

11.9 Western Surface Coal Mining

11.9.1 General¹

There are 12 major coal fields in the western states (excluding the Pacific Coast and Alaskan fields), as shown in Figure 11.9-1. Together, they account for more than 64 percent of the surface minable coal reserves in the United States.² The 12 coal fields have varying characteristics that may influence fugitive dust emission rates from mining operations including overburden and coal seam thicknesses and structure, mining equipment, operating procedures, terrain, vegetation, precipitation and surface moisture, wind speeds, and temperatures. The operations at a typical western surface mine are shown in Figure 11.9-2. All operations that involve movement of soil, coal, or equipment, or exposure of erodible surfaces, generate some amount of fugitive dust.

The initial operation is removal of topsoil and subsoil with large scrapers. The topsoil is carried by the scrapers to cover a previously mined and regraded area as part of the reclamation process or is placed in temporary stockpiles. The exposed overburden, the earth that is between the topsoil and the coal seam, is leveled, drilled, and blasted. Then the overburden material is removed down to the coal seam, usually by a dragline or a shovel and truck operation. It is placed in the adjacent mined cut, forming a spoils pile. The uncovered coal seam is then drilled and blasted. A shovel or front end loader loads the broken coal into haul trucks, and it is taken out of the pit along graded haul roads to the tipple, or truck dump. Raw coal sometimes may be dumped onto a temporary storage pile and later rehandled by a front end loader or bulldozer.

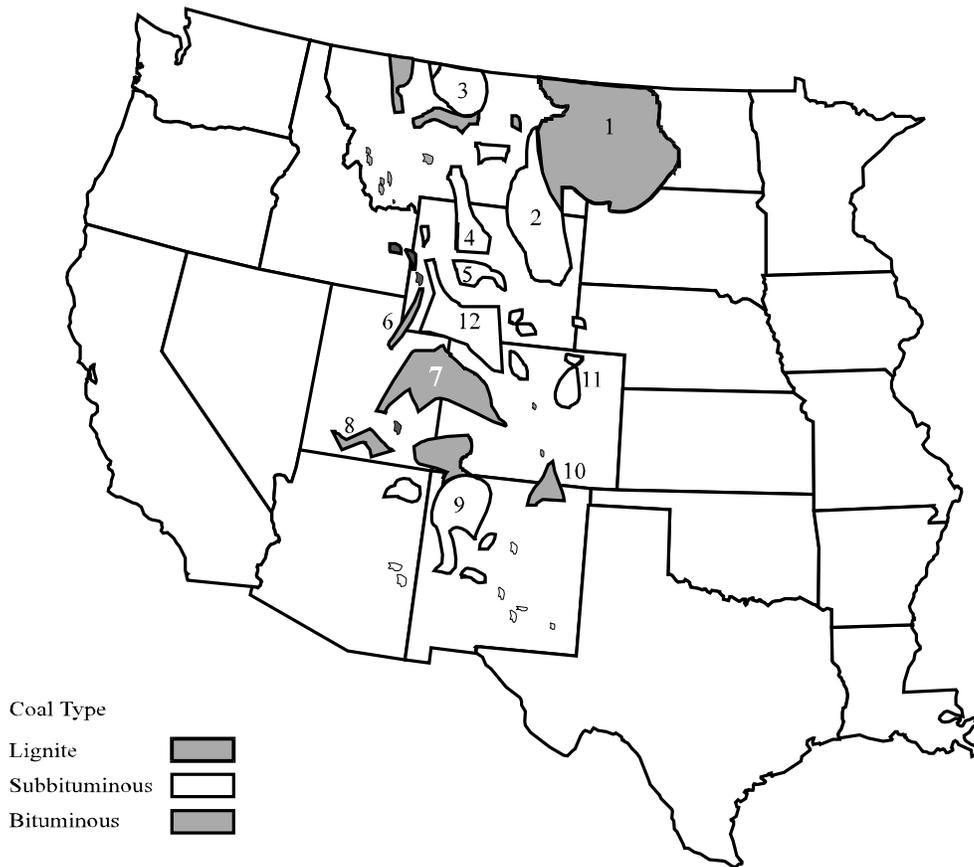
At the tipple, the coal is dumped into a hopper that feeds the primary crusher, then is conveyed through additional coal preparation equipment such as secondary crushers and screens to the storage area. If the mine has open storage piles, the crushed coal passes through a coal stacker onto the pile. The piles, usually worked by bulldozers, are subject to wind erosion. From the storage area, the coal is conveyed to a train loading facility and is put into rail cars. At a captive mine, coal will go from the storage pile to the power plant.

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, mulching, etc. From the time an area is disturbed until the new vegetation emerges, all disturbed areas are subject to wind erosion.

11.9.2 Emissions

Predictive emission factor equations for open dust sources at western surface coal mines are presented in Tables 11.9-1 and 11.9-2. Each equation is for a single dust-generating activity, such as vehicle traffic on unpaved roads. The predictive equation explains much of the observed variance in emission factors by relating emissions to 3 sets of source parameters: (1) measures of source activity or energy expended (e. g., speed and weight of a vehicle traveling on an unpaved road); (2) properties of the material being disturbed (e. g., suspendable fines in the surface material of an unpaved road); and (3) climate (in this case, mean wind speed).

The equations may be used to estimate particulate emissions generated per unit of source extent (e. g., vehicle distance traveled or mass of material transferred). The equations were



	Coal Field	Strippable Reserves (10 ⁶ tons)
1	Fort Union	23,529
2	Powder River	56,727
3	North Central	All underground
4	Bighorn Basin	All underground
5	Wind River	3
6	Hams Fork	1,000
7	Uinta	308
8	Southwestern Utah	224
9	San Juan River	2,318
10	Raton Mesa	All underground
11	Denver	All underground
12	Green River	2,120

Figure 11.9-1. Coal fields of the western United States.

Table 11.9-1 (Metric Units). EMISSION FACTOR EQUATIONS FOR UNCONTROLLED OPEN DUST SOURCES AT WESTERN SURFACE COAL MINES^a

Operation	Material	Emissions By Particle Size Range (Aerodynamic Diameter) ^{b,c}				Units	EMISSION FACTOR RATING
		TSP ≤ 30 μm	≤15 μm	≤10 μm ^d	≤2.5 μm/TSP ^e		
Blasting	Coal or overburden	0.00022 ^{1.5}	ND	0.52 ^e	ND	kg/blast	C
Truck loading	Coal	$\frac{0.580}{(M)^{1.2}}$	$\frac{0.0596}{(M)^{0.9}}$	0.75	0.019	kg/Mg	B
Bulldozing	Coal	$\frac{35.6 (s)^{1.2}}{(M)^{1.4}}$	$\frac{8.44 (s)^{1.5}}{(M)^{1.4}}$	0.75	0.022	kg/hr	B
	Overburden	$\frac{2.6 (s)^{1.2}}{(M)^{1.3}}$	$\frac{0.45 (s)^{1.5}}{(M)^{1.4}}$	0.75	0.105	kg/hr	B
Dragline	Overburden	$\frac{0.0046 (d)^{1.1}}{(M)^{0.3}}$	$\frac{0.0029 (d)^{0.7}}{(M)^{0.3}}$	0.75	0.017	kg/m ³	B
Scraper (travel mode)		9.6 x 10 ⁻⁶ (s) ^{1.3} (W) ^{2.4}	2.2 x 10 ⁻⁶ (s) ^{1.4} (W) ^{2.5}	0.60	0.026	kg/VKT	A
Grading		0.0034 (S) ^{2.5}	0.0056 (S) ^{2.0}	0.60	0.031	kg/VKT	B
Vehicle traffic (light/medium duty)		$\frac{1.63}{(M)^{4.0}}$	$\frac{1.05}{(M)^{4.3}}$	0.60	0.040	kg/VKT	B
Haul truck		0.0019 (w) ^{3.4} (L) ^{0.2}	0.0014 (w) ^{3.5}	0.60	0.017	kg/VKT	A
Active storage pile (wind erosion and maintenance)	Coal	1.8 u	ND	ND	ND	$\frac{\text{kg}}{(\text{hectare})(\text{hr})}$	C ^f

^a Reference 1, except for coal storage pile equation from Reference 4. TSP = total suspended particulate. VKT = vehicle kilometers traveled. ND = no data.

^b TSP denotes what is measured by a standard high volume sampler (see Section 13.2).

^c Symbols for equations:

A = horizontal area, with blasting depth ≤21 m. Not for vertical face of a bench.

M = material moisture content (%)

Table 11.9-1 (cont.).

s = material silt content (%)

u = wind speed (m/sec)

d = drop height (m)

W = mean vehicle weight (Mg)

S = mean vehicle speed (kph)

w = mean number of wheels

L = road surface silt loading (g/m^2)

^d Multiply the $\leq 15 \mu\text{m}$ equation by this fraction to determine emissions.

^e Multiply the TSP predictive equation by this fraction to determine emissions in the $\leq 2.5 \mu\text{m}$ size range.

^f Rating applicable to Mine Types I, II, and IV (see Tables 11.9-5 and 11.9-6).

Table 11.9-2 (English Units). EMISSION FACTOR EQUATIONS FOR UNCONTROLLED OPEN DUST SOURCES AT WESTERN SURFACE COAL MINES^a

Operation	Material	Emissions By Particle Size Range (Aerodynamic Diameter) ^{b,c}				Units	EMISSION FACTOR RATING
		TSP ≤ 30 μm	≤15 μm	≤10 μm ^d	≤2.5 μm/TSP ^e		
Blasting	Coal or overburden	$0.0005A^{1.5}$ 	ND	0.52^e	ND	lb/blast	C
Truck loading	Coal	$\frac{1.16}{(M)^{1.2}}$	$\frac{0.119}{(M)^{0.9}}$	0.75	0.019	lb/ton	B
Bulldozing	Coal	$\frac{78.4 (s)^{1.2}}{(M)^{1.3}}$	$\frac{18.6 (s)^{1.5}}{(M)^{1.4}}$	0.75	0.022	lb/ton	 B
	Overburden	$\frac{5.7 (s)^{1.2}}{(M)^{1.3}}$	$\frac{1.0 (c)^{1.5}}{(M)^{1.4}}$ 	0.75	0.105	lb/ton	B
Dragline	Overburden	$\frac{0.0021 (d)^{1.1}}{(M)^{0.3}}$	$\frac{0.0021 (d)^{0.7}}{(M)^{0.3}}$	0.75	0.017	lb/yd ³	B
Scraper (travel mode)		$2.7 \times 10^{-5} (s)^{1.3} (W)^{2.4}$	$6.2 \times 10^{-6} (s)^{1.4} (W)^{2.5}$	0.60	0.026	lb/VMT	A
Grading		$0.040 (S)^{2.5}$	$0.051 (S)^{2.0}$	0.60	0.031	lb/VMT	B
Vehicle traffic (light/medium duty)		$\frac{5.79}{(M)^{4.0}}$	$\frac{3.72}{(M)^{4.3}}$	0.60	0.040	lb/VMT	B
Haul truck		$0.0067 (w)^{3.4} (L)^{0.2}$	$0.0051 (w)^{3.5}$	0.60	0.017	lb/VMT	A
Active storage pile (wind erosion and maintenance)	Coal	1.6 u	ND	ND	ND	$\frac{\text{lb}}{(\text{acre})(\text{hr})}$	C ^f

^a Reference 1, except for coal storage pile equation from Reference 4. TSP = total suspended particulate. VMT = vehicle miles traveled.

ND = no data.

^b TSP denotes what is measured by a standard high volume sampler (see Section 13.2).

^c Symbols for equations:

A = horizontal area, with blasting depth ≤70 ft. Not for vertical face of a bench.

M = material moisture content (%)

Table 11.9-2 (cont.).

s = material silt content (%)

u = wind speed (m/sec)

d = drop height (ft)

W = mean vehicle weight (tons)

S = mean vehicle speed (mph)

w = mean number of wheels

L = road surface silt loading (g/m^2)

^d Multiply the $\leq 15 \mu\text{m}$ equation by this fraction to determine emissions.

^e Multiply the TSP predictive equation by this fraction to determine emissions in the $\leq 2.5 \mu\text{m}$ size range.

^f Rating applicable to Mine Types I, II, and IV (see Tables 11.9-5 and 11.9-6).

developed through field sampling of various western surface mine types and are thus applicable to any of the surface coal mines located in the western United States.

In Tables 11.9-1 and 11.9-2, the assigned quality ratings apply within the ranges of source conditions that were tested in developing the equations given in Table 11.9-3. However, the equations should be derated 1 letter value (e. g., A to B) if applied to eastern surface coal mines.

In using the equations to estimate emissions from sources found in a specific western surface mine, it is necessary that reliable values for correction parameters be determined for the specific sources of interest if the assigned quality ranges of the equations are to be applicable. For example, 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 11.9-3 may be used, but the assigned quality rating of each emission factor equation should be reduced by 1 level (e. g., A to B).

Emission factors for open dust sources not covered in Table 11.9-3 are in Table 11.9-4. These factors were determined through source testing at various western coal mines.

Table 11.9-3 (Metric And English Units). TYPICAL VALUES FOR CORRECTION FACTORS APPLICABLE TO THE PREDICTIVE EMISSION FACTOR EQUATIONS^a

Source	Correction Factor	Number Of Test Samples	Range	Geometric Mean	Units
Coal loading	Moisture	7	6.6 - 38	17.8	%
Bulldozers					
Coal	Moisture	3	4.0 - 22.0	10.4	%
	Silt	3	6.0 - 11.3	8.6	%
Overburden	Moisture	8	2.2 - 16.8	7.9	%
	Silt	8	3.8 - 15.1	6.9	%
Dragline	Drop distance	19	1.5 - 30	8.6	m
	Drop distance	19	5 - 100	28.1	ft
	Moisture	7	0.2 - 16.3	3.2	%
Scraper	Silt	10	7.2 - 25.2	16.4	%
	Weight	15	33 - 64	48.8	Mg
	Weight	15	36 - 70	53.8	ton
Grader	Speed	7	8.0 - 19.0	11.4	kph
	Speed		5.0 - 11.8	7.1	mph
Light/Medium duty vehicle	Moisture	7	0.9 - 1.70	1.2	%
Haul truck	Wheels	29	6.1 - 10.0	8.1	number
	Silt loading	26	3.8 - 254	40.8	g/m ²
	Silt loading	26	34 - 2270	364	lb/acre

^a Reference 1.

Table 11.9-4 (English And Metric Units). UNCONTROLLED PARTICULATE EMISSION FACTORS FOR OPEN DUST SOURCES AT WESTERN SURFACE COAL MINES

Source	Material	Mine Location ^a	TSP Emission Factor ^b	Units	EMISSION FACTOR RATING
Drilling	Overburden	Any	1.3	lb/hole	B
			0.59	kg/hole	B
	Coal	V	0.22	lb/hole	E
			0.10	kg/hole	E
Topsoil removal by scraper	Topsoil	Any	0.058	lb/ton	E
			0.029	kg/Mg	E
		IV	0.44	lb/ton	D
			0.22	kg/Mg	D
Overburden replacement	Overburden	Any	0.012	lb/ton	C
			0.0060	kg/Mg	C
Truck loading by power shovel (batch drop) ^c	Overburden	V	0.037	lb/ton	C
			0.018	kg/Mg	C
Train loading (batch or continuous drop) ^c	Coal	Any	0.028	lb/ton	D
			0.014	kg/Mg	D
		III	0.0002	lb/ton	D
			0.0001	kg/Mg	D
Bottom dump truck unloading (batch drop) ^c	Overburden	V	0.002	lb/ton	E
			0.001	kg/ton	E
	Coal	IV	0.027	lb/ton	E
			0.014	kg/Mg	E
		III	0.005	lb/ton	E
			0.002	kg/Mg	E
		II	0.020	lb/ton	E
			0.010	kg/Mg	E

Table 11.9-4 (cont.).

Source	Material	Mine Location ^a	TSP Emission Factor ^b	Units	EMISSION FACTOR RATING
End dump truck unloading (batch drop) ^c	Coal	I	0.014	lb/T	D
			0.0070	kg/Mg	D
		Any	0.066	lb/T	D
			0.033	kg/Mg	D
		V	0.007	lb/T	E
			0.004	kg/Mg	E
Scraper unloading (batch drop) ^c	Topsoil	IV	0.04	lb/T	C
			0.02	kg/Mg	C
Wind erosion of exposed areas	Seeded land, stripped overburden, graded overburden	Any	0.38	$\frac{T}{(\text{acre})(\text{yr})}$	C
				0.85	$\frac{Mg}{(\text{hectare})(\text{yr})}$

^a Roman numerals I through V refer to specific mine locations for which the corresponding emission factors were developed.

Tables 11.9-4 and 11.9-5 present characteristics of each of these mines. See text for correct use of these "mine-specific" emission factors.

The other factors (from Reference 5 except for overburden drilling from Reference 1) can be applied to any western surface coal mine.

^b Total suspended particulate (TSP) denotes what is measured by a standard high volume sampler (see Section 13.2).

^c Predictive emission factor equations, which generally provide more accurate estimates of emissions, are presented in Chapter 13.

The factors in Table 11.9-4 for mine locations I through V were developed for specific geographical areas. Tables 11.9-5 and 11.9-6 present characteristics of each of these mines (areas). A "mine-specific" emission factor should be used only if the characteristics of the mine for which an emissions estimate is needed are very similar to those of the mine for which the emission factor was developed. The other (nonspecific) emission factors were developed at a variety of mine types and thus are applicable to any western surface coal mine.

As an alternative to the single valued emission factors given in Table 11.9-4 for train or truck loading and for truck or scraper unloading, 2 empirically derived emission factor equations are presented in Section 13.2.4 of this document. Each equation was developed for a source operation (i. e., batch drop and continuous drop, respectively) comprising a single dust-generating mechanism that crosses industry lines.

Because the predictive equations allow emission factor adjustment to specific source conditions, the equations should be used in place of the factors in Table 11.9-4 for the sources identified above if emission estimates for a specific western surface coal mine are needed. However, the generally higher quality ratings assigned to the equations are applicable only if: (1) reliable values of correction parameters have been determined for the specific sources of interest, and (2) the correction parameter values lie within the ranges tested in developing the equations. Table 11.9-3 lists measured properties of aggregate materials that can be used to estimate correction parameter values for the predictive emission factor equations in Chapter 13, in the event that site-specific values are not available. Use of mean correction parameter values from Table 11.9-3 will reduce the quality ratings of the emission factor equations in Chapter 13 by 1 level.

Table 11.9-5 (Metric And English Units). GENERAL CHARACTERISTICS OF SURFACE COAL MINES
REFERRED TO IN TABLE 11.9-4^a

Mine	Location	Type Of Coal Mined	Terrain	Vegetative Cover	Surface Soil Type And Erodibility Index	Mean Wind Speed		Mean Annual Precipitation	
						m/s	mph	cm	in.
I	N.W. Colorado	Subbitum.	Moderately steep	Moderate, sagebrush	Clayey loamy (71)	2.3	5.1	38	15
II	S.W. Wyoming	Subbitum.	Semirugged	Sparse, sagebrush	Arid soil with clay and alkali or carbonate accumulation (86)	6.0	13.4	36	14
III	S.E. Montana	Subbitum.	Gently rolling to semirugged	Sparse, moderate, prairie grassland	Shallow clay loamy deposits on bedrock (47)	4.8	10.7	28 - 41	11 - 16
IV	Central North Dakota	Lignite	Gently rolling	Moderate, prairie grassland	Loamy, loamy to sandy (71)	5.0	11.2	43	17
V	N.E. Wyoming	Subbitum.	Flat to gently rolling	Sparse, sagebrush	Loamy, sandy, clayey, and clay loamy (102)	6.0	13.4	36	14

^a Reference 4.

Table 11.9-6 (English Units). OPERATING CHARACTERISTICS OF THE COAL MINES REFERRED TO IN TABLE 11.9-4^a

Parameter	Required Information	Units	Mine				
			I	II	III	IV	V
Production rate	Coal mined	10 ⁶ ton/yr	1.13	5.0	9.5	3.8	12.0 ^b
Coal transport	Avg. unit train frequency	per day	NA	NA	2	NA	2
Stratigraphic data	Overburden thickness	ft	21	80	90	65	35
	Overburden density	lb/yd ³	4000	3705	3000	—	—
	Coal seam thicknesses	ft	9,35	15,9	27	2,4,8	70
	Parting thicknesses	ft	50	15	NA	32,16	NA
	Spoils bulking factor	%	22	24	25	20	—
	Active pit depth	ft	52	100	114	80	105
	Coal analysis data	Moisture	%	10	18	24	38
Ash		%, wet	8	10	8	7	6
Sulfur		%, wet	0.46	0.59	0.75	0.65	0.48
Heat content		Btu/lb	11000	9632	8628	8500	8020
Surface disposition		Total disturbed land	acre	168	1030	2112	1975
	Active pit	acre	34	202	87	—	71
	Spoils	acre	57	326	144	—	100
	Reclaimed	acre	100	221	950	—	100
	Barren land	acre	—	30	455	—	—
	Associated disturbances	acre	12	186	476	—	46
	Storage	Capacity	ton	NA	NA	—	NA
Blasting	Frequency, total	per week	4	4	3	7	7 ^b
	Frequency, overburden	per week	3	0.5	3	NA	7 ^b
	Area blasted, coal	ft ²	16000	40000	—	30000	—
	Area blasted, overburden	ft ²	20000	—	—	NA	—

^a Reference 4. NA = not applicable. Dash = no data.

^b Estimate.

References For Section 11.9

1. K. Axetell and C. Cowherd, *Improved Emission Factors For Fugitive Dust From Western Surface Coal Mining Sources*, 2 Volumes, EPA Contract No. 68-03-2924, U. S. Environmental Protection Agency, Cincinnati, OH, July 1981.

2. *Reserve Base Of U. S. Coals By Sulfur Content: Part 2, The Western States*, IC8693, Bureau Of Mines, U. S. Department Of The Interior, Washington, DC, 1975.
3. *Bituminous Coal And Lignite Production And Mine Operations - 1978*, DOE/EIA-0118(78), U. S. Department of Energy, Washington, DC, June 1980.
4. K. Axetell, *Survey Of Fugitive Dust From Coal Mines*, EPA-908/1-78-003, U. S. Environmental Protection Agency, Denver, CO, February 1978.
5. D. L. Shearer, *et al.*, *Coal Mining Emission Factor Development And Modeling Study*, Amax Coal Company, Carter Mining Company, Sunoco Energy Development Company, Mobil Oil Corporation, and Atlantic Richfield Company, Denver, CO, July 1981.