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GAP FILLING PM_{10} EMISSION FACTORS FOR SELECTED OPEN AREA DUST SOURCES

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Gap Filling PM_{10} Emission Factors For Selected Open Area Dust Sources

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EPA-450/4-88-003

CONTENTS

CONTENTS (concluded)

TABLES

SECTION 1.0

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has revised the National Ambient Air Quality Standard (NAAQS) for particulate matter (PM). The new standard is based on PM with an aerodynamic diameter of less than or equal to 10 µm (PM_{10}). Revision of this standard means that states must review their PM emission inventories and State Implementation Plans (SIPs).

EPA publishes an Agency document, *Compilation of Air Pollutant Emission Factors (AP-42)*,[1] to provide the states with quality-rated emission factors for use in preparing emission inventories and SIPs. However, PM_{10} emission factors for some open dust sources are not presently contained in AP-42. The purpose of this report is to fill gaps that exist in the PM_{10} emission factors for those sources. PM_{10} factors have been derived using scientific and engineering judgement and employing data transfer techniques.

The PM_{10} factors derived in this study represent uncontrolled emissions (unless noted) and should be used cautiously to fill gaps in PM_{10} emission inventories. The most reliable emission factors are based on source-specific test data. The reader is cautioned to use the gap filling factors only for situations where the stated caveats and assumptions are valid and for those sources where no direct test data are otherwise available.

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[1] *Compilation of Air Pollutant Emission Factors (AP-42)*, Volumes I and II, U.S. Environmental Protection Agency, Office of Air and Radiation, Research Triangle Park, NC, Fourth Edition: September 1985 and Supplement A: October 1986.

SECTION 2.0

DEVELOPMENT OF PROPOSED PM_{10} EMISSION FACTORS

In this study, the first step consisted of the review of current AP-42 factors for applicability, with particular emphasis on particle size information. For some open area dust sources, AP-42 presents particulate emission factors for total suspended particulates (TSP) or other particle size fractions which can be used in estimating PM_{10}. The second step was to search for other documents which could contribute applicable PM_{10} emission factor information. Finally, all technical information was evaluated and methods were proposed and then used to develop PM_{10} emission factors for the sources of interest.

In particular, three general techniques were used to develop PM_{10} factors. The first technique consisted of dividing a source activity into generic components and then combining available emission factors for these activities into a new emission factor for the source of interest. The second technique involved the formulation of a new factor using marginally applicable but related factors and size-specific data. The third technique was to base a PM_{10} factor on field testing data not currently reported in AP-42.

The above procedures resulted in PM_{10} emission factors for the sources presented in Table 1. Each source is identified by category and dust-emitting activity. Related AP-42 emission factors are listed, if available, together with the basis for the proposed PM_{10} emission factor.

Table 2 summarizes and assigns quality ratings to the proposed PM_{10} emission factors for open area dust sources of interest and notes the relevant section of this report for each source. The quality ratings (A-E) are estimates of the reliability of the factors and apply only when emission parameters are within stated limits. Sections 3.0 through 17.0 present detailed background information and methodology for each of the proposed PM_{10} factors, and state all assumptions and caveats. Background documents used as references and to prepare the PM_{10} emission factors have been assembled and are on file at the Criteria Emissions Section of EPA's Office of Air Quality Planning and Standards.

TABLE 1. PM_{10} EMISSION FACTOR DEVELOPMENT

Source		Applicable AP-42 sections	Basis for proposed PM_{10} emission factor
Category	Activity		
Agricultural tilling	Tilling (mechanical)	11.2.2	Current AP-42 factor is specific to PM_{10}.
Agricultural harvesting of cotton	Harvesting, loading, field transport (mechanical)	6.16	PM_{10} factors are closely represented by PM_7 factors in AP-42.
Agricultural harvesting of grain	Harvesting, loading, field transport (mechanical)	6.17	PM_{10} factors are closely represented by PM_7 factors in AP-42.
Waste disposal by burning	Burning (combustion)	2.4	Current TSP factors in AP-42 are noted as being mostly submicron and thus also representative of PM_{10} factors.
Airport runways (unpaved)	Aircraft landings and takeoffs (mechanical and wind erosion)	11.2.1	Unpaved road PM_{10} factor is used with representative parameters for small aircraft runways together with a wind erosion multiplier.
Cattle feedlots	Surface disturbance (mechanical); exposed erodible surface (wind erosion); traffic (mechanical)	6.15 11.2.2	Current TSP factors are made specific to PM_{10} using an aerodynamic particle size multiplier from agricultural soils.
Construction site preparation	Traffic and materials handling (mechanical and wind erosion)	11.2	TSP factors back-calculated using dispersion modeling are made specific to PM_{10} using an average PM_{10}/TSP ratio measured in the field.
Demolition of structures	Building destruction a. Explosive detonation b. Mechanical impact Debris cleanup a. Debris loading (mechanical and wind erosion) b. Truck traffic	11.2	Current AP-42 PM_{10} factors for batch drop operations and unpaved road truck travel are used together with two measured TSP factors (corrected to PM_{10} using a generic particle size multiplier) for truck filling. The PM_{10} factors are combined and related to the floor space of a demolished building using relationships from a survey of demolished buildings.
Off-highway vehicle traffic	Traffic (mechanical); surface disturbance (wind erosion)	—	Measured PM_{10} factors for vehicle travel on natural desert terrain are used for four-wheel vehicles and are corrected per AP-42 for motorcycle wheels and weight.

(continued)

TABLE 1 (Continued)

Source		Applicable AP-42 sections	Basis for proposed PM_{10} emission factor
Category	Activity		
Municipal solid waste landfills	Traffic (mechanical); dumping (mechanical); covering with soil (mechanical and wind erosion)	11.2	Emission inventories for two landfill studies are the basis for emissions from unpaved road travel, handling of fill materials, and dozer activity. Current AP-42 factors are used to obtain a PM_{10} factor for MSW landfills based on MSW volume receipts and on-site travel distance to the disposal site.
Coarse, dry tailings ponds	Exposed erodible surface (wind erosion)	—	PM_{10} factor is closely represented by measured PM_{12} factor.
Transportation tire wear	Traffic (mechanical)	11.2.5	PM_{10} factor was developed by EPA from laboratory and field studies.
Transportation brake wear	Traffic (mechanical)	11.2.5	PM_{10} factor was developed by EPA from laboratory studies.
Road sanding/salting	Traffic (mechanical)	11.2.5	Entire PM_{10} fraction (contained in the silt fraction) of the sand mixture is assumed to become airborne. These fractions are based on measured values for sand and for western sandy soils. Five percent of the applied salt is assumed to dry on roadway and 10 percent of this film is assumed to be driven off as PM_{10} emissions.
Unpaved parking lots	Traffic (mechanical); exposed erodible surface (wind erosion)	11.2.1	PM_{10} factor is based on AP-42 unpaved road factor with default values for silt, number of wheels, vehicle weight, and vehicle speed.

TABLE 2. PROPOSED GAP FILLING EMISSION FACTORS

Source category	Estimated PM_{10} emission factor	Estimated rating	Applicable report section
Agricultural tilling	AP-42 Equation 1 in 11.2.2.[a]	B	3.0
Agricultural harvesting of cotton	AP-42 Table 6.16-2	C	4.0
Agricultural harvesting of grain	AP-42 Table 6.17-1	D	5.0
Waste disposal by burning	AP-42 Tables 2.4-1, 2.4-2, and 2.4-3	B	6.0
Airport runways (unpaved)	75s g/LTO 0.19s lb/LTO	E	7.0
Cattle feedlots	70 kg/day/1,000-head capacity 180 lb/day/1,000-head capacity or 15 metric ton/1,000-head throughput 17 tons/1,000-head throughout	E	8.0
Construction site preparation	5.7 kg/VKT, 20 lb/VMT } topsoil removal 1.2 kg/VKT, 4.3 lb/VMT } cut and fill operations 2.8 kg/VKT, 10 lb/VMT } truck haulage	D	9.0
Demolition of structures	56 g/m^2 of demolished floor area 0.011 lb/ft^{-2} of demolished floor area	D	10.0
Off-highway vehicle travel	1.8 kg/VKT, 6.3 lb/VMT } 4-wheel vehicles 0.25 kg/VKT, 0.89 lb/VMT } motorcycles	D	11.0
Municipal solid waste landfills	$\frac{0.4}{DD}$ g/m^3-mi	D	12.0
Coarse, dry tailings ponds	50 T_v mg/m^2 of exposed tailings area 4.6 T_v mg/ft^2 of exposed tailings area	D	13.0
Transportation tire wear	1 mg/VKT 2 mg/VMT	B	14.0
Transportation brake wear	7.8 mg/VKT 13 mg/VMT	C	15.0

(continued)

TABLE 2 (Continued)

Category	Estimated PM_{10} emission factor	Estimated rating	Applicable report section
Road sanding/salting	13s g/metric ton of applied sand 0.03s lb/ton of applied sand 4.3 kg/metric ton of applied salt 10 lb/ton of applied salt	E	16.0
Unpaved parking lots	$0.2 \frac{(365-p)}{365} (L \cdot W)$ g/vehicle parked (English unit not suitable)	D	17.0

s = Silt content (%)
LTO = Landing/takeoff cycles
VMT = Vehicle miles traveled
VKT = Vehicle kilometers traveled
Q = MSW volume (m^3)
D = Distance between gate and MSW disposal site (mi)
T_v = Number of minutes that wind velocity exceeds 19 m/s (42 mph) at 10 m above surface during specific time period of interest
L = Dimension of parking lot perpendicular to aisles (m)
W = Dimension of parking lot parallel to aisles (m)

SECTION 3.0

AGRICULTURAL TILLING

3.1 BACKGROUND

The mechanical tilling of agricultural land injects dust particles into the atmosphere as the soil is loosened or turned under by plowing, disking, harrowing, one-waying, etc. There is a predictive emission factor equation in AP-42, §11.2.2 for the estimation of dust emissions from agricultural tilling.

$$E = k(5.38)(s)^{0.6} \text{ kg/ha}$$

$$E = k(4.80)(s)^{0.6} \text{ lb/acre}$$

where s = silt content (percent) of surface soil (default value of 18 percent)
k = particle size multiplier (dimensionless)

3.2 DERIVATION OF PM_{10} EMISSION FACTOR

Field measurement tests are cited in AP-42 §11.2.2, "Agricultural Tilling," and provide the basis for deriving the PM_{10} emission factor. In this instance, AP-42 provides an aerodynamic multiplier to convert total suspended particulate value to a PM_{10} value. The particle size multiplier, k, is given as 0.21 for PM_{10}.

3.3 RECOMMENDED PM_{10} EMISSION FACTOR(S)

If a silt value can be obtained, the emission factor equation (with an AP-42 rating of B) is:

$$E_{10} = (0.21)(5.38)(s)^{0.6} \text{ kg/ha}$$

$$= 1.1(s)^{0.6} \text{ kg/ha}$$

$$= 1.0(s)^{0.6} \text{ lb/acre}$$

If a silt value cannot be obtained, a default value of 18 percent is used, and the emission factor equation (with a C rating) is:

$$E_{10} = (0.21)(5.38)(18)^{0.6} \text{ kg/ha}$$

$$= 6.4 \text{ kg/ha}$$

$$= 5.7 \text{ lb/acre}$$

The above equations are based solely on information currently contained in AP-42. Silt content of tested soils ranged from 1.7 to 88 percent.

3.4 REFERENCE DOCUMENTS

AP-42, §11.2.2 (with its references), including

Cuscino, T. A., Jr., et al., *The Role of Agricultural Practices in Fugitive Dust Emissions*, California Air Resources Board, Sacramento, CA, June 1981.

SECTION 4.0

AGRICULTURAL HARVESTING OF COTTON

4.1 BACKGROUND

Mechanical harvesting of cotton involves three unit operations: harvesting, trailer loading (basket dumping), and transport of trailers in the field. Particulate emission factors from these operations were developed by sampling downwind concentrations and then applying atmospheric diffusion models. These emissions factors are shown in AP-42. Emissions are related to machine speed, basket and trailer capacity, lint cotton yield, free silica content, and transport speed. The particulates are composed mainly of raw cotton dust and solid dust, which contains free silica.

4.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

Field measurement tests are cited in AP-42, §6.16. These tests produced the particulate emission factors presented in Table 3 (AP-42 Table 6.16-2). Emission factors are for total respirable particulate < 7 µm mean aerodynamic diameter.

4.3 RECOMMENDED PM_{10} EMISSION FACTOR(S)

PM_{10} factors are closely represented by the factors presented in Table 3 (< 7 µm mean aerodynamic diameter). The factors are based on average machine speed of 1.34 m/s (3.0 mph) for pickers and 2.25 m/s (5.03 mph) for strippers, on a basket capacity of 109 kg (240 lb), on a trailer capacity of six baskets, on a lint cotton yield of 63.0 metric tons/km² (1.17 bales/acre) for pickers and 41.2 metric tons/km² (0.77 bale/acre) for strippers, and on a transport speed of 4.47 m/s (10.0 mph).

4.4 REFERENCE DOCUMENTS

AP-42, §6.16, including

Snyder, J. W., and T. R. Blackwood, *Source Assessment: Mechanical Harvesting of Cotton - State of the Art*, EPA-600/2-77-107d, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 1977.

TABLE 3. PARTICULATE EMISSION FACTORS FOR COTTON HARVESTING OPERATIONS[a]
(Table 6.16-2 from AP-42)
EMISSION FACTOR RATING: C

Type of harvester	Harvesting		Trailer loading		Transport		Total	
	$\frac{kg}{km^2}$	$\frac{lb}{mi^2}$	$\frac{kg}{km^2}$	$\frac{lb}{mi^2}$	$\frac{kg}{km^2}$	$\frac{lb}{mi^2}$	$\frac{kg}{km^2}$	$\frac{lb}{mi^2}$
Picker[c]								
Two-row, with basket	0.46	2.6	0.070	0.40	0.43	2.5	0.96	5.4
Stripper[d]								
Two-row, pulled trailer	7.4	42	b	-	0.28	1.6	7.7	44
Two-row, with basket	2.3	13	0.092	0.52	0.28	1.6	2.7	15
Four-row, with basket	2.3	13	0.092	0.52	0.28	1.6	2.7	15
Weighted average[e]	4.3	24	0.056	0.32	0.28	1.6	4.6	26

[a]Emission factors are from Snyder, 1977 for particulate of < 7 um mean diameter.
[b]Not applicable.
[c]Free silica content is 7.9%: maximum content of pesticides and defoliants is 0.02%.
[d]Free silica content is 2.3%: maximum content of pesticides and desiccants is 0.2%.
[e]The weighted stripping factors are based on estimates that 2% of all strippers are four-row models with baskets, and of the remainder, 40% are two-row models with pulling trailers and 60% are two-row models with mounted baskets.

SECTION 5.0

AGRICULTURAL HARVESTING OF GRAIN

5.1 BACKGROUND

Mechanical harvesting of grain includes three operations: (1) crop handling by harvest machine, (2) loading of harvested crop into trucks, and (3) transport by trucks on the field. Particulate emission rates from these operations were developed by sampling downwind concentrations and then applying atmospheric diffusion models. These emission rates/factors are given in AP-42 Table 6.17-1. Emissions are related to combine speed, combine swath width, field transport speed, truck loading time, truck capacity, and truck travel time.

5.2 DERIVATION OF PM_{10} EMISSION FACTOR

Field measurement tests are cited in AP-42 §6.17. These tests produced the particulate emission factors/rates in Table 4 (AP-42 Table 6.17-1) Emission factors are for total respirable particulate of < 7 µm mean aerodynamic diameter and also are estimates of PM_{10} factors.

5.3 RECOMMENDED PM_{10} EMISSION FACTOR(S)

PM_{10} factors are closely represented by the factors presented in AP-42 Table 4 (< 7 µm mean aerodynamic diameter). Assumptions are an average combine speed of 3.36 m/s, combine swath width of 6.07 m, a field transport speed of 4.48 m/s, a truck loading time of 6 min, a truck capacity of 0.52 km^2 for wheat and 0.029 km^2 for sorghum, and a filled truck travel time of 125 s per load.

5.4 REFERENCE DOCUMENTS

AP-42, §6.17, including

Wachter, R. A., and T. R. Blackwood, *Source Assessment: Harvesting of Grain. State of the Art*, EPA 600/2-79-107f, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 1977.

TABLE 4. EMISSION RATES/FACTORS FROM THE HARVESTING GRAIN[a]
(Table 6.17-1 from AP-42)
EMISSION FACTOR RATING: D

	Emission rate[b]				Emission factor[c]			
	Wheat		Sorghum		Wheat		Sorghum	
Operation	lb/h	mg/s	lb/h	mg/s	lb/mi²	g/km²	lb/mi²	g/km²
Harvest machine	0.027	3.4	0.18	23.0	0.96	170.0	6.5	1,100.0
Truck loading	0.014	1.8	0.014	1.8	0.07	12.0	0.13	22.0
Field transport	0.37	47.0	0.37	47.0	0.65	110.0	1.2	200.0

[a]From Wachter, 1977 for particulate of < 7 μm mean aerodynamic diameter.
[b]Assumptions from Wachter, 1977 are an average combine speed of 3.36 m/s, combine swath width of 6.07 meters, and a field transport speed of 4.48 m/s.
[c]In addition to Note b, assumptions are a truck loading time of 6 min, a truck capacity of 0.052 km² for wheat and 0.029 km² for sorghum, and a filled truck travel time of 125 s/load.

SECTION 6.0

WASTE DISPOSAL BY BURNING

6.1 BACKGROUND

Open burning is used to dispose of both industrial and agricultural wastes. Various burning emission factors are reported in AP-42, §2.4, but there is no indication of "exact" particle size. Dominant activities influencing emission levels are firing techniques, moisture content, and "fuel" type.

6.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

Total particulate values for open and agricultural burning in AP-42 Tables 2.4-2 and 2.4-3 are footnoted as being mostly submicron, and thus should represent PM_{10} emission factors well.

6.3 RECOMMENDED PM_{10} EMISSION FACTOR(S)

It is assumed that all emission factors given in Tables 5 to 7 (AP-42 Tables 2.4-1 to 2.4-3) are ≤ 10 µmA. As a result, the attached AP-42 Tables 2.4-1, 2.4-2, and 2.4-3 are representative also of PM_{10} emission factors.

6.4 REFERENCE DOCUMENTS

AP-42, §2.4 (with its refer[illegible]).

TABLE 5. EMISSION FACTORS FOR OPEN BURNING OF NONAGRICULTURAL MATERIAL
(Table 2.4-1 from AP-42)
EMISSION FACTOR RATING: B

Source	Particulate	Sulfur oxides	Carbon monoxide	VOC[a] Methane	VOC[a] Nonmethane	Nitrogen oxides
Municipal refuse[b]						
kg/Mg	8	0.5	42	6.5	15	3
lb/ton	16	1	85	13	30	6
Automobile components[c]						
kg/Mg	50	Neg.	62	5	16	2
lb/ton	100	Neg.	125	10	32	4

[a] Data indicate that VOC emissions are approximately 25% methane, 8% other saturates, 18% olefins, 42% others (oxygenates, acetylene, aromatics, trace formaldehyde).
[b] References 2, 7 from AP-42, §2.4.
[c] Reference 2 from AP-42, §2.4. Upholstery, belts, hoses, and tires burned together.

TABLE 6. EMISSION FACTORS AND FUEL LOADING FACTORS FOR OPEN BURNING OF AGRICULTURAL MATERIALS[a]
(Table 2.4-2 from AP-42)
EMISSION FACTOR RATING: B

Refuse category	Particulate[b] kg/Mg	Particulate[b] lb/ton	Carbon monoxide kg/Mg	Carbon monoxide lb/ton	VOC[c] Methane kg/Mg	VOC[c] Methane lb/ton	VOC[c] Nonmethane kg/Mg	VOC[c] Nonmethane lb/ton	Fuel loading factors (waste production) Mg/ha	Fuel loading factors (waste production) tons/acre
Field crops[d]										
Unspecified	11	21	58	117	2.7	5.4	9	18	4.5	2
Burning techniques not significant[e]										
Asparagus[f]	20	40	75	150	10	20	33	66	3.4	1.5
Barley	11	22	78	157	2.2	4.5	7.5	15	3.8	1.7
Corn	7	14	54	108	2	4	6	12	9.4	4.2
Cotton	4	8	88	176	0.7	1.4	2.5	5	3.8	1.7
Grasses	8	16	50	101	2.2	4.5	7.5	15		
Pineapple[g]	4	8	56	112	1	2	3	6		
Rice[h]	4	9	41	83	1.2	2.4	4	8	6.7	3.0
Safflower	9	18	72	144	3	6	10	20	2.9	1.3
Sorghum	9	18	38	77	1	2	3.5	7	6.5	2.9
Sugar cane[i]	2.5-3.5	6-8.4	30-41	60-81	0.6-2	1.2-3.8	2-6	4-12	8-46	3-17
Headfire burning[j]										
Alfalfa	23	45	53	106	4.2	8.5	14	28	1.8	0.8
Bean (red)	22	43	93	186	5.5	11	18	36	5.6	2.5
Hay (wild)	16	32	70	139	2.5	5	8.5	17	2.2	1.0
Oats	22	44	68	137	4	7.8	13	26	3.6	1.6
Pea	16	31	74	147	4.5	9	15	29	5.6	2.5
Wheat	11	22	64	128	2	4	6.5	13	4.3	1.9
Backfire burning[k]										
Alfalfa	14	29	60	119	4.5	9	14	29	1.8	0.8
Bean (red), pea	7	14	72	148	3	6	10	19	5.6	2.5
Hay (wild)	8	17	75	150	2	4	6.5	13	2.2	1.0
Oats	11	21	68	136	2	4	7	14	3.6	1.6
Wheat	6	13	54	108	1.3	2.6	4.5	9	4.3	1.9
Vine crops	3	5	26	51	0.8	1.7	3	5	5.6	2.5
Weeds										
Unspecified	8	15	42	85	1.5	3	4.5	9	7.2	3.2
Russian thistle (tumbleweed)	11	22	154	309	0.2	0.5	0.8	1.5	0.2	0.1
Tules (wild reeds)	3	5	17	34	3.2	6.5	10	21		
Orchard crops[d,l,m]										
Unspecified	3	6	26	52	1.2	2.5	4	8	5.6	2.5
Almond	3	6	23	46	1	2	2	4	5.6	2.5
Apple	2	4	21	42	0.5	1	1.5	3	5.2	2.3
Apricot	3	6	24	49	1	2	3	6	4	1.8
Avocado	10	21	58	116	3.8	7.5	12	25	3.4	1.5
Cherry	4	8	22	44	1.2	2.5	4	8	2.2	1.0
Citrus (orange, lemon)	3	6	40	81	1.5	3	5	9	2.2	1.0
Date palm	5	10	28	56	0.8	1.7	3	5	2.2	1.0
Fig	4	7	28	57	1.2	2.5	4	8	4.9	2.2
Nectarine	2	4	16	33	0.5	1	1.5	3	4.5	2.0
Olive	6	12	57	114	2	4	7	14	2.7	1.2
Peach	3	6	21	42	0.6	1.2	2	4	5.6	2.5
Pear	4	9	28	57	1	2	3.5	7	5.8	2.6
Prune	2	3	21	42	0.4	0.7	1	2	2.7	1.2
Walnut	3	6	24	47	1	2	3	6	2.7	1.2

(continued)

TABLE 6 (continued)

Refuse category	Particulate[b] kg/Mg	Particulate[b] lb/ton	Carbon monoxide kg/Mg	Carbon monoxide lb/ton	VOC[c] Methane kg/Mg	VOC[c] Methane lb/ton	VOC[c] Nonmethane kg/Mg	VOC[c] Nonmethane lb/ton	Fuel loading factors (waste production) Mg/ha	Fuel loading factors (waste production) tons/acre
Forest residues[n]										
Unspecified	8	17	70	140	2.8	5.7	9	19	157	70
Hemlock, Douglas fir, cedar[p]	2	4	45	90	0.6	1.2	2	4		
Ponderosa pine[q]	6	12	98	195	1.7	3.3	5.5	11		

Note: References below are cited in AP-42, §2.4.

[a]Expressed as weight of pollutant emitted/weight of refuse material burned.

[b]Reference 12. Particulate matter from most agricultural refuse burning has been found to be in the submicrometer size range.

[c]Data indicate that VOC emissions average 22% methane, 7.5% other saturates, 17% olefins, 15% acetylene, 38.5% unidentified. Unidentified VOC are expected to include aldehydes, ketones, aromatics, cycloparaffins.

[d]References 12-13 for emission factors; Reference 14 for fuel loading factors.

For these refuse materials, no significant difference exists between emissions from headfiring or backfiring.

[f]Factors represent emissions under typical high moisture conditions. If ferns are dried to < 15% moisture, particulate emissions will be reduced by 30%, CO emissions 23%, VOC 74%.

[g]Reference 11. When pineapple is allowed to dry to < 20% moisture, as it usually is, firing technique is not important. When headfired at 20% moisture, particulate emissions will increase to 11.5 kg/Mg (23 lb/ton) and VOC will increase to 6.5 kg/Mg (13 lb/ton).

[h]Factors are for dry (15% moisture) rice straw. If rice straw is burned at higher moisture levels, particulate emissions will increase to 14.5 kg/Mg (29 lb/ton), CO emissions to 80.5 kg/Mg (181 lb/ton), and VOC emissions to 11.5 kg/Mg (23 lb/ton).

[i]Reference 20. See Section 8.12 for discussion of sugar cane burning. The following fuel loading factors are to be used in the corresponding states: Louisiana, 8-13.6 Mg/ha (3-5 tons/acre); Florida, 11-19 Mg/ha (4-7 tons/acre); Hawaii, 30-48 Mg/ha (11-17 tons/acre). For other areas, values generally increase with length of growing season. Use the larger end of the emission factor range for lower loading factors.

[j]See text for definition of headfiring.

[k]See text for definition of backfiring. This category, for emission estimation purposes, includes another technique used occasionally to limit emissions, called into-the-wind striplighting, which is lighting fields in strips into the wind at 100-200-m (300-600-ft) intervals.

[l]Orchard prunings are usually burned in piles. There are no significant differences in emissions between burning a "cold pile" and using a roll-on technique, where prunings are bulldozed onto the embers of a preceding fire.

[m]If orchard removal is the purpose of a burn, 66 Mg/ha (30 tons/acre) of waste will be produced.

[n]Reference 10. NO_x emissions estimated at 2 kg/Mg (4 lb/ton).

[p]Reference 15.

[q]Reference 16.

TABLE 7. EMISSION FACTORS FOR LEAF BURNING[a]
(Table 2.4-3 from AP-42)
EMISSION FACTOR RATING: B

Leaf species	Particulate[b]		Carbon monoxide		VOC[c] Methane		VOC[c] Nonmethane	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Black Ash	18	36	63.5	127	5.5	11	13.5	27
Modesto Ash	16	32	81.5	163	5	10	12	24
White Ash	21.5	43	57	113	6.5	13	16	32
Catalpa	8.5	17	44.5	89	2.5	5	6.5	13
Horse Chestnut	27	54	73.5	147	8	17	20	40
Cottonwood	19	38	45	90	6	12	14	28
American Elm	13	26	59.5	119	4	8	9.5	19
Eucalyptus	18	36	45	90	5.5	11	13.5	27
Sweet Gum	16.5	33	70	140	5	10	12.5	25
Black Locust	35	70	65	130	11	22	26	52
Magnolia	6.5	13	27.5	55	2	4	5	10
Silver Maple	33	66	51	102	10	20	24.5	49
American Sycamore	7.5	15	57.5	115	2.5	5	5.5	11
California Sycamore	5	10	52	104	1.5	3	3.5	7
Tulip	10	20	38.5	77	3	6	7.5	15
Red Oak	46	92	68.5	137	14	28	34	69
Sugar Maple	26.5	53	54	108	8	16	20	40
Unspecified	19	38	56	112	6	12	14	23

[a]References 18-19 from AP-42, §2.4. Factors are an arithmetic average of results obtained by burning high and low moisture content conical piles, ignited either at the top or around the periphery of the bottom. The windrow arrangement was only tested on Modesto Ash, Catalpa, American Elm, Sweet Gum, Silver Maple, and Tulip, and results are included in the averages for these species.
[b]The majority of particulates is submicron in size.
[c]Tests indicate that VOC emissions average 29% methane, 11% other saturates, 33% olefins, 27% other (aromatics, acetylene, oxygenates).

SECTION 7.0

AIRPORT RUNWAYS (UNPAVED)

7.1 BACKGROUND

Emissions from aircraft landings and takeoffs are caused by mechanical entrainment of soil by aircraft wheel/surface contact and by wind erosion from the aircraft wake. There is no directly applicable emission factor in AP-42. However, unpaved road emissions are quantified in AP-42, §11.2.1, and are believed to be appropriate for estimating emissions from unpaved airport runways. Runways are a minor source (i.e., compared to rural unpaved roads). Emissions vary with geographic area as reflected in dry days and soil texture.

7.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

The unpaved road equation from AP-42, §11.2.1, should be used:

$$E = k(1.7) \left(\frac{s}{12}\right) \left(\frac{S}{48}\right) \left(\frac{W}{2.7}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \left(\frac{365-p}{365}\right) \text{ kg/VKT}$$

$$E = k(5.9) \left(\frac{s}{12}\right) \left(\frac{S}{30}\right) \left(\frac{W}{3}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \left(\frac{365-p}{365}\right) \text{ lb/VMT}$$

where
- E = emission factor
- k = particle size multiplier (dimensionless)
- s = silt content of road surface material (%)
- S = mean vehicle speed, km/h (mph)
- W = mean vehicle weight, Mg (ton)
- w = mean number of wheels
- p = number of days with at least 0.254 mm (0.01 in) of precipitation per year

A wind erosion multiplier of 2 should be added to the above equation as recommended in the MRI national survey of fugitive dust sources (EPA-450/3-74-085).

7.3 RECOMMENDED PM_{10} EMISSION FACTOR

The proposed emission factor is based on aircraft landing/takeoff cycles (LTO):

$$E_{10} = 86 \text{ s g/LTO } (0.19 \text{ s lb/LTO})$$

where s = silt content of runway surface material (default value of 12%)

This factor applies to dry dirt airstrips only. Default values are:

LTO average speed = 40 mph
LTO runway length = 1 mi
Plane weight = 1 ton
Number of wheels = 3
Precipitation days = 0
Wind erosion multiplier = 2

7.4 REFERENCE DOCUMENTS

AP-42 §11.2.1 (with its references), and

Cowherd, C. Jr., et al., *Emissions Inventory of Agricultural Tilling, Unpaved Roads and Airstrips, and Construction Sites*, EPA-450/3-74-085, U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1974.

SECTION 8.0

CATTLE FEEDLOTS

8.1 BACKGROUND

Particulate emissions from cattle feedlots result from surface disturbance (mechanical), exposed erodible surface (wind erosion), and vehicle traffic (mechanical). The current AP-42 emission factor in §6.15 is based on either feedlot capacity or feedlot throughput:

280 lb/day/1,000-head capacity (TSP)
27 ton/1,000-head throughout (TSP)

Emissions are related to climate, soil texture, season, cattle density, natural mitigation of cattle in holding pens, and pen cleaning cycle.

8.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

The AP-42 TSP emission factors (Rating E) for cattle feedlots are made specific to PM_{10} using an aerodynamic particle size multiplier (PM_{10}/TSP) for agricultural tilling found in AP-42, §11.2.2, assuming that TSP is equivalent to PM_{30}. Mechanical disturbance of loose soil causes emissions for both cattle feedlots and agricultural tilling. The emission factor is derived as follows:

$$E_{10} = \frac{PM_{10}}{TSP} E_{TSP}$$

where the ratio, $\frac{PM_{10}}{TSP} = \frac{0.21}{0.33}$

8.3 RECOMMENDED PM_{10} EMISSION FACTOR(S)

The following calculated values represent emissions for cattle feedlots:

E_{10} = 0.21/0.33 x 280 lb/day/1,000-head capacity = 180 lb/day/1,000-head capacity (70 kg/day/1,000-head capacity)

or = 0.21/0.33 x 27 tons/1,000-head throughput = 17 tons/1,000-head throughput (15 metric tons/1,000-head throughput)

8.4 ASSUMPTIONS AND CAVEATS

Suspended particulate from cattle feedlots is assumed to be of same particle size distribution as from "generic" agricultural soil with 18 percent silt fraction. In addition, TSP is assumed to be equivalent to PM_{30}. Emissions are related to climate and natural mitigation of cattle and cattle density.

8.5 REFERENCE DOCUMENTS

AP-42, §6.15 and §11.2.2.

Cuscino, T. A., Jr., et al., *The Role of Agricultural Practices in Fugitive Dust Emissions*, California Air Resources Board, Sacramento, CA, June 1981.

Peters, J. A., and T. R. Blackwood, *Source Assessment: Beef Cattle Feedlots*, EPA-600/2-77-107, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1977.

SECTION 9.0

CONSTRUCTION SITE PREPARATION

9.1 BACKGROUND

The current AP-42 emission factor (related to particles < 30 µmS) is 1.2 tons/acre/month for an entire construction site. However, three different source activities usually comprise construction site preparation: topsoil removal (generally with scrapers), earthmoving (cut and fill operations), and truck haulage. These are represented separately in the sections below to produce estimated PM_{10} emission factors for each activity.

The most applicable reference document (Kinsey, 1983) indicates that the ambient PM_{10} concentration (C) downwind of road construction activity is related to surface silt content (s), traffic density (T_d), and surface moisture (M) by:

$$C = 60\ (s)^{0.88} \times (T_d)^{1.04} \times (M)^{-0.40}$$

at a downwind distance of 50 m. Therefore, PM_{10} emission factors should also be related to similar parameters.

9.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTORS

The PM_{10} emission factors were determined from TSP emission factors (back-calculated using dispersion modeling) and an average PM_{10}/TSP ratio measured in the field.

9.2.1 Measured Emission Factors for Construction Site Preparation

The data in Table 8 were presented by J. S. Kinsey et al. in *Study of Construction Related Dust Control.*

Three different construction activities were tested and are separated below by run number:

- Run Nos. AH-1 and AH-2 = Topsoil removal
- Run Nos. AH-4, AH-5, AH-7, and AH-10 = Earthmoving (cut and fill)
- Run Nos. AH-11 and AH-12 = Aggregate hauling (on dirt)

TABLE 8. CALCULATED EMISSION FACTORS FOR CONSTRUCTION-RELATED FUGITIVE DUST[a]
(Table 5-4 from Kinsey, 1983)

Run No.	Control scenario	Stability classification	Virtual distance (σ_o in meters)	Dispersion coefficient (σ_z)	Mean wind speed (m/s)	Net downwind concentration (10^{-6} g/m^3)	Vehicle passes/ minute	TSP emission factor[a] kg/veh-km	TSP emission factor[a] lb/VMT
AH-1	Uncontrolled	D	83.7	6.01	4.4	13,292	1.03	21.3	75.5
AH-2	Uncontrolled	D	83.7	6.01	5.1	16,996	1.57	20.7	73.4
AH-3	Uncontrolled	C	50.8	7.49	4.1	595	0.47	2.37	8.41
AH-4	Uncontrolled	B	35.1	9.12	3.1	7,642	1.12	11.7	41.5
AH-5	Uncontrolled	D	83.7	6.01	3.8	3,281	1.26	3.71	13.2
AH-6	Uncontrolled	D	83.7	6.01	8.0	292	0.94	0.932	3.31
AH-7	Uncontrolled	C	50.8	7.49	4.9	124	0.07	3.98	14.1
AH-9	Uncontrolled	B	35.1	9.12	2.8	676	0.86	1.21	4.29
AH-10	Uncontrolled	D	83.7	6.01	6.7	977	0.88	2.78	9.86
AH-11	Uncontrolled	C	50.8	7.49	5.5	604	0.21	7.26	25.8
AH-12	Uncontrolled	C	50.8	7.49	5.8	2,448	0.38	17.2	61.0
AH-13	Controlled	D	83.7	6.01	3.1	249	0.51	0.567	2.01
AH-14	Uncontrolled	C	50.8	7.49	3.4	845	0.68	1.94	6.88
AH-15	Controlled	D	83.7	6.01	5.6	159	0.39	0.857	3.04
AH-16	Controlled	C	50.8	7.49	6.2	1,472	0.54	7.74	27.5
AH-17	Controlled	B	35.1	9.12	4.6	564	0.59	2.42	8.58
AH-18	Controlled	D	83.7	6.01	8.0	384	0.60	1.92	6.81
AH-19	Controlled	C	50.8	7.49	8.4	219	0.74	1.14	4.04
Average uncontrolled emission factor								7.92	28.1
Average controlled emission factor								2.44	8.66

[a]TSP = particles < ~ 30 µmA
VMT = vehicle miles traveled.

The TSP emission factors were calculated from test data obtained at a distance of 50 m downwind of the construction activity. Ratios of PM_{10}/TSP were also obtained during the AH-test series and are presented in Table 9.

9.2.2 Calculation of PM_{10} Emission Factors

For topsoil removal, Tests AH-1 and AH-2 are applicable. The following calculations were made to obtain estimated PM_{10} emission factors for this activity:

$$\text{Average TSP emission factor} = \frac{21.3 + 20.7 \text{ kg/VKT}}{2} = 21 \text{ kg/VKT}$$

$$\text{Average } PM_{10}\text{/TSP ratio} = \frac{0.26 + 0.27}{2} = 0.27$$

Therefore for topsoil removal:

$$\text{Average } PM_{10} \text{ emission factor} = 0.27 \times 21 \text{ kg/VKT} = 5.7 \text{ kg/VKT}$$

For earthmoving (cut and fill), Tests AH-4, AH-5, AH-7, and AH-10 are applicable. The following calculations were made to obtain estimated PM_{10} emission factors for this activity.

$$\text{Average TSP emission factor} = \frac{11.7 + 3.71 + 3.98 + 2.78 \text{ kg/VKT}}{4} = 5.54 \text{ kg/VKT}$$

$$\text{Average } PM_{10}\text{/TSP ratio} = \frac{0.22 + 0.23 + 0.19 + 0.25}{4} = 0.22$$

Therefore for earthmoving (cut and fill):

$$\text{Average } PM_{10} \text{ emission factor} = 0.22 \times 5.54 \text{ kg/VKT} = 1.2 \text{ kg/VKT}$$

For aggregate hauling (on dirt), Tests AH-11 and AH-12 are applicable. The following calculations were made to obtain estimated PM_{10} emission factors for this activity:

$$\text{Average TSP emission factor} = \frac{7.26 + 17.2 \text{ kg/VKT}}{2} = 12.2 \text{ kg/VKT}$$

$$\text{Average } PM_{10}\text{/TSP ratio} = \frac{0.23 + 0.22}{2} = 0.23$$

Therefore for aggregate hauling (on dirt):

$$\text{Average } PM_{10} \text{ emission factor} = 0.23 \times 12.2 \text{ kg/VKT} = 2.8 \text{ kg/VKT}$$

TABLE 9. NET PARTICULATE CONCENTRATIONS AND RATIOS
(Table 4-3 from Kinsey, 1983)

Test ID	Net concentration at 25 m (ug/m^3)				Net concentration at 50 m (ug/m^3)				Ratios (net concentration) at 25 m			Ratios (net concentration) at 50 m		
	TSP	IP	PM_{10}	FP	TSP	IP	PM_{10}	FP	IP/TSP	PM_{10}/TSP	FP/TSP	IP/TSP	PM_{10}/TSP	FP/TSP
AH-1	19,781	5,505	4,338	1,461	13,292	4,303	3,444	1,194	0.28	0.22	0.07	0.32	0.26	0.09
AH-2	36,639	12,115	9,514	3,295	16,996	5,799	4,577	1,698	0.33	0.26	0.09	0.34	0.27	0.10
AH-3	1,285	232	171	39	595	119	81	11	0.18	0.13	0.03	0.20	0.14	0.02
AH-4	9,104	3,321	2,648	769	7,642	2,517	1,991	721	0.36	0.29	0.08	0.33	0.22	0.08
AH-5	4,419	1,226	986	344	3,281	965	758	288	0.28	0.22	0.08	0.29	0.23	0.09
AH-6	230	98	80	37	292	10[illegible]	39	36	0.43	0.35	0.16	0.37	0.30	0.12
AH-7	192	56	45	17	124	33	24	6	0.29	0.23	0.09	0.27	0.19	0.05
AH-9	1,260	27	236	176	676	146	94	62	0.18	0.19	0.14	0.22	0.14	0.09
AH-10	2,915	782	627	214	977	[illegible]98	242	79	0.27	0.22	0.07	0.30	0.25	0.08
AH-11	692	239	192	78	604	166	13[illegible]	48	0.34	0.28	0.11	0.27	0.23	0.08
AH-12	3,267	746	551	177	2,448	706	540	178	0.23	0.17	0.05	0.29	0.22	0.07
AH-13	755	259	212	96	249	51	40	13	0.34	0.28	0.13	0.20	0.16	0.05
AH-14	1,136	309	243	106	845	218	178	84	0.27	0.22	0.09	0.25	0.21	0.10
AH-15	933	235	167	60	159	94	43	15	0.25	0.18	0.06	0.59	0.27	0.09
AH-16	1,845	401	311	121	1,472	281	217	78	0.22	0.17	0.07	0.19	0.15	0.07
AH-17	835	147	112	40	554	95	62	14	0.18	0.13	0.05	0.17	0.11	0.05
AH-18	303	99	78	29	384	76	56	19	0.33	0.26	0.10	0.20	0.14	0.10
AH-19	295	77	55	16	219	70	50	14	0.26	0.19	0.05	0.32	0.23	0.05

9.3 RECOMMENDED PM_{10} EMISSION FACTORS

Based on the above calculations, the estimated PM_{10} emission factors are:

- E_{10} = 5.7 kg/VKT (20 lb/VMT) for topsoil removal

The above factor applies only to: 15 m³ capacity pan scrapers; topsoil with a < 56 percent silt; and surface moisture in range of 1.4 to 1.9 percent.

- E_{10} = 1.2 kg/VKT (4.3 lb/VMT) for earthmoving (cut and fill operations)

The above factor applies only to: 15-m³ capacity pan scrapers; soil with silt content in range of 13 to 34 percent; and surface moisture in range of 2 to 11 percent.

- E_{10} = 2.8 kg/VKT (10 lb/VMT) for truck haulage

The above factor applies only to 9- to 13-m³ capacity dump trucks having three to five axles; surface silt content in range of 17 to 20 percent; and surface moisture of 1.3 percent.

9.4 REFERENCE DOCUMENTS

AP-42, §11.2 (with references), and

Kinsey, J. S., et al., *Study of Construction Related Dust Control*, Contract No. 32200-07976-01, Minnesota Pollution Control Agency, Roseville, MN, April 19, 1983.

SECTION 10.0

DEMOLITION OF STRUCTURES

10.1 BACKGROUND

The demolition of structures involves two primary sources of emissions: destruction by explosion or wrecking ball and site removal of debris. There is no AP-42 factor for the first category, but PM_{10} emission factor equations are available for on-site materials handling and vehicle traffic.

10.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

Current AP-42 equations can be used for the dismemberment and transport of debris. Also available are two measured TSP factors for truck loading with crushed limestone using a front-end loader. These emission factors can be related to structural floor space as shown in the following sections and then combined to produce a composite factor.

10.2.1 PM_{10} Emission Factor Calculations for Demolition of Structures

Three operations are necessary in demolishing and removing structures from a site:

- Mechanical or explosive dismemberment
- Debris loading
- On-site truck traffic

10.2.2 Mechanical or Explosive Dismemberment

The first operation is addressed through the use of the AP-42 materials handling equation, since no emission factor data are available for blasting or wrecking a building.

The proposed emission factor for dismemberment and collapse of a structure can be estimated using the AP-42 equation for batch drop operations:

$$E_D = k(0.0032)\ \frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\ \text{lb/ton}$$

where $k = 0.35$ for PM_{10}
U = mean wind speed (default = 5 mph)
M = material moisture content (Default = 2%)

and $$E_D = 0.0011 \text{ lb/ton (with default parameters)}$$

This factor can be modified for waste tonnage related to structural floor space. The following relationships were determined from a 1976 analysis by Murphy and Chatterjee of the demolition of 12 commercial brick, concrete, and steel buildings:

1 ft^2 floor space = 10 ft^3 original building volume
1 ft^3 building volume = 0.25 ft^3 waste volume
1 yd^3 building waste = 0.5 ton weight
Mean truck capacity = 30 yd^3 haulage volume

From these data, 1 ft^2 of floor space represents 0.046 ton of waste material, and a revised emission factor related to structural floor space can be obtained:

$$E_D = 0.0011 \text{ lb/ton} \cdot \frac{0.046 \text{ ton}}{ft^2} = 0.000051 \text{ lb/ft}^2$$

10.2.3 Debris Loading

The proposed emission factor for debris loading is based on two tests of the filling of trucks with crushed limestone using a front-end loader, part of the test basis for the batch drop equation in AP-42, §11.2.3. Crushed limestone was considered closest in composition to the broken brick and plaster found in demolished commercial buildings. The measured emission factors for crushed limestone were 0.053 and 0.063 lb/ton TSP. To convert the average TSP factor, 0.058 lb/ton, to a PM_{10} factor with source extent of structural floor space, the previously determined estimate of 0.046 ton/ft^2 and a particle size multiplier must be used. The result is the emission factor for debris loading:

$$E_L = k(0.058) \text{ lb/ton} \cdot \frac{0.046 \text{ ton}}{ft^2} = 0.00093 \text{ lb/ft}^2$$

where $k = 0.35$ is taken from the new recommended particle size multipliers developed by Muleski (1987).

10.2.4 On-Site Truck Traffic

The proposed emission factor for on-site truck traffic is based on the unpaved road equation from AP-42:

$$E = k(5.9) \left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \left(\frac{365-P}{365}\right) \text{ lb/VMT}$$

where $k = 0.36$ for PM_{10}
s = silt content (default = 12%)
S = truck speed (default = 10 mph)
W = truck weight (default = 22 tons)
w = truck wheels (default = 10 wheels)
p = number of days with precipitation (default = 0 days)

For a demolition site, 10-wheel trucks of mean 22-ton gross weight are estimated to travel 1/4 mile on-site for each round trip to remove dry debris. With this information and default values for the unpaved road equation, the proposed emission factor for on-site truck traffic becomes:

$$E_T = (0.36)(5.9)\left(\frac{12}{12}\right)\left(\frac{10}{30}\right)\left(\frac{22}{3}\right)^{0.7}\left(\frac{10}{4}\right)^{0.5}\left(\frac{365-0}{365}\right) \text{ lb/VMT} = 4.5 \text{ lb/VMT}$$

To convert this emission factor from lb/VMT to lb/ft² of structural floor space, it is necessary to use the previously described relationships obtained from a study by Murphy and Chatterjee.

$$\frac{0.25 \text{ mi}}{30 \text{ yd}^3 \text{ waste}} \cdot \frac{\text{yd}^3 \text{ waste}}{4 \text{ yd}^3 \text{ volume}} \cdot \frac{10 \text{ yd}^3 \text{ volume}}{\text{yd}^2 \text{ floor space}} \cdot \frac{\text{yd}^2}{9 \text{ ft}^2} = 0.0023 \text{ mi/ft}^2$$

and $E_T = 4.5 \text{ lb/VMT} \times 0.0023 \text{ mi/ft}^2$
$= 0.010 \text{ lb/ft}^2$

10.3 RECOMMENDED PM_{10} EMISSION FACTOR

The combined emission factor for building demolition, debris loading, and truck traffic is thus:

$$E_{10} = E_D + E_L + E_T$$

$$= 0.000051 + 0.00093 + 0.010 \text{ lb/ft}^2$$

$$= 56 \text{ g/m}^2 \text{ } (0.011 \text{ lb/ft}^2) \text{ of demolished floor area}$$

It is easily seen that emissions from on-site truck traffic constitute the overwhelming portion of PM_{10} emissions from building demolition and removal.

10.4 REFERENCE DOCUMENTS

AP-42, §11.2 (with associated references), and

Muleski, G., C. Cowherd, Jr., and P. Englehart, *Update of Fugitive Dust Emission Factors in AP-42 Section 11.2*, Final Report prepared by Midwest Research Institute for U.S. Environmental Protection Agency, EPA Contract No. 68-02-3891, Assignment No. 19, July 14, 1987.

Murphy, K. S., and S. Chatterjee, *Development of Predictive Criteria for Demolition and Construction Solid Waste Management*, Final Report prepared by Battelle Columbus Laboratories for the U.S. Army Corps of Engineers, NTIS ADA 033646, October 1976.

SECTION 11.0

OFF-HIGHWAY VEHICLE TRAVEL

11.1 BACKGROUND

Travel on natural unpaved surfaces by two- and four-wheel vehicles is generally related to unpaved road traffic, but the current emission factor in AP-42 is not deemed applicable. The mechanisms of dust generation are similar to those for unpaved roads but the travel surface is not compacted.

11.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

A field study of vehicle travel on natural desert terrain in Kern County, California, produced the data in Table 10.

TABLE 10. COMPARISON OF EMISSION FACTORS FOR ROAD 2
(Table 2 from Muleski et al., 1982)

	Emission factor (lb/veh-mi)				
	< 50 µmA	< 30 µmA	< 10 µmA	< 5 µmA	< 3 µmA
1 Predicted value [a]	7.67	6.06	2.83	1.53	0.929
2 Preliminary field value[a]	10.0	8.52	3.76	2.01	1.13
3 Revised field value	16.6	14.2	6.26	3.35	1.88
Ratio of 2 to 1 [b]	1.30	1.40	1.33	1.31	1.22
Ratio of 3 to 1 [b]	2.16	2.34	2.21	2.19	2.02

[a]Values taken from Table 1 of cited report.
[b]Dimensionless.

Per the above table, a PM_{10} emission factor for 4-wheeled light-duty vehicle traveling over essentially natural desert terrain was obtained by:

$$E_{10} = 6.26 \text{ lb/VMT} \times 0.454 \text{ kg/lb} \times \frac{1 \text{ mi}}{1.609 \text{ km}}$$

$$= 1.77 \text{ kg/VKT}$$

For off-road motorcycles it can be assumed that:

- The emission factor for 4-wheeled vehicles can be corrected for the number of wheels and weight as in MRI unpaved road equation.
- Motorcycle weight = 400 lb (vehicle + rider).
- Pick-up truck weight = 4000 lb.

Therefore:

$$E_{10} = 1.77 \text{ kg/VKT} \times \left(\frac{0.2}{2}\right)^{0.7} \times \left(\frac{2}{4}\right)^{0.5}$$

$$= 0.25 \text{ kg/VKT}$$

11.3 RECOMMENDED PM_{10} EMISSION FACTORS

The tentative PM_{10} emission factors for off-highway vehicle travel are:

- E_{10} = 1.8 kg/VKT (6.3 lb/VMT) for 4-wheel vehicles
- E_{10} = 0.25 kg/VKT (0.89 lb/VMT) for motorcycles

The above emission factors apply only to: soil silt = 28 to 31 percent; and soil moisture = 0.5 to 1.0 percent.

11.4 REFERENCE DOCUMENTS

AP-42, §11.2.1 and

Muleski, G. E., and C. Cowherd, Jr., *Measurement of Fine Particle Fraction of Road Dust Emissions*, Final Report Addendum, MRI Project No. 7267-L, Kernridge Oil Company, McKittrick, CA, April 23, 1982.

SECTION 12.0

MUNICIPAL SOLID WASTE LANDFILLS

12.1 BACKGROUND

Municipal solid waste (MSW) landfills emit particulates due to traffic, materials handling, and covering waste with soil. Although no single emission value for landfills is given in AP-42, many of the unit operations in MSW landfilling practice fall into the generic operations discussed in Section 11.2. Traffic is the most important source of particulate emissions.

12.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

In 1987 PM_{10} emission inventories were prepared for two landfills in the Chicago area. Unit operations of interest in this study were travel on unpaved roads, materials handling of cover and other fill materials, and dozer activity (both on the access area proximate to the lift and in spreading cover). Current AP-42 equations were used in these inventories. Handling and compaction of MSW were deemed negligible in terms of dust emissions because of the generally wet and/or containerized nature. Wind erosion of all materials considered was found to be insignificant. The two landfills were adjacent to one another, and thus no large variation in soil/surface characteristics was noted.

Summary information is shown below:

	Landfill 1	Landfill 2
Average daily receipts (yd^3)		
--MSW	2,400	2,000
--Cover and other material	1,900	300
Cover material (yd^3) used daily	750	1,200
One-way travel distance (mi) from gate to disposal area	1.0	0.33
Uncontrolled PM_{10} emission rate (lb/day)	1,400	1,000
Fraction of uncontrolled emission rate due to unpaved road travel	82%	84%

Because the major portion of emissions is due to unpaved road traffic (i.e., exclusive of dozer movement), it appears reasonable to obtain a rough, preliminary estimate of emissions based on travel distance to the MSW disposal site:

Landfill 1: (1,400 lb/day)/(2,400 yd^3/day)/(1.0 mi)
or, 0.6 lb/yd^3/mi
Landfill 2: (1,000 lb/day)/(2,000 yd^3/day)/(0.33 mi)
or, 1.5 lb/yd^3/mi
Average: 1 lb/yd^3/mi

12.3 RECOMMENDED PM_{10} EMISSION FACTOR (PRELIMINARY)

The recommended preliminary emission factor is:

$$E_{10} = 0.4 \text{ kg/m}^3\text{/mi}$$
$$= (1 \text{ lb/yd}^3\text{/mi})$$

where the source extent is expressed as the product of: (1) the volume of MSW disposed and (2) the distance between the gate and the disposal area. Note that (2) may vary dramatically over the life of the facility, as the active disposal area changes with time.

This preliminary emission estimate is subject to considerable uncertainty. Major sources of uncertainty are discussed below:

a. The above estimate assumed that surface and traffic conditions, operating practices, travel routes, excavated earth characteristics, etc., at two adjacent landfills in the Chicago area are representative of MSW site conditions throughout the United States.

b. Because there are no applicable PM_{10} emissions data for dozer movement at landfills, the AP-42 TSP dozer equation for overburden removal at western surface coal mines was used. This introduces considerable uncertainty because of: (1) the vastly different operating characteristics (e.g., speed, travel distance) between surface coal mines and landfills and (2) use of a TSP model to estimate PM_{10} emissions.

c. Both inventoried landfills regularly apply water to control dust and thus improve visibility. (Control efficiency values of roughly 80 percent were found.) Common practice in the geographic area of interest should be determined prior to using the estimate.

12.4 REFERENCE DOCUMENTS

Muleski, G., and D. Hecht, *PM_{10} Emission Inventory of Landfills in the Lake Calumet Area*, MRI Final Report, EPA Contract No. 68-02-3891, Work Assignment 30, September 23, 1987.

SECTION 13.0

COARSE, DRY TAILINGS PONDS

13.1 BACKGROUND

Wind erosion of coarse, dry tailings ponds is currently not addressed in AP-42. However, the discussion of wind erosion of storage piles in AP-42 §11.2.3.3 notes that factors influencing emissions are silt and moisture content of the erodible surface and the threshold wind velocity.

13.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

A 1983 study produced an average emission factor measured for particles < 12 µmA. This PM_{12} factor is specific to a particle size very close to PM_{10} and can thus be used to estimate PM_{10} emissions. Table 11 presents emission factor test results for PM_{12} for an uncontrolled tailings pond.

TABLE 11. WIND EROSION EMISSION FACTOR TESTING
(Table 7 from Bohn, 1983)

Test No.	Date	Product and dilution	Tailings (moisture) (%)	Tailings (silt) (%)	Threshold velocity (10 m height-mph)	Test velocity (10 m height-mph)	Emission factor (x 0.001) < 2 um (grams/minute/square meter)	Emission factor (x 0.001) < 2.1 um (grams/minute/square meter)
1	5/28	Coherex 12:1	0.26	0.05	53	50	2.02	1.23
2	5/28	Coherex 9:1	0.38	0.03	53	50	2.63	1.28
3	5/28	Lignosulfonate 8:1	0.32	4.4	50	50	2.58	2.58
4	6/15	Coherex 12:1	0.46	1.6	32	40	77.2	7.16
5	5/15	Coherex 12:1	0.46	1.6	32	40	16.2	2.13
6	5/15	Coherex 9:1	0.29	1.3	46	50	0.881	0.396
7	5/15	Lignosulfonate 3:1	0.35	2.3	31	40	1.50	0.190
15	7/27	Lignosulfonate 4:1	0.28	3.3	43	50	283	54.0
16	7/27	Lignosulfonate 8:1	0.30	0.30	46	50	1360	216
18	7/28	Nalco 655	0.10	1.30	45	50	116	18.2
19	7/28	Magnesium chloride (tested on dry section)	0.57	6.50	31	40	1500	213
42a	9/22	Uncontrolled	0.37	0.50	40	45	73.8	17.2
43	9/22	Uncontrolled	0.35	1.0	43	50	25.6	3.10

The average PM_{12} emission factor and threshold wind velocity can be calculated from Tests 42a and 43 by:

- Average PM_{12} emission factor $= \frac{73.8 + 25.6 \text{ mg/m}^2\text{/min of erosion time}}{2}$

  $= 49.7 \text{ mg/m}^2\text{/min}$

- Average threshold velocity $= \frac{40 + 43 \text{ mph}}{2} = 42 \text{ mph} \times 0.447 \frac{\text{m/s}}{\text{mph}}$

  $= 19 \text{ m/s}$

Assuming $PM_{12} = PM_{10}$ and rearranging in equation form:

$$E_{10} = 49.7\ T_v$$

where E_{10} = PM_{10} emission factor per unit surface area of exposed tailings (mg/m²) per time period of interest

T_v = number of minutes wind velocity exceeds 19 m/s at 10 m above surface during time period of interest

Application of the above equation requires detailed site-specific data for both source parameters and meteorology. An acceptable procedure to estimate the wind velocity term (T_v) would involve use of historical data from a nearby operating weather station operated by the National Weather Service. These data are available for many locations in the U.S. from the National Climatic Data Center, Asheville, North Carolina. The actual procedure would involve ordering the individual data points from lowest to highest wind speed and then simply determining the percentage of observations that exceed the calculated threshold velocity.

If the data are reported for 3-h periods and by the mean number of days per year that winds exist in each period, the above equation could be modified as follows:

$$E_{10} = 49.7\ T_v = 49.7 \times 180 \frac{\text{min}}{\text{period}} \times \frac{\text{No. of days}}{\text{year}} = 8{,}950\ T_{VA}$$

where E_{10} = PM_{10} emission factor per unit surface area of exposed tailings (mg/m²)

T_{VA} = No. of days per year that winds exceed 33 knots (as indicated by NCDC data) for each 3-h period

Due to the nature of how the wind data are collected and reported, it is expected that very small (if any) T_{VA} values will be shown for most reporting stations and thus severely limit application of the above equation.

13.3 RECOMMENDED PM_{10} EMISSION FACTOR

The following tentative emission factor is proposed for coarse, dry tailings.

E_{10} = 50 T_v mg/m² (4.6 mg/ft²) of exposed tailings surface per unit time period

where T_v = number of minutes wind velocity exceeds 19 m/s (42 mph) at 10 m above surface during time period of interest (e.g., annual).

The assumptions which underlie the above estimate of PM_{10} emissions are:

1. The emission factor for < 12 µmA particles is essentially equal to PM_{10}.
2. A surface moisture content of 0.35 to 0.37 percent (dry conditions).
3. A surface silt content of 0.5 to 1.0 percent (coarse tailings).

13.4 REFERENCE DOCUMENTS

AP-42, §11.2.3.3 (with its references), and

Bohn, R. R., and J. D. Johnson, *Dust Control of Active Tailings Ponds*, Contract No. J0218024, U.S. Bureau of Mines, Washington, DC, February 1983.

SECTION 14.0

TRANSPORTATION TIRE WEAR

14.1 BACKGROUND

The particles emitted from vehicle tires are known to be related to traffic type and use (roadway classification). AP-42 currently does not report any factors to estimate tire wear emissions.

14.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

Several laboratory and roadway studies have been made of particles emitted from rubber tires of light-duty vehicles. After review of these studies, the EPA developed a PM_{10} factor in a 1985 document, EPA 460/3-85-005.

14.3 RECOMMENDED PM_{10} EMISSION FACTOR

The estimated PM_{10} emission factor is:

$$E_{10} = 1 \text{ mg/VKT } (2 \text{ mg/VMT})$$

The above factor was developed for light-duty vehicles.

14.4 REFERENCE DOCUMENTS

Site Specific Total Particulate Emission Factors for Mobile Sources, EPA 460/3-85-005, Prepared for EPA, Ann Arbor, MI, by Energy and Environmental Analysis, Inc., August 1985.

SECTION 15.0

TRANSPORTATION BRAKE WEAR

15.1 BACKGROUND

The use of brakes in vehicle traffic causes emissions of asbestos-containing brake material as the brake pads are worn away with each brake application. Emissions are related to vehicle type, number of stops/mile and to severity of braking. Currently no emission factor exists in AP-42.

15.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

Airborne particulate emissions have been determined as related to braking action and corrected to PM_{10}. These laboratory-derived factors are reported in a 1985 report, EPA 460/3-85-005.

15.3 RECOMMENDED PM_{10} EMISSION FACTOR

The estimated PM_{10} factor is:

$$E_{10} = 7.8 \text{ mg/VKT } (13 \text{ mg/VMT})$$

and applies to light-duty vehicles.

15.4 REFERENCE DOCUMENTS

Site Specific Total Particulate Emission Factors for Mobile Sources, EPA 460/3-85-005, Prepared for EPA, Ann Arbor, MI, by Energy and Environmental Analysis, Inc., August 1985.

SECTION 16.0

ROAD SANDING/SALTING

16.1 BACKGROUND

After sand/salt mixtures are applied to roads to increase traction on snow and ice, vehicle traffic serves to reentrain the particulate, particularly the silt fraction deposited in active lanes. Some additional silt is formed by grinding. Emissions are much greater under dry road conditions. A current AP-42 emission factor equation for loaded (industrial) paved roads is relevant for short-term periods (hours to days) only, as the sand/salt mixture is quickly depleted from the travel surface.

16.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

The following table presents typical mixtures of salt and sand for road sanding:

Locality	Parts NaCl	Parts Sand
Colorado	1	10 to 20
Kansas	1	0 to 4
Kansas City, MO	1	3 to 4
Overland Park, KS	1	3

The above discussion is presented to show that road sand commonly includes a significant salt fraction. For purposes of emission factor development, the salt and sand road loadings are treated separately below.

16.2.1 PM_{10} Emissions from Sand

The entire PM_{10} fraction contained in the silt of the applied sand is assumed to become airborne. The mass of emissions reentrained by road traffic is related to sand quantity and size distribution. According to a Kansas City road sand supplier, river sand is washed, with > 99.5 percent then being retained on a 200-mesh (75-μm) screen. Missouri State sample analysis has shown 0.2 to 0.5 percent < 75 μm. A calculated mean silt has been reported at 0.35 percent. An analysis of PM_{10}/PM_{75} ratios for western sandy soils gives an average ratio of 0.0026. See Table 12.

TABLE 12. RESULTS OF SIEVE ANALYSES[a]
(Table 4 from Kinsey, 1986)

Particle size range (μm physical diameter)	Sandy ASL soil sample No. 1[b] (weight % in stated range)				Sandy ASL soil sample No. 2[c] (weight % in stated range)				SAE coarse test dust[d] (weight % in stated range)			
	Split 1	Split 2	Split 3	Average	Split 1	Split 2	Split 3	Average	Split 1	Split 2	Split 3	Average
> 149	71.6	71.3	71.1	71.3	77.3	77.1	76.9	77.1	1.04	0.513	1.10	0.884
105-149	10.0	10.6	10.1	10.2	10.2	10.6	10.8	10.5	10.5	3.58	4.39	6.16
74-105	8.93	7.02	9.10	8.35	5.15	3.99	4.12	4.42	13.1	10.3	5.49	9.63
53-74	3.48	4.61	3.57	3.88	3.91	4.56	4.50	4.32	38.2	48.6	49.0	45.3
30-53	4.66	4.96	4.95	4.82	2.44	2.55	2.56	2.52	29.5	32.9	31.7	31.4
10-30	1.26	1.48	1.28	1.34	1.00	1.13	1.08	1.07	7.68	4.12	8.26	6.69
< 10	0.0236	0.0511	0.0446	0.0404	0.00729	0.00660	0.0131	0.00900	Nil[e]	Nil[e]	Nil[e]	Nil[e]

[a]All data rounded to three significant figures. Particles < 74 μmP classified by sonic sieving.
[b]Sample marked "SHD Soil Sample at Rain Site."
[c]Sample marked "DGT II Top Layer."
[d]SAE coarse grade test dust obtained from Powder Technology, Inc., Burnsville, MN. Material consists of graded Arizona road dust.
[e]No material was found to pass the 10-μm sieve. Upon examination of the sieves by optical microscopy, it was determined that the particles had formed almost homogeneous, spherical agglomerates during the sonic classification process. These agglomerates may be the result of triboelectric effects created during sieving.

The estimated PM_{10} emissions from road sanding are calculated as follows:

$$E_{10} = 2,000\ f\ (s/100)\ \text{lb/ton of sand applied}$$

$$= 7.5\ \text{g/metric ton}\ (0.018\ \text{lb/ton})$$

where f is the proportion of PM_{10} in the silt fraction of sand (default fraction of 0.0026), and s is the silt content (percent) of the sand (default of 0.35 percent).

16.2.2 PM_{10} Emissions from Salt

Both calcium chloride and sodium chloride are used for treating icy roads. Only PM_{10} emissions from sodium chloride (rock salt) will be estimated since the amount of applied calcium chloride is usually quite small.

The very finest screenings of rock salt of 98 to 99 percent purity contain relatively large concentrations of anhydrite grains. A considerable amount of this material is assumed to dry on the road and eventually to become airborne as PM_{10}, i.e., 0.2 percent of the total salt applied.

An estimate of PM_{10} emissions from the 98 to 99 percent pure salt is based on an estimate of 5 percent of the salt remaining as a dried film on the road pavement, and 10 percent of this salt film driven off as particles of < 10 μm physical diameter. This latter number is based on a sonic sieve analysis of powdered NaCl. PM_{10} emissions from salt applied to roads are calculated as follows:

$$E_{10} = (0.05)(0.10)(2,000\ \text{lb})/\text{ton of salt applied}$$

$$= 10\ \text{lb/ton of salt applied}$$

16.2.3 Example Calculation of Annual PM_{10} Emissions from Sand/Salt Application

An example calculation of yearly PM_{10} emissions from the State of Iowa demonstrates the use of the sand and salt emission factors. In Iowa, the typical application rate of salt per snow day is known to be 510 lb/mi; the application rate for sand is estimated at 1,000 lb/mi. Mean annual snow days for Iowa are 10 days with 13,100 mi treated with salt/sand (Table 13). PM_{10} emissions are calculated as follows:

$$E_{10} = 13,100\ \text{1-lane mi} \times \frac{1,000\ \text{lb sand}}{\text{2-lane mi}} \times \frac{0.018\ \text{lb}\ PM_{10}}{2,000\ \text{lb sand}} \times 10\ \text{snow days}$$

$$+ 13,100\ \text{1-lane mi} \times \frac{510\ \text{lb salt}}{\text{2-lane mi}} \times 10\ \text{snow days} \times \frac{10\ \text{lb}\ PM_{10}}{2,000\ \text{lb sand}}$$

$$= 167,615\ \text{lb/yr}$$
$$= 84\ \text{ton/yr}$$

As is shown above, the emissions from salt predominate.

TABLE 13. MILEAGE OF TREATED HIGHWAYS AND TOLLWAYS, AND MEAN ANNUAL SNOW DAYS BY STATE (Table H-2 from McElroy, 1976)

State	Single-lane kilometers treated x 1,000[a]	Single-lane miles treated x 1,000[a]	Mean annual snow days[c]
Northeastern States			
Maine	12.1	7.5	30
New Hampshire	11.3	7.0	30
Vermont	7.4	4.6	20
Massachusetts	15.1	9.4	18
Connecticut	15.1	9.4	15
Rhode Island	8.4[b]	5.2[b]	12
New York	59.4	36.9	20
Pennsylvania	89.0	55.3	18
New Jersey	12.9	8.0	7
Delaware	1.3	0.8	5
Maryland	10.8	6.7	8
Virginia	22.2	13.8	5
North-Central States			
Ohio	173.1[b]	107.6[b]	10
West Virginia	27.2	16.9	12
Kentucky	34.9	21.7	5
Indiana	25.3	15.7	8
Illinois	62.9	39.1	9
Michigan	37.8	23.5	20
Wisconsin	40.0	25.0	13
Minnesota	186.0[b]	115.6[b]	15
North Dakota	111.8[b]	69.5[b]	10
Southern States			
Arkansas	NA	NA	3
Tennessee	NA	NA	3
North Carolina	12.2	7.6	3
Mississippi	5.3	3.3	1
Alabama	0.1	0.1	1
Georgia	7.2	4.5	1
South Carolina	NA	NA	1
Louisiana	NA	NA	1
Florida	0.0	0.0	0

(continued)

TABLE 13 (Continued)

State	Single-lane kilometers treated x 1,000[a]	Single-lane miles treated x 1,000[a]	Mean annual snow days[c]
West-Central States			
Iowa	21.1	13.1	10
Missouri	51.5	32.0	7
Kansas	41.7	25.9	7
South Dakota	96.9[b]	60.2[b]	10
Nebraska	123.9[b]	77.0[b]	10
Colorado	3.9	2.4	20
Southwestern States			
Oklahoma	NA	NA	3
New Mexico	11.7	7.3	10
Texas	NA	NA	3
Western States			
Washington	24.6	15.3	15
Idaho	16.1	10.0	20
Montana	3.2	2.0	20
Oregon	29.8	18.5	20
Wyoming	20.3	12.6	20
California	9.7	6.0	5
Nevada	NA	NA	10
Utah	20.4	12.7	20
Arizona	NA	NA	10
District of Columbia	1.3	0.8	7
Alaska	NA	NA	23
Hawaii	0.0	0.0	0

[a]Source: Hanes, R. E., L. W. Zelazny, and R. E. Blaser, *Effects of Deicing Salts on Water Quality and Biota*, Highway Research Board, National Cooperative Highway Research Program Report 91 (1970).
[b]MRI estimates.
[c]Source: U.S. Department of the Interior, Geological Survey, *The National Atlas of the United States* (1970).
NA = Not available.

16.3 RECOMMENDED PM_{10} EMISSION FACTOR(S)

The recommended PM_{10} factor for sand application to roads is:

E_{10} = 2,000 f (s/100) lb/ton of sand applied

= 7.5 g/metric ton (0.018 lb/ton)

where f is the proportion of PM_{10} in the silt fraction of sand (default value of 0.0026), and s is the silt content (percent) of the sand (default of 0.35 percent).

The recommended PM_{10} factor for salt application to roads is:

E_{10} = 4.3 kg/metric ton (10 lb/ton)

The above factors apply to typical application scenarios of river sand and salt mixtures applied to snow and ice covered travel lanes. Emissions of road sand mixture < 10 µm occur over long periods of time (weeks) following road sanding. Runoff of PM_{10} fraction in melted ice and snow is assumed to be offset by traffic grinding of the sand and salt mixture and creation of new PM_{10} fractions.

16.4 REFERENCE DOCUMENTS

AP-42, §11.2.5 (with associated references), and

Cowherd, C. Jr., and M. A. Grelinger, *Prediction of Inhalation Exposure to Particulates for New Chemical Review*, Final Report prepared for EPA, Washington, D.C. by Midwest Research Institute, October 1987.

Kaufmann, D. W., editor, *Sodium Chloride: The Production and Properties of Salt and Brine*, American Chemical Society Monograph Series, Hafner Publishing Co., New York, NY, 1968.

Kinsey, J. S., *Mineral Characterization of Selected Soil Samples*, Final Report prepared by Midwest Research Institute for New Mexico University Physical Sciences Laboratory, Las Cruces, NM, January 1985.

McElroy, A. D., et al., Loading Functions for Assessment of Water Pollution from Nonpoint Sources, EPA-600/2-76-151, Prepared for EPA, Washington, DC, by Midwest Research Institute, May 1976.

SECTION 17.0

UNPAVED PARKING LOTS

17.1 INTRODUCTION

Particle emissions are produced by vehicle traffic on any unpaved surface, including parking lots. Average vehicle characteristics (such as speed, weight, etc.) are dependent upon the size and purpose of lot. Source extent (i.e., distance traveled in the lot) is also dependent upon those factors, as well as the average fraction of the lot in use over an averaging time, driver preference, orientation of entrance/exit(s), and ultimate destination(s), etc.

17.2 BASIS FOR DERIVATION OF PM_{10} EMISSION FACTOR

The AP-42 PM_{10} unpaved road predictive emission factor equation was used to estimate travel emissions from vehicles in parking lots. This unpaved road equation is:

$$E = 0.61 \left(\frac{s}{12}\right) \left(\frac{S}{48}\right) \left(\frac{W}{2.7}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \left(\frac{365-p}{365}\right) \text{ Kg/VKT}$$

$$E = 2.1 \left(\frac{s}{12}\right) \left(\frac{S}{30}\right) \left(\frac{W}{3}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \left(\frac{365-p}{365}\right) \text{ lb/VMT}$$

where:
- s = silt content of aggregate or road surface material (%)
- S = average vehicle speed, kph (mph)
- W = average vehicle weight, Mg (tons)
- w = average number of vehicle wheels
- p = number of wet days ($\geq$ 0.254 mm or 0.01 in of precipitation)

The emission factor is based on assumed values of:

Silt = 12 percent
Avg. No. of wheels = 4
Avg. weight = 3 tons (2.7 Mg)

and an assumed speed of 10 mph (16 kph) in the lot. Ten miles per hour was assumed here to restrict attention to parking lots only.

The source extent used in the proposed emission factor equation, L+W meters, assumed that the average one-way trip consists of driving between the middle of the lot and the exit. It is further assumed that the one-way distance is (L+W)/2 (i.e., the vehicle travels halfway down the perpendicular dimension and halfway down the parallel dimension). Because each vehicle parked must travel both legs of (L+W)/2, the total distance traveled by each vehicle parked is 2 x (L+W)/2 = L+W.

17.3 RECOMMENDED PM_{10} EMISSION FACTOR

$$E_{10} = 0.2 \frac{365-p}{365} (L + W) \text{ g/vehicle parked (in time period of interest)}$$

where p = number of days/year with rain (Figure 11.2.1-1 in AP-42)
L = dimension of parking lot (m) perpendicular to aisles
W = dimension of parking lot (m) parallel to aisles

Several assumptions were made in obtaining the preliminary estimate. These were described in Section 17.2. In addition, several caveats should be noted:

a. The emission factor and the source extent may be very site-specific in that use of the lot may be by heavier vehicles, or may be shared by a number of facilities (thus resulting in clusters, each with their own source extent). In addition, driver preference may result in substantially higher travel speeds or in longer travel distances.

b. The equation recommended earlier will require that the total number of vehicles parked per unit time be determined by counting or other means. This may not be practical in all instances.

17.4 REFERENCE DOCUMENTS

AP-42 §11.2.

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