PM Speciation Profiles for Residential Fuel Combustion—Natural Gas (PM122)

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1 Introduction

The residential natural gas combustion emissions category is one of the top 20 total PM (TPM) emission sources based on current estimates of the 2007 emission inventory. The current CARB PM speciation profile for residential fuel combustion—natural gas is PM121. This profile, which is based on an industrial boiler source test that was conducted in 1979 [1, 2], shows that PM emitted from residential natural gas combustion consists of 50% elemental carbon (EC) and 20% sulfate, and the species of the other 30% of the PM are not identified. This composition is too simplified to meet current air quality modeling needs and has questionably-high EC content for natural gas combustion particles. Therefore, the current profile (PM121) needs to be updated using more accurate source testing data.

A source test on natural gas home appliances was performed in 1991 and the test data can be used to create PM speciation profiles that are more appropriate for use in air quality modeling [3]. In this test, a natural gas fired space heater and a water heater were utilized to produce emissions from natural gas combustion at a single-family home. A dilution source sampling system was used to collect primary fine PM emitted from the two devices.

2 Methodology

The chemical characteristics measured in the source test are tabulated in Hildemann et al's paper [3]. The results are averages of three replicate experiments. However, the non-carbon organic matter (NCOM) and the oxygen associated with geological elements are not counted in the reported dataset.

The following steps are used to develop the new residential natural gas combustion profile:

1. OC (organic carbon) was reported, thus, the corresponding OM (organic matter) can be estimated by multiplying the OM/OC conversion factor and the NCOM is calculated by subtracting OC from OM. The conversion factor of OM/OC is 1.11 for this profile and it is obtained based on the information of the identified organic aerosol species [4].
2. A species group named 'others' is created to capture the mass 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 percentages of these five elements, respectively[5].

3. The sulfur content is much less than the sulfate content, so the sulfur is neglected in the new profile to avoid a double-counting issue.
4. The weight percentages of all the species are added up as the total percentage of the $PM_{2.5}$ mass; and then this total percentage is used as the denominator in calculating the normalized speciation profile.

3 Results and Discussion

The updated $PM_{2.5}$ speciation profile for residential combustion–natural gas is listed in Table 1. Compared to the profile currently in-use (PM121) with 50% EC and 20% sulfate, the new profile has much lower EC (5.3%) and sulfate (9.9%). The dominant species in the new profile is OC, which is 67.0% of the $PM_{2.5}$ mass.

Table 1. $PM_{2.5}$ speciation profile for residential combustion—natural gas

Species Name	SAROAD	Weight Percentage (%)
Aluminum	12101	0.1737
Ammonium	12301	0.3474
Bromine	12109	0.0316
Calcium	12111	0.8211
Chlorine	12115	3.0632
Chromium	12112	0.0395
Elemental Carbon	12116	5.2896
Iron	12126	0.0711
Manganese	12132	0.0158
NCOM	11103	7.3730
Nickel	12136	0.0711
Nitrate	12306	2.6922
Organic Carbon	11102	67.0274
Other	12999	0.8185
Phosphorous	12152	0.0237
Potassium	12180	0.1342
Rubidium	12176	0.0158
Selenium	12154	0.0482
Silicon	12165	0.2211
Sodium	12184	1.6816
Sulfate	12403	9.9475
Titanium	12161	0.0790
Vanadium	12164	0.0142
Total		*100.0000*

Two assumptions related to these profiles are proposed in this work:

- In PM121, the current residential natural gas combustion profile, the ratios of PM_{10}/TPM and $PM_{2.5}$/TPM are both 1.0, which indicates that all of the particles generated from natural gas combustion are fine particles. Since no particle size distribution was measured in the Hidlemann et al test, the same PM_{10}/TPM and $PM_{2.5}$/TPM ratios from PM121 will be used for the new profiles (i.e., in the updated profile it is assumed that PM_{10}/TPM = 1.0 and $PM_{2.5}$/TPM = 1.0).
- The source test and the associated chemical profile discussed above are based on source testing for fine PM exhaust. For the total PM profile update, a homogeneous chemical composition for all PM is assumed. That is, the chemical compositions of PM_{10} and TPM are assumed to be the same as that of fine PM (Table 1).

4 Estimated Impacts of the Profile Update on the Emission Inventory

The newly-developed profile, PM122, will replace the current profile, PM121, for the fuel combustion categories associated with residential natural gas combustion. The SCCs/EICs associated with such categories are summarized in Table 2.

Table 2. SCCs/EICs associated with residential fuel combustion—natural gas

SCC/EIC	Names		
47191	Fuel combustion	Residential	Natural gas unspecified
47217	Fuel combustion	Residential	L.P.G
54569	Fuel combustion	Residential	Natural gas space heater
54577	Fuel combustion	Residential	Natural gas water heater
54585	Fuel combustion	Residential	Natural gas cooking
61060601100000	Fuel combustion	Residential	Natural gas space heater
61060801100000	Fuel combustion	Residential	Natural gas water heater
61061001100000	Fuel combustion	Residential	Natural gas cooking
61099501100000	Fuel combustion	Residential	Natural gas unspecified
61099501200000	Fuel combustion	Residential	L.P.G

Air quality modeling for PM currently involves five PM model species: OC, EC, sulfate, nitrate, and 'other'. Using Profile PM122 to replace PM121, the changes in PM modeling species for year 2007 South Coast emissions are estimated in Table 3. Given the 2007 district-wide annual average residential natural gas combustion emissions of 2.39 tons/day [6], the OC increases from 0 to 1.60 tons/day, but EC decreases from 1.20 to 0.13 tons/day which is 89.4% less compared to the emission calculated using the current profile. Emissions of sulfate and all other lumped species decrease 50% when the new profile is used.

Table 3. Changes on emissions of $PM_{2.5}$ species for residential combustion—natural gas categories (2007)

SC Annual Ave. Emissions	Current PM121 (tons/day)	New PM122 (tons/day)	Change	
			Emissions (tons/day)	Percentage
OC	0	1.60	+1.60	N/A
EC	1.20	0.13	-1.07	-89.4%
Sulfate	0.48	0.24	-0.24	-50.3%
Nitrate	0	0.06	+0.06	N/A
Other species	0.72	0.36	-0.36	-49.9%

5 Version Control

This section will be completed after management approval and after the CEIDARS FRACTION table and PMPROFILE table are updated. Version information from CEIDARS FRACTION table will be copied here.

References:

1. Taback, H. J.; Brienza, A. R.; Macko, J. F.; Brunetz, N. *Fine Particle Emissions from Stationary and Miscellanceous Sources in the South Coast Air Basin*; CARB A6-191-30; California Air Resources Board: Sacramento, 1979.
2. California Air Resources Board Main Speciation Profiles. In Jan 1, 2012 ed.; California Air Resources Board: 2012.
3. Hildemann, L. M.; Markowski, G. R.; Cass, G. R., Chemical composition of emissions from urban sources of fine organic aerosol. *Environmental Science & Technology* **1991,** *25*, (4), 744-759.
4. Rogge, W. F.; Hildemann, L. M.; Mazurek, M. A.; Cass, G. R.; Simoneit, B. R. T., Sources of fine organic aerosol. 5. Natural-gas home appliances. *Environmental Science & Technology* **1993,** *27*, (13), 2736-2744.
5. Allen, P., Developing PM Species Profiles for Emission Inventory. In 2008.
6. CEPAM. In California Air Resources Board: 2011.