

DOE's Gasoline/Diesel PM Split Study

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Study Objective

Quantify the relative contribution of gasoline and diesel PM to ambient PM concentrations in the South Coast (Los Angeles) Air Basin

Gasoline/Diesel PM Split Study

Participants

- Bureau of Automotive Repair and SCAQMD
 - Light-duty vehicle recruitment
 - Smog check
- California Trucking Association
 - Heavy-duty vehicle recruitment
- Ralphs Grocery Distribution Center
 - Test site and logistics
- U.S. Environmental Protection Agency and CAVTC/BKI
 - LD vehicle dynamometer measurements
- West Virginia University
 - MDD and HDD Truck dynamometer measurements
- Desert Research Institute and University of Wisconsin – Madison
 - Source and ambient measurements and source apportionment

Outline of Presentation

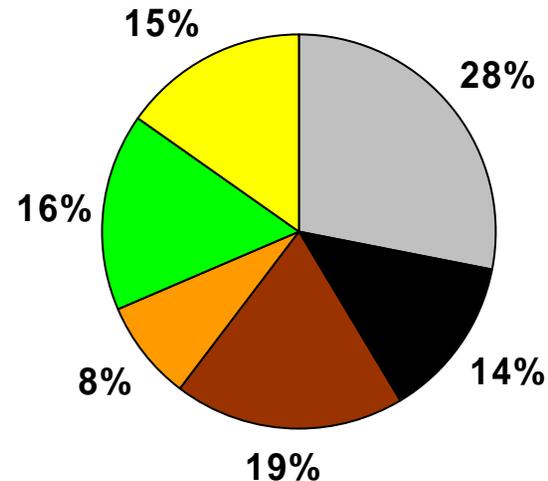
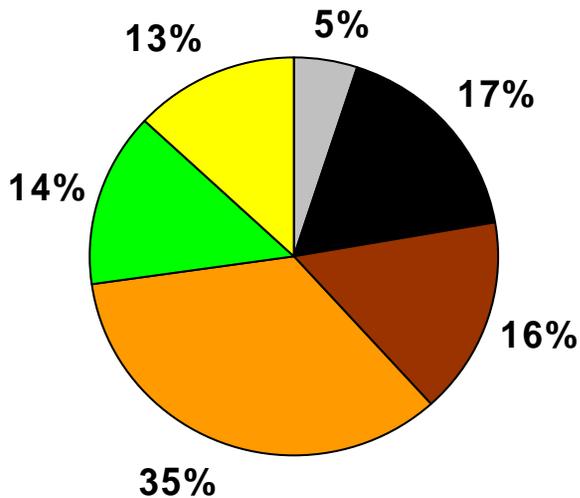
- Previous Studies
- Description of Study
 - Ambient Measurements
 - Source Measurements
 - Analytical Results
- Study Results (to date)

Previous Studies

Phoenix PM_{2.5} Source Apportionment and Inventory Comparison

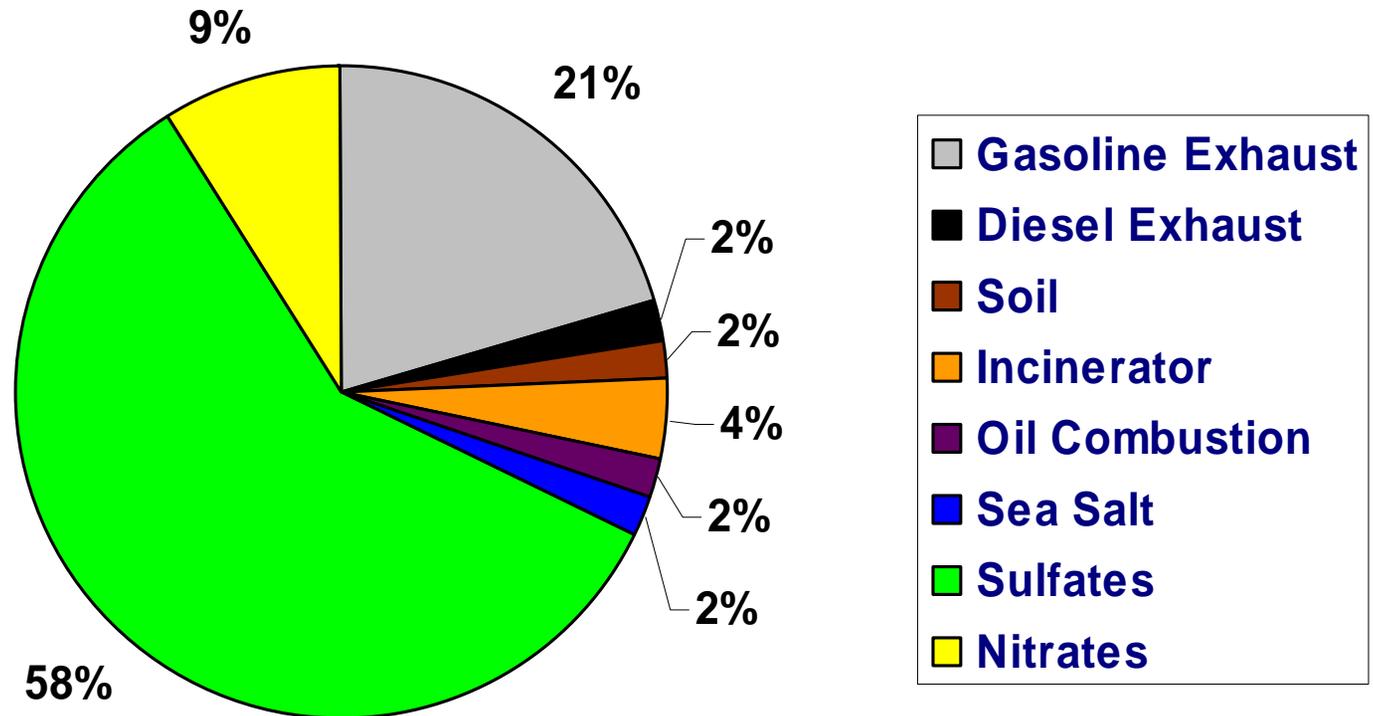
Emission Inventory

Ambient Data/Receptor Modeling



Legend: Gasoline Exhaust (grey), Diesel Exhaust (black), Soil (brown), Vegetative Burning (orange), Sulfates (green), Nitrates (yellow)

Washington, DC PM_{2.5} Source Apportionment Aug. '88 to Dec. '97 -- 718 PM_{2.5} samples



Source: Kim and Hopke, *JAWMA*, July 2004

Ambient Measurements

Fixed Site and Mobile Ambient Sampling

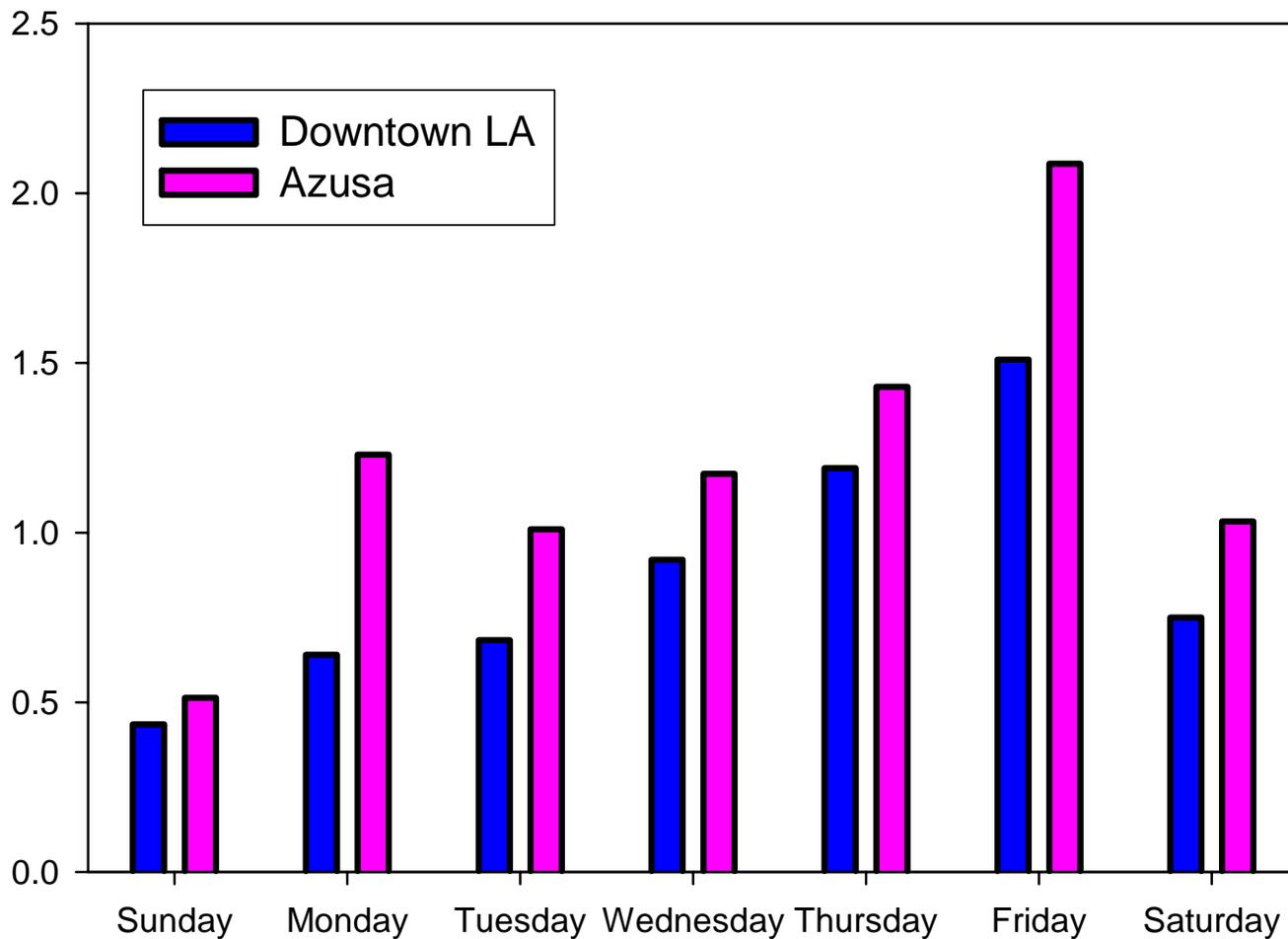


- Downtown Los Angeles and Azusa – July 2001 – Daily 24-hour ambient samples for three weeks, composited by day of week to exploit the weekday/weekend change in emissions
- Variety of locations with differing amounts of gasoline and diesel traffic

Gasoline/Diesel PM Split Study – Ambient Samples

- PM_{2.5} Measurements
 - Gravimetric mass
 - Ions by IC, Colorimetry, AA
 - Elements by XRF
 - PM organic speciation by TIGF/PUF/XAD and GC/MS (PAH, hopanes, steranes, alkanes, polar compounds)
 - Continuous black carbon by photoacoustic spectrometer
 - Continuous PM_{2.5} by DustTrak nephelometer
- Fixed Site Monitoring
 - Los Angeles-N. Main and Azusa
 - Daily 24 hr, from midnight PST; July 2001
 - Composite by day of week
- Mobile Sampling
 - Regional background
 - Spark-ignition (SI) vehicle dominated
 - Compression-ignition (CI) vehicle dominated
 - SI and CI mix
 - Specific mixed samples

Average Fine Particle EC Concentration ($\mu\text{g}/\text{m}^3$)
Measured by NIOSH 5040 - July 8-21, 2001



Source Measurements

Light-Duty Vehicle Dynamometer Testing



Test Site: Ralphs Grocery Distribution Center,
Riverside, CA

Gasoline/Diesel PM Split Study

- **Dynamometer Testing**
 - EPA/BKI
- **Sampling and Analysis**
 - Desert Research Institute
 - Univ. Wisconsin Madison
- **Vehicle Recruitment**
 - BKI
 - Bureau Automotive Repair
 - South Coast AQMD
- **Test Vehicles**
 - 51 LDGV (9 groups of model years and mileage)
 - 6 LDGV smokers
 - 2 LDDV
- **Test Cycle**
 - Modified UDC

LDV and HDV Exhaust Sampling Systems



Gasoline/Diesel PM Split Study

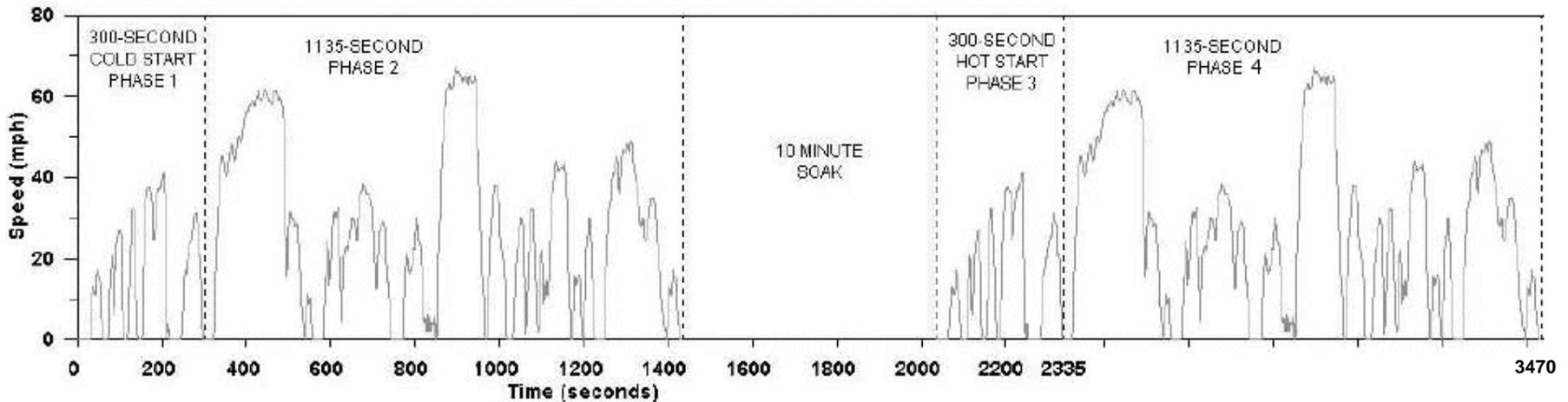
LD Vehicle Recruitment Sample

Category	Model Year	Odometer (miles)	Number of Vehicles	Number of Composites
1	1996 and newer	low mileage (< 50,000)	4	1
2	1993-95	low mileage (< 75,000)	4	1
3	1996 and newer	high mileage (> 100,000)	4	1
4	1990-92	lower mileage (< 100,000)	4	1
5	1993-95	higher mileage (> 125,000)	8	2
6	1990-92	> 125,000	9	3
7	1986-89	> 125,000	6	3
8	1981-85	> 125,000	6	3
9	1980 and earlier	> 125,000	6	3
10	Smoker	no model year or odometer criteria	6	6
11	LD Diesel	no model year or odometer criteria	2	2
		Total	59	26

Gasoline/Diesel PM Split Study – Light-Duty Vehicle Driving Cycle: Modified Unified Driving Cycle (LA92)

Cold Phase

Warm Phase



- Modified Unified Cycle – Phases 3 and 4 are a warm repeat of phases 1 and 2
- 2 sampling phases: “Cold” phase and “Warm” phase, each lasting 1435 seconds; 24.6 mph ave. speed; 67 mph max. speed; 6.9 mph/sec max acceleration
- PM Summary Statistics: Min=0 mg/mi; Max=185 mg/mi; Mean=19 mg/mi; Median=5 mg/mi; Mode=0 mg/mi (skewed distribution)

Gasoline/Diesel PM Split Study – LD Vehicle Recruitment

Recruitment:

- BAR recruited first 9 LD vehicle categories; BKI recruited “smokers” and diesels
- Incentives: \$200 and free rental car; \$50 if vehicle was rejected; free repairs up to \$500 if vehicle failed California Smog Check inspection

Rejects and Why:

- 74 vehicles recruited; 15 rejected
 - 6 rejected because category was over-recruited
 - 4 due to engine/exhaust problems; 3 were too large/incompatible with EPA’s transportable dynamometer
 - 2 for other reasons: engine rebuilt at 230,000 miles; owner brought in vehicle wrong day

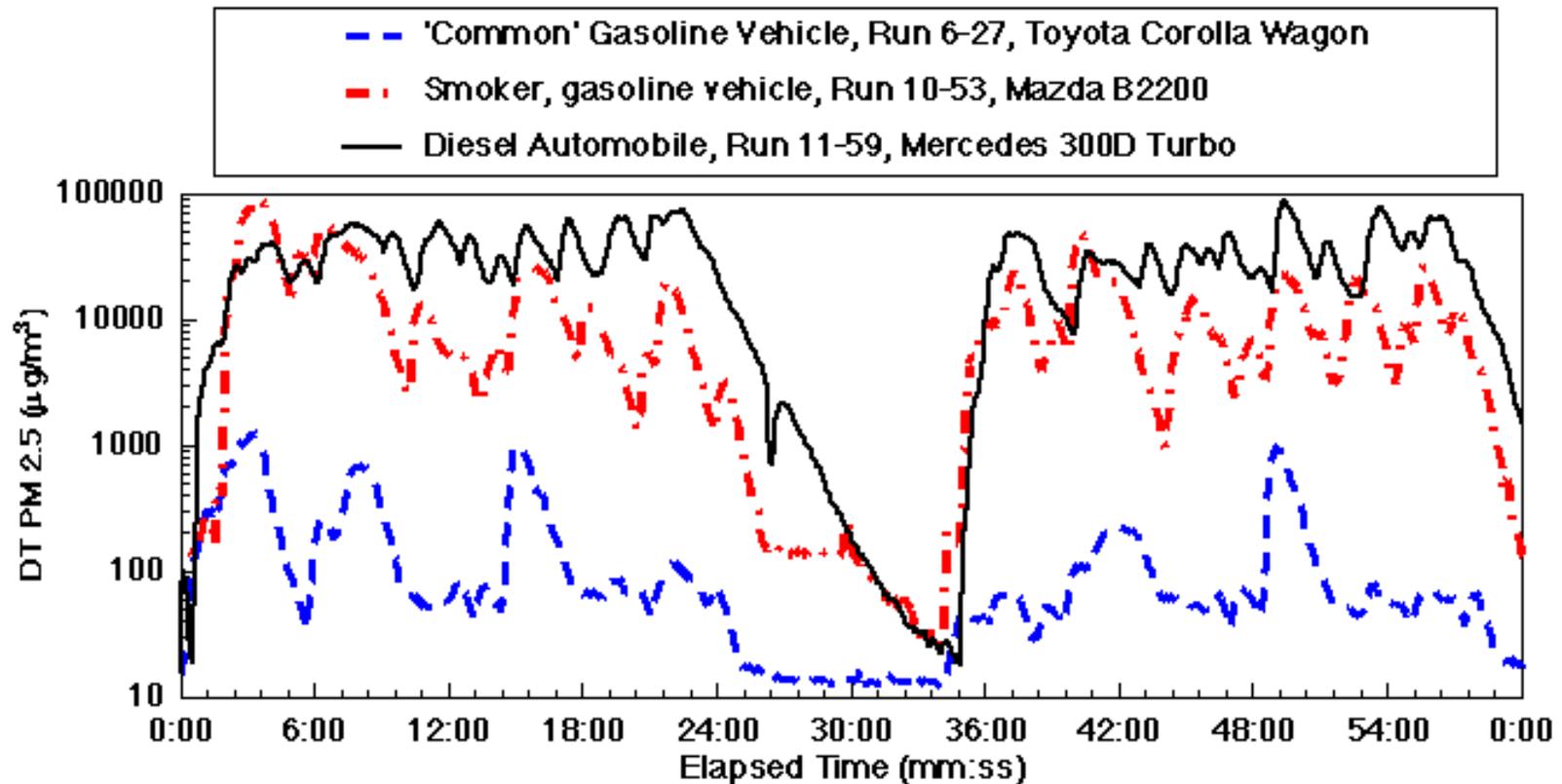
Other:

- 1 overheated on cold phase of Unified Cycle
- 1 had brakes catch fire during cold phase of Unified Cycle

Smog Check Results:

- 33 vehicles passed; 24 vehicles failed Smog Check
 - 7 “gross polluters” according to Smog Check criteria; 5 were tampered with
 - the only 1996+ vehicle that failed Smog Check did not have its MIL illuminated (OBD “false pass”)
 - 2 aborted Smog Check inspections; 2 vehicles were diesels

Second-by-Second PM Emission Rates, Light-Duty Vehicles



Heavy-Duty Truck Dynamometer Testing



Test Site: Ralphs Grocery Distribution Center,
Riverside, CA

Gasoline/Diesel PM Split Study

- **Dynamometer Testing**
 - Univ. West Virginia
- **Sampling and Analysis**
 - Desert Research Institute
 - Univ. Wisconsin Madison
- **Vehicle Recruitment**
 - California Trucking Assoc.
- **Test Vehicles**
 - 32 HDDV (3 weight class and 4 model-years groups)
 - 2 transit buses
- **Test Cycles**
 - City/Suburban
 - Highway
 - Idle
 - Manhattan

Gasoline/Diesel PM Split Study HD Vehicle Recruitment & Test Matrix

GVW (lbs.)	Pre 90	90-93	94-97	98-current	Total
	BOX 1	BOX 2	BOX 3	BOX 4	
	Total 1	Total 1	Total 2	Total 4	8
	(C) [1]	(C) [2]	(B) [3]	(D) [5]	
			(C) [4]	(C) [6]	
				(C) [7]	
8501> 14000				(C) [34]	
	BOX 5	BOX 6	BOX 7	BOX 8	
	Total 2	Total 0	Total 3	Total 3	8
	(C) [8]		(B) [10]	(D) [13]	
	(C) [9]		(C) [11]	(B) [14]	
			(C) [12]	(C) [15]	
14001> 33000					
	BOX 9	BOX 10	BOX 11	BOX 12	
	Total 2	Total 3	Total 6	Total 5	16
	(B) [16]	(B) [18]	(C) [21]	(E) [26]	
	(E) [17]	(C) [19]	(C) [22]	(B) [27]	
		(C) [20]	(C) [23]	(C) [28]	
			(C) [24]	(C) [29]	
			(C) [25]	(C) [30]	
			(C) [33]		
33001> 80000					
Total	5	4	11	12	32

Transit Buses			
One Powered By Electronic Controlled Diesel - (A)	[32]		
One Powered By Manual Controlled Diesel - (A)	[31]		

Letters in () are Set ID

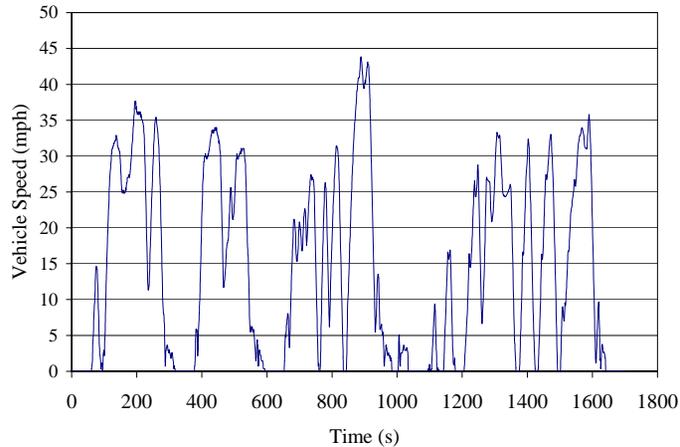
Numbers in [] are Vehicle Number

Cycle Set:

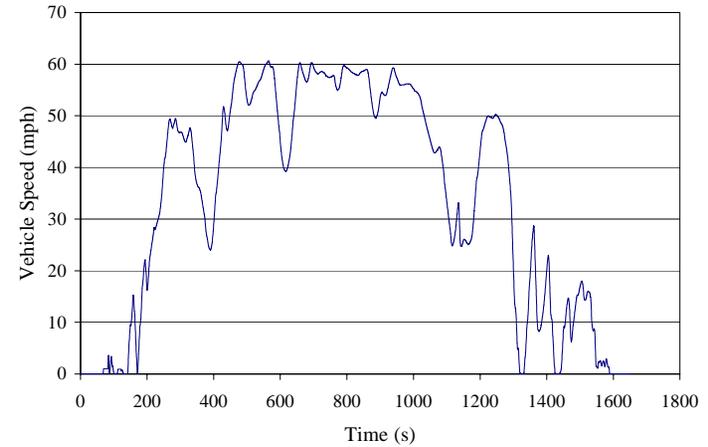
- (A) CSHVR + Manhattan + Idle
- (B) Cold CSHVR + CSHVR + Highway +Idle
- (C) CSHVR + Highway +Idle
- (D) Cold CSHVR + Highway + Idle + Repeat CSHVRs
- (E) Cold CSHVR w/engine brake + CSHVR + Highway + Idle + Cold Idle + UDDS + CSHVR w/engine brake

All vehicles tested with CA diesel fuel; 5 tested with federal diesel fuel

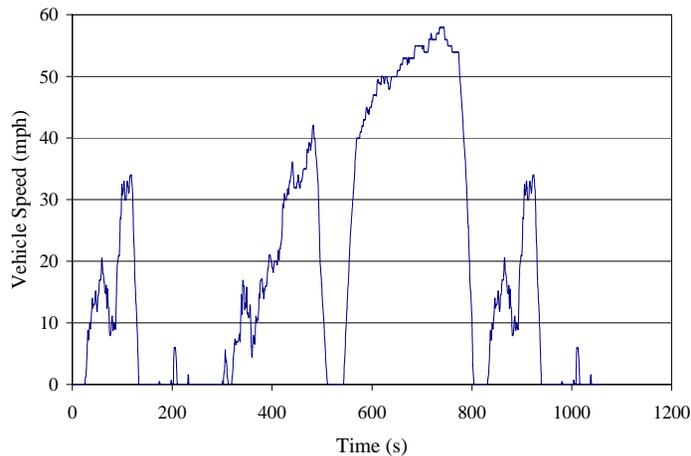
Gasoline/Diesel PM Split Study – Heavy-Duty Vehicle Test Cycles



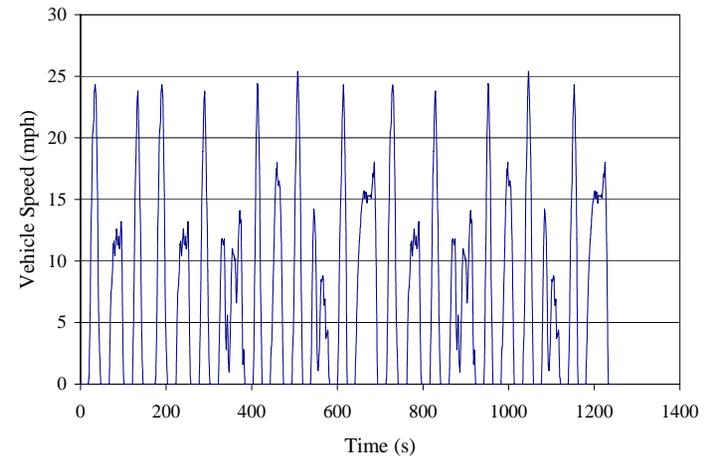
City/Suburban Heavy Vehicle Route (CSHVR)



Highway



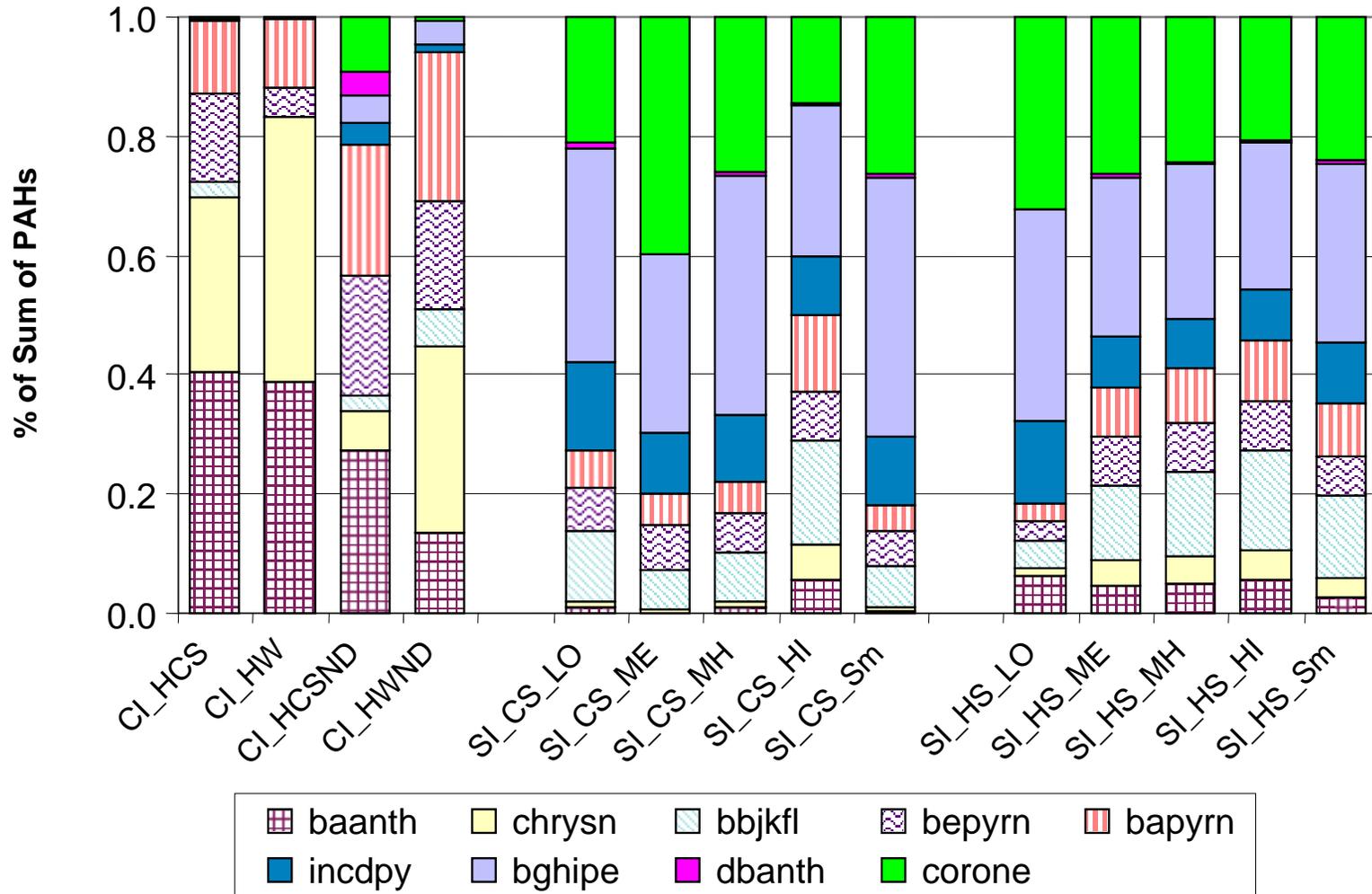
HD Urban Dynamometer Driving Schedule (UDDS)



Manhattan

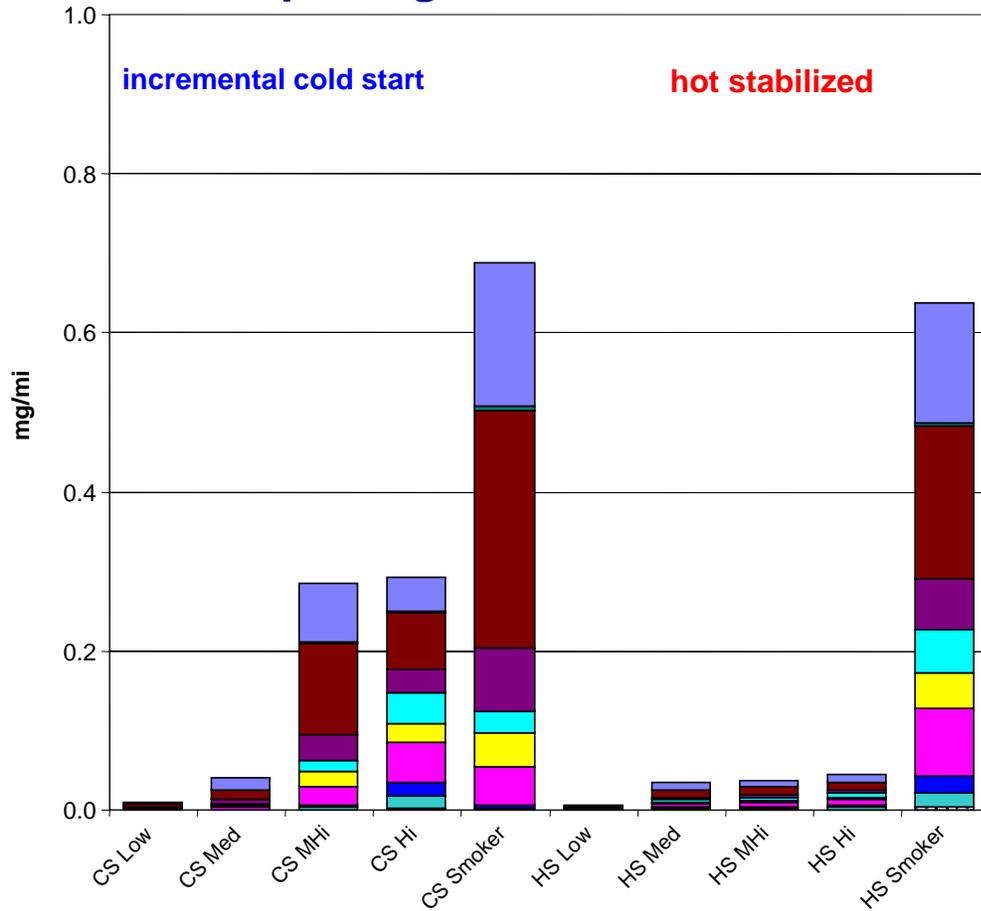
Analytical Results

High-Molecular Weight PAHs in Vehicle Exhaust

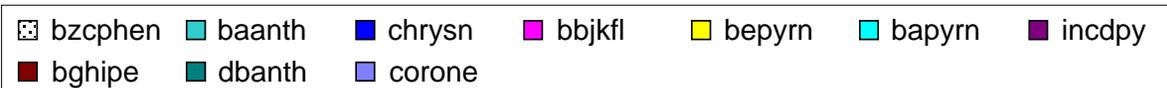
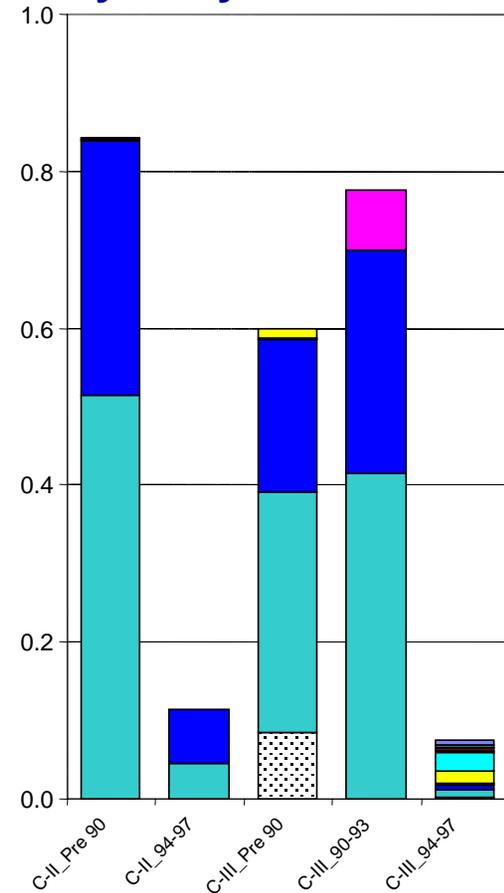


Gasoline/Diesel PM Split Study – Particle PAH in Exhaust

Spark-ignition vehicles

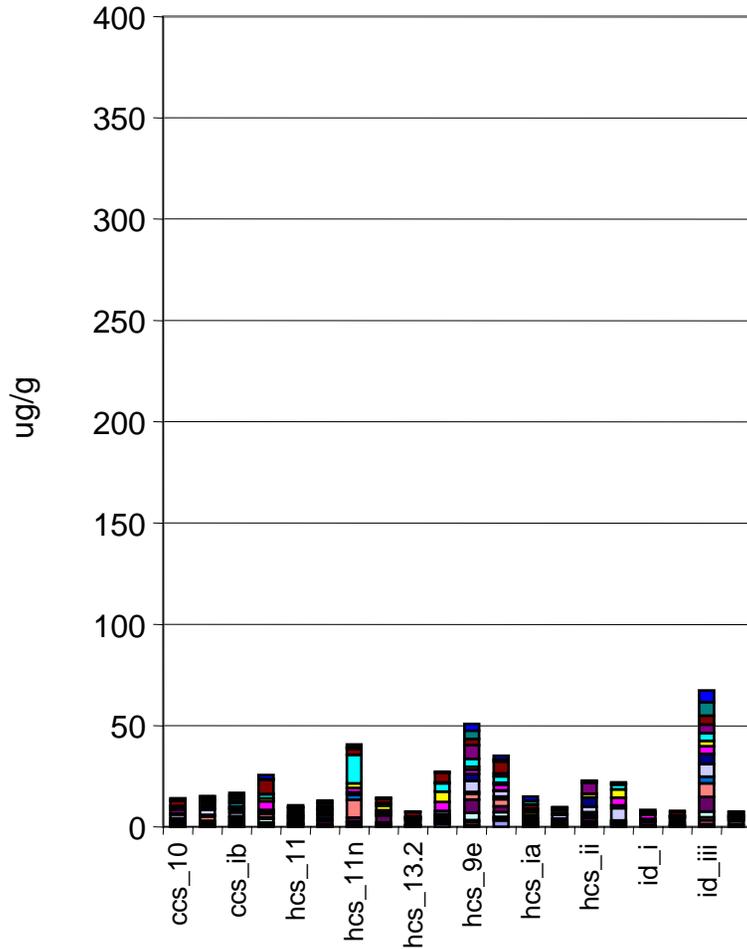


Heavy-Duty Diesel Vehicles

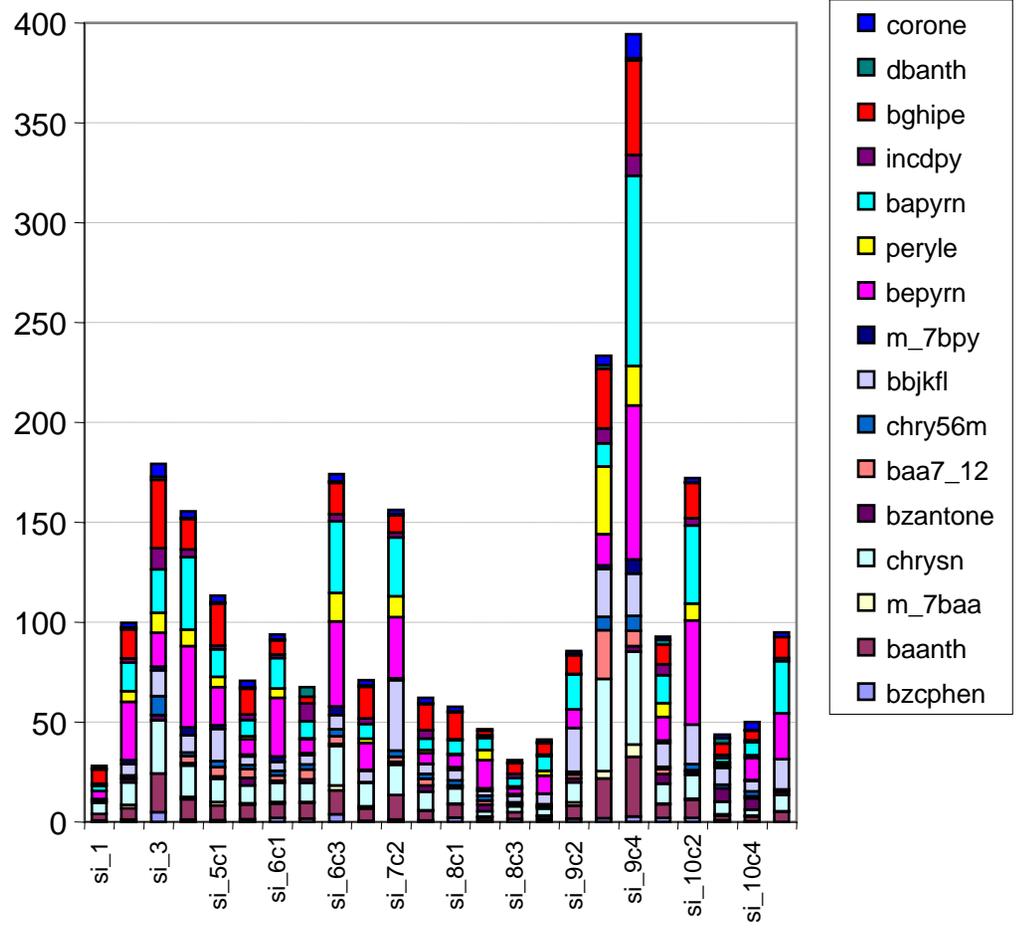


Gasoline/Diesel PM Split Study Particle-Phase PAH in Lube Oil

Lube Oil - Diesel



Lube Oil - Spark Ignition



- corone
- dbanth
- bghipe
- incdpy
- bapyrn
- peryle
- bepyrn
- m_7bpy
- bbjkfl
- chry56m
- baa7_12
- bzantone
- chrysn
- m_7baa
- baanth
- bzcphen

Summary

- Chemical composition of PM emissions in engine exhaust
 - Diesel vehicles are the dominant source of elemental carbon but EC is not a unique tracer.
 - For “normal” emitters, most PM emissions during UDC are from the cold start and high accels/speed with higher fraction of black carbon.
 - Hopanes and steranes are present in lubrication oil with similar composition for both gasoline and diesel vehicles. Much higher for high emitters.
 - Emission rates of high molecular weight PAH (e.g., indeno(cd)pyrene, benzo(ghi)perylene, and coronene) are higher for gasoline vehicles than diesel.
 - Combustion produced particle-phase PAHs tend to build up in lubricating oil of gasoline vehicles. This is not the case for diesel vehicles.
- Ambient Source Apportionment
 - Relative amounts of EC and sum of high-MW PAHs in ambient samples are consistent with the relative amount of diesel and gasoline vehicle traffic.
 - Significant fraction of the organic carbon in the ambient samples cannot be apportioned to directly-emitted PM emissions from motor vehicles.
- Remaining Work
 - Comparison and reconciliation of source apportionment results by DRI and UWM.
 - Papers completed this fall.