PM Speciation Profiles for Asphalt Concrete Manufacturing Plant —PM3421, PM3422, PM3423 and PM3424

Wenli Yang, PhD, PE

Air Quality Planning and Science Division

September 29, 2016

1 Introduction

This memo presents a set of new PM size and chemical speciation profiles for asphalt concrete manufacturing categories. The new profiles will be used to replace the currently in-use CARB PM342 (Asphalt Concrete Batch Plant) for describing the particle size distributions and chemical compositions of the emissions from asphalt manufacturing plants. PM342 was developed based on measurements conducted on a batch hot-mix asphalt plant back in 1979 [1], which is outdated and needs to be updated with newer test data.

Asphalt concrete plants or asphalt pavement mixing facilities are industrial operations that mix liquid asphalt cement with aggregates (such as crushed stone and gravel) to make firm, tough surfaces for pavement. There are two types of asphalt mixes: hot mix and cold mix. Hot mix asphalt (HMA) is more commonly used on high traffic pavements while cold mix asphalt is usually used as a patching material and on low-trafficked roads.

Hot mix facilities may be classified as a batch facility or a drum mix facility. Batch-type hot mixing facilities use different size fractions of hot aggregates which are drawn from storage bins to prepare one batch for mixing. The combination of aggregates is transferred into a mixing chamber and then mixed with weighed asphalt. The drum-mixing process heats and blends the aggregates with asphalt all at the same time in the drum mixer.

Like most facilities in the mineral products industry, the asphalt mix plants have two major types of emissions: ducted sources and fugitive sources. A number of control equipment have been introduced to reduce the PM emissions, including electrostatic precipitators, primary dust collectors using single or multiple cone cyclones, and secondary collection units consisting of fabric filter collectors (baghouses).

The four new profiles developed in this work include:

- PM3421—Asphalt Concrete Batch Mix Plant (Uncontrolled)
- PM3422—Asphalt Concrete Batch Mix Plant (Controlled)
- PM3423—Asphalt Concrete Drum Mix Plant (Uncontrolled)
- PM3424—Asphalt Concrete Drum Mix Plant (Controlled)

2 Methodology

A complete PM profile has two indispensable components: size profile and chemical speciation profile. The development of these two components is described in this section.

2.1 Size fraction profile

- Batch Mix Plant

As stated earlier, ducted sources and fugitive sources are two major categories of emissions from batch mix HMA plants. The most significant ducted source of emissions from batch mix HMA plants is the rotary drum dryer. Other potential emission sources include the hot-side conveying, classifying, and mixing equipment, which are vented either to the primary dust collector or to a separate dust collection system. The choice of applicable emission controls for PM emissions from dryer and vent line includes dry mechanical collectors, scrubbers, and fabric filters. Based on the emission factors of $PM_{1.0}$, $PM_{2.5}$, PM_{10} and Total PM (TPM) for batch mix dryers, hot screens and mixers obtained from *AP 42* [2] (Table 1), the ratios of $PM_{1.0}$/TPM, $PM_{2.5}$/TPM and PM_{10}/TPM are calculated for uncontrolled and controlled batch mixing processes.

Table 1. Emission factors for batch mix plant (from AP42)

PM Size	*$PM_{1.0}$*	*$PM_{2.5}$*	*PM_{10}*	*TPM*
Uncontrolled *(lb/ton*)*	N/A	0.27	4.5	32
Controlled *(lb/ton*)*	0.0075	0.0083	0.0098	0.025

**Emission factor unit is lb/ton of HMA produced.*

- Drum Mix Plant

As in the batch mix plants, the rotary drum dryer is the major source of ducted emissions from drum mix plants. Fugitive PM emissions are mainly from transport and handling of the HMA from the drum mixer to the storage silo and also from the load-out operations to the delivery trucks. Based on the emission factors of $PM_{1.0}$, $PM_{2.5}$, PM_{10} and TPM for drum mix dryers obtained from *AP 42* [2] (Table 2), the ratios of $PM_{1.0}$/TPM, $PM_{2.5}$/TPM and PM_{10}/TPM are calculated for uncontrolled and controlled drum mixing processes.

Table 2. Emission factors for drum mix plant (from AP42)

PM size	*$PM_{1.0}$*	*$PM_{2.5}$*	*PM_{10}*	*TPM*
Uncontrolled *(lb/ton)*	N/A	1.5	6.4	28
Controlled *(lb/ton)*	0.0021	0.0029	0.0039	0.014

**Emission factor unit is lb/ton of HMA produced.*

2.2 Chemical speciation profile

In EPA's SPECIATE 4.4 database, there are two PM speciation profiles for asphalt manufacturing: #4082 (PM_{10}) and #4083 ($PM_{2.5}$) [2]. They were derived based on measurements of the particle samples collected from an asphalt concrete plant in Tlalpan, Mexico in the late 1990s by DRI researchers [3-5]. The following steps are implemented to create the CARB PM chemical speciation profiles using the data provided in EPA Profiles #4082 and #4083:

a. NCOM (Non-Carbon Organic Matter) is calculated by subtracting OC (organic carbon) from OM (organic matter) which can be estimated from OC by multiplying by the ratio of OM/OC. A default OM/OC ratio of 1.4 is applied for the asphalt manufacturing categories [6].

b. A species group named 'Other' is created to capture the mass of oxygen associated with the five geological elements (i.e., Al, Si, Ca, Fe, and Ti) using the following formula:

$$0.89\times[Al]+1.14\times[Si]+0.40\times[Ca]+0.43\times[Fe]+0.67\times[Ti]$$

where [Al], [Si], [Ca], [Fe] and [Ti] are weight fractions of these five elements, respectively [7].

c. Because different analytical methods are performed on PM samples to determine more complete speciation information for multiple purposes, some species are overlapped in the EPA profiles. For example, total sulfate and sulfur are both reported for the same profile. To avoid double counting of the sulfur fraction contained in the reported sulfate, non-sulfate sulfur is calculated to replace the total sulfur in the profile. Resulting negative values are set to zero [7].

d. For mass balance, a species named 'Unknown' is added to the profiles to make the total weight fractions of all species 1.0.

3 Results and Discussion

3.1 Size fraction profile

The PM size profiles for batch mix plant and drum mix plant are listed in Table 3 and Table 4, respectively. Table 3 indicates that 14.06% of the total PM emitted from uncontrolled batch mix plant is PM_{10}, and only 0.84% is $PM_{2.5}$. The ratios of PM_{10} and $PM_{2.5}$ over TPM from controlled batch mix plant are 0.3920 and 0.3320. The controlled ratios are much higher than the uncontrolled ones; however, they are very close to the PM342 size profile, in which PM_{10}/TPM is 0.4000 and $PM_{2.5}$/TPM is 0.3330. Similarly, as shown in Table 4 the PM_{10}/TPM and $PM_{2.5}$/TPM fractions for controlled drum mix plants are higher than the ones for uncontrolled plants.

The ratio of $PM_{2.5}/PM_{10}$ is 0.8469 for PM3422 and 0.7434 for PM3424, while the ratio is 0.8325 for the current PM342. The numbers are comparable.

Table 3. Particle size fractions for batch mix plant

PM Profile	*$PM_{1.0}$/TPM*	*$PM_{2.5}$/TPM*	*PM_{10}/TPM*
PM3421 (Uncontrolled Batch Mix Plant)	N/A	0.0084	0.1406
PM3422 (Controlled Batch Mix Plant)	0.3000	0.3320	0.3920

Table 4. Particle size fractions for drum mix plants

PM size	*$PM_{1.0}$/TPM*	*$PM_{2.5}$/TPM*	*PM_{10}/TPM*
PM3423 (Uncontrolled Drum Mix Plant)	N/A	0.0536	0.2286
PM3424 (Controlled Drum Mix Plant)	0.1500	0.2071	0.2786

3.2 Chemical speciation profile

Since no specific information is known about the control status and mix type for the asphalt mix facility that the EPA profiles #4082 and #4083 are based on, we assume they are applicable to all the new profiles developed in this work (PM3421-3424) although there could be a difference between controlled and uncontrolled profiles. Also, because the speciation data are only available for PM_{10} and $PM_{2.5}$, a homogeneous chemical composition is assumed for PM_{10} and TPM. That is, the chemical speciation profiles for PM_{10} and TPM are assumed to be the same. The detailed chemical compositions for profiles PM3421-3424 are summarized in Table 5.

Table 5. Chemical Speciation Profile for Asphalt Concrete Manufacturing (PM3421—3424)

Species Name	*SAROAD*	*Weight Percentage (%)*		
		TPM	*PM_{10}*	*$PM_{2.5}$*
Aluminum	12101	11.0392	11.0392	5.9495
Ammonium	12301	0.0339	0.0339	0.1556
Antimony	12102	0.01	0.01	
Barium	12107	0.0997	0.0997	0.2162
Bromine	12109	0.0021	0.0021	0.0018
Cadmium	12110			0.0028
Calcium	12111	4.9224	4.9224	6.0245
Chlorine	12115			0.0357
Chloride	12203	0.0479	0.0479	
Chlorine Insoluble	12202	0.0382	0.0382	
Chromium	12112	0.0056	0.0056	

Species Name	*SAROAD*	*Weight Percentage (%)*		
		TPM	*PM_{10}*	*$PM_{2.5}$*
Copper	12114	0.0066	0.0066	0.0064
Elemental Carbon (EC)	12116	1.3856	1.3856	5.7178
Gallium	12124	0.0013	0.0013	0.0003
Gold	12143	0.0001	0.0001	
Iron	12126	3.7840	3.7840	3.2776
Lanthanum	12146	0.0418	0.0418	0.2270
Lead	12128	0.0008	0.0008	
Magnesium	12140	0.2805	0.2805	0.2122
Manganese	12132	0.0662	0.0662	0.0572
Mercury	12142	0.0007	0.0007	0.0002
Molybdenum	12134	0.0019	0.0019	0.0036
Non-Carbon Organic Matter (NCOM)	11103	0.7380	0.7380	1.7294
Nickel	12136	0.0017	0.0017	0.0011
Nitrate	12306	0.0339	0.0339	0.1009
Organic Carbon	11102	1.8451	1.8451	4.3234
Palladium	12151	0.0032	0.0032	0.0041
Phosphorous	12152	0.1130	0.1130	0.1106
Potassium Ion	65312	0.0588	0.0588	0.2590
Potassium Insoluble	12182	0.9854	0.9854	0.4565
Rubidium	12176	0.0030	0.0030	0.0028
Selenium	12154	0.0002	0.0002	0.0005
Silicon	12165	26.3597	26.3597	14.6638
Sodium Ion	12181	0.1632	0.1632	0.6731
Sodium Insoluble	12186	0.7639	0.7639	0.5648
Strontium	12168	0.0436	0.0436	0.0349
Sulfate	12403	0.2181	0.2181	0.6643
Non-SO4 Sulfur	12404	0.0645	0.0645	0.0107
Thallium	12173	0.0013	0.0013	0.0023
Tin	12160	0.0069	0.0069	
Titanium	12161	0.5850	0.5850	0.4375
Uranium	12179	0.0013	0.0013	0.0008
Vanadium	12164	0.0018	0.0018	
Yttrium	12183	0.0031	0.0031	0.0012
Zinc	12167	0.0056	0.0056	
Zirconium	12185	0.0254	0.0254	0.0189
Other	12999	43.8630	43.8630	26.1241
Unknown	12000	2.3428	2.3428	27.9269
Total		*100.0000*	*100.0000*	*100.0000*

4 Estimated Impacts of the Profile Update on the Emission Inventory

Asphalt concrete mix facilities are well-regulated by local environmental agencies in California, and they employ multiple emission control systems to reduce the emissions released from the processes. Therefore, we assume that all asphalt mix plants in California are controlled, and the two profiles PM3422 (controlled batch mix) and PM3424 (controlled drum mix) will be used to replace the current profile PM342 for the associated categories. The affected SCCs/EICs and their assignment are summarized in Appendix 1.

Given the 2012 base year statewide annual average TPM emissions from asphalt mix manufacturing facilities of 6.21 tons/day (0.24% of grand total) [8]; the estimated $PM_{2.5}$ emissions will be 2.06 tons/day if profile PM 3422 is used. This is only 0.30% less than the estimate using the current profile PM342. The use of PM3424 will result in 1.29 tons/day of $PM_{2.5}$, a 37.81% reduction from PM342.

Air quality modeling for PM involves OC, EC, sulfate, nitrate, and other species. Except for the unspecified species, EC is the most abundant species in the current profile PM342. However, the current profile doesn't contain any OC and nitrate [1]. Based on the 2012 statewide annual average TPM emissions of 6.21 tons/day for asphalt concrete mix plant [8], $PM_{2.5}$ EC will decrease 0.172 tons/day by applying the new profile PM3422 to the related categories, but the OC will increase from zero to 0.089 tons/day (Table 6a). If PM3424 is applied to these categories, the OC emissions will increase from zero to 0.056 tons/day, but the EC emissions will decrease 0.216 tons/day, a 74.5% drop due to the profile change (Table 6b).

Table 6. Changes on Emissions Using Updated Asphalt Concrete Mix Plant Profiles (2012 Statewide Annual Average)

a. Using PM3422 (Controlled Batch Mix Plant)

State Annual Ave. Emissions	*Using Current Profile PM342 (tons/day)*	*Using New Profile PM3422 (tons/day)*	*Change*	
			Emissions (tons/day)	*Percentage*
$PM_{2.5}$—OC	0	0.089	+0.089	N/A
$PM_{2.5}$—EC	0.290	0.118	-0.172	-59.3%
$PM_{2.5}$—Nitrate	0	0.002	+0.002	N/A
$PM_{2.5}$—Sulfate	0.011	0.014	+0.003	+27.3%

b. Using PM3424 (Controlled Drum Mix Plant)

State Annual Ave. Emissions	*Using Current Profile PM342 (tons/day)*	*Using New Profile PM3424 (tons/day)*	*Change*	
			Emissions (tons/day)	*Percentage*
$PM_{2.5}$—OC	0	0.056	+0.056	N/A
$PM_{2.5}$—EC	0.290	0.074	-0.216	-74.5%
$PM_{2.5}$—Nitrate	0	0.001	+0.001	N/A
$PM_{2.5}$—Sulfate	0.011	0.009	-0.002	-18.2%

References:

1. *California Air Resources Board Main Speciation Profiles,* 2015, California Air Resources Board, *Accessed*: October 20, 2015.
2. *SPECIATE Version 4.4,* 2014, US EPA, *Accessed*: July 31, 2015.
3. Chow, J.C., et al., *Chemical composition of PM2.5 and PM10 in Mexico City during winter 1997.* Science of The Total Environment, 2002. **287**(3): p. 177-201.
4. Vega, E., et al., *Analysis of PM2.5 and PM10 in the atmosphere of Mexico City during 2000-2002.* Journal of Air & Waste Management Association 2004. **54**(7): p. 786-798.
5. Vega, E., et al., *Fine particle receptor modeling in the atmosphere of Mexico City.* Journal of the Air & Waste Management Association, 2009. **12**(Dec): p. 12.
6. Reff, A., et al., *Emissions Inventory of PM2.5 Trace Elements across the United States.* Environmental Science & Technology, 2009. **43**(15): p. 5790-5796.
7. Allen, P., *Developing PM Species Profiles for Emission Inventory,* 2008.
8. *CEIDARS,* 2015, California Air Resources Board, *Accessed*: Feburary 14, 2015.

Appendix 1. EICs/SCCs to be associated with asphalt mixing concrete profiles

EIC/SCC	*Names*				*PM Profile*
30500201	PETROLEUM INDRY	ASPHALT CONCRETE	ROTARY DRYER	CONVENTIONAL PLNT	3422
30500202	PETROLEUM INDRY	ASPHALT CONCRETE	HOT ELEVATORS	SCREENS,BINS,MIXR	3422
30500203	PETROLEUM INDRY	ASPHALT CONCRETE	STORAGE PILES		3422
30500204	PETROLEUM INDRY	ASPHALT CONCRETE	COLD AGRGTE HANDLING		3422
30500205	PETROLEUM INDRY	ASPHALT CONCRETE	DRUM DRYER	HOT ASPHALT PLANT	3424
30500211	PETROLEUM INDRY	ASPHALT CONCRETE	ROTRY DRYER CONVENTN	PLANT W/CYCLONE	3422
30500212	PETROLEUM INDRY	ASPHALT CONCRETE	HEATD ASPH STRG TNKS	DRUM MIX	3424
30500213	PETROLEUM INDRY	ASPHALT CONCRETE	STORAGE SILO		3422
30500214	PETROLEUM INDRY	ASPHALT CONCRETE	TRUCK LOAD-OUT		3422
30500215	PETROLEUM INDRY	ASPHALT CONCRETE	IN-PLACE RECYCLING	PROPANE	3422
30500216	PETROLEUM INDRY	ASPHALT CONCRETE	COLD AGGREGATE	FEED BINS	3422
30500217	PETROLEUM INDRY	ASPHALT CONCRETE	COLD AGGREGATE	CONVEYORS & ELEVATRS	3422
30500220	PETROLEUM INDRY	ASPHALT CONCRETE	BATCH PROCESS	ELEVATORS	3422
30500221	PETROLEUM INDRY	ASPHALT CONCRETE	CONTINUOUS PROCESS	ELEVATORS	3422
30500230	PETROLEUM INDRY	ASPHALT CONCRETE	HOT BINS & SCREENS	BATCH PROCESS	3422
30500231	PETROLEUM INDRY	ASPHALT CONCRETE	HOT BINS & SCREENS	CONTINUOUS PROCESS	3422

30500240	PETROLEUM INDRY	ASPHALT CONCRETE	MIXERS	BATCH PROCESS	3422
30500241	PETROLEUM INDRY	ASPHALT CONCRETE	MIXERS	CONTINUOUS PROCESS	3424
30500242	PETROLEUM INDRY	ASPHALT CONCRETE	DRUM MIX PROCESS	MIXERS	3424
30500245	MINERAL PRODUCTS	ASPHALT CONCRETE	BATCH MIX PLANT	HOT ELEVATORS,SCREEN	3422
30500251	MINERAL PRODUCTS	ASPHALT CONCRETE	CONVENTIONAL BATCH MIX PLANT	ROTARY DRUM DRYER: NG FIRED	3422
30500255	MINERAL PRODUCTS	ASPHALT CONCRETE	DRUM MIX PLANT	ROTARY DRUM DRYER: NG FIRED	3424
30500256	MINERAL PRODUCTS	ASPHALT CONCRETE	PARALLEL FLOW DRUM MIX PLANT	ROTARY DRUM DRYER: NG FIRED	3424
30500258	MINERAL PRODUCTS	ASPHALT CONCRETE	DRUM MIX PLANT	ROTARY DRUM DRYER: OIL FIRED	3424
30500290	PETROLEUM INDRY	ASPHALT CONCRETE	HAUL ROADS	GENERAL	3422
30500298	PETROLEUM INDRY	ASPHALT CONCRETE	OTHER	NOT CLASSIFIED	3422
30500299	PETROLEUM INDRY	ASPHALT CONCRETE	NOT CLASSIFIED	SEE COMMENT **	3422
30505005	MINERAL PRODUCTS	NONMETALLIC MINERAL	ASPHALT STORAGE	PRIOR to BLOWING	3422
43042470000000	MINERAL PROCESSES	ASPHALTIC CONCRETE PRODUCTION	MINERAL AND METAL PRODUCTS		3422
43042470060000	MINERAL PROCESSES	ASPHALTIC CONCRETE PRODUCTION	ASPHALTIC CONCRETE		3422
43043670060000	MINERAL PROCESSES	STORAGE PILES	ASPHALTIC CONCRETE		3422