

Source Profile Speciation Documentation

PM Speciation Profile for Structural and Vehicle Fire

PM458 and PM459

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Prepared July 24, 2026

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Introduction

Structural fires and vehicle fires are distinct combustion source categories that can occur as wildfire, residential, commercial, roadside, parking-area, or industrial fire incidents. Although their statewide Particulate Matter (PM) emissions are relatively small, these sources are chemically important because they involve combustion of mixed engineered, consumer, and petroleum-derived materials. Structural fires can burn wood products, gypsum board, insulation, roofing, carpeting, furniture, textiles, plastics, coatings, wiring, electronics, and household contents. Vehicle fires can burn plastics, foams, rubber, tires, fabrics, wiring, fluids, fuels, and metal-containing components. These mixtures can produce PM containing carbonaceous aerosol, halogens, mineral or ash-related material, and trace metals (Lönnermark and Blomqvist, 2006; Holder et al., 2023; Kim et al., 2025)[1-3]. The relative abundance of these PM components can vary with fuel mixture, combustion efficiency, ventilation, and the degree of flaming or smoldering combustion.

The existing CARB structural-fire PM profile, PM137[4], appears to be derived from an older estimate-based structural-fire profile and includes only a limited set of species: calcium, chlorine, carbon, iron, potassium, silicon, sulfate, and plus an Others category. PM137 also assigns 30% of PM mass to a single carbon field and does not distinguish organic carbon (OC), elemental carbon (EC), or non-carbon organic matter (NCOM), limiting its usefulness for modern PM speciation, chemical mass closure, emissions inventory interpretation, and air quality modeling. A separate vehicle-fire profile is also needed because automobile fires are not well represented by the structural-fire profile or by a tire-fire proxy alone. Vehicle fires have distinct carbon, ion, and metal signatures associated with polymers, rubber, tires, wiring, fluids, vehicle components, and, for electric vehicles, battery-related materials.

Recent emission-factor compilations and source studies provide a stronger basis for updating structural and vehicle fire PM profiles. Holder et al. (2023)[2] compiled data from fires involving structures, vehicles, furnishings, plastics, electronics, wiring, chemicals, and related urban materials, including full-scale, large-scale, and small-scale experiments. Kim et al. (2025)[3] provides direct PM chemical composition data for full-scale electric vehicle and internal-combustion-engine vehicle fires, including OC, EC, inorganic ions, and elements. For the updated vehicle-fire profile, Kim et al. (2025)[3] was used as the primary data source, and Holder et al. (2023)[2] was used only as a secondary source for selected vehicle-fire metals not reported in Kim et al. (2025)[3] dataset. This report documents two updated PM profiles:

- PM458 – Structural fires
- PM459 – Vehicle fires

Data Sources and Methods

Reference datasets and measurement basis

For PM458 structural fires, the primary data source was the house/structure category from Holder et al. (2023)[2]. Holder et al. compiled emission factor data for fires involving structures, furnishings, plastics, electronics, wiring, chemicals, vehicles, and other urban materials, and organized the retained data into broad source categories. The house category includes structural and household materials such as furnishings, textiles, wood products, plastics, and other materials commonly present in buildings. These data were used as the primary basis for structural-fire PM, OC, EC, chlorine, bromine, lead, antimony, and other PM-associated species where available. Because the Holder et al. structural-fire data do not provide a complete soluble-ion or mineral profile, EPA SPECIATE profile 4003 was used as a secondary source for missing ions, and PM137 was retained only as a tertiary source for selected mineral or ash-related species.

For PM459 vehicle fires, Kim et al. (2025)[3] was used as the primary PM chemical composition source because it directly reported OC, EC, inorganic ions, and inorganic elements in smoke PM from full-scale electric vehicle and internal-combustion-engine vehicle fires. The study included six electric vehicle fires and two internal-combustion-engine vehicle fires, allowing separate electric vehicle (EV) and internal-combustion-engine vehicle (ICEV) average compositions to be developed before constructing a California vehicle-registration-weighted vehicle-fire profile. Holder et al. (2023) was used only as a secondary source for selected PM-associated vehicle metals that were not retained from the Kim et al. dataset. Specifically, cadmium, chromium, and vanadium were filled from the Holder et al. vehicle category. Because the ICEV sample size was limited to two fires, the ICEV component is a major source of uncertainty in PM459. This uncertainty is important because ICEVs and non-battery-electric vehicles dominate the registration-weighted profile. This limitation is discussed in the uncertainty section and should be revisited when additional full-scale vehicle-fire PM speciation data become available.

Development of PM Speciation Profiles from Emission Factors

The profiles were developed using the following sequence.

1. Estimation of non-carbon organic matter:
   Organic carbon was converted to organic matter using source-specific OM/OC assumptions. For PM458, a structural-fire composite OM/OC ratio was developed from the residential building surrogate composition reported by Link et al. (2025)[5]. The combustible surrogate was treated as ~67% wood-derived material and ~33% synthetic polymer material. The wood fraction was represented using a fresh biomass-burning organic aerosol OM/OC value of 1.63 from Aiken et al. (2008)[6], and the polymer fraction was represented using a plastic-burning organic aerosol

OM/OC value of 1.29 from Mohr et al. (2009)[7]. The resulting composite OM/OC ratio was:

$$\frac{\mathrm{OM}}{\mathrm{OC}} = (0.67 \times 1.63) + (0.33 \times 1.29) = 1.52$$

Therefore, for PM458:

$$\mathrm{NCOM} = (1.52 - 1) \times \mathrm{OC} = 0.52 \times \mathrm{OC}$$

The OM/OC ratio was used as a base-case assumption. Sensitivity calculations using OM/OC values from 1.4 to 2.0 did not exceed total PM mass; the only effect was redistribution between NCOM and the unresolved closure mass included in "others," with no change to measured EC, OC, ions, or metals.

For PM459, wood was not included in the OM/OC basis because vehicle fires are dominated by polymers, rubber, tires, fluids, wiring, and other vehicle materials. NCOM was estimated using a general combustion-source OM/OC ratio of 1.4 as reported by Reff et al. (2009)[8], who used source-specific OM/OC ratios and applied 1.4 to source categories outside motor-vehicle exhaust and wood-combustion categories. The 1.4 value was used for PM459 because the relative contributions of vehicle polymers, rubber, tires, fluids, wiring, and other combustible materials are not known. Therefore, for PM459:

$$\mathrm{NCOM} = (1.4 - 1) \times \mathrm{OC} = 0.4 \times \mathrm{OC}$$

This value is treated as a base-case assumption rather than a vehicle-fire-specific measurement. Sensitivity calculations using OM/OC values from 1.4 to 2.0 were prepared to show the effect on NCOM and the unresolved closure mass included in Others category (SAROAD 12999).

2. Conversion of emission factors to PM mass percentages:
Species reported by Holder et al. (2023)[2] as emission factors were converted to PM mass percentages using the corresponding PM emission factor for the same source category:

$$\text{Species wt\% of PM} = \frac{\text{species emission factor, g/kg}}{\text{PM emission factor, g/kg}} \times 100$$

Only PM-associated species were included in PM458. For PM458, Holder et al. (2023)[2] structure-category values were used for PM-associated OC, EC, chlorine, bromine, lead, and antimony. Kim et al. measured fluoride, chloride, and bromide by ion chromatography. In the CARB profile, chloride is retained as chloride ion (SAROAD 12203). Because the current chemical master list does not contain separate fluoride-ion or bromide-ion entries, fluoride is represented as fluorine (SAROAD 42222) and bromide as bromine (SAROAD 12109). For PM459, species reported by Kim et al. (2025)[3] in µg/g of smoke PM were converted directly to PM mass percentages:

$$\text{Species wt\% of PM} = \frac{\text{Species concentration } (^{\mu g}/_{g\ PM})}{10{,}000}$$

Kim et al. (2025)[3] reported separate PM composition data for six electric vehicle fires and two internal-combustion-engine vehicle fires. The EV and ICEV profiles were averaged separately and then combined using 2024 California vehicle registration counts to develop a vehicle-registration-weighted vehicle-fire profile[9]. The resulting vehicle-fire profile was calculated as 0.041 times the electric vehicle average plus 0.959 times the internal-combustion-engine/non-battery-electric vehicle average. Registration weighting was used as a surrogate because California vehicle-fire occurrence data by powertrain were not available. Registration shares may not reflect actual fire events due to factors like age, mileage, crashes, maintenance, and battery design. Publicly available, non-peer-reviewed fire-rate estimates suggest that EV and ICEV fire occurrence rates may differ, but those estimates were not used for quantitative weighting. These estimates were not used for weighting because they are not California-specific and may rely on sales rather than registered fleet or exposure.

3. Filling missing species using secondary or tertiary data:
   Missing species were filled only after the primary-source species and calculated NCOM were included. For PM458, EPA SPECIATE profile 4003 was used as a secondary fill source for missing soluble ions, including sulfate, nitrate, ammonium, and sodium ion. PM137 was used only as a tertiary fill source for missing mineral or ash-related species, including calcium, iron, silicon, and potassium. For PM459, Kim et al. (2025) was used as the primary source for OC, EC, inorganic ions, and inorganic elements. Holder et al. (2023)[2] vehicle-category values were used only for cadmium, chromium, and vanadium because these species were not reported in the Kim et al. dataset.
4. Calculation of metal-bound oxygen (MBO):
   Metal-bound oxygen was first calculated from selected mineral and crustal elements. This calculated value was then included as one component of the Others category. Where oxide reconstruction was applied, metal-bound oxygen was calculated using the same approach used in previous CARB PM profile development:

$$\text{Others} = 0.89[\text{Al}] + 1.14[\text{Si}] + 0.40[\text{Ca}] + 0.43[\text{Fe}] + 0.67[\text{Ti}]$$

   The oxide reconstruction was limited to Al, Si, Ca, Fe, and Ti to remain consistent with prior CARB PM profile development practice for crustal and mineral oxygen. Other metals, including Mn, Zn, Cu, Ni, Co, and Cr, may also occur partly as oxides, but their oxidation states and bonding forms are source- and condition-dependent. These metals were retained as measured elemental mass, and additional oxygen was not assigned because the available measurements do not identify their chemical forms or oxidation states. This avoids adding poorly constrained oxygen mass. Zinc is 2.62% of PM459, so this decision is based on chemical-form uncertainty rather than an assumption that all omitted metals are below 1% of PM mass.

5. Mass closure and assignment to Others (SAROAD 12999):
   After measured species, NCOM, filled species, and calculated MBO were included, the remaining mass required to close the profile to 100% was assigned to unknown:

   $$\text{Unknown} = 100\% - \sum(\text{measured species} + \text{NCOM} + \text{filled species} + \text{MBO})$$

   If the calculated unknown mass was greater than or equal to zero, it was combined with calculated metal-bound oxygen in the Others category:

   $$\text{Others} = \text{Unknown} + \text{MBO}$$

   If the calculated unknown mass was less than zero, the secondary and tertiary filled species were proportionally scaled down so that the unknown mass equaled zero and total PM mass closure was maintained. For PM458 and PM459, the reconstructed mass did not exceed 100%, so the remaining mass was incorporated into Others, and no scaling was required.
6. Because no source-specific Total Particulate Matter (TPM), PM10, and PM2.5 chemical speciation profiles were available for structural fires or whole vehicle fires, the final PM458 and PM459 chemical compositions were applied uniformly across all three PM size fractions. This is a major uncertainty. EC and combustion-derived organic material are often enriched in fine particles, while mineral ash and some metal components may be more important in larger particles. The adopted size fractions therefore control only the particle-size mass allocation and do not provide size-resolved chemistry. This assumption may affect speciated toxic-emission estimates and exposure modeling if carbonaceous material, metals, or ash are distributed differently among particle sizes. It should be revisited when source-specific size-resolved chemical data become available.

Size Fractionation

Source-specific PM size-fraction measurements were not available for structural fires or whole vehicle fires. Therefore, size fractions for the updated profiles were adopted from the closest existing PM profiles used for these source categories. For PM458, the PM2.5/TPM and PM10/TPM fractions were adopted from PM137, Unplanned structural fires. For PM459, no prior vehicle-fire PM profile was available; therefore, the size fractions were adopted from PM1302, Uncontrolled open tire fire, which was previously used as the proxy profile for vehicle-fire PM. The adopted size fractions are summarized below in Table 1.

Table 1. Adopted PM size fractions for updated structural-fire and vehicle-fire PM profiles

New profile	Size-fraction adopted from	PM2.5/TPM	PM10/TPM
PM458	PM137 – Unplanned structural fires	0.914	0.98
PM459	PM1302 – Uncontrolled open tire fire	0.9316	0.9825

Results and Discussion

Table 2. Description of new profiles introduced in this document.

Profile ID	Profile Name	Data Source Description
PM458	Structural fires	Developed primarily from the Holder et al. (2023)[2] house/structure category for PM-associated organic carbon (OC), elemental carbon (EC), chlorine, bromine, lead, and antimony. U.S. Environmental Protection Agency (U.S. EPA) SPECIATE profile 4003 was used for selected ions, and PM137 was used only for selected mineral and ash-related species.
PM459	Vehicle fires	Developed primarily from Kim et al. (2025)[3] full-scale electric vehicle (EV) and internal-combustion-engine vehicle (ICEV) fire data. EV and ICEV

		averages were combined using California vehicle-registration fractions. Holder et al. (2023) was used only for cadmium, chromium, and vanadium secondary fill.

Chemical Composition

PM458 is characterized by a moderate reconstructed carbonaceous fraction and a relatively large residual unresolved fraction. PM458 contains 19.54% elemental carbon (EC), 4.48% organic carbon (OC), and 2.33% non-carbon organic matter (NCOM), for a total reconstructed carbonaceous mass of 26.35%. Ions and halogen species account for 10.02% of the profile, driven primarily by chlorine. Elements and metals account for 18.16%, reflecting retained mineral and ash-related species from PM137 and selected trace species from the source data. The Others category accounts for 45.48% of PM458 and includes 12.67% calculated metal-bound oxygen plus 32.81% unresolved closure mass. Possible contributors to the unresolved closure include oxygenated organic material not captured by the base OM/OC assumption, semi-volatile particle-phase material, unmeasured inorganic and phosphorus-containing material, additional metal-bound oxygen, particle-bound water, and measurement and cross-source reconstruction uncertainty. The PM458 EC/OC ratio is approximately 4.4. Although this is high relative to wood combustion and many biomass-burning profiles, it is consistent with EC-rich particles reported for flaming combustion of structural and furnishing materials (e.g., Reisen et al., 2014)[10]. The high EC/OC ratio suggests that PM458 may be more representative of soot-rich, flaming-dominated conditions than of smoldering-rich conditions. Because the Holder et al. structure category combines heterogeneous tests and does not provide a flaming-versus-smoldering weighting, the extent to which smoldering emissions are represented cannot be quantified and smoldering-rich emissions may be underrepresented.

The California vehicle-registration-weighted profile contains 50.48% EC, 15.21% OC, and 6.08% NCOM, for a total reconstructed carbonaceous mass of 71.77%. Ions and halogen species account for 5.62% of the profile and include chloride, nitrate, bromide, sulfate, fluoride, and phosphate. Elements and metals account for 6.98%, with zinc, calcium, nickel, sodium, magnesium, cobalt, silicon, manganese, and aluminum contributing the largest fractions. Cadmium, chromium, and vanadium were added from the Holder et al. vehicle category as secondary-fill species because they were not retained from the Kim et al. dataset. The Others category accounts for 15.64% of PM459 and includes 1.02% calculated metal-bound oxygen plus 14.61% unresolved closure mass. The lower unresolved closure mass in PM459 reflects the broader set of OC, EC, ions, and inorganic elements measured directly by Kim et al. compared with the more limited structural-fire PM dataset used for PM458.

Table 3. Comparison of key chemical components across previous and updated structural-fire PM profiles (PM137 vs. PM458) and between tire-burning and updated vehicle-fire PM profiles (PM1302 vs. PM459)

Component or group	PM137 structural fire old (%)	PM458 structural fire new (%)	PM1302 tire-burning (%)	PM459 vehicle fire (%)
Organic carbon (OC)	Only total carbon reported	4.48	23.15	15.21
Non-carbon organic matter (NCOM)	Only total carbon reported	2.33	9.26	6.08
Elemental carbon (EC)	Only total carbon reported	19.54	6.38	50.48
Total carbon	30	24.02	29.53	65.69
Total ions and halogen species	2	10.02	19.95	5.62
Total elements and metals	18	18.16	28.73	6.98
Others	50	45.48	12.53	15.64
Total	**100**	**100**	**100**	**100**

Comparison with previous profiles

The updated PM458 profile changes the chemical representation of structural-fire PM relative to PM137. The old PM137 profile assigned 30% of PM mass to a single carbon field without separating OC, EC, and NCOM. PM458 replaces this simplified representation with explicit EC, OC, and NCOM fractions and tracks calculated metal-bound oxygen and unresolved closure mass separately during profile development, although both are combined in the final Others category (SAROAD 12999). The total reconstructed carbonaceous fraction decreases slightly from 30.00% in PM137 to 26.35% in PM458, but the updated profile provides a more detailed carbon split. Chlorine increases from 2.00% in PM137 to 9.06% in PM458. Calcium, iron, silicon, and potassium remain unchanged in this preliminary reconstruction because PM137 was used as the tertiary fill source for these mineral/ash-related species. This tertiary fill was retained only for mineral and ash-related species that were not available in the primary structural-fire dataset. To make the contribution of each data source transparent, the profile source contribution was summarized by primary measured species, secondary fill, tertiary fill, calculated metal-bound oxygen, and unresolved closure mass included in Others. PM458 profile mass comprises 33.12% Holder et al. (2023) primary measured species, 2.33% NCOM calculated from Holder OC, 1.07% secondary fill from EPA SPECIATE 4003, and 18.00% tertiary mineral and ash-related species from PM137. The 45.48% Others category comprises 12.67% calculated metal-bound oxygen and 32.81% unresolved closure mass.

PM459 does not have a direct legacy CARB vehicle-fire PM profile for one-to-one replacement. PM1302 is therefore best treated only as a related comparison profile for uncontrolled open tire combustion, not as a predecessor to PM459. Compared with PM1302, the updated PM459 profile is much more EC-rich and has a smaller contribution from sulfate, nitrate, ammonium, and mineral/ash-related species. This reflects the change from an open tire-combustion comparison profile to direct full-scale vehicle-fire PM composition. PM459 also includes vehicle-fire metals and battery- or vehicle-associated elements, including nickel, cobalt, manganese, lithium, antimony, cadmium, chromium, and vanadium. Zinc remains lower in PM459 than in PM1302 because PM1302 represents open tire combustion, which has a high tire-associated zinc fraction. Kim et al. found that EV fire smoke PM contained higher inorganic-element fractions than ICEV fire smoke PM, with Ni, Mn, Co, and Li as important EV-associated elements, while ICEV fire smoke was more strongly associated with Zn.

Table 4. A summary of chemical composition of the profiles in this study compared to previous profiles.

Component / group	PM137 – old structural profile	PM458 structural fire	PM1302 open tire burning	PM459 vehicle fire
EC (%)	Not separated	19.54	6.39	50.48
OC (%)	Not separated	4.48	23.15	15.21
NCOM (%)	Not separated	2.33	9.26	6.08
Total reconstructed carbonaceous mass (%)	30.00	26.35	38.79	71.77
Chlorine / chloride (%)	2.00 as chlorine	9.06 as chlorine		3.68 as chloride
Bromine / bromide (%)		0.014 bromine		0.43 as bromide
Sulfate (%)	0	0.52	10.38	0.25
Nitrate (%)		0.16	3.19	0.91
Ammonium (%)		0.08	6.39	
Major mineral/ash elements: Al + Si + Ca + Fe + K + Ti (%)	18	18.01	20.52	1.85
Zinc (%)		0.12	6.3	2.62
Others (%)	50.00	45.48	12.53	15.64

Comparison between structural-fire and vehicle-fire PM

The main compositional difference between PM458 and PM459 is the carbonaceous fraction. PM459 is dominated by reconstructed carbonaceous material, especially EC, whereas PM458 has a lower total carbonaceous fraction and a larger Others fraction used for closure. PM459 is dominated by EC and has a total reconstructed carbonaceous mass of 71.77%, while PM458 has a lower carbonaceous fraction of 26.35%, compared with the 30% undifferentiated carbon field in PM137. PM458 contains a larger contribution from structural mineral and ash-related fill species, particularly silicon and potassium. PM459 contains a broader set of vehicle-associated metals and ions, including species associated with vehicle components, fluids, rubber, metals, and electric vehicle batteries.

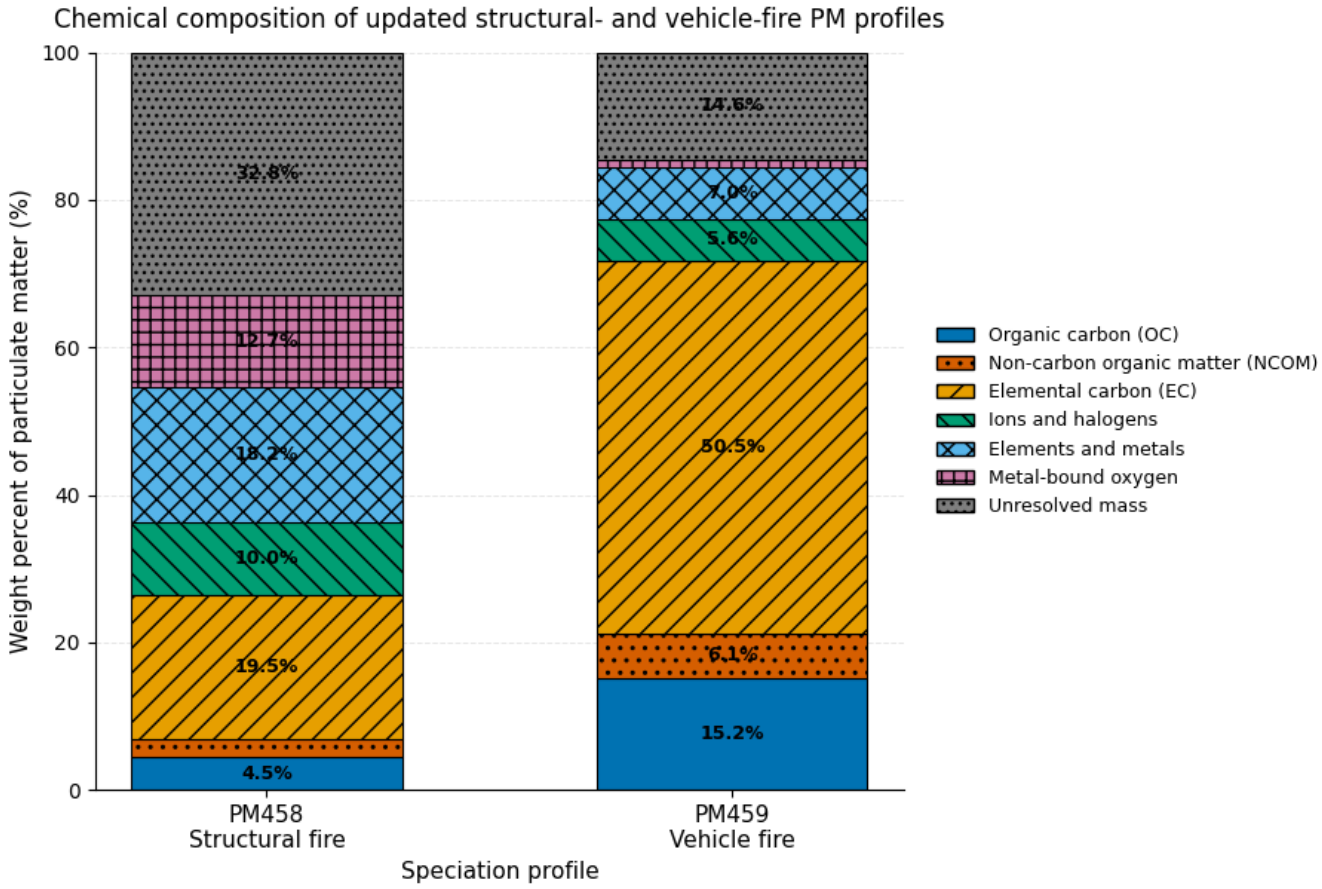


Figure 1. A stacked column chart comparing the new vehicle fire profile with new structural fire profile

Implications for Emission Inventory and Modeling

Emission of modeling relevant species

The CEPAM2019 PM2.5 inventory estimates 2023 emissions of 0.813 tons/day for structural fires and 0.262 tons/day for automobile fires. In this report, “tons” means U.S. short tons. The updated profiles increase the explicitly resolved carbonaceous PM fraction. Elemental

carbon increases from 0.2606 to 0.2911 tons/day, and organic carbon increases from 0.0606 to 0.0763 tons/day. Non-carbon organic matter also increases, from 0.0243 to 0.0349 tons/day, because both updated profiles explicitly reconstruct NCOM from OC.

The inorganic ion changes are species-specific. Sulfate, nitrate, and ammonium decrease substantially because PM1302, the open tire-fire comparison profile, contains relatively high sulfate, nitrate, and ammonium fractions. In contrast, PM459 contains lower directly measured sulfate and nitrate, and ammonium is not included in the current PM459 reconstruction. Chlorine/chloride increases from 0.0163 to 0.0833 tons/day because PM458 includes much higher chlorine than PM137, 9.06% versus 2.00%, and PM459 adds chloride that was not present in the PM1302 tire-fire proxy. Sodium also increases mainly because PM137 did not include sodium, whereas PM458 adds sodium ion from secondary fill data.

The change in the Others fraction differs between the profile pairs: it decreases from 50.00% in PM137 to 45.48% in PM458, and increases from 12.53% in PM1302 to 15.64% in PM459. In the updated profiles, SAROAD 12999 ("others") includes calculated metal-bound oxygen and unresolved closure mass. For PM458, these components are 12.67% and 32.81%, respectively; for PM459, they are 1.02% and 14.61%. The components are tracked separately during profile development but combined in the final profile. Unresolved closure mass is not a separate profile species.

Table 5. Change in annual emissions of modeling relevant species

Species	Using old profiles (tons/year)	Using new profiles (tons/year)	Change (tons/year)	Percent change (%)
Aluminum	2.06	0.252	-1.81	-88
Arsenic	0.00114	0.000574	-0.000571	-50
Calcium	16.0	4.09	-11.9	-74
Cadmium	0.000458	0.000861	0.000403	88
Chlorine/chloride	4.75	30.4	25.7	540
Elemental carbon (EC)	95.1	106	11.1	12
Iron	9.42	6.02	-3.40	-36

Species	Using old profiles (tons/year)	Using new profiles (tons/year)	Change (tons/year)	Percent change (%)
Potassium	15.9	14.9	-0.941	-6
Magnesium	0.783	0.259	-0.524	-67
Manganese	0.0319	0.233	0.201	631
Others	157	150	-6.96	-4
Sodium/sodium ion	0.340	0.849	0.509	150
Non-carbon organic matter (NCOM)	8.85	12.7	3.88	44
Ammonium	6.11	0.230	-5.88	-96
Nickel	0.00488	0.819	0.814	16672
Nitrate	3.05	1.33	-1.72	-56
Organic carbon (OC)	22.1	27.8	5.70	26
Lead	0.0141	0.126	0.112	792
Silicon	34.2	29.9	-4.29	-13
Sulfate	10.1	1.80	-8.27	-82
Titanium	0.183	0.0167	-0.166	-91

Toxics inventory

For structural fires, PM458 adds lead, antimony, manganese, selenium, and zinc at low mass fractions that were not explicitly represented in PM137. These additions come from the Holder et al. structural-fire dataset and the secondary-fill species used to complete the profile. As a result, the updated structural-fire profile provides a more explicit representation of PM-associated toxic metals than the previous PM137 profile, which was limited mainly to bulk carbon, chlorine, calcium, iron, silicon, potassium, sulfate, and "other."

For vehicle fires, PM459 changes the metal distribution substantially relative to the PM1302 tire-fire proxy. These changes are large enough to affect toxic-emission estimates and should be interpreted primarily as a data-source change from open tire burning to whole-vehicle fire measurements. Using the current 2023 automobile-fire PM2.5 total of 0.262 tons/day, nickel increases from approximately 12 g/day with PM1302 to 2,036 g/day with PM459. The increase is caused mainly by replacing the tire-fire comparison profile with a whole-vehicle fire profile containing vehicle- and battery-associated metals. The 4.1% EV weighting increases nickel further, but it is not the sole cause: the all-ICEV sensitivity profile already contains about 0.50% nickel, compared with 0.86% in the 4.1% EV base profile. Kim et al. reported that EV fire PM was enriched in Ni, Mn, Co, and Li, while ICEV fire PM was more strongly associated with Zn. Because PM459 is based on six EV fires and only two ICEV fires, the statewide nickel estimate should be treated as provisional. Additional full-scale vehicle-fire measurements and fire-occurrence-weighted data would improve confidence in future updates.

Table 6. Change in toxic emission estimation using old and new profiles

SAROAD	Species	Using previous profiles (g/day)	Using new profiles (g/day)	Change (g/day)
12102	Antimony	7.0	256.2	249.2
12103	Arsenic	2.8	1.4	-1.4
12110	Cadmium	1.1	2.1	1.0
12112	Chromium	12.3	19.5	7.2
12113	Cobalt	257.0	608.9	351.9

12114	Copper	119.7	212.7	93.0
12128	Lead	35.1	313.0	277.9
12132	Manganese	79.3	579.9	500.6
12142	Mercury	0.0	0.0	0.0
12136	Nickel	12.1	2036.2	2024.1
12154	Selenium	0.4	8.1	7.7
12164	Vanadium	7.2	2.1	-5.1
12167	Zinc	14963.8	7088.9	-7875.0

Sensitivity Analysis

Sensitivity of OM/OC assumptions

Because NCOM is calculated from OC, the selected OM/OC ratio affects NCOM and the unresolved closure mass included in Others. It does not change measured EC, OC, ions, or metals. For PM458, using OM/OC values from 1.4 to 2.0 changed NCOM from 1.79% to 4.48% and changed the unresolved closure component from 33.35% to 30.66%. For PM459, using OM/OC values from 1.4 to 2.0 changed NCOM from 6.08% to 15.21% and changed the unresolved closure component from 14.61% to 5.49%. The base profiles retain OM/OC = 1.52 for PM458 and OM/OC = 1.4 for PM459.

Profile	OM/OC	NCOM (%)	Others (%)	Profile	OM/OC	NCOM (%)	Others (%)
PM458	1.40	1.79	33.35	PM459	1.40 base	6.08	14.61
PM458	1.52 base	2.33	32.81	PM459	1.60	9.13	11.57
PM458	1.80	3.58	31.56	PM459	1.80	12.17	8.53

Profile	OM/OC	NCOM (%)	Others (%)	Profile	OM/OC	NCOM (%)	Others (%)
PM458	2.00	4.48	30.66	PM459	2.00	15.21	5.49

Sensitivity of EV and ICEV weighting

The base PM459 profile uses 4.1% EV and 95.9% ICEV based on California vehicle registrations. Because registration fractions may not match vehicle-fire occurrence fractions, additional sensitivity calculations were prepared. EC remains high in the all-ICEV case at 51.45%, compared with 50.48% in the 4.1% EV base case, indicating that the high EC fraction is not driven only by EV battery involvement. Increasing the EV fraction mainly increases Ni, Co, Mn, Li, and fluoride, while the ICEV-dominated case has higher Zn.

Scenario	EC (%)	OC (%)	Ni (%)	Co (%)	Mn (%)	Li (%)	Zn (%)	Fluoride (%)
0% EV, all ICEV	51.45	14.90	0.50	0.15	0.13	0.02	2.66	0.14
4.1% EV, base	50.48	15.21	0.86	0.26	0.24	0.09	2.62	0.18
10% EV sensitivity	49.07	15.66	1.37	0.42	0.40	0.18	2.55	0.24

Uncertainty and limitations

The updated PM458 and PM459 profiles provide improved representation of primary particulate matter composition from structural and vehicle fires; however, several uncertainties remain. Structural-fire PM composition can vary with building materials, building age, furnishings, insulation, roofing, electronics, flame-retarded materials, PVC-containing products, and battery involvement. Vehicle-fire PM composition can vary with vehicle age, fuel type, tire and plastic involvement, fluids, metal components, and the extent of electric-vehicle battery participation.

For PM458, uncertainty is introduced by the need to combine speciation data from primary structural-fire profile data with secondary and tertiary profile for missing ions, minerals, and metal components. For PM459, uncertainty is associated with the limited number of full-scale vehicle-fire measurements and the use of California vehicle-registration weighting to combine electric-vehicle and internal-combustion-engine vehicle compositions. The Kim et al. test-level data show substantial variability. Across the six EV tests, EC averaged 27.70%

with a standard deviation (SD) of 11.40% and coefficient of variation (CV) of 41% (range 9.23-42.73%); OC averaged 22.55% with SD 9.70% and CV 43% (range 15.27-39.66%); and nickel averaged 9.13% with SD 4.64% and CV 51% (range 3.85-14.25%). Across the two ICEV tests, EC averaged 51.45% with SD 6.33% and CV 12% (range 46.97-55.93%), OC averaged 14.90% with SD 0.13% and CV 0.9% (range 14.80-14.99%), and nickel averaged 0.503% with SD 0.689% and CV 137% (range 0.016-0.990%). Because only two ICEV tests are available, their SD and CV describe variability between the tested vehicles and should not be interpreted as a robust population uncertainty estimate. These limitations introduce representativeness uncertainty.

Because source-specific TPM, PM10, and PM2.5 chemical speciation data were not available for structural fires or whole vehicle fires, the final PM458 and PM459 chemical compositions were applied uniformly across all three PM size fractions. This introduces uncertainty because carbonaceous material, metals, and ash may not have the same size distribution. The assumption should be revisited if future studies provide size-resolved chemical composition data for these source types. However, it is important to note that for CMAQ modeling purposes only PM2.5 speciation and size fractionation matter most.

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Appendix

Table A1. Mapping of EICs to the newly added profiles

EIC/SCC	Category	Sub-Category 1	Sub-Category 2	Sub-Category 3	New PM Profile ID
66065602000000	FIRES	STRUCTURAL FIRES	Solid Fuel (Unspecified)	SUB-CATEGORY UNSPECIFIED	PM458
66065802000000	FIRES	VEHICLE FIRES	Solid Fuel (Unspecified)	SUB-CATEGORY UNSPECIFIED	PM459
93065702000000	WILDFIRES	WILDFIRE CAUSED STRUCTURAL FIRES	Solid Fuel (Unspecified)	SUB-CATEGORY UNSPECIFIED	PM458
93065902000000	WILDFIRES	WILDFIRE CAUSED VEHICLE FIRES	Solid Fuel (Unspecified)	SUB-CATEGORY UNSPECIFIED	PM459

Table A2. PM composition of newly added structural fire profile – PM458

SAROAD	Species	Chemical formula	Reference	TPM weight percentage (%)	PM10 weight percentage (%)	PM2.5 weight percentage (%)
11102	organic carbon	OC	Holder et al. (2023)	4.4784	4.4784	4.4784

SAROAD	Species	Chemical formula	Reference	TPM weight percentage (%)	PM10 weight percentage (%)	PM2.5 weight percentage (%)
11103	non-carbon organic matter	NCOM	Calculated from OC	2.3288	2.3288	2.3288
12116	elemental carbon	EC	Holder et al. (2023)	19.5420	19.5420	19.5420
12115	chlorine	Cl	Holder et al. (2023)	9.0585	9.0585	9.0585
12109	bromine	Br	Holder et al. (2023)	0.0135	0.0135	0.0135
12181	sodium ion	Na+	EPA SPECIATE profile 4003	0.1856	0.1856	0.1856
12301	ammonium	NH4+	EPA SPECIATE profile 4003	0.0776	0.0776	0.0776
12306	nitrates	NO3-	EPA SPECIATE profile 4003	0.1556	0.1556	0.1556
12403	sulfate	SO4	EPA SPECIATE profile 4003	0.5243	0.5243	0.5243
12101	aluminum	Al	EPA SPECIATE profile 4003	0.0074	0.0074	0.0074

SAROAD	Species	Chemical formula	Reference	TPM weight percentage (%)	PM10 weight percentage (%)	PM2.5 weight percentage (%)
12102	antimony	Sb	Holder et al. (2023)	0.0010	0.0010	0.0010
12111	calcium	Ca	PM137	1.0000	1.0000	1.0000
12126	iron	Fe	PM137	2.0000	2.0000	2.0000
12128	lead	Pb	Holder et al. (2023)	0.0280	0.0280	0.0280
12132	manganese	Mn	EPA SPECIATE profile 4003	0.0008	0.0008	0.0008
12154	selenium	Se	EPA SPECIATE profile 4003	0.0011	0.0011	0.0011
12165	silicon	Si	PM137	10.0000	10.0000	10.0000
12167	zinc	Zn	EPA SPECIATE profile 4003	0.1184	0.1184	0.1184
12180	potassium	K	PM137	5.0000	5.0000	5.0000
12999	others		Calculated	45.4790	45.4790	45.4790

Table A3. PM composition of newly added vehicle fire profile – PM459

SAROAD	Species	Chemical formula	Reference	TPM weight percentage (%)	PM10 weight percentage (%)	PM2.5 weight percentage (%)
11102	organic carbon	OC	Kim et al. (2025)	15.2098	15.2098	15.2098
11103	non-carbon organic matter	NCOM	Calculated from OC	6.0839	6.0839	6.0839
12116	elemental carbon	EC	Kim et al. (2025)	50.4754	50.4754	50.4754
42222	fluorine	F	Kim et al. (2025)	0.1833	0.1833	0.1833
12203	chloride	Cl^-	Kim et al. (2025)	3.6808	3.6808	3.6808
12109	bromine	Br	Kim et al. (2025)	0.431	0.431	0.431
12306	nitrates	NO_3^-	Kim et al. (2025)	0.9109	0.9109	0.9109
12403	sulfate	SO_4^{2-}	Kim et al. (2025)	0.2523	0.2523	0.2523
12153	phosphate	PO_4^{3-}	Kim et al. (2025)	0.1583	0.1583	0.1583
12101	aluminum	Al	Kim et al. (2025)	0.2408	0.2408	0.2408

SAROAD	Species	Chemical formula	Reference	TPM weight percentage (%)	PM10 weight percentage (%)	PM2.5 weight percentage (%)
12102	antimony	Sb	Kim et al. (2025)	0.1047	0.1047	0.1047
12103	arsenic	As	Kim et al. (2025)	0.0006	0.0006	0.0006
12106	bismuth	Bi	Kim et al. (2025)	0.0623	0.0623	0.0623
12107	barium	Ba	Kim et al. (2025)	0.1385	0.1385	0.1385
12110	cadmium	Cd	Holder et al. (2023)	0.0009	0.0009	0.0009
12111	calcium	Ca	Kim et al. (2025)	1.1723	1.1723	1.1723
12112	chromium	Cr	Holder et al. (2023)	0.0082	0.0082	0.0082
12113	cobalt	Co	Kim et al. (2025)	0.2562	0.2562	0.2562
12114	copper	Cu	Kim et al. (2025)	0.0895	0.0895	0.0895
12119	tungsten	W	Kim et al. (2025)	0.0038	0.0038	0.0038
12126	iron	Fe	Kim et al. (2025)	0.0913	0.0913	0.0913
12128	lead	Pb	Kim et al. (2025)	0.0448	0.0448	0.0448

SAROAD	Species	Chemical formula	Reference	TPM weight percentage (%)	PM10 weight percentage (%)	PM2.5 weight percentage (%)
12132	manganese	Mn	Kim et al. (2025)	0.2415	0.2415	0.2415
12136	nickel	Ni	Kim et al. (2025)	0.8567	0.8567	0.8567
12138	lithium	Li	Kim et al. (2025)	0.0867	0.0867	0.0867
12140	magnesium	Mg	Kim et al. (2025)	0.2706	0.2706	0.2706
12160	tin	Sn	Kim et al. (2025)	0.0278	0.0278	0.0278
12161	titanium	Ti	Kim et al. (2025)	0.0175	0.0175	0.0175
12164	vanadium	V	Holder et al. (2023)	0.0009	0.0009	0.0009
12165	silicon	Si	Kim et al. (2025)	0.2523	0.2523	0.2523
12167	zinc	Zn	Kim et al. (2025)	2.6151	2.6151	2.6151
12168	strontium	Sr	Kim et al. (2025)	0.0067	0.0067	0.0067
12180	potassium	K	Kim et al. (2025)	0.0763	0.0763	0.0763
12184	sodium	Na	Kim et al. (2025)	0.3118	0.3118	0.3118

SAROAD	Species	Chemical formula	Reference	TPM weight percentage (%)	PM10 weight percentage (%)	PM2.5 weight percentage (%)
12999	others		Calculated	15.6365	15.6365	15.6365