Organic Gas Speciation Profile for Residential Wood Combustion - Fireplace (Pine Wood)

—OG5491

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I. Introduction

The organic gas (OG) speciation profile currently used to represent emissions from residential wood combustion (RWC) is OG549 (Red oak combustion--without catalyst). This profile is composed primarily of methane (51.1%), heptane isomers (18.8%), and other 12 organic compounds [1]. However, recent studies [2-4] have demonstrated that wood combustion emits a complex mixture of volatile and semi-volatile organic compounds (SVOC), many of which are not captured in OG549. To address these limitations and improve the chemical representation of RWC emissions, a new OG speciation profile, OG5491, has been developed in this work. This updated profile is based on a comprehensive emissions study of wood combustion conducted by Schauer et al. [5] and aims to more accurately characterize the diversity and reactivity of organic compounds emitted during residential wood burning.

II. Methodology

Schauer et al. [5] conducted the combustion source testing using oak, pine, and eucalyptus wood in a residential fireplace located in a two-story house in Southern California. Emissions were withdrawn from a port installed in the chimney, and sampled using a dilution system coupled with a residence time chamber to simulate ambient conditions and allow for gas-particle partitioning. Volatile compounds and SVOCs were collected using filter/PUF trains and XAD-coated annular denuder systems.

Chemical analysis was performed using gas chromatography–mass spectrometry (GC-MS) and liquid chromatography-UV detection (LC-UV) to identify and quantify a wide range of organic species, including alkanes, aromatics, aldehydes, phenols, and other oxygenated compounds. Emission rates of the gaseous organic compounds were normalized to their sum, i.e., total organic gases (TOG), to develop the speciation profile.

Although the source tests were conducted for three wood types (oak, pine, and eucalyptus), the full set of measurements was only available for pine wood. Therefore, the speciation profile OG5491 was developed solely from the pine wood data to ensure completeness and consistency.

As part of this work, 27 new organic species not currently listed in CARB's CEIDARS pollutant table were identified. These species, along with their assigned CARB SAROAD codes, are provided in Table 1.

Table 1: New CARB SAROAD codes to be added to CEIDARS pollutant table

CARB SAROAD	CAS	Chemical Name	Formula	Molecular Weight
43568	108-46-3	m-benzenediol	C6H6O2	110.11
43569	120-80-9	o-benzenediol	C6H6O2	110.11
43570	121-33-5	vanillin	C8H8O3	152.15
43571	123-31-9	p-benzenediol	C6H6O2	110.11

CARB SAROAD	CAS	Chemical Name	Formula	Molecular Weight
43573	483-65-8	retene	C18H18	234.34
43574	575-43-9	dimethylnaphthalene	C12H12	156.22
43575	93-51-6	4-methylguaiacol	C8H10O2	138.16
43576	90-05-1	guaiacol	C7H8O2	124.14
43577	4417-81-6	2-oxobutanal	C4H6O2	86.09
43578	2785-89-9	4-ethylguaiacol	C9H12O2	152.19
43579	25376-49-2	hydroxymethylfurfural	C6H6O3	126.11
43580	5932-68-3	trans-isoeugenol	C10H12O2	164.2
43581	2503-46-0	guaiacyl acetone	C10H12O3	180.21
43582	2785-87-7	4-propylguaiacol	C10H14O2	166.21
43584	5912-86-7	cis-isoeugenol	C10H12O2	164.2
43585	498-02-2	acetovanillone	C9H10O3	166.17
43586	494-99-5	3,4-dimethoxytoluene	C9H12O2	152.19
43587	28777-87-9	hydroxybenzaldehyde	C7H6O2	122.12
43588		m- & p-tolualdehyde	C8H8O	120.15
43589	120-14-9	veratraldehyde	C9H10O3	166.17
43590	6638-05-7	4-methylsyringol	C9H12O3	168.18
43591	548-39-0	1H-phenalen-1-one	C13H8O	180.21
43592	19037-58-2	syringyl acetone	C11H14O4	210.23
43593	14059-92-8	4-ethylsyringol	C10H14O3	182.2
43595	506-12-7	n-heptadecanoic acid	C17H34O2	270.45
43596	80934-44-7	methylbenzenediol	C7H8O2	124.14
43597		m- & p-cresol	C7H8O	108.14

III. Results and Discussion

Details of the new profile OG5491 are provided in the Appendix (Table 2). In this updated profile, methane accounts for 21.6% of the TOG, followed by acetaldehyde (8.9%) and formaldehyde (6.1%). OG5491 includes 116 species, representing a significant expansion compared to only 14 species in the current profile OG549.

The methane fraction in OG5491 is less than half of that in OG549 (21.6% vs. 51.1%), resulting in a substantially higher ROG/TOG ratio. Specifically, the ROG/TOG ratio for OG5491 is 0.7219, compared to 0.4543 for OG549.

With the reduced methane contribution, OG5491 introduces numerous highly reactive carbonyls and aromatic compounds that are absent from OG549. For example, acetaldehyde and formaldehyde together contribute over 15% of TOG in OG5491, nearly twice their combined share in OG549. The inclusion of the reactive species enhances the profile's ability to represent ozone formation potential. The profile-weighted Maximum Incremental Reactivity (MIR) is 4.38 g O3/g TOG, more than double that of OG549 (1.86 g O3/g TOG).

In addition, OG549 includes many toxic air contaminants that were not captured in OG549. This includes acrolein (0.33% of TOG), benzene (2.01%), and various others. The inclusion of these species supports more robust health risk assessments.

While OG5491 represents a significant improvement, it is based solely on pine wood combustion as mentioned in the methodology section. Emission compositions may vary with other wood types, moisture content, and combustion conditions. Furthermore, the data reflect emissions from a fireplace, which may differ from those of wood stoves or pellet stoves. Future work may involve developing additional profiles for other wood types and combustion technologies.

Currently, CARB has established 12 Emission Inventory Codes (EICs) for residential wood combustion categories. In the absence of specific profiles for woodstove and pellet stove, OG5491 will be applied across all RWC categories (610-60X-0230-XXXX) as shown in Appendix Table 3.

References:

1. *California Air Resources Board Main Speciation Profiles*. 2025, California Air Resources Board.
2. Traviss, N., G. Allen, and M. Ahmadi, *Criteria, Greenhouse Gas, and Hazardous Air Pollutant Emissions Factors from Residential Cordwood and Pellet Stoves Using an Integrated Duty Cycle Test Protocol.* ACS ES&T Air, 2024. **1**(9): p. 1190-1202.
3. Ahmadi, M., et al., *Effect of operating conditions and technology on residential wood stove emissions of criteria, greenhouse gas, and hazardous air pollutants.* Journal of the Air & Waste Management Association, 2025. **75**(6): p. 483-502.
4. Bhattu, D., et al., *Effect of Stove Technology and Combustion Conditions on Gas and Particulate Emissions from Residential Biomass Combustion.* Environmental Science & Technology, 2019. **53**(4): p. 2209-2219.
5. Schauer, J.J., et al., *Measurement of Emissions from Air Pollution Sources. 3. C1−C29 Organic Compounds from Fireplace Combustion of Wood.* Environmental Science & Technology, 2001. **35**(9): p. 1716-1728.

IV. Appendix

Table 2: Profile OG5491: Residential Wood Combustion – Fireplace (Pine Wood)

Species Name	CARB-SAROAD	Weight Percentage (%)
1,3-butadiene	43218	0.614321
1-butene	43213	0.476230
1H-phenalen-1-one	43591	0.001496
1-methylnaphthalene	91124	0.055656
1-methylphenanthrene	97010	0.011656
1-pentene	43224	0.045155
2,3-butanedione	47033	0.467304
2,5-dimethylbenzaldehyde	47029	0.063007
2-butanone	43552	1.128880
2-methyl-1-butene	43225	0.072458
2-methyl-2-butene	43228	0.070358
2-methyl-2-pentene	98004	0.036229
2-methyl-2-propenal	43506	0.120764
2-methylanthracene	97008	0.005566
2-methylhexane	43275	0.013652
2-methylnaphthalene	91123	0.078759
2-methylpentane	43229	0.045155
2-methylphenanthrene	91297	0.009766
2-oxobutanal	43577	1.265396
3,4-dimethoxytoluene	43586	0.066683
3-methyl-1-butene	43223	0.036229
3-methylphenanthrene	97006	0.006353
4-ethylguaiacol	43578	1.065873
4-ethylsyringol	43593	0.001187
4-methylguaiacol	43575	1.779956
4-methylsyringol	43590	0.001580
4-propylguaiacol	43582	0.365442
5-methylfurfural	43363	0.052506
9-methylphenanthrene	97009	0.007876
acenaphthene	97002	0.010606
acenaphthylene	97001	0.097661
acephenanthrylene	97014	0.005046
acetaldehyde	43503	8.947034
acetone	43551	3.932704
acetophenone	50218	0.020477
acetovanillone	43585	0.163819
acetylene	43206	3.685926
acrolein	43505	0.330788

Species Name	CARB-SAROAD	Weight Percentage (%)
anthracene	98015	0.018062
benzaldehyde	45501	0.257280
benzene	45201	2.010982
benzo[ghi]fluoranthene	97017	0.000431
butyraldehyde	43510	0.504058
C1-MW 202 PAH	47017	0.003933
C2-MW 178 PAH	97011	0.018797
cis-2-butene	43217	0.185871
cis-2-pentene	43227	0.054606
cis-isoeugenol	43584	0.216325
crotonaldehyde	98156	1.449167
cyclopentene	43292	0.040955
dimethylnaphthalene	43574	0.072458
docosane	43287	0.000446
eicosane	43285	0.000919
ethane	43202	2.247260
ethene	43203	5.880680
ethylbenzene	45203	0.120239
eugenol	43317	0.300335
fluoranthene	97013	0.016014
fluorene	97003	0.023313
fluorenone	47031	0.035074
formaldehyde	43502	6.116957
furfural	99312	0.582817
glyoxal	90121	3.517907
guaiacol	43576	1.464919
guaiacyl acetone	43581	0.465204
heneicosane	43286	0.000583
heptanal	47021	2.200004
hexaldehyde	98159	2.194754
hydroxybenzaldehyde	43587	0.063532
hydroxymethylfurfural	43579	0.745586
indanone	47030	0.091886
isobutylene	43215	0.210549
isopentane	98132	0.029403
isoprene	43243	0.215275
m- & p-xylene	99024	0.315036
m- & p-cresol	43597	1.995231
m- & p-tolualdehyde	43588	0.063007
m-benzenediol	43568	0.014754
methane	43201	21.632503
methylbenzenediol	43596	0.054606

Species Name	CARB-SAROAD	Weight Percentage (%)
methylcyclohexane	43261	0.045155
methylglyoxal	90122	4.951322
naphthalene	98046	1.191888
n-butane	43212	0.135991
n-heptadecanoic acid	43595	0.000431
n-heptane	43232	0.151743
n-nonane	43235	0.020477
n-octane	43233	0.008926
nonadecane	43284	0.001822
n-pentane	43220	0.024678
n-tetracosane	43429	0.000452
n-tricosane	43428	0.000504
n-valeraldehyde	98200	0.168019
o-benzenediol	43569	1.638189
o-cresol	98021	0.470454
Octadecane	43283	0.001869
o-xylene	45204	0.095036
palmitic acid	99398	0.010501
p-benzenediol	43571	0.090310
phenanthrene	97005	0.082435
phenol	45300	2.756569
propanal	43504	1.338905
propane	43204	0.887353
propene	43205	2.252510
pyrene	97015	0.009819
retene	43573	0.007246
syringyl acetone	43592	0.001360
tetradecanoic acid	47040	0.001874
toluene	45202	0.829596
trans-2-butene	43216	0.349165
trans-2-hexene	98034	0.045155
trans-2-pentene	43226	0.084010
trans-isoeugenol	43580	0.619572
vanillin	43570	0.551314
veratraldehyde	43589	0.006511
xylenol	99225	0.577567
Total		100.000000

Table 3: Mapping of OG5491 to all RWC categories

EIC	EIC Name
61060002300000	Residential Fuel Combustion - Wood Combustion - Wood Stoves - Sub-Category Unspecified
61060002300132	Residential Fuel Combustion - Wood Combustion - Wood Stoves - Wood Stoves (Uncertified)
61060002300133	Residential Fuel Combustion - Wood Combustion - Wood Stoves - Wood Stoves (Certified – Catalytic)
61060002300134	Residential Fuel Combustion - Wood Combustion - Wood Stoves - Wood Stoves (Certified-Non-Catalytic)
61060002300137	Residential Fuel Combustion - Wood Combustion - Wood Stoves - Fireplace Inserts (Uncertified)
61060002300138	Residential Fuel Combustion - Wood Combustion - Wood Stoves - Fireplace Inserts (Certified-Catalytic)
61060002300139	Residential Fuel Combustion - Wood Combustion - Wood Stoves - Fireplace Inserts (Certified-Non-Catalytic)
61060202300000	Residential Fuel Combustion - Wood Combustion - Fireplaces - Sub-Category Unspecified
61060202300135	Residential Fuel Combustion - Wood Combustion - Fireplaces - Cordwood
61060202300136	Residential Fuel Combustion - Wood Combustion - Fireplaces - Manufactured Logs
61060302300000	Residential Fuel Combustion - Wood Combustion - Pellet Stoves - Sub-Category Unspecified
61060402300000	Residential Fuel Combustion - Wood Combustion – Unspecified - Sub-Category Unspecified