

Supplementary Information for Oxidative Potential of Diesel Exhaust Particles: Role of Fuel, Engine Load, and Emissions Control

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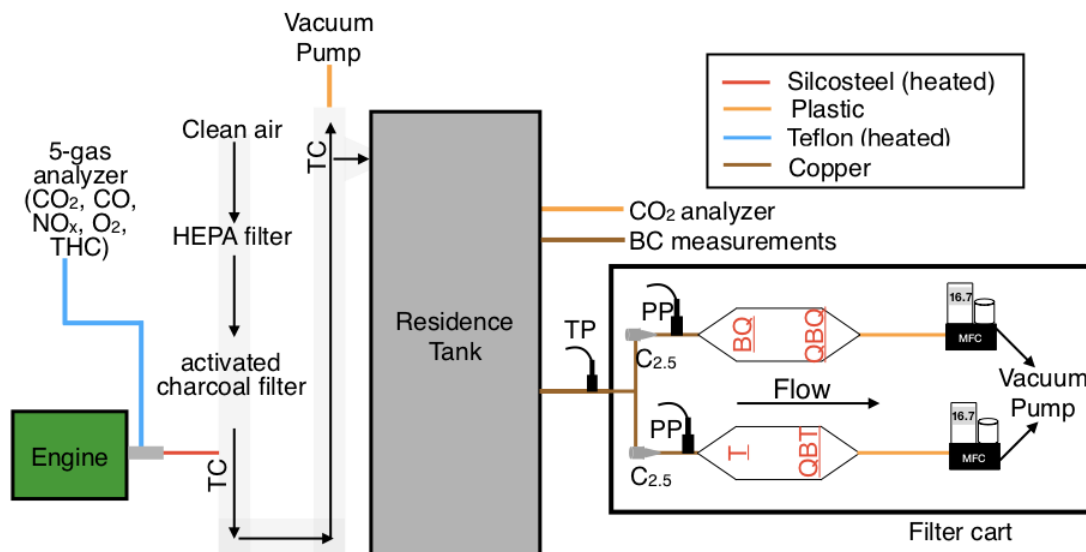


Figure S1: Schematic visualizing the experimental setup and particle collection. MFC = mass flow controller, TC = thermocouple, PP = pressure probe, TP = temperature probe, C_{2.5} = PM_{2.5} cyclone

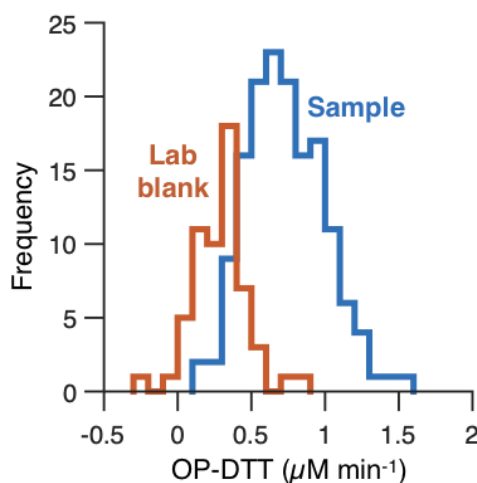


Figure S2: Histogram of the OP-DTT measurements comparing values for the samples against those from the laboratory blanks.

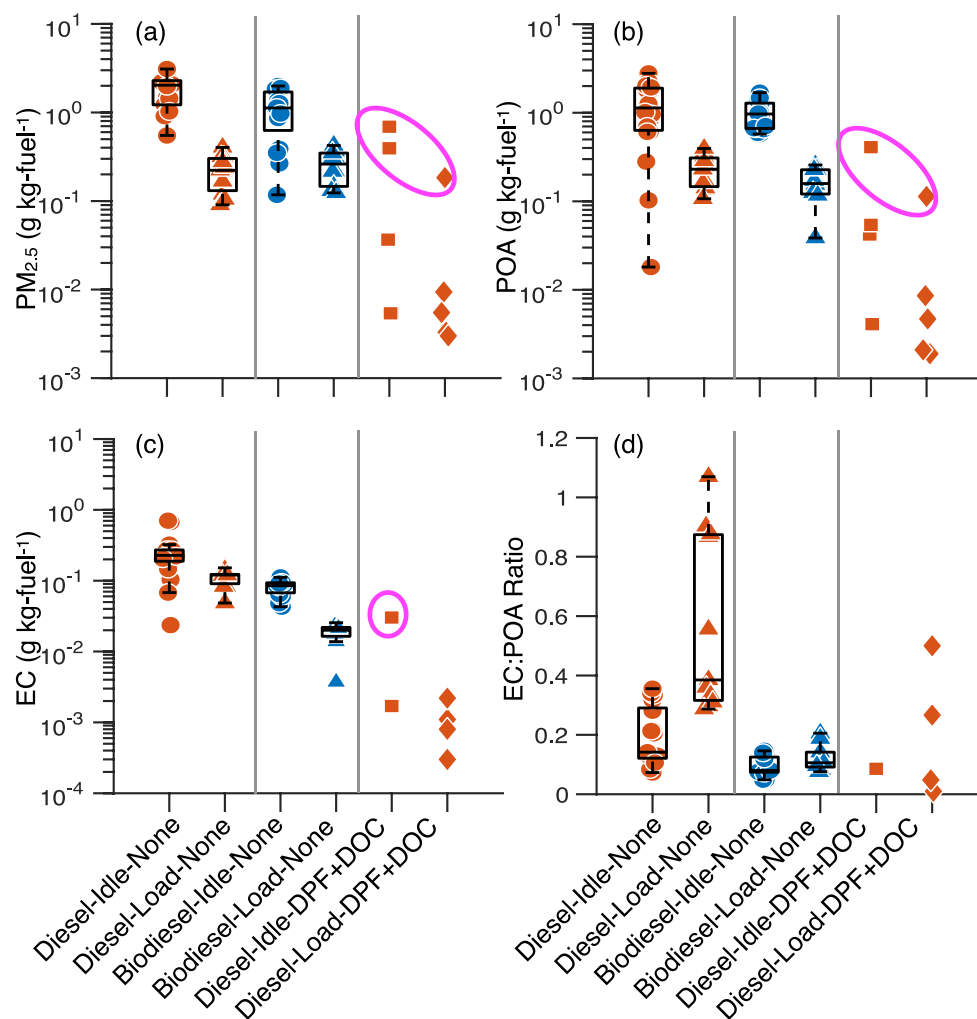


Figure S3: Emission factors for (a) PM_{2.5}, (b) POA, and (c) EC in units of g kg-fuel⁻¹ and the (d) EC:POA ratio for the various fuel-engine load-emissions control combinations. Panels include both the box plot and the individual data used to create the box plot. The box presents the 25th, 50th, and 75th percentile of the data and the whiskers present the lowest and highest values that are not outliers. Outliers are defined as points that lie three times beyond the interquartile range. Outliers in the DPF+DOC data are circled in magenta. Values smaller than zero are not shown.

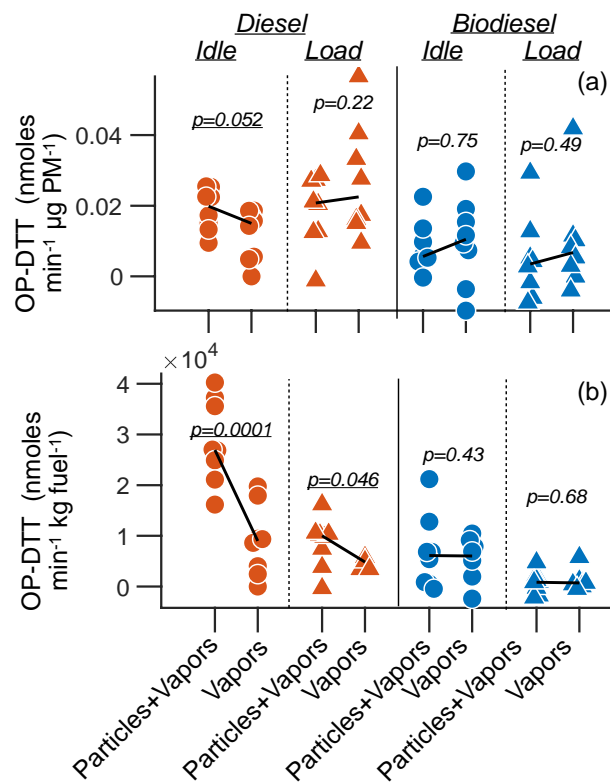


Figure S4: Measured OP-DTT of DEPs resolved by phase of the material (particles+vapors and vapors) in two different units (a) nmoles min⁻¹ μg PM⁻¹ and (b) nmoles min⁻¹ kg-fuel⁻¹. The presented data are resolved by fuel (diesel=orange, biodiesel=blue) and engine load (idle=circle, load=triangle). The black solid line connects the medians of the distributions that are compared and p-values are shown in italic with significant p-values underlined.

Table S1: List of the fuel-engine load-emissions control experiments performed for OP-DTT work with their dilution ratio and emission factor data.

Date of Experiment	Fuel-Load-Emissions control	Dilution Ratio	EF PM _{2.5} (g·kg fuel ⁻¹)	EF POA (g·kg fuel ⁻¹)	EF EC (g·kg fuel ⁻¹)
12/10/15	Diesel-Idle-None	138.73	1.474±0.0430	0.581±0.000	0.240±0.0233
12/17/15	Diesel-Idle-None	88.59	2.205±0.0284	1.210±0.175	0.323±0.0346
3/15/16	Diesel-Idle-None	71.3	0.910±0.0118	0.278±0.0832	0.220±0.0170
	Diesel-Idle-None	122.43	1.028±0.0203	0.189±0.125	0.205±0.0178
	Diesel-Idle-None	71.3	0.967±0.0115	0.660±0.0940	0.219±0.0249
12/10/15	Diesel-Load-None	173.3	0.277±0.000	0.136±0.0642	0.120±0.0113
10/8/15	Diesel-Load-None	55.75	0.215±0.00384	0.0739±0.0230	0.152±0.0117
10/10/15	Diesel-Load-None	13.41	0.167±0.00335	0.231±0.0206	0.121±0.00967
	Diesel-Load-None	222.54	0.223±0.00663	0.0758±0.0748	0.143±0.0138
	Diesel-Load-None	27.1	0.0904±0.00391	0.0640±0.0150	0.123±0.0108
11/24/15	Biodiesel-Idle-None	62.84	1.364±0.0149	0.461±0.0882	0.0817±0.00916
3/16/16	Biodiesel-Idle-None	72.34	1.117±0.0121	0.441±0.0725	0.0884±0.00813
	Biodiesel-Idle-None	179.09	0.351±0.0180	0.523±0.167	0.111±0.0169
	Biodiesel-Idle-None	199.72	0.973±0.0237	0.213±0.177	0.0914±0.0135
	Biodiesel-Idle-None	199.7	0.867±0.0215	0.183±0.176	0.0942±0.0137
3/16/16	Biodiesel-Load-None	83.31	0.306±0.00417	0.113±0.0290	0.0231±0.00316
	Biodiesel-Load-None	83.31	0.349±0.00464	0.119±0.0289	0.0213±0.00308

12/18/15	Biodiesel-Load-None	59.06	0.131±0.00194	0.0649±0.0194	0.0255±0.00258
	Biodiesel-Load-None	126.93	0.124±0.00275	0.00341±0.0389	0.0219±0.00321
	Biodiesel-Load-None	13.5	0.146±0.00172	0.00125±0.00545	0.00367±0.00122
12/22/15	Diesel-Load- DPF+DOC	8.8	0.00938±0.000239	0.00201±0.00303	0.00219±0.000293
	Diesel-Load- DPF+DOC	6.7	0.00554±0.000292	-0.00387±0.0023	<0.0001

Table S2: Details of the number of DTT assays performed in this work resolved by experiment type (fuel-engine load-emissions control combination), filter media, solvent used for extraction, and treatment of the extract (filtered versus unfiltered).

Fuel-load-emissions control	Water based solvent (Phosphate Buffer)					Organic solvent (DCM)		
	Particles+vapors (BQ)		Vapors (QBT)	Particles (Teflon®)		Particles+vapors (BQ)		Vapors (QBT)
	Filtered	Unfiltered	(QBT)	Filtered	Unfiltered	Filtered	Unfiltered	(QBT)
Diesel-Idle-None	4	4	4	2	2	1	1	1
Diesel-Load-None	4	4	4	2	2	1	1	1
Biodiesel-Idle-None	4	4	4	2	2	1	1	1
Biodiesel-Load-None	4	4	4	2	2	1	1	1
Diesel-Load-DPF+DOC	2	2	2	-	-	-	-	-
Handling Blank	-	3	-	-	1	-	1	-
Dynamic Blank	-	4	-	-	1	-	1	-
Total sample filters	25		18	10		6		4

BQ=bare quartz, QBT=quartz behind Teflon®, DCM=dichloromethane, DPF=diesel particulate filter, DOC=diesel oxidation catalyst

Table S3: Emission factors for POA, EC, inorganic compounds, and trace metals for all fuel-engine load combinations without emissions control. The inorganic ions and metals were not measured for the experiments with emissions control.

Type	Species	Diesel-Idle-None	Diesel-Load-None	Biodiesel-Idle-None	Biodiesel-Load-None
Carbon (g kg-fuel ⁻¹)	POA	1.22±0.616 (N=19)	0.232±0.088 (N=11)	0.903±0.332 (N=16)	0.160±0.050 (N=10)
	EC	0.229±0.117 (N=19)	0.111±0.034 (N=11)	0.076±0.041 (N=16)	0.018±0.007 (N=10)
Inorganic [#] (mg kg-fuel ⁻¹)	Sulfate (SO ₄)	7.83	14.65	2.85	0.73
	Nitrate (NO ₃)	14.20	7.30	7.65	3.76
	Nitrite (NO ₂)	26.90	23.14	14.45	2.05
	Ammonium (NH ₄)	1.91	1.04	1.09	0.57
	Cl	0.25	0.31	BDL	BDL
	Ca	28.83	9.41	12.95	2.08
	Na	ND	Outlier	0.53	0.06
	Mg	4.51	0.97	0.33	0.12
Metals ^{&} (mg kg-fuel ⁻¹)	K	5.06	5.75	0.96	0.51
	Cu	9.90	5.17	2.99	0.21
	Fe	8.51	3.08	0.01	0.71
	Mn	3.33	1.46	0.57	~0
	Zn	0.64	0.37	0.77	0.47
	Pb	1.15	0.32	0.06	0.04

BDL=below detection limit, ND=no data, [#]=results from a single quartz filter sample, [&]=averaged results from two BQ filter samples

Table S4: Compilation of OP-DTT measurements from engine and vehicle tests, ambient sampling, and chamber studies. The OP-DTT value refers to the mean value measured in that study.

Engine or Vehicle Testing			
Study	Source	Feedstock	OP-DTT
Geller et al. (2006)	Euro 3 diesel vehicle	Conventional diesel (8 ppm sulfur)	0.038 nmoles min ⁻¹ μg ⁻¹
	Euro 3 gasoline vehicle	Conventional gasoline (<50 ppm sulfur)	0.025 nmoles min ⁻¹ μg ⁻¹
	Euro 4 diesel vehicle	Conventional diesel (8 ppm sulfur)	0.11 nmoles min ⁻¹ μg ⁻¹
Biswas et al. (2009)	Heavy-duty vehicle (no emissions control)	Ultra low sulfur diesel fuel (<15 ppm sulfur)	0.019 nmoles min ⁻¹ μg ⁻¹
	Heavy-duty vehicle (w/ emissions control)	Ultra low sulfur diesel fuel (<15 ppm sulfur)	0.014 nmoles min ⁻¹ μg ⁻¹
Cheung et al. (2009, 2010)	Euro 2 diesel vehicle	Diesel (<50 ppm sulfur)	0.019 nmoles min ⁻¹ μg ⁻¹
	Euro 2 soy biodiesel vehicle	Soy biodiesel (sulfur free)	0.0025 nmoles min ⁻¹ μg ⁻¹
	Euro 3 gasoline vehicle	Gasoline (50 ppm sulfur)	0.012 nmoles min ⁻¹ μg ⁻¹
	Euro 4 diesel vehicle	Diesel (<10 ppm sulfur)	0.019 nmoles min ⁻¹ μg ⁻¹
Kooter et al. (2011)	Heavy-duty vehicle (B0 to B20, no DPF)	Conventional diesel (10 ppm sulfur)	0.055 nmoles min ⁻¹ μg ⁻¹
	Heavy-duty vehicle (B100, DPF)	~likely soy biodiesel (10 ppm sulfur)	0.023 nmoles min ⁻¹ μg ⁻¹
McWhinney et al. (2013)	Tier 1 light-duty diesel vehicle	Ultra low sulfur diesel fuel	0.04 nmoles min ⁻¹ μg ⁻¹
Nijland et al. (2013)	Euro 4 diesel vehicle w/o DPF (B0)	Neat diesel (10 ppm sulfur)	0.032 nmoles min ⁻¹ μg ⁻¹
	Euro 4 diesel vehicle w/o DPF (B50)	Rapeseed biodiesel (10 ppm sulfur)	0.011 nmoles min ⁻¹ μg ⁻¹
	Euro 4 diesel vehicle w/ DPF (B0)	Neat diesel (10 ppm sulfur)	0.041 nmoles min ⁻¹ μg ⁻¹
	Euro 4 diesel vehicle w/ DPF (B50)	Rapeseed biodiesel (10 ppm sulfur)	0.011 nmoles min ⁻¹ μg ⁻¹
Fukagawa et al. (2013)	Light-duty diesel engine (B0)	Ultra low sulfur petrodiesel (1.2 ppm sulfur)	0.0072 nmoles min ⁻¹ μg ⁻¹
	Light-duty diesel engine blend (B20)	Soy biodiesel	0.0051 nmoles min ⁻¹ μg ⁻¹
Grigoratos et al. (2014)	Euro 4 Diesel engine w/ DOC on NEDC cycle (B0)	Base diesel fuel (10 ppm sulfur)	0.042 nmoles min ⁻¹ μg ⁻¹
	Euro 4 Diesel engine w/ DPF+DOC on NEDC cycle (B0)	Base diesel fuel (10 ppm sulfur)	0.121 nmoles min ⁻¹ μg ⁻¹

	Euro 4 Diesel engine w/ DOC NEDC cycle (B50)	Rapeseed biodiesel (10 ppm sulfur)	0.057 nmoles min ⁻¹ μg ⁻¹
	Euro 4 Diesel engine w/ DPF+DOC on NEDC cycle (B50)	Rapeseed biodiesel (10 ppm sulfur)	0.138 nmoles min ⁻¹ μg ⁻¹
Holmen et al. (2017)	Light duty engine	Diesel (10 ppm sulfur)	0.021 nmoles min ⁻¹ μg ⁻¹
	Light duty engine (B100)	Soy biodiesel	0.0013 nmoles min ⁻¹ μg ⁻¹
	Light duty engine	Diesel (10 ppm sulfur)	0.023 nmoles min ⁻¹ μg ⁻¹
	Light duty engine (B100)	Waste vegetable oil biodiesel	0.008 nmoles min ⁻¹ μg ⁻¹
Fujitani et al. (2017)	Heavy duty diesel engine	Diesel (6 ppm Sulphur)	0.026 nmoles min ⁻¹ μg ⁻¹
	Gasoline GDI engine	Gasoline fuel	0.032 nmoles min ⁻¹ μg ⁻¹
Ambient Studies			
Study	Source		OP-DTT
Li et al. (2003)	Claremont, 2001-2002, PM _{<1}		0.3 nmoles min ⁻¹ μg ⁻¹
	Claremont, 2001-2002, PM _{1-2.5}		0.024 nmoles min ⁻¹ μg ⁻¹
	Claremont, 2001-2002, PM _{2.5-10}		0.009 nmoles min ⁻¹ μg ⁻¹
	University of Southern California, 2001-2002, PM ₁		0.09 nmoles min ⁻¹ μg ⁻¹
	University of Southern California, 2001-2002, PM _{1-2.5}		0.02 nmoles min ⁻¹ μg ⁻¹
	University of Southern California, 2001-2002, PM _{2.5-10}		0.009 nmoles min ⁻¹ μg ⁻¹
Ruiz et al. (2006)	Mexico city, May 2003, PM _{2.5}		0.015 nmoles min ⁻¹ μg ⁻¹
	Mexico city, May 2003, PM _{2.5-10}		0.03 nmoles min ⁻¹ μg ⁻¹
Ntziachristos et al. (2007)	South Coast Air Basin, 2003-2005, PM _{0.15}		0.082 nmoles min ⁻¹ μg ⁻¹
	South Coast Air Basin, 2003-2005, PM _{0.15-2.5}		0.034 nmoles min ⁻¹ μg ⁻¹
Hu et al. (2008)	Los Angeles-Long Beach, 2007, PM _{0.25}		0.04 nmoles min ⁻¹ μg ⁻¹
	Los Angeles-Long Beach, 2007, PM _{0.25-2.5}		0.02 nmoles min ⁻¹ μg ⁻¹
	Los Angeles-Long Beach, 2007, PM _{2.5-10}		0.013 nmoles min ⁻¹ μg ⁻¹
Verma et al. (2009a)	Los Angeles during wildfires, 2007		0.019 nmoles min ⁻¹ μg ⁻¹
Verma et al. (2009b)	Los Angeles, 2008 (Morning)		0.055 nmoles min ⁻¹ μg ⁻¹
	Los Angeles, 2008 (Afternoon)		0.09 nmoles min ⁻¹ μg ⁻¹
Charrier et al. (2012)	San Joaquin Valley - Fresno, 2006 (urban), PM _{2.5}		0.048 nmoles min ⁻¹ μg ⁻¹
	San Joaquin Valley - Westside, 2008 (rural), PM _{2.5}		0.023 nmoles min ⁻¹ μg ⁻¹
Verma et al. (2012)	Atlanta, 2012 (water extract)		0.023 nmoles min ⁻¹ μg ⁻¹
	Atlanta, 2012 (methanol extract)		0.035 nmoles min ⁻¹ μg ⁻¹
Wang et al. (2013)	Beijing, 2010, PM _{3.3}		0.016 nmoles min ⁻¹ μg ⁻¹
	Beijing, 2010, PM _{3.3-10}		0.008 nmoles min ⁻¹ μg ⁻¹
Verma et al., 2014	Southeast US, 2012-2013		0.03 nmoles min ⁻¹ μg ⁻¹
Saffari et al. (2014)	Los Angeles, Spring, 2008-2009		0.058 nmoles min ⁻¹ μg ⁻¹
	Los Angeles, Summer, 2008-2009		0.055 nmoles min ⁻¹ μg ⁻¹
	Los Angeles, Fall, 2008-2009		0.067 nmoles min ⁻¹ μg ⁻¹

	Los Angeles, Winter, 2008-2009	0.073 nmoles min ⁻¹ μg ⁻¹
Charrier et al. (2014)	Vehicle emissions summer (ultrafine)	0.02 nmoles min ⁻¹ μg ⁻¹
	Vehicle emissions winter (ultrafine)	0.035 nmoles min ⁻¹ μg ⁻¹
Dou et al. (2015)	Nansha and Guangzhou- ship emissions	0.0072 nmoles min ⁻¹ μg ⁻¹
	Nansha and Guangzhou- biomass burning	0.0052 nmoles min ⁻¹ μg ⁻¹
	Nansha and Guangzhou- secondary process	0.006 nmoles min ⁻¹ μg ⁻¹
Verma et al. (2015)	Ambient PM	0.030 nmoles min ⁻¹ μg ⁻¹
	Isoprene OA	0.010 nmoles min ⁻¹ μg ⁻¹
	Oxidized OA	0.038 nmoles min ⁻¹ μg ⁻¹
	Cooking OA	0.090 nmoles min ⁻¹ μg ⁻¹
	Biomass burning OA	0.150 nmoles min ⁻¹ μg ⁻¹
Fang et al. (2015)	Urban- Jefferson street	0.035 nmoles min ⁻¹ μg ⁻¹
	Urban- Birmingham	0.035 nmoles min ⁻¹ μg ⁻¹
	Rural- Yorkville	0.030 nmoles min ⁻¹ μg ⁻¹
	Rural- Centerville	0.040 nmoles min ⁻¹ μg ⁻¹
	Roadside	0.036 nmoles min ⁻¹ μg ⁻¹
	Georgia Tech	0.025 nmoles min ⁻¹ μg ⁻¹
Sauvin et al. (2015)	Tunnel, 2009, PM _{>2.5}	0.008 nmoles min ⁻¹ μg ⁻¹
	Depot, 2009, PM _{>2.5}	0.009 nmoles min ⁻¹ μg ⁻¹
Vreeland et al. (2017)	Atlanta, 2012-2013 (inside vehicle)	0.025 nmoles min ⁻¹ μg ⁻¹
	Atlanta, 2012-2013 (roadside)	0.05 nmoles min ⁻¹ μg ⁻¹
Chamber Studies		
Study	SOA precursor	OP-DTT
Kramer et al. (2016)	Outdoor samples, isoprene SOA	2.1 nmoles min ⁻¹ μg ⁻¹
	Outdoor samples, methacrolein SOA	2.3 nmoles min ⁻¹ μg ⁻¹
	Indoor samples, isoprene derived epoxides SOA	1.79 nmoles min ⁻¹ μg ⁻¹
	Indoor samples, methacrylic acid epoxides SOA	3.13 nmoles min ⁻¹ μg ⁻¹
Jiang et al. (2016)	Toluene SOA, w/ charcoal denuder	0.045 nmoles min ⁻¹ μg ⁻¹
	Toluene SOA, w/o charcoal denuder	0.026 nmoles min ⁻¹ μg ⁻¹
	1,3,5-trimethyl benzene SOA, w/ charcoal denuder	0.014 nmoles min ⁻¹ μg ⁻¹
	1,3,5-trimethyl benzene SOA, w/o charcoal denuder	0.021 nmoles min ⁻¹ μg ⁻¹
	Isoprene SOA, w/ charcoal denuder	0.031 nmoles min ⁻¹ μg ⁻¹
	Isoprene SOA, w/o charcoal denuder	0.058 nmoles min ⁻¹ μg ⁻¹
	α-pinene SOA, w/ charcoal denuder	0.01 nmoles min ⁻¹ μg ⁻¹
	α-pinene SOA, w/o charcoal denuder	0.007 nmoles min ⁻¹ μg ⁻¹
Wood smoke, w/o charcoal denuder	0.025 nmoles min ⁻¹ μg ⁻¹	
Tuet et al. (2017)	Isoprene SOA	0.01 nmoles min ⁻¹ μg ⁻¹
	α-pinene SOA	0.024 nmoles min ⁻¹ μg ⁻¹
	β-caryophyllene SOA	0.018 nmoles min ⁻¹ μg ⁻¹
	Pentadecane SOA	0.014 nmoles min ⁻¹ μg ⁻¹
	m-xylene SOA	0.03 nmoles min ⁻¹ μg ⁻¹
	Naphthalene SOA	0.17 nmoles min ⁻¹ μg ⁻¹

Fujitani et al. (2017)	α -pinene SOA, Ozonolysis, pinene rich	0.012 nmoles min ⁻¹ μ g ⁻¹
	α -pinene SOA, Ozonolysis, ozone rich	0.016 nmoles min ⁻¹ μ g ⁻¹

Filter Preparation, Handling, and Storage

Prior to use in the filter cartridge, the Teflon[®] filters were stored in 50 mm sterile petri dishes (VWR International, Pennsylvania) and equilibrated for 24 hours in a temperature- and relative humidity-controlled room. The quartz filters were prepared for use in the filter cartridges by baking punched filters in a muffle furnace (ThermoFisher Scientific, MA) at 800 °C for seven hours and placed in 50 mm sterile petri dishes after they had cooled to room temperature. At the end of each experiment, petri dishes containing the filter samples were marked with a unique identifier (date-experiment number-filter type-fuel-engine load-emissions control), sealed with Teflon[®] tape, placed into an experiment-specific ziplock bag, and stored in a freezer at -20 °C.

Gravimetric Measurements

Petri dishes containing the Teflon[®] filters were removed from the freezer and kept in the temperature- and relative humidity-controlled microbalance room for 24 hours to equilibrate to its surroundings. After equilibration and placing the filter on a Polonium radiation strip to remove static charges, three mass measurements were performed on an MX5 microbalance (Mettler Toledo, Switzerland) for each Teflon[®] sample. The microbalance used for this study was calibrated every day before start of measurements. A 20,000 μ g calibration lab weight and a lab filter (without any mass loading) was used for the calibration. The data was recorded and observed for any measurement deviation. There were no such deviations observed during the course of this study. The average of the three measurements was recorded in units of μ g. The average mass flow rate in standard cubic meters per minute recorded by the MFC in the LabVIEW software was multiplied by the sampling time in minutes to calculate the total volume of air at STP (standard temperature and pressure) conditions in units of m³. The mass and volume were used to calculate the PM_{2.5} mass concentration in units of μ g m⁻³. All raw gravimetric PM_{2.5} masses were corrected for mass collected on the Teflon[®] filters during handling and storage using the median value obtained from the handling blanks (handling artifact=7.7 μ g, N=5) and all gravimetric PM_{2.5} mass concentrations were corrected for vapor collection on Teflon[®] filters with the median value obtained from the dynamic blanks (dynamic artifact=2.7 μ g m⁻³, N=9). Note that the dynamic blank filters also had to be corrected for handling and storage artifacts.

Sunset OC/EC Measurements

The organic (or primary organic aerosol) and elemental carbon (OC/POA and EC) fractions of PM_{2.5} were measured using the field (or semi-continuous) version of the Sunset OC/EC analyzer (Sunset Laboratory Inc., Oregon) following the NIOSH 5040 method (Eller and Cassinelli, 1996). All BQ and QBT filters were analyzed for OC and EC but only a fraction of the QBQ filters were analyzed for OC and EC since that data was only used for diagnostic purposes (e.g., determining breakthrough of EC particles, studying vapor artifacts behind a quartz filter). Briefly, a 2.27 cm² punch from a quartz filter is placed into the analyzer. Carbon in the sample is determined by thermal-optical transmission (TOT)(Birch and Cary, 1996) and a non-dispersive infrared detector is used to measure the total carbon evolved during thermal desorption from the filter as carbon dioxide. OC is determined first in a helium environment, while EC is determined second in a helium/oxygen environment. The transmission through the filter is monitored to correct for any OC that is pyrolyzed to EC during the thermal desorption process. The Sunset OC/EC was calibrated for OC using a sucrose standard stock solution (10 μ g C). The OC and EC masses measured by the instrument data acquisition system (μ g C) were divided by the punch surface area (2.27 cm²), multiplied by the active surface area of the filter (12.01 cm²), and divided by the sampled mass of air at STP conditions to calculate OC and EC mass concentrations in units of μ g C m⁻³.

Inorganic Ions and Water Soluble Organic Carbon

For each sample, particles on the Teflon® filter were extracted into 15 ml of deionized (DI) water in a Nalgene Amber HDPE (high-density polyethylene) bottle by sonicating without heat for 40 minutes. The extracts were filtered to ensure that the insoluble particles were removed using a 0.2 µm PTFE (polytetrafluoroethylene) syringe filter. The water-soluble ions were measured using a dual channel Dionex ICS-3000 ion chromatography system. Each channel includes a pump, self-regenerating anion or cation SRS-ULTRA suppressor, and conductivity detector. The inorganic cations were separated using a Dionex IonPac CS12A analytical column (3×150 mm) with an eluent of 20 mM methanesulfonic acid at a flow rate of 0.5 ml min⁻¹. A Dionex IonPac AS14A analytical (4×250 mm) column employing an eluent of 1 mM sodium bicarbonate/8 mM sodium carbonate at a flow rate of 1 ml min⁻¹ was used for the inorganic anion analysis. The injection volume and analysis time for both methods was 50 µL and 17 minutes, respectively. Each channel was calibrated using eight multi-compound standards in order to create calibration curves. The WSOC concentration of each liquid extract was determined using a Sievers Model 800 Turbo Total Organic Carbon (TOC) Analyzer. The analyzer converts the organic carbon in the sample to carbon dioxide by employing chemical oxidation via reaction with ultraviolet light and ammonium persulfate. The carbon dioxide formed is measured by conductivity. The increase in the observed conductivity is proportional to the amount of organic carbon in the sample. When measuring the liquid extracts the analyzer was run in Turbo mode to provide a 3 second integrated measurement. The TOC Analyzer was factory calibrated and the calibration was periodically verified by injection of oxalic acid standards. The masses measured by the instrument data acquisition system in µg were divided by the sampled mass of air at STP conditions to calculate mass concentrations of sulfate, nitrate, ammonium, chloride, and WSOC in units of µg m⁻³.

Metals

Small square sections of the quartz filter were cut using a ceramic scissor instead of a conventional metal punch to avoid contaminating the ICP-MS sample. A high-resolution photograph of the remaining quartz filter was used and the GIMP open-source software was used to determine the coordinates of the punch. A google Excel spreadsheet was used to perform the calculation and following the surface area of the ICP-MS sample was determined. The ICP-MS filter sample was placed in a 50 ml extraction tube containing 20 ml of 3.5% HNO₃ spiked with 50 ppb of Galium (Ga), Indium (In), and Bismuth (Bi), that were used as internal standards. The extraction tube was heated to and kept at 95 °C for one hour and allowed to cool for 30 minutes, before diluting with deionized water to create a 50 ml liquid sample. The liquid sample was vortexed for 10 seconds, allowed to stand for at least 30 minutes, shaken again, and finally allowed to settle for an hour. The liquid sample was run through an ELAN ICP-MS (PerkinElmer Inc., Massachusetts) where the solution was nebulized into a high temperature argon plasma to produce ionized gaseous elements that were detected in a mass spectrometer. Each sample solution was analyzed three times and the average of the three measurements was recorded. The ICP-MS was calibrated using a laboratory prepared multi-element stock solution prior to its use in this work. The raw mass measurements in µg, corrected for with the internal standard data, were divided by the cutout surface area, multiplied by the active surface area of the filter (12.01 cm²), and divided by the sampled mass of air at STP conditions to calculate trace metal mass concentrations in units of µg m⁻³.

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Properties for Diesel

<i>Property</i>	<i>Test Data</i>	<i>Specifications</i>
Gravity API	37.9	30.0 Min.
Color	0.0	2.5 Max.
Flash PMCC	155	130°F Min.
Sulphur, ppm	10.46	15.0 ppm Max.
Carbon Residue	0.028	0.35 Max.
Corrosion	1A	1 Max.
W & S Vol. %	<0.05	0.05 Max.
Pour Point, F	-40	-15°F Max.
Viscosity	2.44	1.9 to 3.4 CST
Cetane Index, D4737A	49.0	40.0 Min.
Cloud Point, F	-13.0	5°F Max.
Thermal Stability	99	75 Min.
CFPP		-25°F Max.
Distilled: % Evaporated		
Initial	348.1	540 – 640°F
10%	396.9	
50%	486.7	
90%	598.9	
EP	661.6	

Inspection report by Frontier Refining LLC.



13611 B Street □ Omaha, Nebraska 68144-3693 □ (402) 334-7770 □ FAX (402) 334-9121 □ www.midwestlabs.com

Certificate of Analysis

Report #: 15-118-4277

Reported to:	EMERGENT GREEN ENERGY PO BOX 538 MINNEOLA KS 67865-0538	Acct #: 22017
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Lab #: 2391256

Date Sampled: Not Available

Sample ID: B100

Date Received: 2015-04-20

Analysis	Level Found	Status	ASTM 6751 Limits	Method	Date of Analysis
Oxidation Stability (hrs)	10.9	Pass	3 hour min	EN 15751	2015/04/28
Flash Point (deg C) **	161	Pass	93 or 130 min	ASTM D93	2015/04/28
Methanol (% mass)	n.d.	NA	0.2 max	EN 14110	2015/04/28
Water and Sediment (% volume)	< 0.01	Pass	0.05 max	ASTM D2709	2015/04/23
Viscosity Kinematic (mm ² /s)	4.19	Pass	1.9-6.0	ASTM D445	2015/04/28
Sulfated Ash (% mass)	<0.01	Pass	0.02 max	ASTM D874	2015/04/28
Sulfur (total) (ppm)	4.1	Pass	15 ppm	ASTM D5453	2015/04/21
Copper corrosion (3hr @ 50°C)	1a	Pass	No. 3 max	ASTM D130	2015/04/24
Cloud Point (deg C)	2	NA	Report	ASTM D2500	2015/04/28
Carbon Residue (% mass)	<0.02	Pass	0.05 max	ASTM D4530	2015/04/28
Acid Number (mg KOH/g)	0.22	Pass	0.50 max	ASTM D664	2015/04/28
Free Glycerine (% mass)	<0.001	Pass	0.020 max	ASTM D6584	2015/04/28
Total Glycerine (% mass)	0.144	Pass	0.240 max	ASTM D6584	2015/04/28
Monoglycedride (% mass)	0.052			ASTM D6584	2015/04/28
Diglyceride (% mass)	0.050			ASTM D6584	2015/04/28
Triglycerides (% mass)	0.042			ASTM D6584	2015/04/28
Boiling Temp-Dist Temp (deg C)	346	Pass	360 max	ASTM D1160	2015/04/24
Phosphorus (% mass)	<0.0001	Pass	0.001 max	ASTM D4951	2015/04/22
Magnesium/Calcium (ppm)	2.02	Pass	5 max	EN 14538	2015/04/22
Potassium/Sodium (ppm)	<4.00	Pass	5 max	EN 14538	2015/04/22
Workmanship	#1		N/A	D4176	2015/04/23
Cold Soak Filtration (seconds)	98	Pass	360 sec. max	ASTM D7501	2015/04/24
Potassium (ppm)	n.d.	Pass	5 max	EN 14538	2015/04/22

SIGNATURE REDACTED

Heather Ramig

Client Services - Midwest Laboratories, Inc.

* Cetane Number analysis is performed by a subcontracted Laboratory.

** If Flash Point is < 130 Celsius, then the Methanol test is done.

If Methanol passes and Flash Point is above 93 Celsius,
then the Flash Point passes.