

The Importance of In-Vehicle Exposures



**Presentation to the
Board**

December 9, 2004

**Dr. Scott Fruin, P.E.
Research Division**

Outline

- **Overview of in-vehicle exposures**
- **In-vehicle studies conducted in CA**
 - **In-vehicle diesel PM exposures calculated from black carbon measurements, 1997 chase study¹**
 - **Ultrafine particle exposures from 2003 measurements on LA freeways²**
- **Implications of in-vehicle exposures**
- **Measures of progress**

¹Rodes et al., 1998; Fruin et al., 2004

²Westerdahl et al., 2004

Overview of In-Vehicle Concentrations

- Air exchange rates in vehicles high
- Concentrations:

In-Vehicle = Centerline > Roadside >> Ambient

Examples of in-vehicle-to-ambient concentration ratios:

Benzene: 4 to 8 times higher¹

Diesel PM: 5 to 15 times higher²

1,3-butadiene: 50 to 100 times higher³

¹Rodes et al., 1998

²Fruin et al., 2004

³Duffy and Nelson, 1997

Overview of In-Vehicle Exposures

- **~90 minutes per day in vehicles**
- **Benzene: 15-20% of total exposure (LA)¹**
- **Diesel PM: 30 - 55% of total exposure (CA)²**
- **1,3-butadiene, ultrafine particles:
likely > 50%**
- **6% of day driving can give up to half
of our exposures**

^{1,2} Fruin et al., 2001; 2004

Estimating In-Vehicle Diesel PM Exposures

- Sacramento and Los Angeles, 1997
- Real-time measures of fine particle counts and black carbon
- Diesel vehicle chase-study design

Charles Rodes et al., 1998. RTI, Sierra Research, Aerosol Dynamics; SCAQMD co-funding

Average Black Carbon Concentration behind Different Vehicle Types, LA:

<u>Vehicle Type Followed</u>	<u>Black carbon ($\mu\text{g}/\text{m}^3$)</u>	<u>Number of vehicles</u>
(Urban background)	~1	
(Roadway background)	4.8	
Diesel tractor trailer	13	47
Diesel transit bus, high exhaust	16	12
Diesel passenger car (PC)	19	8
Gasoline-powered PC, smoky	19	6
Diesel transit bus, low exhaust	95	16
Highest emitter observed	>400	

In-Vehicle Diesel PM Concentrations: Realistic-Driving Conditions

- **High congestion: 11 to 33 $\mu\text{g}/\text{m}^3$ (LA and Bay Area)**
- **Moderate congestion: 6 to 17 $\mu\text{g}/\text{m}^3$**
- **5 to 15 times calculated ambient concentrations**
- **30 to 55% of total diesel PM exposure**
 - **In-vehicle time most important route of exposure on a per-time basis**

1997 In-Vehicle Exposure Results

- On-road diesel PM emissions very effective at producing exposures
- On-road reductions yield 2 to 5 times more health benefit than equal off-road reduction

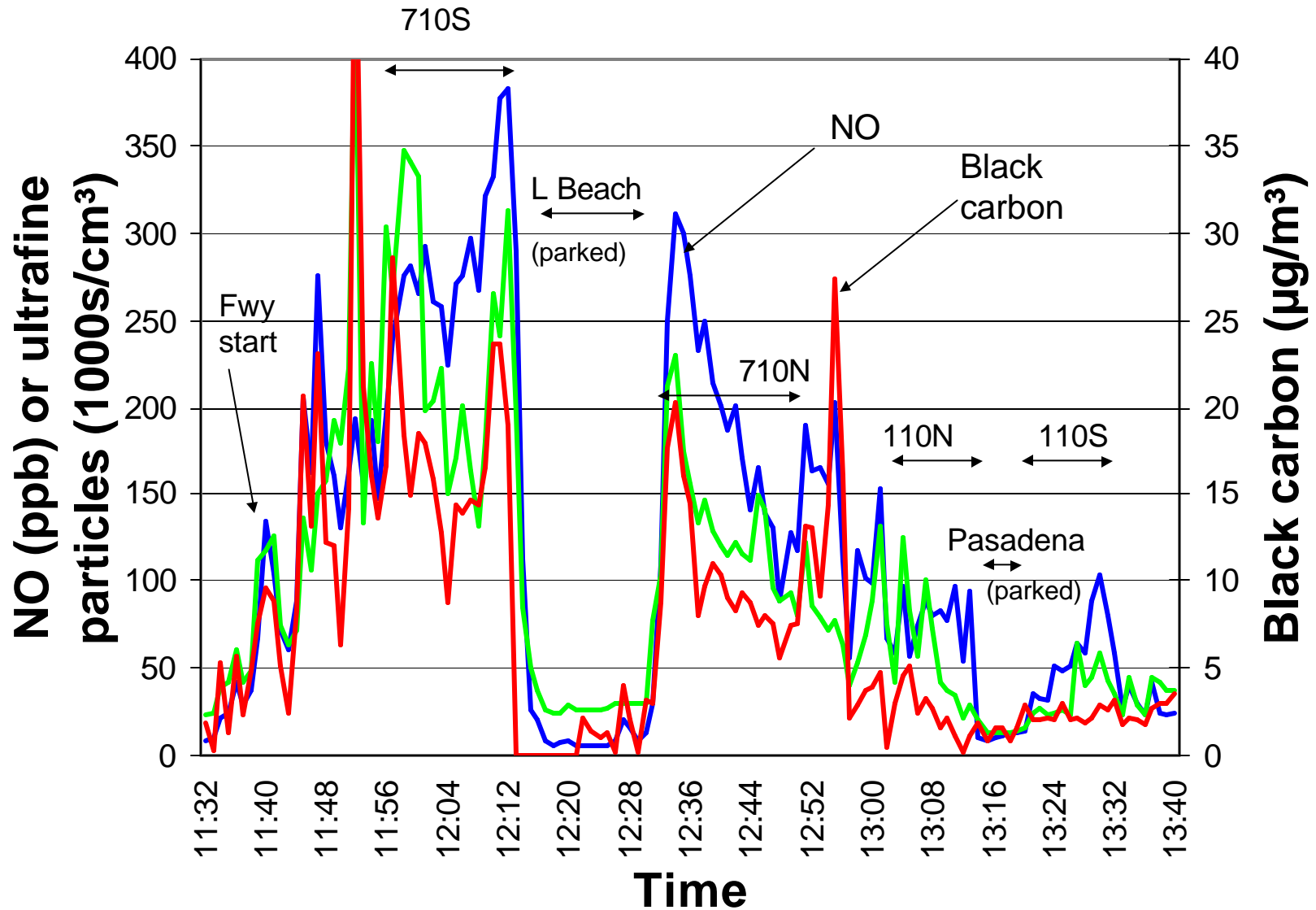
2003 Field Study Route



Continuous pollutant measurements:

Black carbon, ultrafine particles, NO, NO₂, CO, CO₂, particle-bound PAHs, PM_{2.5}

Time Series: NO, Ultrafine Particle Number, and Black Carbon



High Emitter of Black Carbon, PM2.5



High Ultrafine Particle Emitter

Diesel truck, no visible emissions



High Ultrafine Particle Emitter

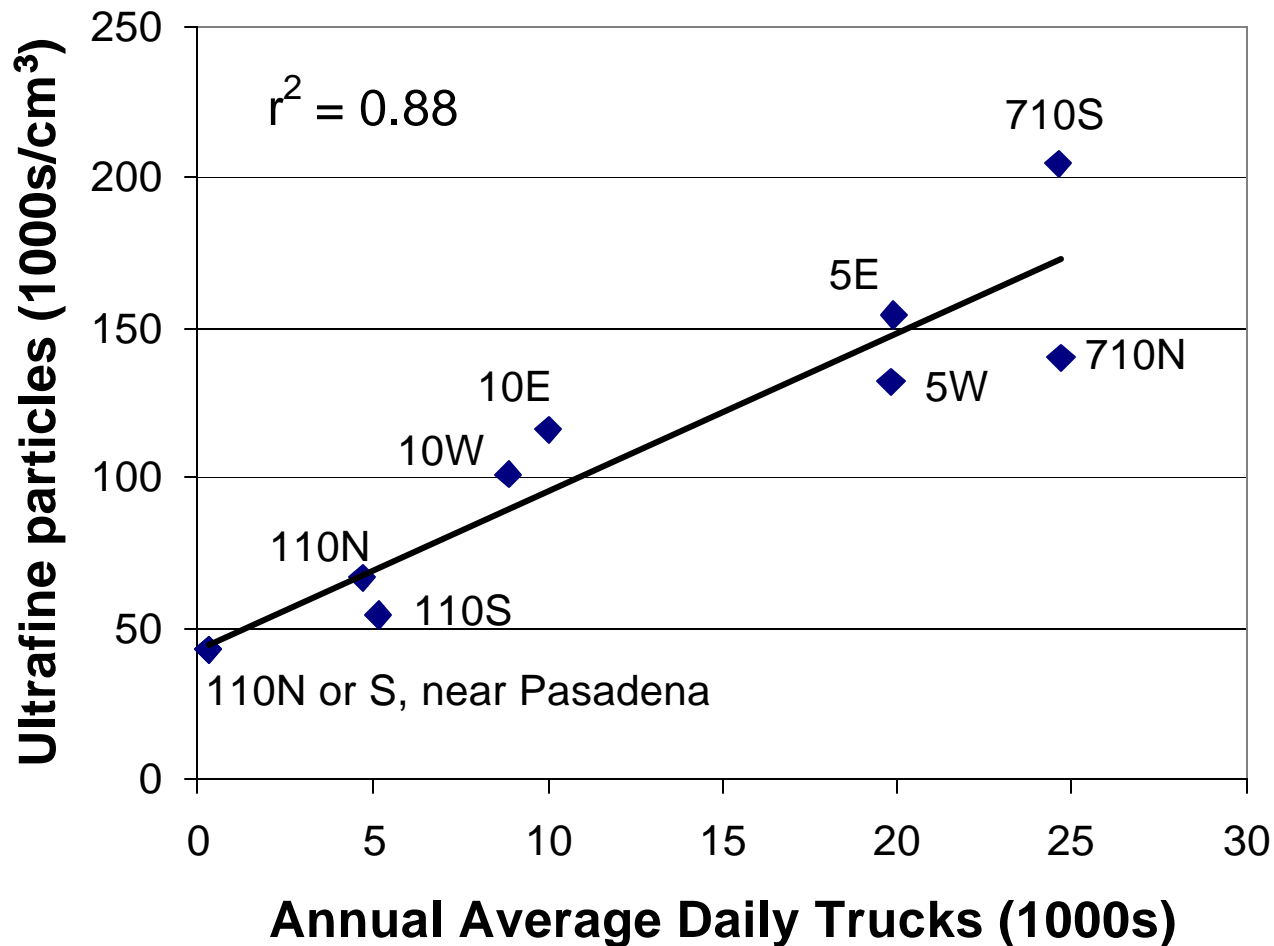
Gasoline-powered van



Average In-Vehicle Concentrations for Four Days

Location or roadway	Ultrafine particle conc. (#/ cm ³)	NO (ppb)	Black carbon (μg/m ³)	CO ₂ (ppm)	Avg. min. per run
Residential Street (Long Beach)	27,000	19	1.4	420	14
110N freeway near Pasadena (~300 trucks/day)	43,000	150	1.6	770	15
110N freeway (~3000 trucks/day)	67,000	230	3.9	850	10
710S freeway (~25,000 trucks/day)	200,000	400	14	850	21

Ultrafine Particle Number by Freeway Segment versus Average Daily Truck Count



In-Vehicle Fraction of Total Ultrafine Particle Exposure

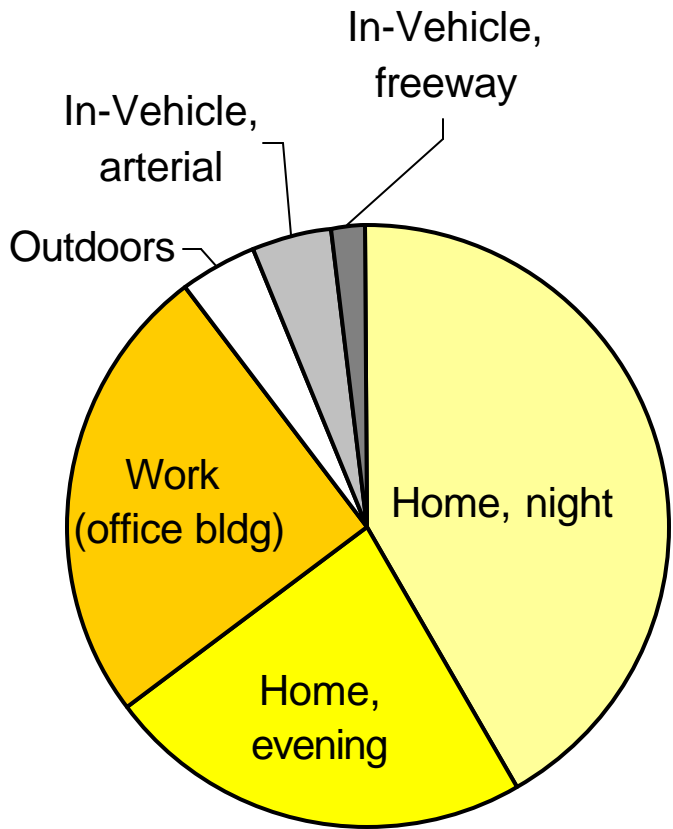
- Average ultrafine particle number and time spent:

<u>Location</u>	<u>Time (Hrs)</u>	<u>Concentration (1000s/cm³)</u>
Residential	9	2 (night) ¹
Residential	5.5	5 (evening) ¹
Workplace	7	5
Outdoors	1	20
In-vehicle arterial	1	50
In-vehicle freeway	0.5	150

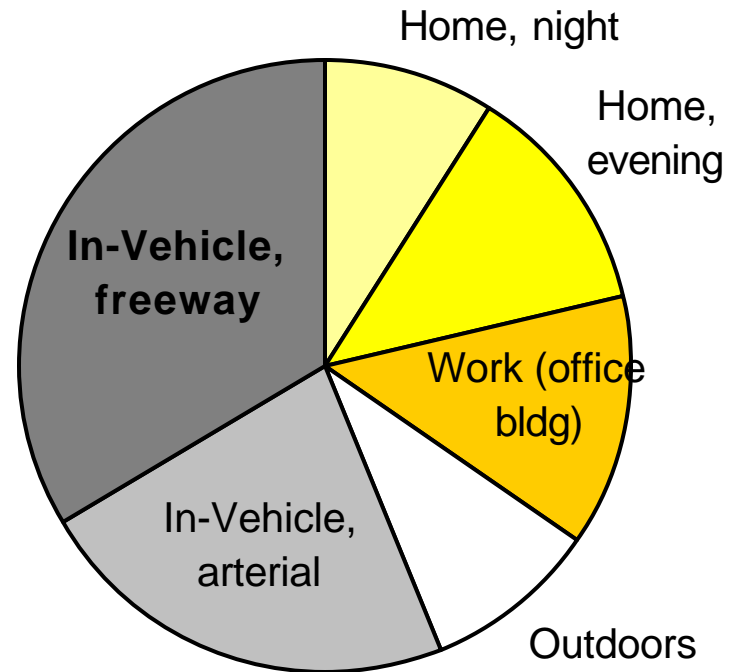
- >50% exposure from in-vehicle time

¹Wallace et al., 2004

In-Vehicle Fraction of Total Ultrafine Particle Exposure



Average Time Spent



Contribution to Exposure

In-Vehicle Studies as Measure of Progress

- **Similar to tunnel studies**
- **Gasoline-powered vehicle success:**
1987 ambient VOC concentrations in LA¹ ~
1997 in-vehicle concentrations²
- **Diesel-related:**
Results more mixed

¹Shikiya et al., 1989

²Rodes et al., 1998

Take Home Messages

- **In-vehicle exposures important to overall exposures to vehicle-related pollutants**
- **Ultrafine particle exposure depends on:**
 - **Length of your commute**
 - **Diesel truck volumes**
 - **Types of vehicles followed**

Take Home Messages

- **Location of emissions matter:**
 - On-road emissions produce greater overall exposures than off-road
 - Exhaust at low and rear of vehicle produces greater in-vehicle impacts than exhaust at high and front of vehicle
- **Reductions in on-road diesel emissions are critical to reducing in-vehicle exposures**

Do In-Vehicle Particles Play an Important Role in Heart Disease?

- Recent study found association with being in traffic and heart attack in following hour¹
- Study of North Carolina troopers found changes in cardiac rhythm and blood markers of inflammation and coagulation²
- Proposed ARB study of ultrafine particles from freeway driving and cardiovascular and blood marker symptoms

¹Peters et al., 2004

²Reidiker et al., 2004