13.2.2 Unpaved Roads

13.2.2.1 General

Dust plumes trailing behind vehicles traveling on unpaved roads are a familiar sight in rural areas of the United States. When a vehicle travels an unpaved road, the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed.

13.2.2.2 Emissions Calculation And Correction Parameters

The quantity of dust emissions from a given segment of unpaved road varies linearly with the volume of traffic. Field investigations also have shown that emissions depend on correction parameters (average vehicle speed, average vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture) that characterize the condition of a particular road and the associated vehicle traffic.[1-4]

Dust emissions from unpaved roads have been found to vary in direct proportion to the fraction of silt (particles smaller than 75 micrometers [µm] in diameter) in the road surface materials.[1] The silt fraction is determined by measuring the proportion of loose dry surface dust that passes a 200-mesh screen, using the ASTM-C-136 method. Table 13.2.2-1 summarizes measured silt values for industrial and rural unpaved roads.

Since the silt content of a rural dirt road will vary with location, it should be measured for use in projecting emissions. As a conservative approximation, the silt content of the parent soil in the area can be used. Tests, however, show that road silt content is normally lower than in the surrounding parent soil, because the fines are continually removed by the vehicle traffic, leaving a higher percentage of coarse particles.

Unpaved roads have a hard, generally nonporous surface that usually dries quickly after a rainfall. The temporary reduction in emissions caused by precipitation may be accounted for by not considering emissions on "wet" days (more than 0.254 millimeters [mm] [0.01 inches (in.)] of precipitation).

The following empirical expression may be used to estimate the quantity of size-specific particulate emissions from an unpaved road, per vehicle kilometer traveled (VKT) or vehicle mile traveled (VMT):

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

(1)

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

Table 13.2.2-1. TYPICAL SILT CONTENT VALUES OF SURFACE MATERIAL ON INDUSTRIAL AND RURAL UNPAVED ROADS[a]

Industry	Road Use Or Surface Material	Plant Sites	No. Of Samples	Silt Content (%)	
				Range	Mean
Copper smelting	Plant road	1	3	16 - 19	17
Iron and steel production	Plant road	19	135	0.2 - 19	6.0
Sand and gravel processing	Plant road	1	3	4.1 - 6.0	4.8
Stone quarrying and processing	Plant road	2	10	2.4 - 16	10
	Haul road	1	10	5.0 - 15	9.6
Taconite mining and processing	Service road	1	8	2.4 - 7.1	4.3
	Haul road	1	12	3.9 - 9.7	5.8
Western surface coal mining	Haul road	3	21	2.8 - 18	8.4
	Access road	2	2	4.9 - 5.3	5.1
	Scraper route	3	10	7.2 - 25	17
	Haul road (freshly graded)	2	5	18 - 29	24
Rural roads	Gravel/crushed limestone	3	9	5.0 - 13	8.9
	Dirt	7	32	1.6 - 68	12
Municipal roads	Unspecified	3	26	0.4 - 13	5.7
Municipal solid waste landfills	Disposal routes	4	20	2.2 - 21	6.4

[a] References 1,5-16.

where:

E = emission factor
k = particle size multiplier (dimensionless)
s = silt content of road surface material (%)
S = mean vehicle speed, kilometers per hour (km/hr) (miles per hour [mph])
W = mean vehicle weight, megagrams (Mg) (ton)
w = mean number of wheels
p = number of days with at least 0.254 mm (0.01 in.) of precipitation per year (see discussion below about the effect of precipitation.)

The particle size multiplier in the equation, k, varies with aerodynamic particle size range as follows:

Aerodynamic Particle Size Multiplier (k) For Equation 1					
≤30 μm[a]	≤30 μm	≤15 μm	≤10 μm	≤5 μm	≤2.5 μm
1.0	0.80	0.50	0.36	0.20	0.095

[a] Stokes diameter.

It is important to note that Equation 1 calls for the average speed, weight, and number of wheels of all vehicles traveling the road. For example, if 98 percent of traffic on the road are 4-wheeled cars and trucks while the remaining 2 percent consists of 18-wheeled trucks, then the mean number of wheels "w" is 4.3. More specifically, Equation 1 is *not* intended to be used to calculate a separate emission factor for each vehicle class. Instead, only one emission factor should be calculated that represents the "fleet" average of all vehicles traveling the road.

The number of wet days per year, p, for the geographical area of interest should be determined from local climatic data. Figure 13.2.2-1 gives the geographical distribution of the mean annual number of wet days per year in the United States.[17] The equation is rated "A" for dry conditions ($p = 0$) and "B" for annual or seasonal conditions ($p > 0$). The lower rating is applied because extrapolation to seasonal or annual conditions assumes that emissions occur at the estimated rate on days without measurable precipitation and, conversely, are absent on days with measurable precipitation. Clearly, natural mitigation depends not only on how much precipitation falls, but also on other factors affecting the evaporation rate, such as ambient air temperature, wind speed, and humidity. Persons in dry, arid portions of the country may wish to base p (the number of wet days) on a greater amount of precipitation than 0.254 mm (0.01 in.). In addition, Reference 18 contains procedures to estimate the emission reduction achieved by the application of water to an unpaved road surface.

The equation retains the assigned quality rating, if applied within the ranges of source conditions that were tested in developing the equation, as follows:

Ranges Of Source Conditions For Equation					
Road Silt Content (wt %)	Mean Vehicle Weight		Mean Vehicle Speed		Mean No. Of Wheels
	Mg	ton	km/hr	mph	
4.3 - 20	2.7 - 142	3 - 157	21 - 64	13 - 40	4 - 13

Moreover, to retain the quality rating of the equation when addressing a specific unpaved road, it is necessary that reliable correction parameter values be determined for the road in question. The field and laboratory procedures for determining road surface silt content are given in AP-42 Appendices C.1 and C.2. In the event that site-specific values for correction parameters cannot be obtained, the appropriate mean values from Table 13.2.2-1 may be used, but the quality rating of the equation is reduced by 1 letter.

For calculating annual average emissions, the equation is to be multiplied by annual vehicle distance traveled (VDT). Annual average values for each of the correction parameters are to be

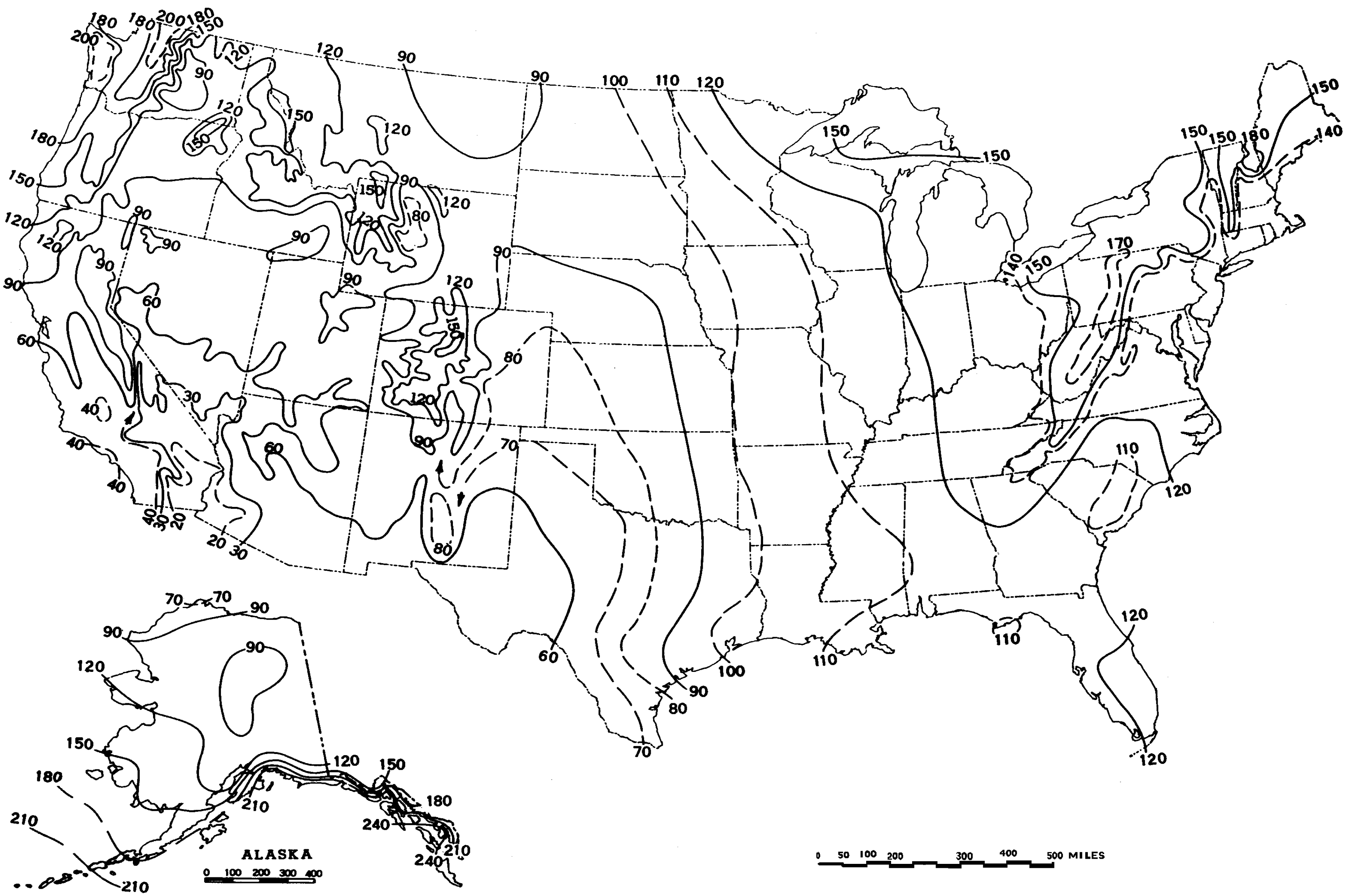

Figure 13.2.2-1. Mean number of days with 0.01 inch or more of precipitation in United States.

substituted for the equation. Worst-case emissions, corresponding to dry road conditions, may be calculated by setting p = 0 in the equation (equivalent to dropping the last term from the equation). A separate set of nonclimatic correction parameters and a higher than normal VDT value may also be justified for the worst-case average period (usually 24 hours). Similarly, in using the equation to calculate emissions for a 91-day season of the year, replace the term (365-p)/365 with the term (91-p)/91, and set p equal to the number of wet days in the 91-day period. Use appropriate seasonal values for the nonclimatic correction parameters and for VDT.

13.2.2.3 Controls[18-21]

Common control techniques for unpaved roads are paving, surface treating with penetration chemicals, working stabilization chemicals into the roadbed, watering, and traffic control regulations. Chemical stabilizers work either by binding the surface material or by enhancing moisture retention. Paving, as a control technique, is often not economically practical. Surface chemical treatment and watering can be accomplished at moderate to low costs, but frequent treatments are required. Traffic controls, such as speed limits and traffic volume restrictions, provide moderate emission reductions, but may be difficult to enforce. The control efficiency obtained by speed reduction can be calculated using the predictive emission factor equation given above.

The control efficiencies achievable by paving can be estimated by comparing emission factors for unpaved and paved road conditions, relative to airborne particle size range of interest. The predictive emission factor equation for paved roads, given in Section 13.2.4, requires estimation of the silt loading on the traveled portion of the paved surface, which in turn depends on whether the pavement is periodically cleaned. Unless curbing is to be installed, the effects of vehicle excursion onto shoulders (berms) also must be taken into account in estimating control efficiency.

The control efficiencies afforded by the periodic use of road stabilization chemicals are much more difficult to estimate. The application parameters that determine control efficiency include dilution ratio, application intensity, mass of diluted chemical per road area, and application frequency. Other factors that affect the performance of chemical stabilizers include vehicle characteristics (e. g., traffic volume, average weight) and road characteristics (e. g., bearing strength).

Besides water, petroleum resin products historically have been the dust suppressants most widely used on industrial unpaved roads. Figure 13.2.2-2 presents a method to estimate average control efficiencies associated with petroleum resins applied to unpaved roads.[19] Several items should be noted:

1. The term "ground inventory" represents the total volume (per unit area) of petroleum resin concentrate (*not solution*) applied since the start of the dust control season.

2. Because petroleum resin products must be periodically reapplied to unpaved roads, the use of a time-averaged control efficiency value is appropriate. Figure 13.2.2-2 presents control efficiency values averaged over 2 common application intervals, 2 weeks and 1 month. Other application intervals will require interpolation.

3. Note that zero efficiency is assigned until the ground inventory reaches 0.2 liter per square meter (L/m^2) (0.05 gallon per square yard [gal/yd^2]).

As an example of the application of Figure 13.2.2-2, suppose that the equation was used to estimate an emission factor of 2.0 kg/VKT for PM-10 from a particular road. Also, suppose that,

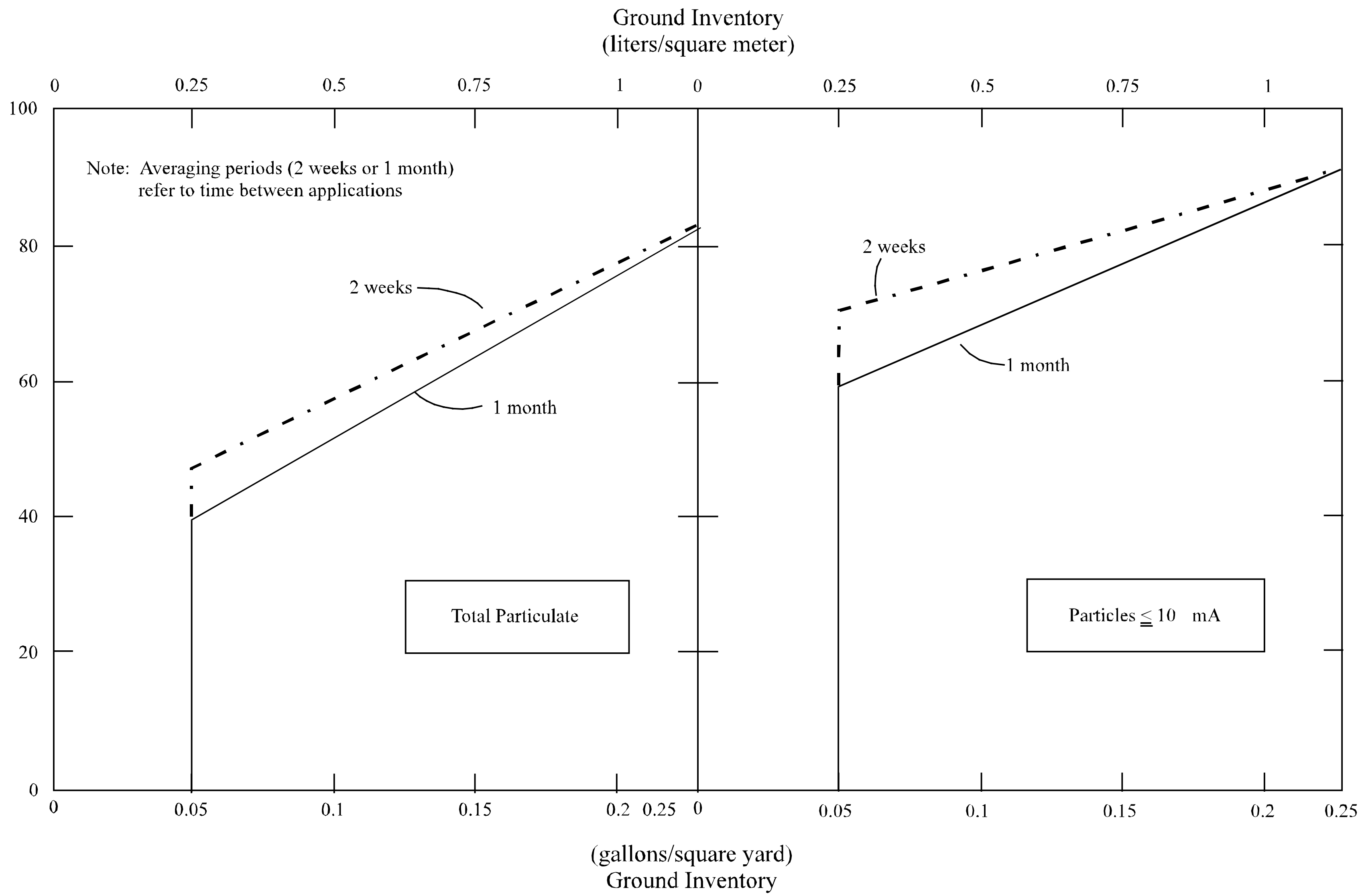

Figure 13.2.2-2. Average control efficiencies over common application intervals.

starting on May 1, the road is treated with 1 L/m^2 of a solution (1 part petroleum resin to 5 parts water) on the first of each month through September. Then, the following average controlled emission factors are found:

Period	Ground Inventory (L/m^2)	Average Control Efficiency[a] (%)	Average Controlled Emission Factor (kg/VKT)
May	0.17	0	2.0
June	0.33	62	0.76
July	0.50	68	0.64
August	0.67	74	0.52
September	0.83	80	0.40

[a] From Figure 13.2.2-2, ≤10 µm. Zero efficiency assigned if ground inventory is less than 0.2 L/m^2 (0.05 gal/yd^2).

Newer dust suppressants are successful in controlling emissions from unpaved roads. Specific test results for those chemicals, as well as for petroleum resins and watering, are provided in References 18 through 21.

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