplement unloading to silo	3.14	1.10
	Weigh hopper loading	0.0051	0.0024
	Mixer loading (central mix)[c]	0.524	0.156
	Truck loading (truck mix)[c]	1.122	0.311
Phosphate Rock	Dryer	5.7	4.8
	Grinder	1.5	ND
	Calciner	15	14.4
Kaolin[d]	Apron dryer	1.2	ND
	Multiple hearth furnace	34	16
	Flash calciner	1,100	560
Fire Clay[d]	Rotary dryer	65	16
	Rotary calciner	120	30
Bentonite[d]	Rotary dryer	290	20
Talc	Railcar unloading	0.00098	ND
Brick Manufacturing	Grinding and screening wet material[e]	0.025	0.0023
	Grinding and screening dry material[f]	8.5	0.53
	Brick dryer	0.077	ND
	Natural gas-fired kiln	0.96	0.87
	Coal-fired kiln	1.79	1.35
	Sawdust-fired kiln	0.93	0.85
	Sawdust-fired kiln and sawdust dryer	1.36	0.31
	Natural gas-fired kiln firing structural clay	1.0	ND
Portland Cement Manufacturing	Wet process kiln	130	31
	Preheater kiln	250	ND
Gypsum	Rotary ore dryers[f]	$0.16(FFF)^{1.7}$	$0.013(FFF)^{1.7}$
	Continuous kettle calciners and hot pit	41[d]	26
	Flash calciners	37[d]	14
Lime Manufacturing	Primary crusher	0.017[d]	ND
	Secondary crusher	0.62[d]	ND
	Product transfer and conveying	2.2[d]	ND
	Product loading, enclosed truck	0.61[d]	ND
	Product loading, open truck	1.5[d]	ND
	Coal-fired rotary kiln	352	44
	Coal- and gas fired rotary kiln	80	ND
	Gas-fired calcimatic kiln	97	ND
	Product cooler	6.8	ND

[a] Emission factors in units of lb/ton of material processed. One lb/ton is equivalent to 0.5 kg/Mg. ND = no data. FFF is the ratio of gas mass rate per unit dryer cross section area to the dry mass feed rate.[1]

[b] Emission factors for tertiary crushers can be used as an upper limit for primary or secondary crushing.

[c] Emission factors for mixer loading and truck loading for concrete batching operations were updated June 2006.

[d] Filterable PM emission factors.

[e,f] Units are lb/ton of raw material processed based on a raw material moisture content of 13% and of 4%, respectively.

11.2.3 Coal

EPA uses the following equation to calculate the PM10 emissions from overburden removal, drilling and blasting, loading and unloading, and overburden replacement from coal mining operations:

$$E_c = A_c\,[10\,(EF_{to} + EF_{or} + EF_{dt}) + EF_v + EF_r + EF_a + 0.5\,(EF_e + EF_t)] \quad (6)$$

where, A_c = coal production at surface mines (tons)
- EF_{to} = PM10 emission factor for truck loading overburden at western surface coal mining operations (lbs/ton of overburden)
- EF_{or} = PM10 emission factor for overburden replacement at western surface coal mining operations (lbs/ton of overburden)
- EF_{dt} = PM10 emission factors for truck unloading: bottom dump-overburden at western surface coal mining operations (lbs/ton of overburden)
- EF_v = PM10 open pit overburden removal emission factor at western surface coal mining operations (lbs/ton)
- EF_r = PM10 drilling/blasting emission factor at western surface coal mining operations (lbs/ton)
- EF_a = PM10 loading emission factor at western surface coal mining operations (lbs/ton)
- EF_e = PM10 truck unloading: end dump-coal emission factor at western surface coal mining operations (lbs/ton)
- EF_t = PM10 truck unloading: bottom dump-coal emission factor at western surface coal mining operations (lbs/ton)

Utilizing the PM10 factors developed for western surface coal mining operations, PM10 emissions from coal mining operations are calculated as follows:

$$E_c = A_c\,[10\,(0.015 + 0.001 + 0.006) + 0.225 + 0.00005 + 0.05 + 0.5\,(0.0035 + 0.033)] = 0.514\,A_c \quad (7)$$

PM10 emissions from loading overburden into trucks and overburden removal account for 29% and 44%, respectively, of the total PM10 emissions from coal mining operations.

PM10 emission factor equations for uncontrolled fugitive dust sources at western surface coal mines are presented in Table 11-4.

Table 11-4. PM10 Emission Factor Equations for Uncontrolled Fugitive Dust from Western Surface Coal Mines[a]

Operation	Material	PM10 Emission Factor Equations	
		English Units	Metric Units
Truck loading	Coal	$0.089 / (M)^{0.9}$ lb/ton	$0.045 / (M)^{0.9}$ kg/Mg
Bulldozing	Coal	$14.0(s)^{1.5} / (M)^{1.4}$ lb/hr	$6.33(s)^{1.5} / (M)^{1.4}$ kg/hr
	Overburden	$0.75(s)^{1.5} / (M)^{1.4}$ lb/hr	$0.34(s)^{1.5} / (M)^{1.4}$ kg/hr
Dragline	Overburden	$0.0016(d)^{0.7} / (M)^{0.3}$ lb/yd^3	$0.0022(d)^{0.7} / (M)^{0.3}$ kg/m^3
Grading	Overburden	$0.031(S)^2$ lb/VMT	$0.0034(S)^2$ kg/VKT

[a] Symbols for equations: VMT = vehicle miles traveled; VKT = vehicle kilometers traveled; ND = no data. M = material moisture content (%); s = material silt content (%); d = drop height (ft); S = mean vehicle speed (mph).

In using the equations presented in Table 11-4 to estimate emissions from sources found at a specific western surface mine, it is necessary that reliable values for correction parameters be obtained for the specific sources of interest. For example, the actual silt content of coal or overburden measured at a facility should be used instead of estimated values. In the event that site-specific values for correction parameters cannot be obtained, the appropriate geometric mean values from Table 11-5 may be used.

Table 11-5. Range and Geometric Mean of Correction Factors Used to Develop Emission Factor Equations Shown in Table 11-4.

Source	Correction Factor	Range (Geometric Mean)	
		English Units	Metric Units
Blasting	Area Blasted	1,100 – 73,000 ft^2 ($17,000\ ft^2$)	100 – 6,800 m^2 ($1,590\ m^2$)
Coal loading	Moisture	6.8 – 38% (17.8%)	
Bulldozers			
Coal	Moisture	4 – 22% (10.4%)	
	Silt	6 – 11.3% (8.6%)	
Overburden	Moisture	2.2 – 16.8% (7.9%)	
	Silt	3.8 – 15.1% (6.9%)	
Dragline	Drop Distance	5 – 100 ft (28.1 ft)	1.5 – 30 m (8.6 m)
	Moisture	0.2 – 16.3% (3.2%)	
Scraper	Silt	7.2 – 25.2% (16.4%)	
	Weight	36 – 70 ton (53.8 ton)	33 – 64 Mg (48.8 Mg)
Grader	Speed	5.0 – 11.8 mph (7.1 mph)	8 – 19 kph (11.4 kph)
Haul truck	Silt content	1.2 – 19.2% (4.3%)	
	Moisture	0.3 – 20.1% (2.4%)	
	Weight	23 – 290 ton (120 ton)	20.9 – 260 Mg (110 Mg)

TSP emission factors for fugitive dust sources not covered in Table 11-4 are presented in Table 11-6. These factors were determined through source testing at various western surface coal mines. It should be pointed out that AP-42 does not list PM10/TSP ratios for fugitive dust sources. Instead it lists TSP and PM15 emission factor equations and PM10/PM15 ratios that range from 0.52 for blasting and 0.60 for grading to 0.75 for other operations. Calculating TSP and PM15 emission factors using typical correction factors provided in Table 11-5 together with the published PM10/PM15 ratios produces PM10/TSP ratios ranging from 0.15 to 0.30 for open area fugitive dust sources at western surface coal mines.

Table 11-6. Uncontrolled TSP Emission Factors for Western Surface Coal Mines[a]

Source	Material	TSP Emission Factor	
		English Units	Metric Units
Blasting	Coal or overburden	$0.000014 (A)^{1.5}$ lb/blast	$0.00022 (A)^{1.5}$ kg/blast
Drilling	Overburden	1.3 lb/hole	0.59 kg/hole
Topsoil removal by scraper	Topsoil	0.058 lb/ton	0.029 kg/Mg
Overburden replacement	Overburden	0.012 lb/ton	0.006 kg/Mg
Train loading by power shovel	Coal	0.028 lb/ton	0.014 kg/Mg
Bottom dump truck unloading	Overburden	0.066 lb/ton	0.033 kg/Mg
Wind erosion of exposed areas[b]	Seeded land, stripped or graded overburden	0.38 ton/acre-yr	0.85 Mg/hectare-yr
Wind erosion of storage pile	Coal	0.72 (u) lb/acre-hr	1.8 (u) kg/hectare-hr

[a] A = horizontal area (ft^2 or m^2) with blasting depth ≤ 70 ft (≤21 m); not for a vertical face of a bench. U = wind speed (mph or m/s)

[b] To estimate wind erosion on a shorter time scale (e.g., worst-case day); see Chapter 8 of the handbook.

11.2.4 Supplemental Emission Factors

TSP and PM10 emission factors for operations associated with ten mineral products industries are published in the EPA's *National Air Pollutant Emission Trends Procedures Document for 1900-1996*.[8] The PM10 emission factors and PM10/TSP ratios for these operations are presented in Table 11-7. It should be pointed out that several of the emission factors shown in Table 11-7 are not consistent with values presented in Tables 11-1 and 11-3. To be conservative, one may wish to adopt the higher of the two values.

Table 11-7. Supplemental PM10 Emission Factors for Mineral Products Industries[a]

Mineral Product Industry	Operation	PM10 (lb/ton)	PM10/TSP Ratio
Copper Ore	Crushing	2.9 to 3.9	0.45
	Open pit overburden removal	0.0003	0.37
	Drill/blasting	0.0008	0.80
	Loading	0.022	0.44
	Truck dumping	0.032	0.80
	Transfer/conveying	0.08	0.53
	Storage	0.7	0.35
Iron Ore	Mining	0.18	0.41
Lead Ore	Crushing	5.1	0.85
Zinc Ore	Crushing	2.3	0.38
Sand and Gravel	Mining	0.029	0.29
Asphalt Concrete	Fugitives	0.15	0.50
Brick Manufacturing	Material Handling	1.4	0.31
Cement Manufacturing	Fugitives	10.4	0.58
Lime Manufacturing	Fugitives	1.75	0.37
Coal	Surface Mining	0.2	0.40
	Coal Handling	0.17	0.34
	Pneumatic Dryer	1.5	0.50

[a] Emission factors in units of lb/ton of material processed. One lb/ton is equivalent to 0.5 kg/Mg.

The predictive emission factor presented in Chapter 4 may be used to calculate emissions for materials handling operations if source specific data (moisture content, wind speed, and silt content) is available.

11.3 Demonstrated Control Techniques

Emissions from mineral processing plants can be controlled by a variety of devices, including wet scrubbers, cyclones, venturi scrubbers, fabric filters, and electrostatic precipitators or baghouses. Rudimentary fallout chambers and cyclone separators can be used to control the larger particles. Conveyor belts moving dried rock may be covered and sometimes enclosed. Transfer points and bucket elevators are sometimes enclosed and evacuated to a control device. Dry rock is often stored in enclosed bins or silos, which are vented to the atmosphere, with fabric filters frequently used to control emissions. Cyclones are often used for product recovery from mechanical processes. In such cases, the cyclones are not considered to be an air pollution control device. Emissions from dryers and calciners can be controlled by a combination of a cyclone or a multiclone and a wet scrubber system. Fabric filters are used at some facilities to control emissions from mechanical processes such as crushing and grinding. Cyclones and fabric filters are used to control emissions from screening, milling, and materials handling and transfer operations.

For moderate to heavy uncontrolled emission rates from typical dry ore operations, a wet scrubber with a pressure drop of 6" to 10" of water will reduce TSP emissions by approximately 95%. With very low uncontrolled emission rates typical of high-moisture conditions, the percentage reduction will be lower (approximately 70%). Wet suppression techniques include application of water, chemicals and/or foam, usually at crusher or conveyor feed and/or discharge points. Such spray systems at transfer points and on material handling operations have been estimated to reduce TSP emissions by 70 to 95%. Spray systems can also reduce loading and wind erosion TSP emissions from storage piles of various materials by 80 to 90%. Venturi scrubbers with a relatively low pressure drop (12" of water) have reported PM10 collection efficiencies of 80 to 99%, whereas high-pressure-drop scrubbers (30" of water) have reported PM10 collection efficiencies of 96 to 99.9%, and electrostatic precipitators have PM10 collection efficiencies of 90 to 99%.

Over a wide range of inlet mass loadings, a well-designed and maintained baghouse will reduce emissions to a relatively constant outlet concentration. Such baghouses tested in the mineral processing industry consistently reduce emissions to less than 0.05 g/m^3 (0.02 $grains/ft^3$), with an average concentration of 0.015 g/m^3 (0.006 $grains/ft^3$). Under conditions of moderate to high uncontrolled emission rates of typical dry ore facilities, this level of controlled emissions represents greater than 99% removal of PM emissions. Control efficiencies depend upon local climatic conditions, source properties and duration of control effectiveness.

Process fugitive emission sources include materials handling and transfer, raw milling operations in dry process facilities, and finish milling operations. Emissions from these processes can be controlled by fabric filtration (baghouses) with reported removal efficiencies of approximately 95 to 99%. The industry uses shaker, reverse air, and pulse jet filters as well as some cartridge units, but most newer facilities use pulse jet filters.

Successful control techniques used for haul roads are dust suppressant application, paving, route modifications, and soil stabilization. Controls for conveyors include covering and wet suppression; for storage piles, wet suppression, windbreaks, enclosure, and soil stabilizers; for conveyor and batch transfer points, wet suppression and various methods to reduce freefall distances (e. g., telescopic chutes, stone ladders, and hinged boom stacker conveyors); and for screening and other size classification, covering and wet suppression. Additional information on these control measures can be found in other chapters of this handbook.

AP-42 lists both uncontrolled and controlled PM10 emission factors for different control devices for many mineral processing industries. Comparing the controlled emission factor for a specific control device to the uncontrolled emission factor provides the PM10 control efficiency for that control device presented in Table 11-8.

Table 11-8. PM10 Control Efficiencies for Mineral Processing Operations

Mineral Products Industry	Source	Control Device	PM10 Control Efficiency (%)
Taconite ore	Natural gas fired kiln	Multiclone	79
Crushed stone	Tertiary crushing	Wet scrubber	78
	Fines crushing	Wet scrubber	92
	Screening	Wet scrubber	91.6
	Fines screening	Wet scrubber	96.9
	Conveyor transfer point	Wet scrubber	95.9
Pulverized mineral	Grinding	Fabric filter	>99.5%
Lightweight aggregate	Rotary Kiln	Wet scrubber	99.4
	Rotary Kiln	Fabric filter	99.8
	Rotary Kiln	Electrostatic precipitator	99.5
Kaolin	Flash calciner	Fabric filter	99.99
Fire clay	Rotary dryer	Cyclone	68
	Rotary calciner	Multiclone and wet scrubber	99.8
Bentonite	Rotary dryer	Fabric filter	99.6
Hot mix asphalt	Dryer	Fabric filter	99.4
Brick manufacturing	Grinding and screening	Fabric filter	99.4
Portland cement	Wet process kiln	Electrostatic precipitator	97.9
Cement batching	Unloading into silo	Wet scrubber	99.9
	Mixer loading (central mix)	Wet scrubber	96.5
	Truck loading (truck mix)	Wet scrubber	91.6
Gypsum manufacturing	Flash calciner	Fabric filter	99.8
Lime manufacturing	Coal-fired rotary kiln	Fabric filter	99.6
	Coal-fired rotary kiln	Electrostatic precipitator	90

11.4 Regulatory Formats

PM stack emissions from taconite ore processing facilities constructed or modified after August 24, 1982 are regulated under 40 CFR 60, subpart LL to 0.05 g/m^3 (0.022 grains/ft^3). In addition, the opacity of stack emissions is limited to 7% unless the stack is equipped with a wet scrubber, and process fugitive emissions are limited to 10%. The standard does not affect emissions from indurating furnaces. Emissions from Portland cement plants constructed or modified after August 17, 1971 are regulated to limit PM emissions from kilns to 0.15 kg/Mg (0.30 lb/ton) of feed, and to limit PM emissions from clinker coolers to 0.050 kg/Mg (0.10 lb/ton) of feed. Emissions of filterable PM from rotary lime kilns constructed or modified after May 3, 1977 are regulated to 0.30 kg/Mg (0.60 lb/ton) of stone feed under 40 CFR Part 60, subpart HH.

Fugitive dust control options have been embedded in many regulations for state and local agencies in the WRAP region. Example regulatory formats downloaded from the Internet for several local air quality agencies in the WRAP region are presented in Table 11-9. The website addresses for obtaining information on fugitive dust regulations for local air quality districts within California, for Clark County, NV, and for Maricopa County, AZ, are as follows:

- Districts within California: www.arb.ca.gov/drdb/drdb.htm
- San Joaquin Valley APCD, CA: valleyair.org/SJV_main.asp
- South Coast AQMD, CA: aqmd.gov/rules
- Clark County, NV: www.co.clark.nv.us/air_quality/regs.htm
- Maricopa County, AZ: www.maricopa.gov/aq

Table 11-9. Example Regulatory Formats for Mineral Processing Operations

Control Measure	Agency
Limits PM emissions from cement kilns to 30 pounds per hour for kiln feed rates of 75 tons per hour or greater. Limits PM emissions to 0.40 pound per ton of kiln feed for kiln feed rates less than 75 tons per hour.	SCAQMD Rule 1112.1 02/07/86
Limits opacity from cement manufacturing facilities to 20 % for open storage piles and unpaved roads and to 10 % for all other operations, Specifies covers for conveying systems and enclosures for conveying system transfer points, and loading/unloading through an enclosed system.	SCAQMD Rule 1156 11/04/05
Limits opacity from an aggregate handling facility to 20% based on an average of 12 consecutive readings, or 50% based on five individual, consecutive readings, using the SCAQMD Opacity Test Method No. 9B.	SCAQMD Rule 1157 01/07/05
Limits (a) PM emissions from stacks at a nonmetallic mineral processing plant to 0.02 grains/dry standard cubic foot (gr/dscf) (50 mg/dscm), (b) opacity of fugitive dust emissions from any transfer point on a conveying system to 7%, and (c) opacity of fugitive dust emissions from any crusher to 15%.	Maricopa Co. Rule 316 6/08/05
No owner or operator of an existing tunnel kiln at a brick or structural product manufacturing facility shall emit more than 0.42 lbs. of particulate matter per ton of fired product from a tunnel kiln with a capacity throughput $\geq$ 1 ton/hour.	Maricopa Co. Rule 325 8/10/05
Limits the opacity of fugitive dust emissions at metallic or non-metallic mineral mining and processing facilities (based on an aggregate of at least 3 minutes in any 1-hour period) to (a) 10% for grinding mills, screening equipment, conveyors, conveyor transfer points, bagging equipment, storage bin, storage piles, stacker, enclosed truck, or rail car loading stations, (b) 15% for crushers, and (c) 7% for emissions from a stack or exhaust from a control device or building vent.	Clark Co. Rule 34 7/01/04

11.5 Compliance Tools

Compliance tools assure that the regulatory requirements, including application of dust controls, are being followed. Three major categories of compliance tools are discussed below.

Record keeping: A compliance plan is typically specified in local air quality rules and mandates record keeping of source operation and compliance activities by the source owner/operator. The plan includes a description of how a source proposes to comply with all applicable requirements, log sheets for daily dust control, and schedules for compliance activities and submittal of progress reports to the air quality agency. The purpose of a compliance plan is to provide a consistent reasonable process for documenting air quality violations, notifying alleged violators, and initiating enforcement action to ensure that violations are addressed in a timely and appropriate manner.

Site inspection: This activity includes (1) review of compliance records, (2) proximate inspections (sampling and analysis of source material), and (3) general observations. An inspector can use photography to document compliance with an air quality regulation.

On-site monitoring: EPA has stated that "An enforceable regulation must also contain test procedures in order to determine whether sources are in compliance." Monitoring can include observation of visible plume opacity, surface testing for crust strength and moisture content, and other means for assuring that specified controls are in place.

Table 11-10 summarizes the compliance tools that are applicable for mineral processing industries.

Table 11-10. Compliance Tools for Mineral Processing Industries

Record keeping	Site inspection/monitoring
Maintain daily records onsite for a period of five years, and make such records available to the Executive Officer upon request for: (a) hours of operation, (b) volume of ore or aggregate mined, (c) watering and sweeping schedule for internal paved roads, (d) number of haul trucks exiting the facility, (e) Fugitive Dust Advisories, (f) Dust Control Plan, (g) Operation and Maintenance Plan for the on-site emission control system (ECS), and (h) twice daily moisture results of aggregate material.	Observation of dust plumes during periods of mining and processing operations; observation of dust plume opacity (visible emissions) exceeding a standard; tests of surface soil stabilization and aggregate moisture content; monitoring device to record pressures, flow rates and other ECS operating conditions; posting of signs restricting speeds to 15 mph; observation of high winds (e.g., >25 mph).

11.6 Sample Cost-Effectiveness Calculation

This section is intended to demonstrate how to select a cost-effective control measure for mineral processing operations. The reader is directed to Sections 4.6, 6.8, and 9.6 of the handbook for examples of calculating the cost effectiveness of specific control measures for several minerals processing operations, namely materials handling, haul trucks traveling on unpaved industrial roads, and storage pile wind erosion, respectively.

A sample cost-effectiveness calculation is presented below for a specific control measure (wet scrubber for tertiary crushing of crushed stone) to illustrate the procedure. The sample calculation includes the entire series of steps for estimating uncontrolled emissions (with correction parameters and source extent), controlled emissions, emission reductions, control costs, and control cost-effectiveness values for PM10 and PM2.5. In selecting the most advantageous control measure for mineral processing, the same procedure is used to evaluate each candidate control measure (utilizing the control measure specific control efficiency and cost data), and the control measure with the most favorable cost-effectiveness and feasibility characteristics is identified.

Sample Calculation for Tertiary Crushing at Crushed Stone Processing Plant

Step 1. Determine source activity and control application parameters.

Material throughput (tons/year)	2,000,000
Control Measure	Wet scrubber
Control application/frequency	Continuous
Economic Life of Control System (yr)	10
Control Efficiency (Reference)	78% (AP-42)

The material throughput and economic life are assumed values for illustrative purposes. A wet scrubber system has been chosen as the control measure for reducing fugitive dust emissions. The moisture content of the crushed stone averages 0.21 to 1.3% for facilities without a wet suppression system and 0.55 to 2.88% for facilities with a wet suppression system.[1]

Step 2. Obtain Uncontrolled PM Emission Factors. The uncontrolled PM10 emission factor for tertiary crushing of crushed stone published in AP-42 is 0.0024 lb/ton of material throughput. The PM2.5/PM10 ratio for crushed stone aggregate is 0.15 (MRI, 2006).[6]

Step 3. Calculate Uncontrolled PM Emissions. The annual uncontrolled PM10 emissions are calculated by multiplying the PM10 emission factor by the material throughput and then divided by 2,000 lbs to compute the annual emissions in tons per year, as follows:

Annual emissions = (EF x Material Throughput)/2,000

Annual PM10 Emissions = (0.0024 x 2,000,000)/2000 = 2.4 tons
Annual PM2.5 Emissions = 0.15 (Annual PM10 Emissions) = 0.36 tons

Step 4. Calculate Controlled PM Emissions. The controlled PM emissions (i.e., the PM emissions remaining after control) are equal to the uncontrolled emissions (calculated above in Step 3) multiplied by the percentage that uncontrolled emissions are reduced, as follows:

Controlled emissions = Uncontrolled emissions x (1 – Control Efficiency).

For this example, a wet scrubber/suppression system with a control efficiency of 78% has been selected as the control measure. Thus, the annual controlled PM10 and PM2.5 emissions estimates are calculated to be:

Annual Controlled PM10 emissions = (2.4 tons) x (1 – 0.78) = 0.53 tons
Annual Controlled PM2.5 emissions = (0.36 tons) x (1 – 0.78) = 0.079 tons

Step 5. Determine Annual Cost to Control PM Emissions.

Capital costs ($)	16,000
Operating/Maintenance costs ($)	12,200
Annual Interest Rate	3%
Capital Recovery Factor	0.12
Annualized Cost ($/yr)	14,076

The capital costs, annual operating and maintenance costs, and annual interest rate (AIR) are assumed values for illustrative purposes. The Capital Recovery Factor (CRF) is calculated from the Annual Interest Rate (AIR) and the Economic Life of the control system, as follows:

$CRF = AIR \times (1+AIR)^{\text{Economic life}} / (1+AIR)^{\text{Economic life}} - 1$
$CRF = 3\% \times (1+3\%)^{10} / (1+3\%)^{10} - 1 = 0.1172$

The Annualized Cost is calculated by adding the product of the Capital Recovery Factor (CRF) multiplied by the Capital costs to the sum of the Operating and Maintenance costs, as follows:

Annualized Cost = (CRF x Capital costs) + Operating/Maintenance costs
Annualized Cost = (0.1172 x $16,000) + $12,200 = $14,076

Step 6. Calculate Cost-effectiveness. Cost-effectiveness is calculated by dividing the annualized cost by the emissions reduction. The emissions reduction is determined by subtracting the controlled emissions from the uncontrolled emissions:

Cost-effectiveness = Annualized Cost/ (Uncontrolled emissions – Controlled emissions)

Cost-effectiveness for PM10 emissions = $14,075 / (2.4 – 0.53) = $7,519/ton
Cost-effectiveness for PM2.5 emissions = $14,075 / (0.36 – 0.079) = $50,127/ton

11.7 References

1. USEPA, 2006. *Compilation of Air Pollutant Emission Factors*, AP-42 Section 11 (Minerals Products Industry), Fifth Edition.

2. USEPA, 2004. *Documentation for the Final 1999 National Emissions Inventory (Version 3.0) for Criteria Pollutants and Ammonia: Area Sources*, report prepared by E. H. Pechan and Associates for the USEPA OAQPS, January 31.

3. USEPA, 1986. *Generalized Particle Size Distributions for Use in Preparing Size-Specific Particulate Emissions Inventories*, EPA-450/4-86-013, July.

4. USEPA, 1990. *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*, EPA-450/4-90-003, March.

5. USEPA, 2001. *Procedures Document for National Emission Inventory, Criteria Air Pollutants, 1985-1999*, EPA-454/R-01-006, March.

6. MRI, 2006. *Background Document for Revisions to Fine Fraction Ratios Used for AP-42 Fugitive Emission Factors*, prepared for the WRAP by Midwest Research Institute, Feb. 1.

7. USEPA, 2006. AP-42 *Section 11.12: Concrete Batching*, updated in June.

8. USEPA, 1998. *National Air Pollutant Emission Trends Procedure Document for 1900-1996*, EPA-454/R-98-008, May.