PROPOSED REVISIONS TO ROADWAY FUGITIVE DUST ESTIMATIONS USING AP-42 CHAPTER 13

This overview first presents a brief history of the current AP-42 paved road emission factor and then summarizes the revision proposed in the background document.

I. AP-42 FUGITIVE DUST METHODOLOGY PRIOR TO 1993

Figure 1 illustrates the situation for AP-42 paved road emission factors prior to the 1993 update. As noted in the background document, there were 3 distinct emission factors, one for "urban" roads and two for "industrial" roads. The figure also shows the data sets supporting each emission factor.

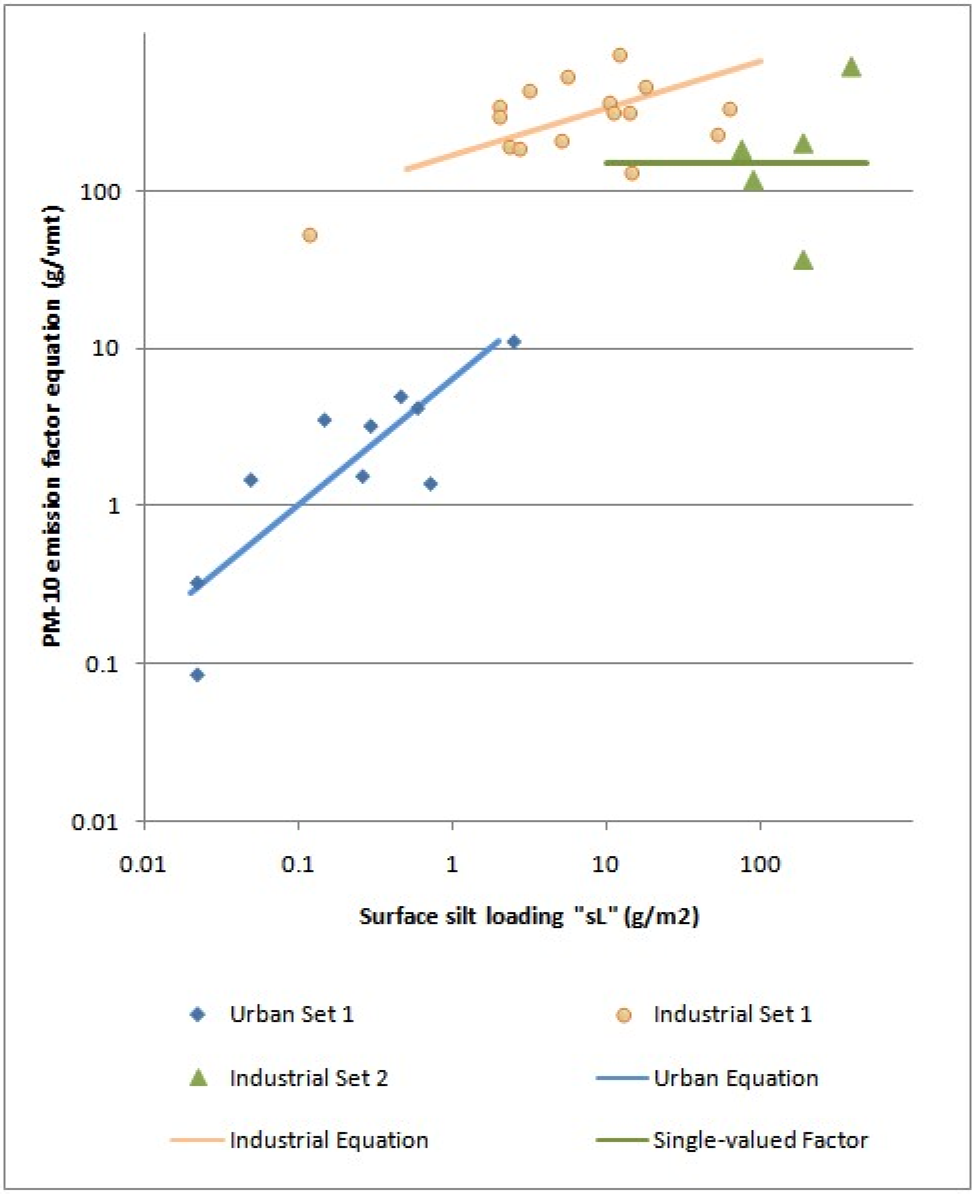

Figure 1. AP-42 paved road emission factors prior to 1993

II. AP-42 FUGITIVE DUST METHODOLOGY AS OF 1993

The 1993 AP-42 update revisited the earlier test data and included additional test results. This is shown in Figure 2 and, in addition to data from Figure 1, it includes:

- Test results excluded from the earlier "urban" data set (these tests are indicated as hollow diamonds ["urban set 2"] in the figure)
- Data from tests of controlled industrial paved road emissions
- Results from tests newly available in 1993

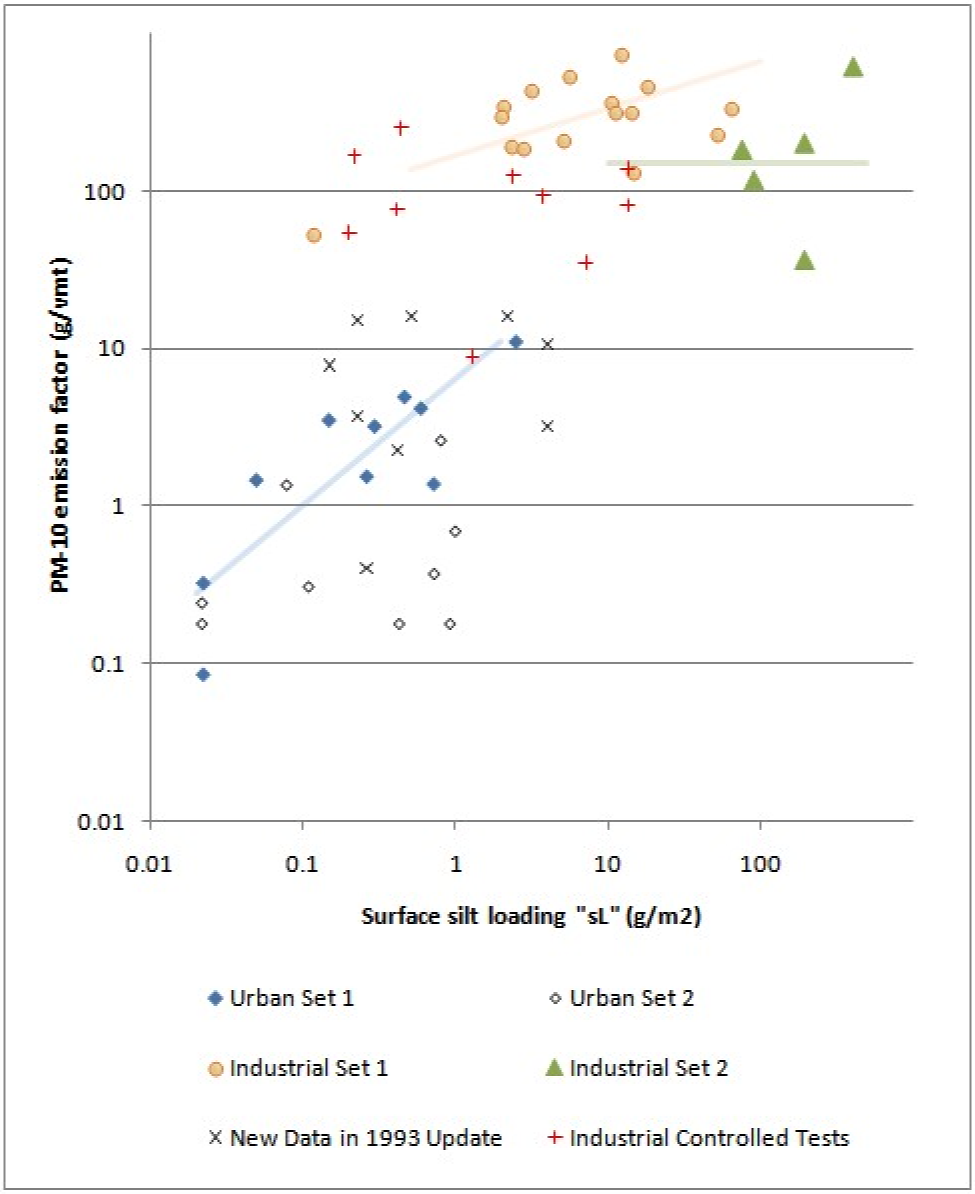

Figure 2. Compilation of the 1993 paved road data set

The 1993 update considered all data points in Figure 2 without regard to "industrial" vs. "urban" or other distinctions. Stepwise linear regression of the data set produced a PM-10 emission factor equation of the following form

$$E_{10} = 7.3\ (sL/2)^{0.65}\ (W/3)^{1.5} \quad (1a)$$

where:

E_{10} = PM-10 emission factor (g/VMT)
sL = road surface silt loading (grams per square meter) (g/m^2)
W = average weight (tons) of the vehicles traveling the road

PM-2.5 emissions were estimated from Equation 1a using a PM-2.5/PM-10 ratio of 0.45:

$$E_{2.5} = 3.3\ (sL/2)^{0.65}\ (W/3)^{1.5} \quad (1b)$$

where:

$E_{2.5}$ = PM-2.5 emission factor (g/VMT)

Both equations were included in Section 13.2.1 ("Paved Roads") in the Fifth Edition.

III. AP-42 FUGITIVE DUST METHODOLOGY AS OF JANUARY 1995

Table 1 lists nine changes made to Section 13.2.1 since the original Fifth Edition appeared in January 1995:

Table 1. Changes listed in Section 13.2.1

Change Number	Description of Change
1)	The particle size multiplier was reduced by approximately 55% [sic] as a result of emission testing specifically to evaluate the PM-2.5 component of the emissions.
2)	Default silt loading values were included in Table 13.2.1-2 replacing the Tables and Figures containing silt loading statistical information.
3)	Editorial changes within the text were made indicating the possible causes of variations in the silt loading between roads within and among different locations. The uncertainty of using the default silt loading value was discussed.
4)	Section 13.2.1.1 was revised to clarify the role of dust loading in re-suspension. Additional minor text changes were made.
5)	Equations 2 and 3, Figure 13.2.1-2, and text were added to incorporate natural mitigation into annual or other long-term average emission factors.
6)	The emission factor equation was adjusted to remove the component of particulate

	emissions- from exhaust, brake wear, and tire wear. The parameter C in the new equation varies with aerodynamic size range of the particulate matter. Table 13.2.1-2 was added to present the new coefficients.
7)	The default silt loading values in Table 13.2.1-3 were revised to incorporate the results from a recent analysis of silt loading data.
8)	The PM-2.5 particle size multiplier was reduced by 40% as the result of wind tunnel studies of a variety of dust emitting surface materials.
9)	References were rearranged and renumbered.

Two of the changes (#4, #9) were editorial. The other, more technical, changes fall in the following categories:

- Reduction of the PM-2.5 particle size multiplier (#1,#8). This has occurred twice, each time in response to specific PM-2.5 measurement programs. Change #8 is described in http://www.epa.gov/ttn/chief/ap42/ch13/bgdocs/b13s02.pdf

- Revisions related to default silt loading values for public roads (#2, #3, #7). Recognizing that not all users will be able to measure silt loading (sL), the section has always included guidance on selecting a default sL value. Nevertheless, the section was revised several times to stress measured, site-specific silt loading values. Data underlying the current guidance in AP-42 Table 13.2.-3 are given in http://www.epa.gov/ttn/chief/conference/ei11/dust/cowherd.pdf

- Refinement of the emission factor in Equation 1a (#5, #6). These changes allow AP-42 estimates to better match other emission inventory tools. Change #5 (documented in the files http://www.epa.gov/ttn/chief/ap42/ch13/draft/d13s02-1memo_oct2001.pdf and http://www.epa.gov/ttn/chief/ap42/ch13/related/rel_c13s0201.pdf) incorporated features that the National Emissions Inventory applies to annual emissions from paved roads. This change multiplies the Equation 1a by a term based on the fraction of time with measurable precipitation. The second modification (#6) "backed out" tailpipe exhaust, brakewear and tirewear emissions from the base factor . This avoids "double counting" of emissions and is accomplished by subtracting a term *C* from the base emission factor in Equation 1a:

$$E_{10} = 7.3\ (sL/2)^{0.65}\ (W/3)^{1.5} - C \qquad (2)$$

For PM-10, C = 0.2119 g/vmt. Other values for *C* and supporting information are presented in the file http://www.epa.gov/ttn/chief/ap42/ch13/related/pavedroadstechmemo_082103.pdf .

IV. PROPOSED AP-42 FUGITIVE DUST METHODOLOGY AS OF AUGUST 2008

None of the nine changes in Table 1 affected the *base* PM-10 emission factor term in Equation 1a, i.e., $7.3\ (sL/2)^{0.65}\ (W/3)^{1.5}$. The new July 18, 2008 background document, on the other hand, changes the base emission factor.

MRI conducted four PM testing programs at Corn Refiners Association (CRA) members' facilities between April 2001 and September 2003. Testing occurred because member companies recognized that paved road conditions at their plants did not match well with source conditions in the supporting database (i.e., Figure 2). Comparing tests with similar vehicle weights, CRA plant roads have substantially lower sL and slower speeds than the AP-42 database.

In each test program, MRI developed site-specific data to better describe actual paved road PM emissions at the facility. Each field program applied the same fundamental emission measurement methodology used to develop the AP-42 database. In other words, the CRA data are directly comparable to the test data supporting the AP-42 paved road section.

In February 2008, CRA and EPA representatives met in Research Triangle Park, NC to discuss how the CRA data could be incorporated into AP-42. The participants discussed the merits of the three following approaches:

1. Regression of the CRA data to produce a separate predictive emission factor equation for slowly moving vehicles on lightly loaded paved roads.
2. Simple averaging of the CRA data to produce a single-valued emission factor for heavy vehicles on clean roads (i.e., the opposite condition considered in the single-valued factor that existed prior to the 1993 AP-42 update).
3. Re-regression of an expanded AP-42 database to extend the factor's applicability to slower speeds and stop-and-go situations.

All parties agreed that the CRA test data shared basic similarity with the existing AP-42 database and that the third approach – inclusion of the CRA tests in the AP-42 database – would extend the applicability of the equation. First, inclusion of the CRA tests would reduce the lowest travel speeds in the AP-42 database from 10 to 5 mph. Next, inclusion would extend the applicability to stop-and-go traffic (which AP-42 Section 13.2.1.3 excludes). Finally, the expanded data set would better reflect a broader spectrum of combinations of silt loading and vehicle weight.

The meeting concluded with EPA requesting that MRI apply the same methods to the expanded database as used in 1993 update to develop and validate a new paved road emission factor. The new background document describes how this was carried out. Section 2 of the background document first thoroughly describes the CRA test programs and pays special attention to reliable quantification for the low emission levels encountered. The background document then describes how stepwise linear regression was used to develop a revised base emission factor. Section 2 in the document concludes with a validation study which found the revised based emission factor to be comparable to the current AP-42 factor in terms of PM-10 predictive accuracy.

Section 3 in the background document summarizes the proposed changes to AP-42. The revision applied the same corrections (i.e., to avoid double counting and account for precipitation) and same PM-2.5/PM-10 ratio (i.e., 0.15) as in the current version of Section 13.2.1. The recommended emission factor model (for dry conditions) is as follows:

$$E = k\,(sL/2)^{0.8} \times (W/3)^{0.8} - C \qquad (3)$$

The “k” and “C” terms are given below.

Size Range	Particle size multiplier k[b]			C term		
	g/VKT	g/VMT	lb/VMT	g/VKT	g/VMT	lb/VMT
PM-2.5[c]	0.93	1.6	0.0034	0.1005	0.1617	0.00036
PM-10	6.5	10	0.023	0.1317	0.2119	0.00047
PM-30[d]	34	54	0.12	0.1317	0.2119	0.00047

In summary, the proposed revision (a) employs data measured the same way as tests supporting the current AP-42 factor; (b) relies on the same procedure to develop (stepwise regression) and to validate (cross-validation) as used in the last AP-42 update (1993) ; and (c) applies the same corrections as have been applied to the 1993 factor.

VI. IMPACT OF PROPOSED AUGUST 2008 METHODOLOGY REVISIONS

To gain practical insight into the effect the proposed revisions might have, MRI compared countywide estimates for the San Joaquin Valley (SJV) and the South Coast (SC) air basins. MRI used California Air Resources Board (CARB) procedures and VMT data taken from http://www.arb.ca.gov/ei/areasrc/PMSJVPavedRoadMethod2003.pdf and http://www.arb.ca.gov/ei/areasrc/fullpdf/full7-9.pdf .

For SJV, CARB uses a mean vehicle weight of 2.4 tons and the following silt loading values:

Road Type	Silt Loading (g/m^2)
Freeway	0.02
Arterial	0.035
Collector	0.035
Local	0.32
Rural	1.6

Figure 3 below compares the emission factors for the SJV silt loadings and Table 2 compares countywide emission estimates by road class. (Note that factors are not adjusted for precipitation or exhaust, brakewear or tirewear. However, the *C* factor for PM-10 of 0.2119 g/vmt is included in Figure 3 for reference.)

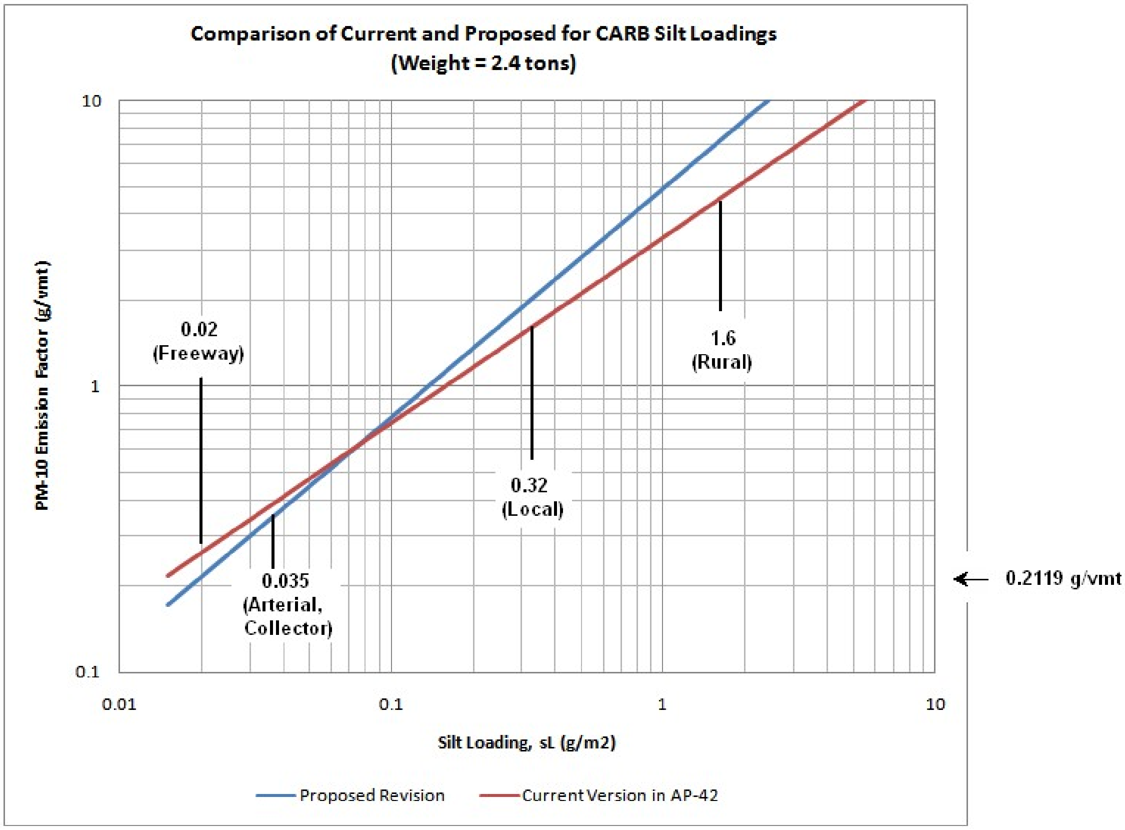

Figure 3. Comparison of emission factors for CARB silt loadings.

Table 2. Comparison of SJV Paved Road Emission Estimates

County	Road Type	1999 VMT (million/yr)	Base Emissions (PM10 tpy) Current AP-42	Base Emissions (PM10 tpy) Proposed Revision
Fresno	Freeway	2139	614	517
	Arterial	3287	1357	1243
	Collector	748	309	283
	Local	372	647	826
	Rural	211	1045	1698
Kern	Freeway	2520	723	609
	Arterial	2285	943	864
	Collector	129	53	49
	Local	170	295	377
	Rural	177	874	1421
Kings	Freeway	361	104	87
	Arterial	387	160	146
	Collector	29	12	11
	Local	101	176	224
	Rural	246	1217	1977
Madera	Freeway	494	142	119

County	Road Type	1999 VMT (million/yr)	Base Emissions (PM10 tpy) Current AP-42	Proposed Revision
	Arterial	425	175	161
	Collector	198	82	75
	Local	38	67	85
	Rural	104	515	838
Merced	Freeway	714	205	173
	Arterial	1135	468	429
	Collector	324	134	122
	Local	27	47	61
	Rural	57	282	459
San Joaquin	Freeway	2706	776	654
	Arterial	1683	694	636
	Collector	654	270	247
	Local	191	332	423
	Rural	126	621	1010
Stanislaus	Freeway	1023	293	247
	Arterial	1242	513	470
	Collector	1333	550	504
	Local	98	170	217
	Rural	56	276	449
Tulare	Freeway	878	252	212
	Arterial	1675	691	633
	Collector	157	65	59
	Local	351	610	779
	Rural	130	642	1044

NOTE: Entries not adjusted for rain or for exhaust, brakewear or tirewear.

The South Coast Air Quality Management District uses the following county-specific vehicle weight averages

County	Mean Vehicle Weight (tons)
Los Angeles	2.7
Orange	2.7
Riverside	3.2
San Bernardino	3.4

together with the silt loadings shown below:

Road Type	Silt Loading (g/m^2)
Freeway	0.02
Arterial	0.037
Collector	0.037
Local	0.24

Note that SC does not include a "rural" category for paved roads. Table 3 compares the two sets of paved road emission estimates for the SC air basin.

Table 3. Comparison of SC Paved Road Emission Estimates

		1993 VMT	Base Emissions (PM10 tpy)	
County	Road Type	(million/yr)	Proposed Revision	Current AP-42
Los Angeles	Freeway	28752	7634	9843
	Major	30133	13088	15387
	Collector	3553	1543	1814
	Local	3355	6504	5777
Orange	Freeway	9912	2632	3393
	Major	10022	4353	5118
	Collector	837	364	427
	Local	1255	2434	2161
Riverside	Freeway	5109	1554	2257
	Major	3835	1908	2526
	Collector	1241	617	817
	Local	1083	2404	2405
San Bernardino	Freeway	4830	1542	2336
	Major	4178	2182	3015
	Collector	890	465	642
	Local	944	2201	2297

NOTE: Entries not adjusted for rain or for exhaust, brakewear or tirewear.

In Table 2, estimates for SJV freeways, arterials and collectors all decrease when the proposed revision is substituted for the current AP-42 factor. Estimates for local and rural roads increase, on the other hand. For the SC air basin, Table 3 shows substantial decreases in estimates for freeways, arterials, and collectors. The estimates for local roads increase by 10 to 15% for Los Angeles and Orange counties, but are essentially unchanged for Riverside and San Bernardino counties.

Practical implications of replacing the current paved emission factor with Equation 3 include the following:

- Overall public paved road emission estimates may increase or decrease, depending upon (a) what values a local agency uses for sL and mean vehicle weight and (b) the amount of VMT on different road classes.

- The proposed revision would effectively shift some of the estimated paved road emissions from high-volume roads to roads with lower traffic levels. High-traffic roads will contribute a smaller fraction of overall emissions while low-ADT roads will represent a higher fraction.

- For high-volume roads, some of the annual emissions will shift from conditions of “ubiquitous” silt loading to more “extraordinary” conditions when the roads have relatively high silt loading values. In other words, PM emissions resulting from antiskid materials and mud/dirt trackout will be higher in importance while “day-to-day” paved road emissions will be less important.