Analysis of Motor Vehicle Emissions in a Houston Tunnel

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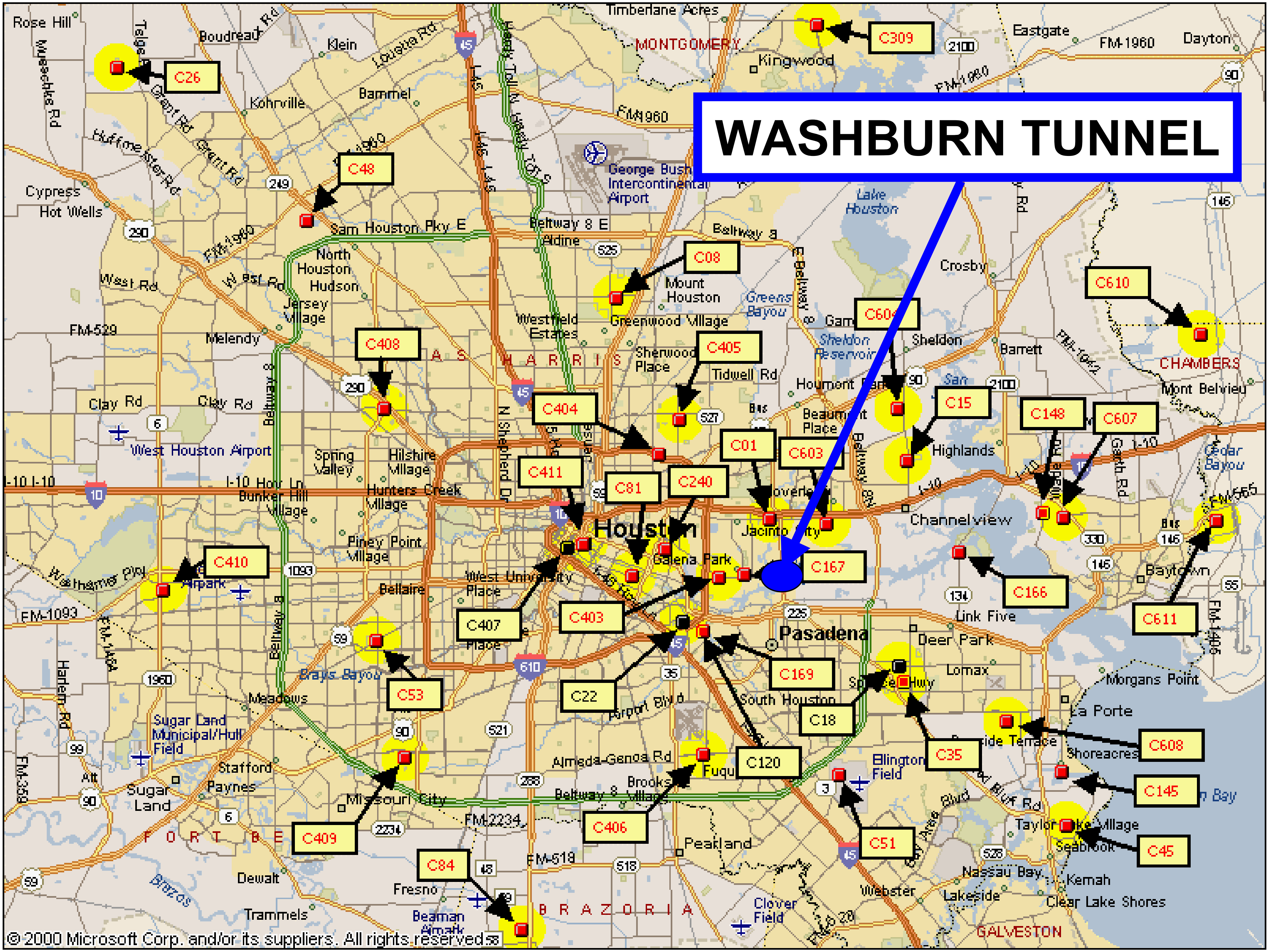
WASHBURN TUNNEL

Tunnel Characteristics

- Runs N-S beneath Houston Ship Channel between Galena Park and Pasadena
- Two-lane, bi-directional, single bore
- 895 meters in length
- Maximum height of 5.5 meters
- 6 percent grade
- Forced longitudinal ventilation via automatic blower fans


WASHBURN TUNNEL
C309
C26
C48
C08
C610
C604
C408
C405
C404
C15
C148
C607
C411
C01
C603
C81
C240
C410
C167
C166
C407
C403
C611
C169
C53
C18
C22
C35
C608
C120
C145
C409
C406
C51
C45
C84
Houston
Pasadena
MONTGOMERY
HARRIS
CHAMBERS
FORT BEND
BRAZORIA
GALVESTON
Kingwood
Timberlane Acres
Eastgate
Dayton
Rose Hill
Klein
Kohrville
Bammel
George Bush Intercontinental Airport
Cypress
Hot Wells
North Houston
Hudson
Jersey Village
Aldine
Mount Houston
Greenwood Village
Westfield Estates
Crosby
Sheldon
Barrett
Mont Belvieu
Sherwood Place
Highlands
Channelview
Baytown
Spring Valley
Hilshire Village
Hunters Creek Village
Bunker Hill Village
Piney Point Village
West University Place
Bellaire
Galena Park
Jacinto City
Deer Park
Lomax
Morgans Point
La Porte
Shoreacres
Link Five
South Houston
Ellington Field
Pearland
Taylor Lake Village
Seabrook
Nassau Bay
Kemah
Webster
Clear Lake Shores
Lakeside
Clover Field
Sugar Land Municipal/Hull Field
Sugar Land
Stafford
Meadows
Missouri City
Dewalt
Fresno
Trammels
West Houston Airport
Lake Houston
Sheldon Reservoir
Greens Bayou
Cedar Bayou
Brays Bayou
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Sampling Periods

- Collected measurements on four consecutive days: Aug 29, 2000 (Tuesday) through Sept 1, 2000 (Friday)

- Two sampling periods each day (higher heavy-duty diesel fraction during mid-day period)
  - 1200 CDT – 1400 CDT
  - 1600 CDT – 1800 CDT

Measurements

- NO_x
- Carbonyls
- $CO/CH_4/CO2$
- Speciated hydrocarbons
- $PM_{2.5}$ (mass, EC, OC)
- Ammonia
- FTIR analysis of size segregated PM (aliphatics, carbonyls, and organonitrates)

Traffic Monitoring

- VHS tapes captured video data recorded by surveillance camera at north entrance
- Observers counted vehicles for each lane of traffic (incoming and outgoing)
- Vehicles were visually classified using four vehicle type categories

Vehicle Type Categories

- Cars and jeeps
- Light-duty trucks
- Medium-duty trucks (passenger trucks with 2 axles and six wheels)
- Heavy-duty trucks (3 or more axles)

Total Traffic Volumes and Percent Vehicle Type by Sampling Period

Date	Time (Local)	Total Vehicles	Cars & Jeeps (%)	LD Trucks (%)	MD Trucks (%)	HD Trucks (%)
8/29	12-2*	403	42.7	51.4	0.7	5.2
	4-6	4766	45.4	51.7	0.6	2.3
8/30	12-2	2152	45.5	47.8	0.7	6.1
	4-6	4621	44.5	52.1	1.1	2.3
8/31	12-2	2272	46.3	48.1	1.4	4.3
	4-6	5244	44.7	52.5	0.8	2.0
9/1	12-2	2815	45.6	49.6	0.7	4.2
	4-6*	3186	49.0	49.1	0.5	1.4

Average Total Traffic Volumes and Percent Vehicle Type

Time (Local)	Total Vehicles	Cars & Jeeps (%)	LD Trucks (%)	MD Trucks (%)	HD Trucks (%)
12-2 pm	2364	45.0	49.2	0.9	5.0
4-6 pm	4867	45.9	51.4	0.8	2.0
TxDOT Harris County Registration Data					
----	----	45.4	51.9		2.2

Ratios of pollutant concentrations measured inside the tunnel to those measured in ambient air

Pollutant	Tunnel/Background Ratio	
	1200 – 1400 CDT	1600 – 1800 CDT
CO_2	1.71	2.14
CO	14.7	16.8
NO_x^*	46	80
NMOC	6.0	7.7
$PM_{2.5}$	3.2	3.1

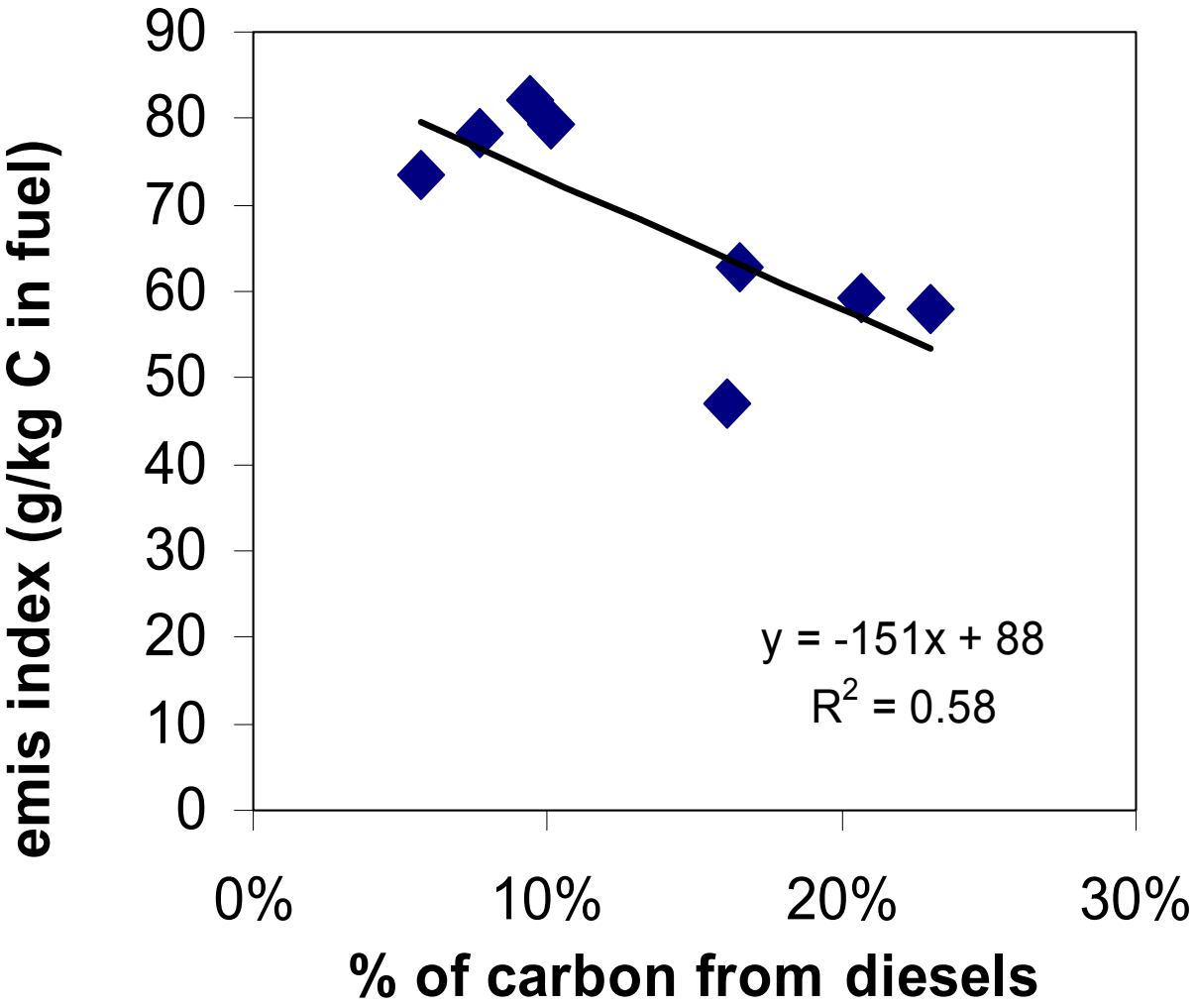
Development of Fuel-Based Emission Factors for NO_x, CO, and NMOC

- By carbon balance, sum of background-corrected CO, CO_2, and VOC provides measure of fuel consumed

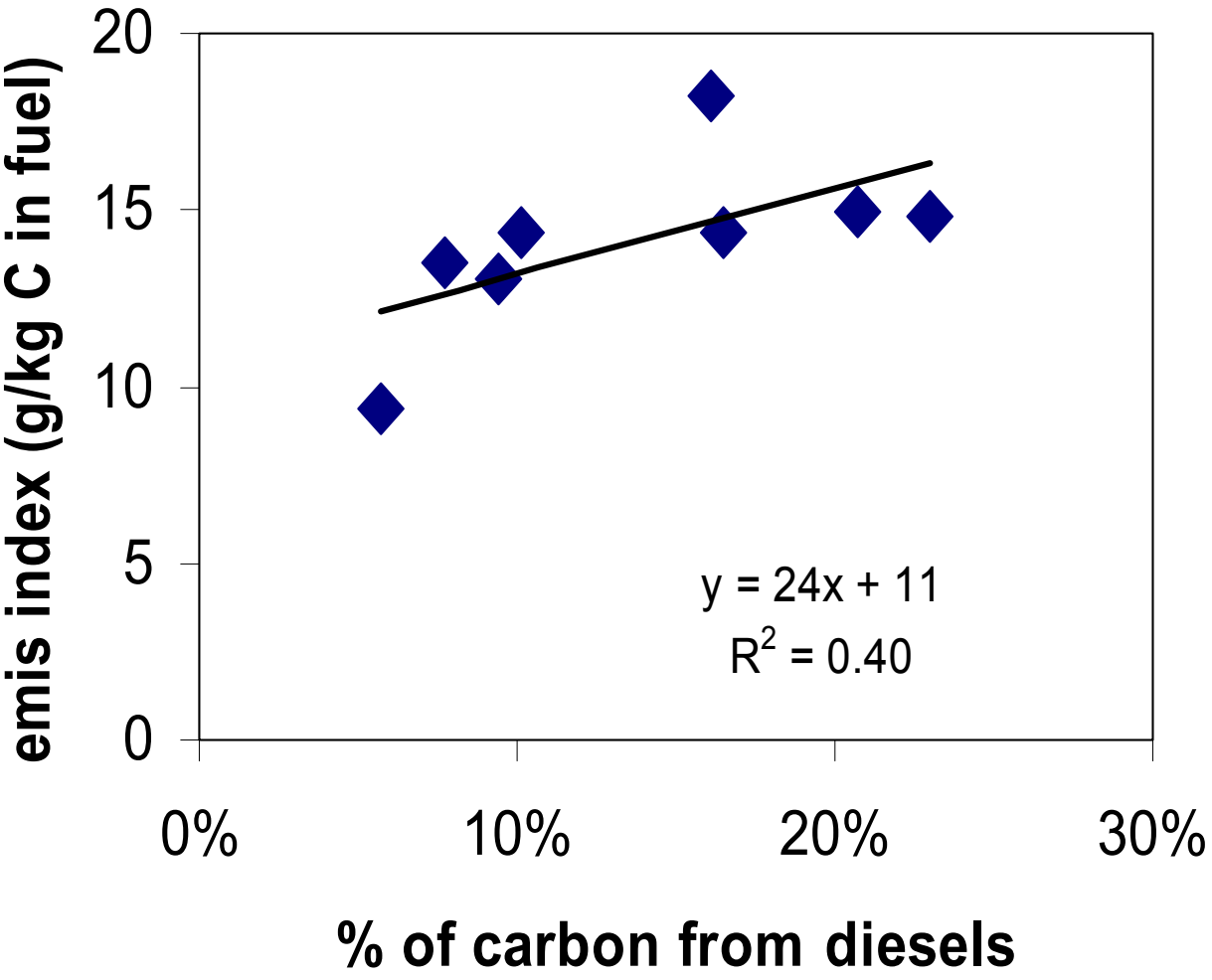
- Fraction of total C from heavy-duty vehicles during each two-hour sampling period estimated by % diesel and assumed fuel economies

- Use regression analysis to estimate light-duty vehicle emission factors

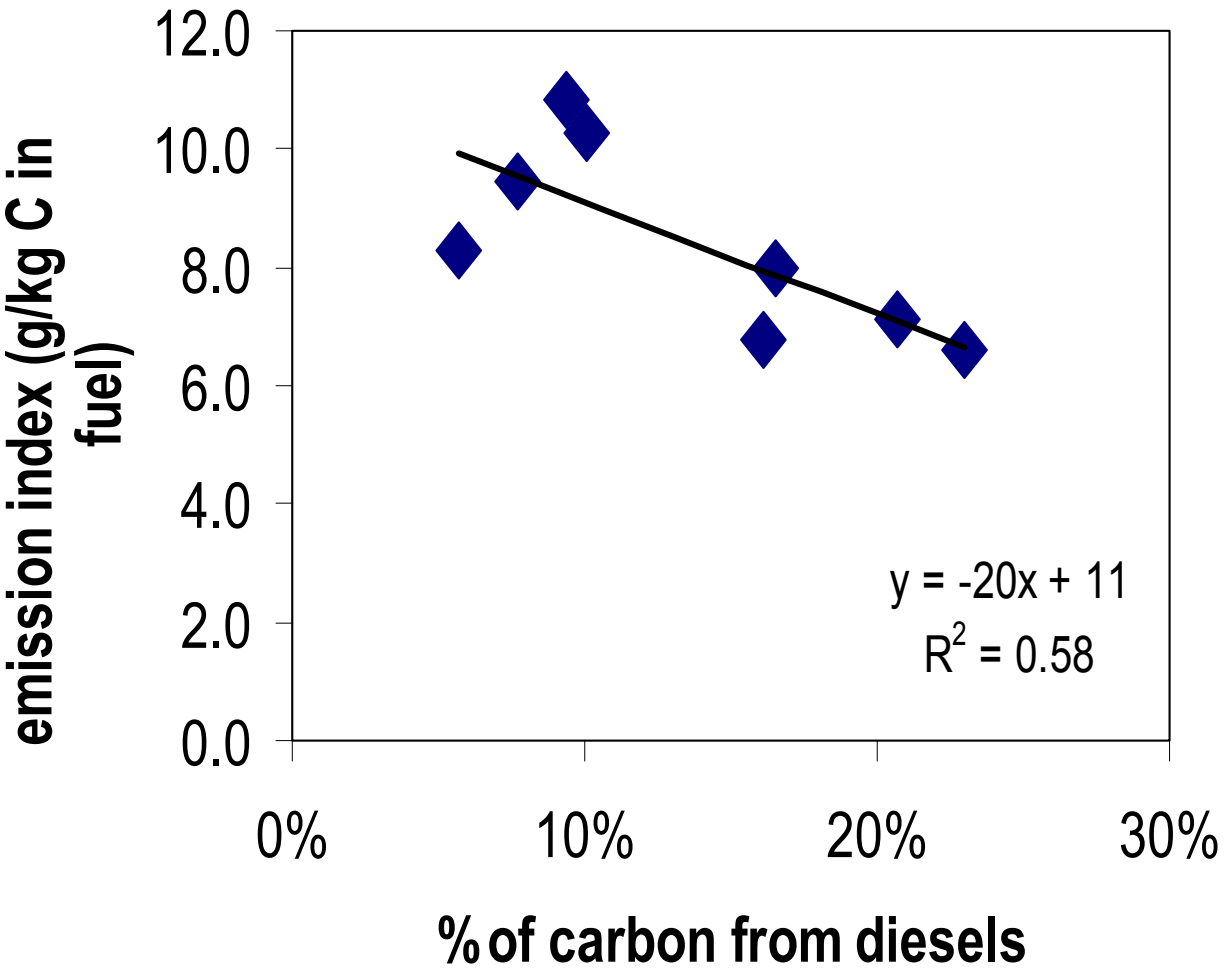
Carbon Monoxide



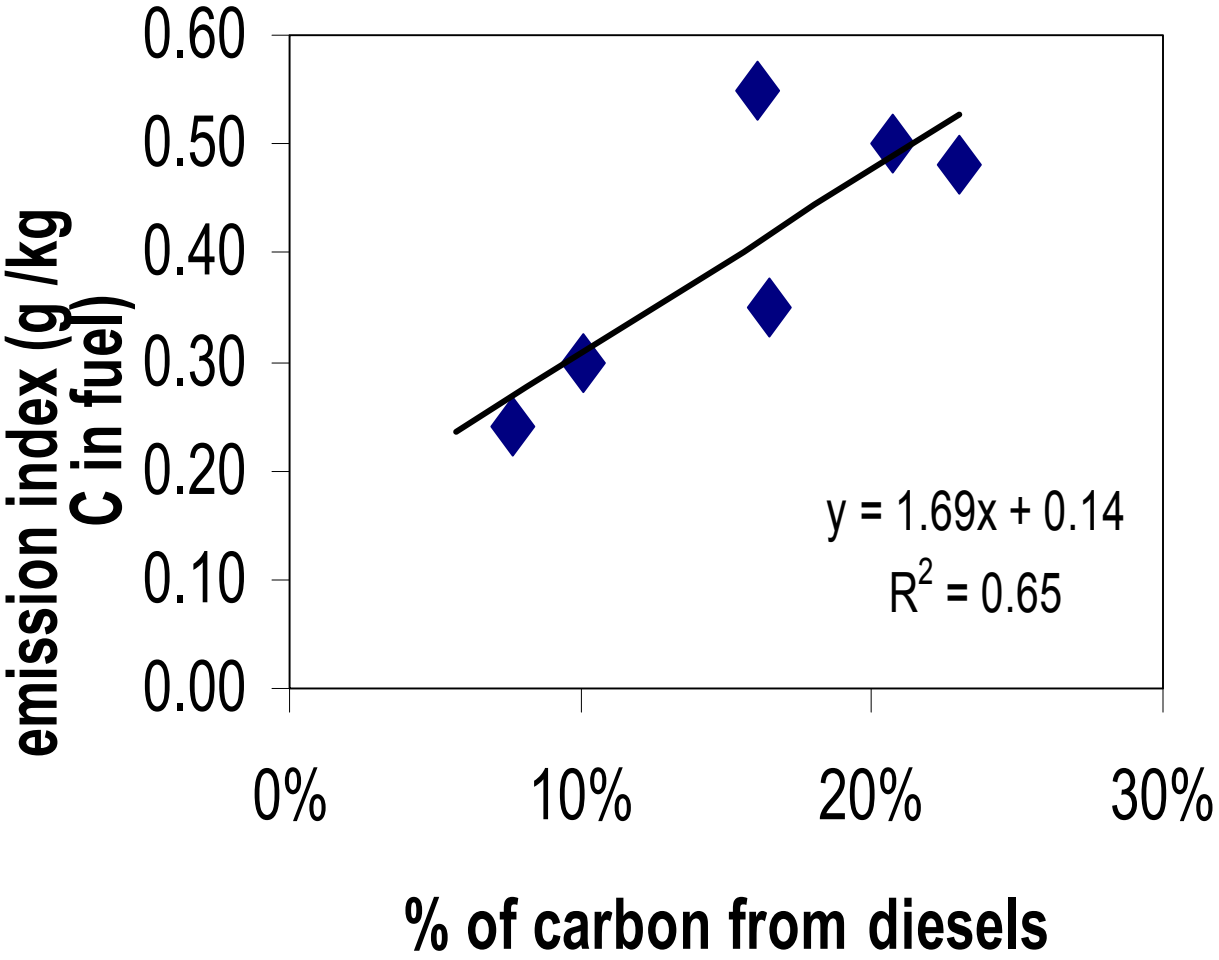
Oxides of Nitrogen



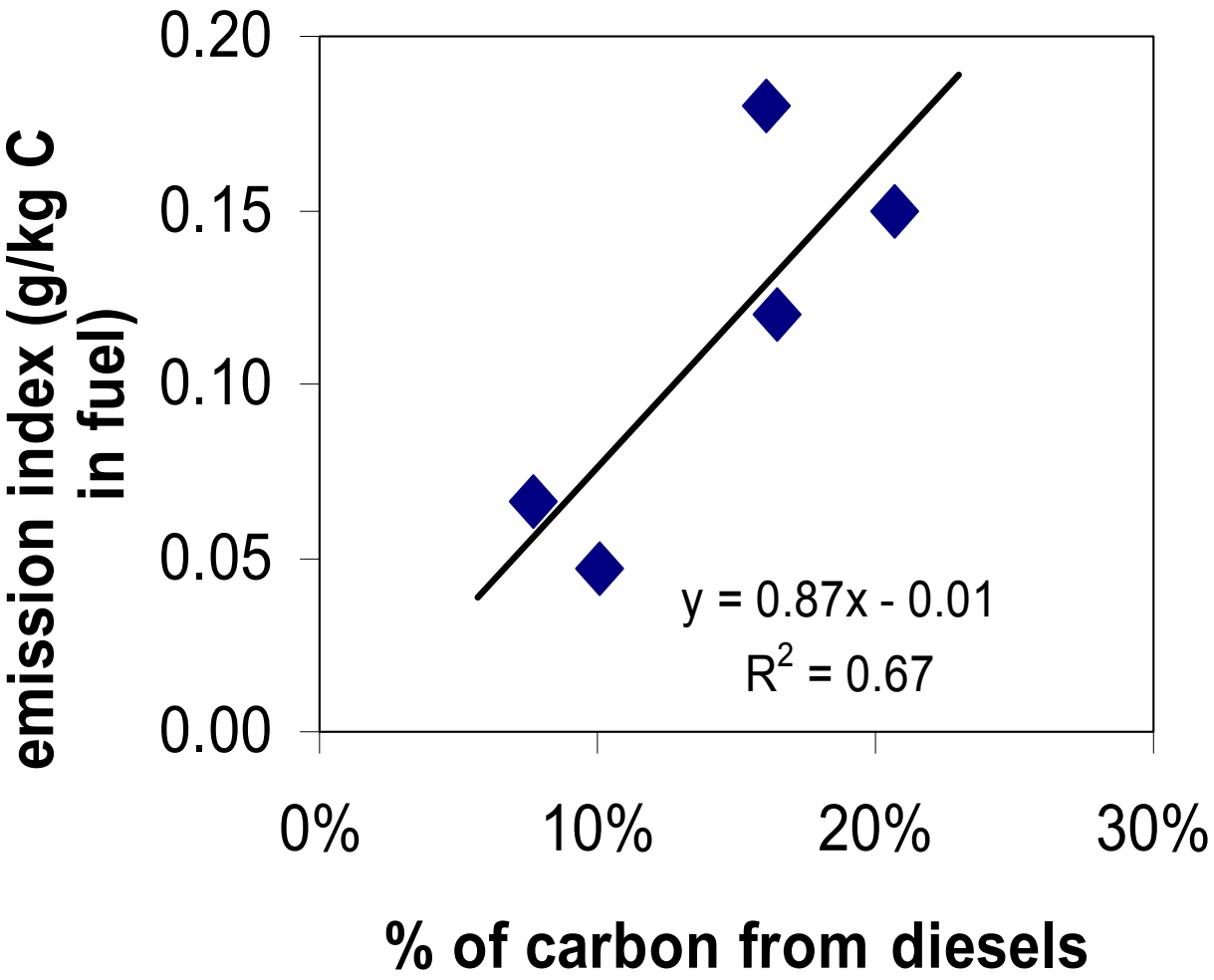
NMOC


12.0
10.0
8.0
6.0
4.0
2.0
0.0
emission index (g/kg C in fuel)
y = -20x + 11
R2 = 0.58
0%
10%
20%
30%
% of carbon from diesels

PM2.5


0.60
0.50
0.40
0.30
0.20
0.10
0.00
emission index (g /kg C in fuel)
y = 1.69x + 0.14
R2 = 0.65
0%
10%
20%
30%
% of carbon from diesels

Elemental Carbon



Calculated Light-Duty Vehicle Emission Factors

Pollutant	**Emission Factor**	
	(g L^{-1})	**(g km^{-1})**
CO	55	6.6
NMOC	7.0	0.84
NO_x	6.7	0.80

Comparison of EF to previous tunnel studies [Adapted from Sawyer et al. (2000)]

Tunnel Location	**Year sampled**	**CO (g/L)**	**NMOC (g/L)**	**NO_x (g/L)**
Tuscarora, Pa	1992	48	2.9	3.9
Baltimore, MD	1992	56/47	4.9/5.0	7.8/5.6
Oakland, CA	1994	77	3.7	7.5
Boston, MA	1995	45	4.5	9.3
New York, NY	1995	39	5.3	11.0
Phoenix, AZ	1995	45	6.1	8.4
Los Angeles, CA	1995	56	5.3	7.3
Van Nuys, CA	1995	91	6.8	7.6
Oakland, CA	1999	39	1.8	4.9
Houston, TX	2000	55	**7.0**	6.7

Comparison of MOBILE5b, MOBILE6, and Tunnel Emission Factors

- VMT calculated from tunnel population

- Age ready vehicle registration distribution was obtained for Harris County (2000) from TCEQ, and was input directly.

Default Settings

- I/M Programs
- Anti-Tampering Rates
- Basic Exhaust Emission rates
- Reid Vapor Pressure
- Operating Modes (hot vs. cold starts)

Assumptions

- One average speed for all vehicles
- Refueling and Idling emissions ignored
- Effect of oxygenated/reformulated fuels neglected
- A/C, Humidity, and Load corrections neglected

Emission Factors for Gasoline Vehicles (g/km)

	Tunnel	MOBILE5b	MOBILE6
NMOC	0.84	0.88	1.2
CO	6.6	6.4	14
NOx	0.80	0.96	0.89

HC Speciation Profiles
Tunnel Emissions

Compound	Wt %
Isopentane	7.7
Methane	7.6
MTBE	6.5
Ethylene	5.4
Toluene	5.1
2,2,4-Trimethylpentane	3.1
Acetylene	3.0
2-Methylpentane	2.7
m-&p-Xylene	2.7
Isobutylene	2.6
Subtotal (top 10)	46%

HC Speciation Profiles
Liquid Gasoline

Compound	Wt %
MTBE	10.9
Toluene	7.3
Isopentane	6.7
2,2,4-Trimethylpentane	5.5
2-Methylpentane	4.1
m-&p-Xylene	3.9
3-Methylpentane	2.7
2,3,4-Trimethylpentane	2.6
n-Hexane	2.5
n-Pentane	2.3
Subtotal (top 10)	49%

HC Speciation Profiles
Gasoline Vapor

Compound	Wt %
Isopentane	23.2
MTBE	16.2
n-Pentane	6.1
2-Methylpentane	5.2
n-Butane	5.1
3-Methylpentane	3.1
2,2,4-Trimethylpentane	2.7
Toluene	2.6
2-Methyl-2-butene	2.5
n-Hexane	2.5
Subtotal (top 10)	69

Conclusions

- CO, NOx, and NMOC emission factors were calculated for light-duty vehicles
  - Washburn CO and NO_X are comparable to those reported in previous studies
  - Washburn NMOC is at high end of range compared to previous studies
- PM2.5 and EC increased as the fraction of heavy-duty vehicles increased

Conclusions (cont.)

- MOBILE6 predictions for CO over twice that provided by tunnel measurements and predicted by MOBILE5b

- HC Speciation profiles were developed for tunnel emissions, liquid gasoline, and gasoline vapor