2020 National Emissions Inventory Technical Support Document: Industrial Processes – Mining and Quarrying

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28 Industrial Processes – Mining and Quarrying

28.1 Sector Descriptions and Overview

Mining and quarrying activities produce particulate matter (PM) emissions due to the variety of processes used to extract the ore and associated overburden, including drilling and blasting, loading and unloading, and overburden replacement. Fugitive dust emissions for mining and quarrying operations are the sum of emissions from the mining of metallic and nonmetallic ores and coal. Each of these mining operations has specific emissions factors accounting for the different means by which the resources are extracted.

28.2 EPA-developed estimates

Four specific activities are included in the emissions estimate for mining and quarrying operations: overburden removal, drilling and blasting, loading and unloading, and overburden replacement. Not included are the transfer and conveyance operations, crushing and screening operations, and storage since the dust emissions from these activities are assumed to be well controlled. Fugitive dust emissions for mining and quarrying operations are the sum of emissions from the mining of metallic and nonmetallic ores and coal. Emissions for each activity are calculated by multiplying the emissions factors by the activity data.

28.2.1 Activity data

Activity data for this source category include state-level metallic and non-metallic (a.k.a. mineral) crude ore handled at surface mines from the U.S. Geologic Survey (USGS) [ref 1] and mine-specific coal production data for surface mines from the Energy Information Administration (EIA) [ref 2]. Emissions are not estimated for underground mining given that emissions factors are calculated exclusively for surface activity.

In some cases, the amount of mining waste is withheld for some states to avoid disclosing company proprietary data. To estimate state-level withheld waste data the fraction of crude ore production in the state is multiplied by the amount of waste data withheld at the national level. The national-level amount of waste withheld is calculated by subtracting all known state-level waste values (i.e. those that are not withheld) from the national-level waste value. Note that this calculation only needs to be completed for states where state-level mining waste data are withheld.

$$W_s = \frac{O_s}{O_{US}} \times W_{US} \quad (1)$$

Where:

W_s = Amount of metallic and non-metallic mining waste for state *s*, in metric tons
W_{US} = Amount of metallic and non-metallic mining waste withheld at the national level, in metric tons
O_s = Amount of crude ore produced in state *s*, in metric tons

O_{US} = Amount of crude ore produced at the national level, in metric tons

The data on state-level mining production and waste is split into production and waste for metallic and nonmetallic ores using the fraction of national-level metallic and non-metallic ore production. Values are also converted from metric tons to short tons. Throughout the remainder of this document references to "ton(s)" refer to short tons, while metric tons will be explicitly labeled.

$$MP_{t,s} = (W_s + O_s) \times \frac{MP_{t,US}}{MP_{US}} \times 1.1023\, {}^{ton}/_{metric\ ton} \quad (1)$$

Where:

$MP_{t,s}$ = Amount of mining material type *t* (i.e. either metallic or non-metallic ore) produced in state *s*, in tons
W_s = Amount of total metallic and non-metallic mining waste for state *s*, in metric tons
O_s = Amount of crude ore produced in state *s*, in metric tons
$MP_{t,US}$ = Amount of mining material type *t* produced at the national-level, in metric tons
MP_{US} = Total metallic and non-metallic ore production at the national level, in metric tons

28.2.2 Allocation procedure

The state-level data on metallic and non-metallic mining materials (from Equation (2)) is distributed to the county level based on the proportion of employees in the metallic and non-metallic ore sectors (see Table 28-1 for a list of NAICS codes), from the U.S. Census Bureau County Business Patterns [ref 3]. Separate fractions are determined for metallic ore mining employees and non-metallic ore mining employees in each county.

$$EmpFrac_{t,c} = \frac{Emp_{t,c}}{Emp_{t,s}} \quad (2)$$

Where:

$EmpFrac_{t,c}$ = The fraction of mining employees for material type *t* in county *c*
$Emp_{t,c}$ = The number of mining employees for material type *t* in county *c*
$Emp_{t,s}$ = The number of mining employees for material type *t* in state *s*

Table 28-1: NAICS Codes for Metallic and Non-Metallic Mining

NAICS Code	Description
2122	Metal Ore Mining
212210	Iron Ore Mining
21222	Gold Ore and Silver Ore Mining
212221	Gold Ore Mining
212222	Silver Ore Mining

NAICS Code	Description
21223	Copper, Nickel, Lead, and Zinc Mining
212231	Lead Ore and Zinc Ore Mining
212234	Copper Ore and Nickel Ore Mining
21229	Other Metal Ore Mining
212291	Uranium-Radium-Vanadium Ore Mining
212299	All Other Metal Ore Mining
2123	Nonmetallic Mineral Mining and Quarrying
21231	Stone Mining and Quarrying
212311	Dimension Stone Mining and Quarrying
212312	Crushed and Broken Limestone Mining and Quarrying
212313	Crushed and Broken Granite Mining and Quarrying
212319	Other Crushed and Broken Stone Mining and Quarrying
21232	Sand, Gravel, Clay, and Ceramic and Refractory Minerals Mining and Quarrying
212321	Construction Sand and Gravel Mining
212322	Industrial Sand Mining
212324	Kaolin and Ball Clay Mining
212325	Clay and Ceramic and Refractory Minerals Mining
21239	Other Nonmetallic Mineral Mining and Quarrying
212391	Potash, Soda, and Borate Mineral Mining
212392	Phosphate Rock Mining
212393	Other Chemical and Fertilizer Mineral Mining
212399	All Other Nonmetallic Mineral Mining

Due to concerns with releasing confidential business information, the CBP does not release exact numbers for a given NAICS code if the data can be traced to an individual business. Instead, a series of range codes is used. To estimate employment in counties and states with withheld data, the following procedure is used for NAICS code being computed.

To gap-fill withheld state-level employment data:

a. State-level data for states with known employment in each NAICS are summed to the national level.
b. The total sum of state-level known employment from step a is subtracted from the national total reported employment for each NAICS in the national-level CBP to determine the employment total for the withheld states.
c. Each of the withheld states is assigned the midpoint of the range code reported for that state. Table 28-2 lists the range codes and midpoints.
d. The midpoints for the states with withheld data are summed to the national level.
e. An adjustment factor is created by dividing the number of withheld employees (calculated in step b of this section) by the sum of the midpoints (step d).
f. For the states with withheld employment data, the midpoint of the range for that state (step c) is multiplied by the adjustment factor (step e) to calculate the adjusted state-level employment for landfills.

These same steps are then followed to fill in withheld data in the county-level business patterns.

g. County-level data for counties with known employment are summed by state.
h. County-level known employment is subtracted from the state total reported in state-level CBP (or, if the state-level data are withheld, from the state total estimated using the procedure discussed above).
i. Each of the withheld counties is assigned the midpoint of the range code (Table 28-2).
j. The midpoints for the counties with withheld data are summed to the state level.
k. An adjustment factor is created by dividing the number of withheld employees (step h) by the sum of the midpoints (step j).
l. For counties with withheld employment data, the midpoints (step i) are multiplied by the adjustment factor (step k) to calculate the adjusted county-level employment for landfills.

Table 28-2: Withheld data ranges and midpoints

Employment Code	Employment Range	Midpoint
A	0-19	10
B	20-99	60
C	100-249	175
E	250-499	375
F	500-999	750
G	1,000-2,499	1,750
H	2,500-4,999	3,750
I	5,000-9,999	7,500
J	10,000-24,999	17,500
K	25,000-49,999	37,500
L	50,000-99,999	75,000
M	100,000+	

As an example, sample county CBP data for NAICS 2123 (Nonmetallic Mineral Mining and Quarrying) are provided in Table 28-3. The values in the table and subsequent steps are for demonstration purposes and are not representative of any specific NEI year or county.

Table 28-3: Example County Business Pattern for NAICS 2123

County FIPS	NAICS	Employment Code	Employment
001	2123		86
003	2123		19
005	2123		30
009	2123	B	withheld
012	2123	A	withheld
013	2123		505
015	2123		55
017	2123		60
019	2123		167
021	2123		72
023	2123	A	withheld
025	2123		144
027	2123		43

1. The total number of employees reported at the county level is 1,181.
2. The state-level CBP reports 1,195 employees for NAICS 2123. This means that there are 14 employees withheld at the county level.
3. The counties with withheld data are assigned midpoints according to the employment codes. For example, County 009 is given a midpoint of 60 employees (since employment code B is 20-99).
4. The sum of the midpoints for all withheld counties is 80 employees.
5. The adjustment factor is 14/80 = 0.175.
6. The adjusted employment for county 009 is 60 × 0.175 = 10.5 employees.

Once county- and state-level metal and non-metal employment are known for each county, the ratio of county to state employees (from equation 3) is multiplied by the state-level metal and non-metal production (from equation 2) to calculate county-level production.

$$MP_{t,c} = MP_{t,s} \times EmpFrac_{t,c} \quad (2)$$

Where:

$MP_{t,c}$ = Amount of mining material type *t* produced in county *c*, in tons
$MPt,_s$ = Amount of mining material type *t* (i.e. either metallic or non-metallic ore) produced in state *s*, in tons
$EmpFrac_{t,c}$ = The fraction of mining employees for material type *t* in county *c*

28.2.3 Emission factors

Emissions factors are calculated separately for metallic ore mining, non-metallic ore mining, and coal mining and are provided in the "Wagon Wheel Emission Factor Compendium" on the 2020 NEI Supporting Data and Summaries site. This section describes those calculations and the relevant data sources.

Metallic Ore Mining

The emissions factor for metallic ore mining includes emissions from overburden removal, drilling and blasting, and loading and unloading activities, and are taken from emissions factors for copper ore mining from EPA's *National Air Pollutant Emission Trends Procedures Document for 1900-1996* [ref 4]. The emissions factors are applied to all three activities with PM10/TSP ratios of 0.35 for overburden removal [ref 5], 0.81 for drilling and blasting [ref 6], and 0.43 for loading and unloading operations [ref 6].

$$EF_{PM10,m} = EF_o + (B \times EF_b) + EF_l + EF_d \quad (3)$$

Where:

$EF_{PM10,m}$ = PM10-PRI metallic ore mining emissions factor, in lbs./ton
EF_o = PM10-PRI open pit overburden removal emissions factor for copper ore, in lbs./ton
B = Fraction of total ore production that is obtained by blasting at metallic ore mines

EF_b = PM10-PRI drilling/blasting emissions factor for copper ore, in lbs./ton
EF_l = PM10-PRI loading emissions factor for copper ore, in lbs./ton
EF_d = PM10-PRI truck dumping emissions factor for copper ore, in lbs./ton

Using values from the *National Air Pollutant Emission Trends Procedures Document for 1900-1996, Table 3.1-3*[ref 4], the PM10-PRI emissions factor is calculated as:

$$0.0548\ lbs/ton = 0.0003 + (0.57625 \times 0.0008) + 0.022 + 0.032 \quad (5a)$$

The PM25-PRI emissions factor is assumed to be 12.5% of the PM10-PRI emissions factor.

$$EF_{PM25,m} = EF_{PM10,m} \times 0.125 \quad (4)$$

$$0.0069 = 0.0548 \times 0.125 \quad (6a)$$

Where:
$EF_{PM25,m}$ = PM25-PRI metallic ore mining emissions factor, in lbs./ton
$EF_{PM10,m}$ = PM10-PRI metallic ore mining emissions factor, in lbs./ton

Non-Metallic Ore Mining

The emissions factor for non-metallic ore mining includes overburden removal, drilling and blasting, and loading and unloading activities. The emissions factor is based on western surface coal mining operations from AP-42 [ref 7] and a PM10/TSP ratio.

$$EF_{PM10,nm} = EF_v + (D \times EF_r) + EF_a + (0.5 \times (EF_e + EF_t)) \quad (5)$$

Where:

$EF_{PM10,nm}$ = PM10-PRI non-metallic ore mining emissions factor, in lbs./ton
EF_v = PM10-PRI open pit overburden removal emissions factor at western surface coal mining operations, in lbs./ton
D = fraction of total ore production that is obtained by blasting at non-metallic ore mines
EF_r = PM10-PRI drilling/blasting emissions factor at western surface coal mining operations, in lbs./ton
EF_a = PM10-PRI loading emissions factor at western surface coal mining operations, in lbs./ton
EF_e = PM10-PRI truck unloading: end dump-coal emissions factor at western surface coal mining operations, in lbs./ton
EF_t = PM10-PRI truck unloading: bottom dump-coal emissions factor at western surface coal mining operations, in lbs./ton

Applying the TSP emissions factors developed for western surface coal mining operations from AP-42 [ref 7] and a PM10/TSP ratio of 0.4 [ref 8] yields the following non-metallic ore mining emissions factor:

$$0.293\ lbs./ton = 0.225 + (0.61542 \times 0.00005) + 0.05 + 0.5\,(0.0035 + 0.033) \quad (7a)$$

The PM25-PRI emissions factor is assumed to be 12.5% of the PM10-PRI emissions factor.

$$EF_{PM25,nm} = EF_{10,nm} \times 0.125 \quad (6)$$

$$0.037\ lbs/ton = 0.293 \times 0.125 \quad (8a)$$

Where:

$EF_{PM25,nm}$ = PM25-PRI non-metallic ore mining emissions factor, in lbs./ton
$EF_{PM10,nm}$ = PM10-PRI non-metallic ore mining emissions factor, in lbs./ton

Coal Mining

The emissions factor for coal mining includes overburden removal, drilling and blasting, loading, and unloading and overburden replacement activities. The amount of overburden material handled is assumed to equal ten times the quantity of coal mined, and coal unloading is assumed to split evenly between end-dump and bottom-dump operations. The emissions factor is based on the PM_{10} emissions factors developed for western surface coal mining operations from AP-42 [ref 7].

$$EF_{PM10,co} = \left(10 \times (EF_{to} + EF_{or} + EF_{dt})\right) + EF_v + EF_r + EF_a + (0.5 \times (EF_e + EF_t)) \quad (7)$$

Where:

$EF_{PM10,co}$ = PM10-PRI coal mining emissions factor, in lbs./ton
EF_{to} = PM10-PRI emissions factor for truck loading overburden at western surface coal mining operations, in lbs./ton of overburden
EF_{or} = PM10-PRI emissions factor for overburden replacement at western surface coal mining operations, in lbs./ton of overburden
EF_{dt} = PM10-PRI emissions factors for truck unloading: bottom dump-overburden at western surface coal mining operations, in lbs./ton of overburden
EF_v = PM10-PRI open pit overburden removal emissions factor at western surface coal mining operations, in lbs./ton
EF_r = PM10-PRI drilling/blasting emissions factor at western surface coal mining operations, in lbs./ton
EF_a = PM10-PRI loading emissions factor at western surface coal mining operations, in lbs./ton
EF_e = PM10-PRI truck unloading: end dump-coal emissions factor at western surface coal mining operations, in lbs./ton
EF_t = PM10-PRI truck unloading: bottom dump-coal emissions factor at western surface coal mining operations, in lbs./ton

Applying the PM10-PRI emissions factors developed for western surface coal mining operations [ref 7] yields the following coal mining emissions factor:

$$0.513\ lbs/ton = (10 \times (0.015 + 0.001 + 0.006)) + 0.225 + 0.00005 + 0.05 + (0.5 \times (0.0035 + 0.033)) \quad (9a)$$

The PM25-PRI emissions factor is assumed to be 12.5% of the PM10-PRI emissions factor.

$$EF_{PM25,co} = EF_{10,co} \times 0.125 \quad (8)$$

Where:

$EF_{PM25,co}$ = PM25-PRI coal mining emissions factor, in lbs./ton
$EF_{PM10,co}$ = PM10-PRI coal mining emissions factor, in lbs./ton

PM-FIL and PM2.5-PRI Emissions Factors

PM-FIL emissions factors are assumed to be the same as PM-PRI emissions factors. In reality, there is a small amount of PM-CON emissions included in the PM-PRI emissions, but insufficient data exists to estimate the PM-CON portion. In 2006, the EPA adopted new PM2.5/PM10 ratios for several fugitive dust categories and concluded that the PM2.5/PM10 ratios for fugitive dust categories should be in the range of 0.1 to 0.15 [ref 9]. Consequently, a ratio of 0.125 was applied to the PM10 emissions factors to estimate PM2.5 emissions factors for mining and quarrying. A summary of emissions factors is are provided in the "Wagon Wheel Emission Factor Compendium" on the 2020 NEI Supporting Data and Summaries site.

28.2.4 Controls

There are no controls assumed for this category.

28.2.5 Emissions

Emissions from mining and quarrying are calculated by multiplying the amount of mining material produced (from equation 4 for metallic and non-metallic mining, and from the EIA [ref 2] for coal) by an emissions factor (from Table 4-129).

$$E_{p,t,c} = EF_{t,p} \times MP_{t,c} \quad (9)$$

Where:

$E_{t,p,c}$ = Annual emissions of pollutant *p* from mining material type *t* in county *c*, in lbs.
$EF_{t,p}$ = Emissions factor for pollutant *p* from mining material type *t*, in lbs./ton of material produced
$MP_{t,c}$ = Amount of mining material type *t* produced in county *c*, in tons

The final step of the process is to sum the mining emissions estimates for each pollutant in each county. Emissions estimates are then converted from pounds to tons.

$$AE_{p,c} = \sum_t E_{p,t,c} \times 0.0005\, {}^{ton}/_{lb.} \quad (10)$$

Where:

$AE_{p,c}$ = Annual emissions of pollutant *p* in county *c*, in tons
$E_{t,p,c}$ = Annual emissions of pollutant *p* from mining material type *t* in county *c*, in lbs.

28.2.6 Example calculations

The steps below provide sample calculations to determine the PM25-PRI emissions from mining and quarrying operations. Constant emissions factor calculations that are used in all counties are not repeated here.

Table 28-4 provides a summary of these calculations. Note that equations 5-10 produce constant emissions factors that are used in all counties. Those calculations are not repeated here. The values in these equations are demonstrating program logic and are not representative of any specific NEI year or county.

Table 28-4: Sample calculations for estimating PM25-PRI emissions from mining and quarrying

Eq. #	Equation	Values	Result
1	$W_s = \frac{O_s}{O_{US}} \times W_{US}$	N/A	Waste data is not withheld for the state
2	$MP_{t,s} = (W_s + O_s) \times \frac{MP_{t,US}}{MP_{US}} \times 1.1023\, {}^{short\ ton}/_{metric\ ton}$	$(3{,}720 + 42{,}900) \times (2{,}660{,}000 \div 5{,}060{,}000) \times 1.1023\, {}^{ton}/_{metric\ ton}$	27,015 thousand tons metallic ore in the state
		$(3{,}720 + 42{,}900) \times (2{,}400{,}000 \div 5{,}060{,}000) \times 1.1023\, {}^{ton}/_{metric\ ton}$	24,375 thousand tons non-metallic ore in the state
3	$EmpFrac_{t,c} = \frac{Emp_{t,c}}{Emp_{t,s}}$	$\frac{25\ metallic\ mining\ employees\ in\ the\ county}{1{,}662\ metallic\ mining\ employees\ in\ the\ sta}$	Metallic employee fraction of 0.015
		$\frac{94\ nonmetallic\ mining\ employees\ in\ the\ co}{1{,}354\ nonmetallic\ mining\ employees\ in\ the}$	Nonmetallic employee fraction of 0.069
4	$MP_{t,c} = MP_{t,s} \times EmpFrac_{t,c}$	$27{,}015\ tons \times 0.015$	27,015 thousand tons metallic ore
		$24{,}375\ tons \times 0.069$	112 thousand tons non-metallic ore

Eq. #	Equation	Values	Result
11	$E_{p,t,c} = EF_{t,p} \times MP_{t,c}$	$0.0068\ {}^{lbs.}/_{ton} \times 27{,}015{,}167\ tons$	184,922.19 lbs. PM25-PRI emissions from metallic ore
		$0.037\ {}^{lbs.}/_{ton} \times 112{,}039\ tons$	4,107.38 lbs. PM25-PRI emissions from non-metallic ore
		$0.064\ {}^{lbs}/_{ton} \times 0\ tons$	0 lbs. PM25-PRI from coal mining
12	$AE_{p,c} = \sum_t E_{p,c} \times 0.0005\ {}^{short\ ton}/_{lb.}$	$184{,}922.19\ lbs. + 4{,}107.38\ lbs. + 0\ lbs. \times 0.0005\ {}^{ton}/_{lb.}$	95 tons PM25-PRI from mining and quarrying

28.2.7 Improvements/Changes in the 2020 NEI

No changes were made to this category. Activity data was updated to reflect the most recent, best available data at the time of the NEI.

28.2.8 Puerto Rico and U.S. Virgin Islands

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in tons for these two Florida counties are divided by their respective populations creating a tons per capita emissions factor. For each Puerto Rico and US Virgin Island county, the tons per capita emissions factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

28.3 References

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