

Final Draft - Paved Roads
August 22, 2003

The EPA's Emission Factor and Inventory Group announce the availability of a draft section on Paved Roads to Chapter 13, Miscellaneous Sources of the document *Compilation of Air Pollutant Emission Factors, Volume I, AP-42*.

The new draft section and the technical memorandum used to develop the emission factors are available on the AP-42 Chapter 13 web site at <http://www.epa.gov/ttn/chief/ap42/ch13/>. The draft section is available in WordPerfect or Acrobat PDF formats.

The draft section was developed to make the AP-42 section complimentary to EPA's MOBILE6 emission factor model. MOBILE6 now calculates particulate matter emissions from the vehicle exhaust, brake wear and tire wear. Previous versions of the Paved Road section produced emission estimates that included these vehicle emission components plus resuspended road dust. The new draft Paved Road section has been revised so that only resuspended road dust is estimated.

Comments are due not later than **September 22, 2003** and should be addressed to Bill Kuykendal of the Emission Factor and Inventory Group in writing. The address is D205-01, US EPA, Research Triangle Park, NC 27711 or by email to kuykendal.bill@epa.gov. His phone number is (919)541-5372.

**Recommendations for
Emission Factor
Equations in AP-42
Paved Roads Section:**

**TECHNICAL
MEMORANDUM**

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I. INTRODUCTION

Section 13.2.1 of AP-42 presents emission factor equations for fugitive dust emissions from paved roads. The current equations estimate PM emissions from reentrained road dust, and vehicle exhaust, brakewear and tirewear emissions. EPA is separating the component of emissions due to exhaust, brakewear and tirewear from the composite fugitive dust emission factor equation in AP-42 for two reasons. The first reason is to eliminate the possibility of double counting emissions. EPA's Mobile6.2 model estimates PM emissions from exhaust, brakewear and tirewear. Double counting results when employing both the fugitive dust emission factors from AP-42 and Mobile6.2 to estimate emissions from vehicle traffic on paved roads. The second reason is to incorporate the decrease in emissions from newer vehicle models and fuel sources. The paved road emission factor equation was developed for vehicles in the 1980 calendar year fleet. Since 1980, improvements in vehicles and fuel have decreased the amount of PM released from exhaust.

The equation in AP-42 was developed from regression analysis of numerous emission tests on paved roads. The tests could not distinguish between emissions from reentrained road dust, exhaust, brakewear and tirewear. Therefore, EPA developed an equation that included all four sources. The PM emission factor equation in AP-42 for the Final Section 13.2.1 Paved Roads dated October 2002 is:

$$E = k \left(\frac{sL}{2} \right)^{0.65} \left(\frac{W}{3} \right)^{1.5}$$

where E = emission factor, in grams per vehicle mile traveled (g/VMT),
 k = particle size factor,
 sL = average silt loading of the road, in grams per square meter (g/m²),
 W = average weight of the vehicle fleet, in tons, and

and 0.65 and 1.5 are curve fitting coefficients. Table 1 gives the particle size factor, k .

Table 1: Particle Size Factor for Paved Road Emission Factor Equation

Particle Size Range	Particle Size Factor, k		
	g/VMT	g/VKT	lb/VMT
PM _{2.5}	1.8	1.1	0.0040
PM ₁₀	7.3	4.6	0.016
PM ₁₅	9.0	5.5	0.020
PM ₃₀	38	24	0.082

The equation is valid for silt loading, mean vehicle weight and mean vehicle speed in the following ranges:

Silt loading:	0.02 - 400 grams per square meter (g/m ²) 0.03 - 570 grains per square foot (gr/ft ²)
Mean vehicle weight:	1.8 - 38 megagrams (Mg) 2.0 - 42 tons
Mean vehicle speed:	16 - 88 kilometers per hour (kph) 10 - 55 miles per hour (mph)

II. DEVELOPMENT OF NEW EMISSION FACTOR EQUATION

The emission factor equation given above must be altered to separate the reentrained road dust component from the mobile source component. In order to accomplish this, the mobile source component of the emission factor must be calculated. The vehicle exhaust, brakewear and tirewear emission factors were obtained from the MOBILE6.2 model. A typical vehicle fleet and fuel source from 1980 was utilized for the model runs. Pechan ran the model for eight different speeds; 25, 30, 35, 40, 45, 50, 55, and 60 mph. The model runs for each speed were executed for a particle size cutoff of 10 microns and 2.5 microns. Tables 2 and 3 present the assumptions used for the model runs.

Table 2: Assumptions Used in MOBILE6.2 Model

Parameter	Value in MOBILE6.2
Calendar Year:	1980
Month:	July
Gasoline Fuel Sulfur Content:	300 ppm
Diesel Fuel Sulfur Content:	500 ppm
Reformulated Gas:	No

Table 3: Vehicle Fleet Assumptions Used in MOBILE6.2 Model

Vehicle Type	LDGV	LDGT12	LDGT34	HDGV	LDDV	LDDT	HDDV	MC
GVWR	3,075	4,105	7,000	35,000	3,705	6,000	70,000	550
VMT Distribution	0.6748	0.1477	0.0758	0.0365	0.0088	0.0118	0.0352	0.0094

The PM₁₀ and PM_{2.5} emission factors in g/VMT were obtained for each vehicle class at the eight different speeds. Table 4 presents the total PM₁₀ and PM_{2.5} emission factors for exhaust, brakewear and tirewear at all 8 speeds. The standard deviation was less than or equal to 0.000223 g/VMT. Based on this

analysis, it is assumed that the vehicle speed was not a factor in exhaust, brakewear and tirewear PM emissions.

**Table 4: Mobile 6.2 Emission Factors for Total PM Emissions
from Exhaust, Brakewear and Tirewear**

Vehicle Type:	LDGV	LDGT12	LDGT34	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Total PM10 from Exhaust, Brakewear and Tirewear										
25 mph	0.1053	0.106	0.2748	0.1633	0.383	0.7206	0.7206	2.1227	0.0926	0.2119
30 mph	0.1053	0.106	0.2747	0.1632	0.3827	0.7206	0.7206	2.1227	0.0923	0.2119
35 mph	0.1053	0.1061	0.2746	0.1632	0.3824	0.7206	0.7206	2.1227	0.0921	0.2119
40 mph	0.1053	0.1061	0.2746	0.1632	0.3824	0.7206	0.7206	2.1227	0.0921	0.2119
45 mph	0.1053	0.1061	0.2746	0.1632	0.3824	0.7206	0.7206	2.1227	0.0921	0.2119
50 mph	0.1053	0.1061	0.2746	0.1632	0.3824	0.7206	0.7206	2.1227	0.0921	0.2119
55 mph	0.1053	0.1061	0.2746	0.1632	0.3824	0.7206	0.7206	2.1227	0.0921	0.2119
60 mph	0.1053	0.1061	0.2746	0.1632	0.3824	0.7206	0.7206	2.1227	0.0921	0.2119
Average	0.1053	0.1061	0.2746	0.1632	0.3825	0.7206	0.7206	2.1227	0.0922	0.2119
Std Dev	2.82E-09	4.63E-05	7.44E-05	3.54E-05	2.23E-04	1.13E-08	1.13E-08	0.00E+00	1.81E-04	0.00E+00
Total PM2.5 from Exhaust, Brakewear and Tirewear										
25 mph	0.0686	0.069	0.1853	0.1084	0.2581	0.6519	0.6521	1.9272	0.0595	0.1617
30 mph	0.0686	0.069	0.1852	0.1084	0.2578	0.6519	0.6521	1.9272	0.0592	0.1617
35 mph	0.0686	0.069	0.1851	0.1084	0.2575	0.6519	0.6521	1.9272	0.0589	0.1617
40 mph	0.0686	0.069	0.1851	0.1084	0.2575	0.6519	0.6521	1.9272	0.0589	0.1617
45 mph	0.0686	0.069	0.1851	0.1084	0.2575	0.6519	0.6521	1.9272	0.0589	0.1617
50 mph	0.0686	0.069	0.1851	0.1084	0.2575	0.6519	0.6521	1.9272	0.0589	0.1617
55 mph	0.0686	0.069	0.1851	0.1084	0.2575	0.6519	0.6521	1.9272	0.0589	0.1617
60 mph	0.0686	0.069	0.1851	0.1084	0.2575	0.6519	0.6521	1.9272	0.0589	0.1617
Average	0.0686	0.0690	0.1851	0.1084	0.2576	0.6519	0.6521	1.9272	0.0590	0.1617
Std Dev	0.00E+00	0.00E+00	7.44E-05	0.00E+00	2.23E-04	0.00E+00	0.00E+00	3.90E-08	2.23E-04	2.82E-09

Pechan developed PM_{10} and $PM_{2.5}$ emission factors using the AP-42 paved roads emission factor equation given above. The mean vehicle weight was set at a value for a typical vehicle fleet on paved roads from year 1980, 3.74 tons (EPA, 2001 and EPA, 2003). Pechan calculated emission factors for silt loadings ranging from 0.02 to 400 g/m². The resulting emission factors are given in Table 5 as “AP-42 Composite”.

Pechan then subtracted the value of the average emission factor for exhaust, brakewear and tirewear developed from Mobile 6.2. From Table 4, this value is 0.2119 for PM_{10} and 0.1617 for $PM_{2.5}$. This produced an emission factor for only the reentrained road dust component. Table 5 presents the results of subtracting the mobile source component for PM_{10} and $PM_{2.5}$. According to Section 13.2.1 of AP-42, the paved road emission factor equation is applicable for silt loadings ranging from 0.02 to 400 g/m². The PM_{10} emission factor is not affected in this range, however, the $PM_{2.5}$ emission factor becomes negative at silt loadings less than 0.029 g/m². Since negative emissions are not physically possible, the equation is now only valid for silt loading ranging from 0.03 to 400 g/m².

Table 5: PM₁₀ and PM_{2.5} Emission Factors for Combined Paved Road Emissions (AP-42) Mobile Source Emissions, and Reentrained Road Dust

Silt Loading	PM10 Emission Factors			PM2.5 Emission Factors		
	AP-42 Composite	Exhaust, Brake wear and Tire wear	Reentrained Road Dust	AP-42 Composite	Exhaust, Brake wear and Tire wear	Reentrained Road Dust
g/m ²	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT	g/VMT
0.02	0.5093	0.2119	0.2974	0.1256	0.1617	-0.0361
0.05	0.9239	0.2119	0.7120	0.2278	0.1617	0.0661
0.075	1.2025	0.2119	0.9906	0.2965	0.1617	0.1348
0.1	1.4497	0.2119	1.2378	0.3575	0.1617	0.1958
0.25	2.6299	0.2119	2.4180	0.6485	0.1617	0.4868
0.5	4.1268	0.2119	3.9149	1.0176	0.1617	0.8559
0.75	5.3712	0.2119	5.1593	1.3244	0.1617	1.1627
1.0	6.4756	0.2119	6.2637	1.5967	0.1617	1.4350
2.0	10.1613	0.2119	9.9494	2.5055	0.1617	2.3438
3.0	13.2254	0.2119	13.0135	3.2610	0.1617	3.0993
4.0	15.9448	0.2119	15.7329	3.9316	0.1617	3.7699
5.0	18.4336	0.2119	18.2217	4.5453	0.1617	4.3836
7.0	22.9400	0.2119	22.7281	5.6564	0.1617	5.4947
10.0	28.9254	0.2119	28.7135	7.1323	0.1617	6.9706
25.0	52.4735	0.2119	52.2616	12.9387	0.1617	12.7770
100.0	129.2049	0.2119	128.9930	31.8587	0.1617	31.6970
400.0	318.1397	0.2119	317.9278	78.4454	0.1617	78.2837

Pechan recommends the emission factor equations for PM_{2.5}, PM₁₀, PM₁₅ and PM₃₀ given below.

$$E = k \left(\frac{sL}{2} \right)^{0.65} \left(\frac{W}{3} \right)^{1.5} - C$$

where E = emission factor, in grams per vehicle mile traveled (g/VMT),
 k = particle size factor,
 sL = average silt loading of the road, in grams per square meter (g/m²),
 W = average weight of the vehicle fleet, in tons,
 C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear,

and Table 7 gives the value of C and k .

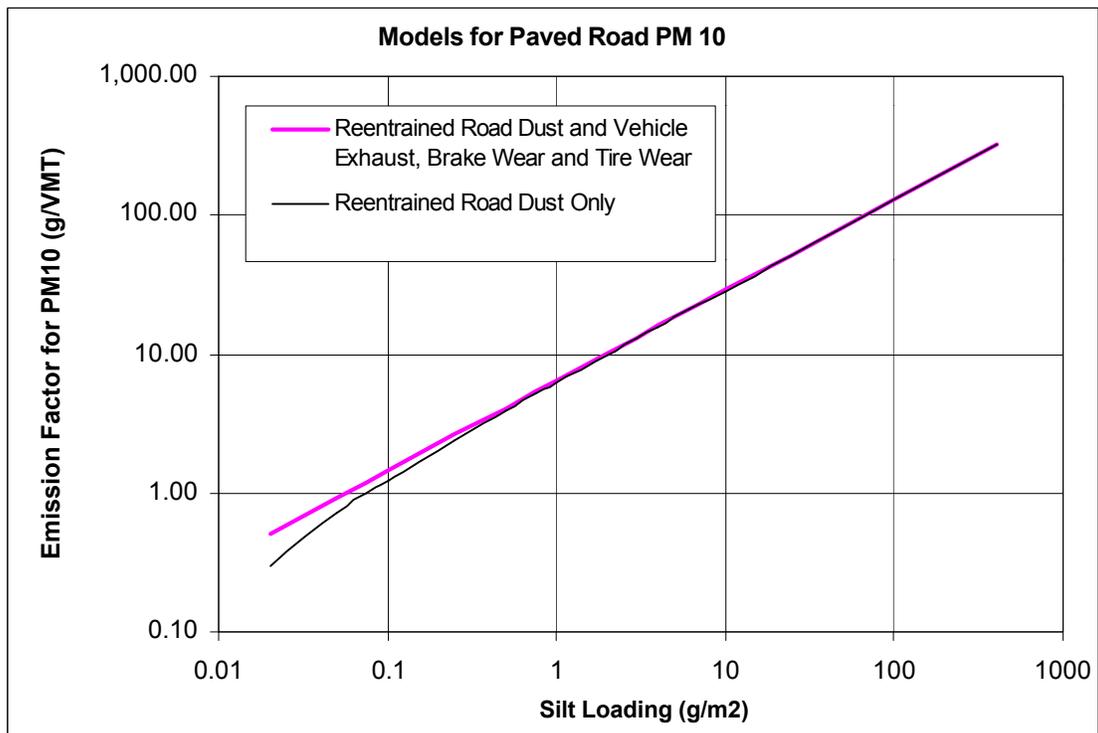
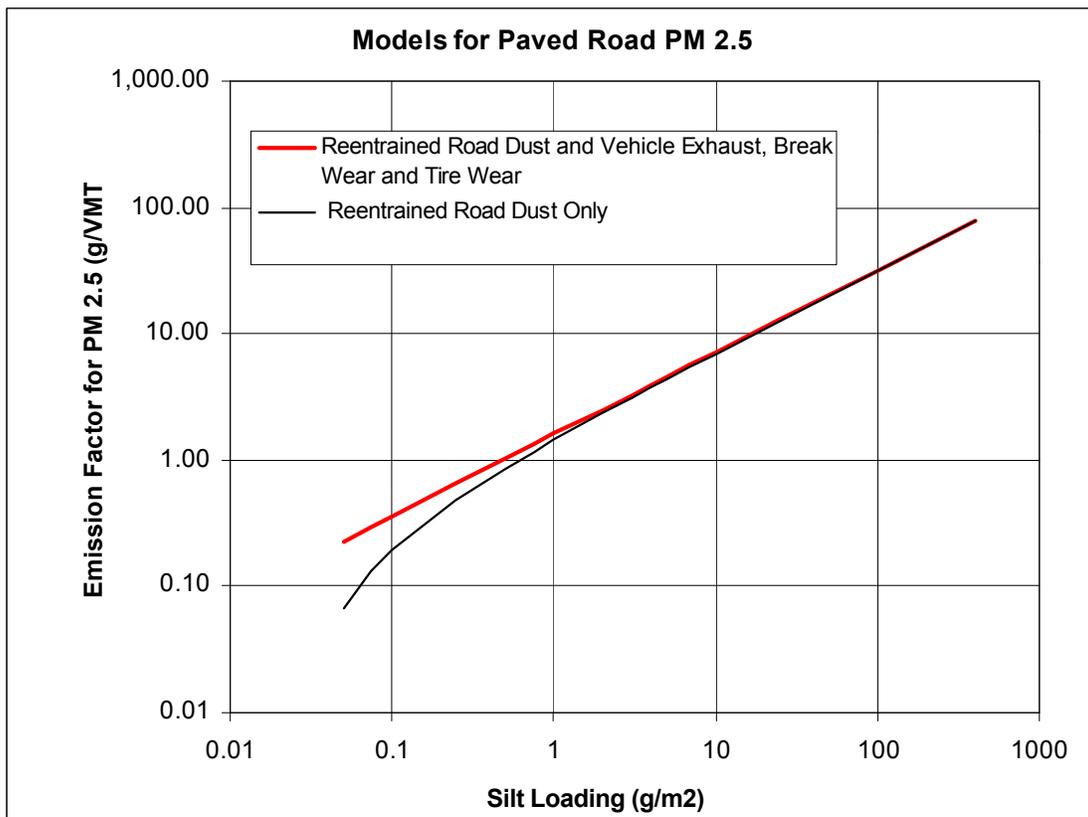
Table 7: Particle Size Factor for Paved Road Emission Factor Equation

Particle Size Range	Emission Factor for Exhaust, Brake Wear and Tire Wear, C			Particle Size Factor, k		
	g/VMT	g/VKT	lb/VMT	g/VMT	g/VKT	lb/VMT
PM _{2.5}	0.1617	0.1005	0.00036	1.8	1.1	0.0040
PM ₁₀	0.2119	0.1317	0.00047	7.3	4.6	0.016
PM ₁₅	0.2119	0.1317	0.00047	9.0	5.5	0.020
PM ₃₀	0.2119	0.1317	0.00047	38	24	0.082

The equation is valid for silt loading, mean vehicle weight and mean vehicle speed in the following ranges:

Silt loading:	0.03 - 400 grams per square meter (g/m ²) 0.04 - 570 grains per square foot (gr/ft ²)
Mean vehicle weight:	1.8 - 38 megagrams (Mg) 2.0 - 42 tons
Mean vehicle speed:	16 - 88 kilometers per hour (kph) 10 - 55 miles per hour (mph)

Figure 1.0 and Figure 2.0 present plots for PM₁₀ and PM_{2.5} of the original emission factor equation with both the reentrained road dust and the vehicle exhaust, brake wear and tire wear components and the modified emission factor with only the reentrained road dust component.

Figure 1.0 Models for PM₁₀ Emission Factor**Figure 2.0 Models for PM_{2.5} Emission Factor**

REFERENCES

- EPA, 2001. *Light-Duty Automotive Technology and Fuel Economy Trends 1975 Through 2001*, United States Environmental Protection Agency, Office of Transportation and Air Quality. Research Triangle Park, NC. EPA420-R-01-008. September, 2001.
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