Catalyst-based Diesel PM Filters: Summary of ARB Findings on Emissions, Exposure and Health

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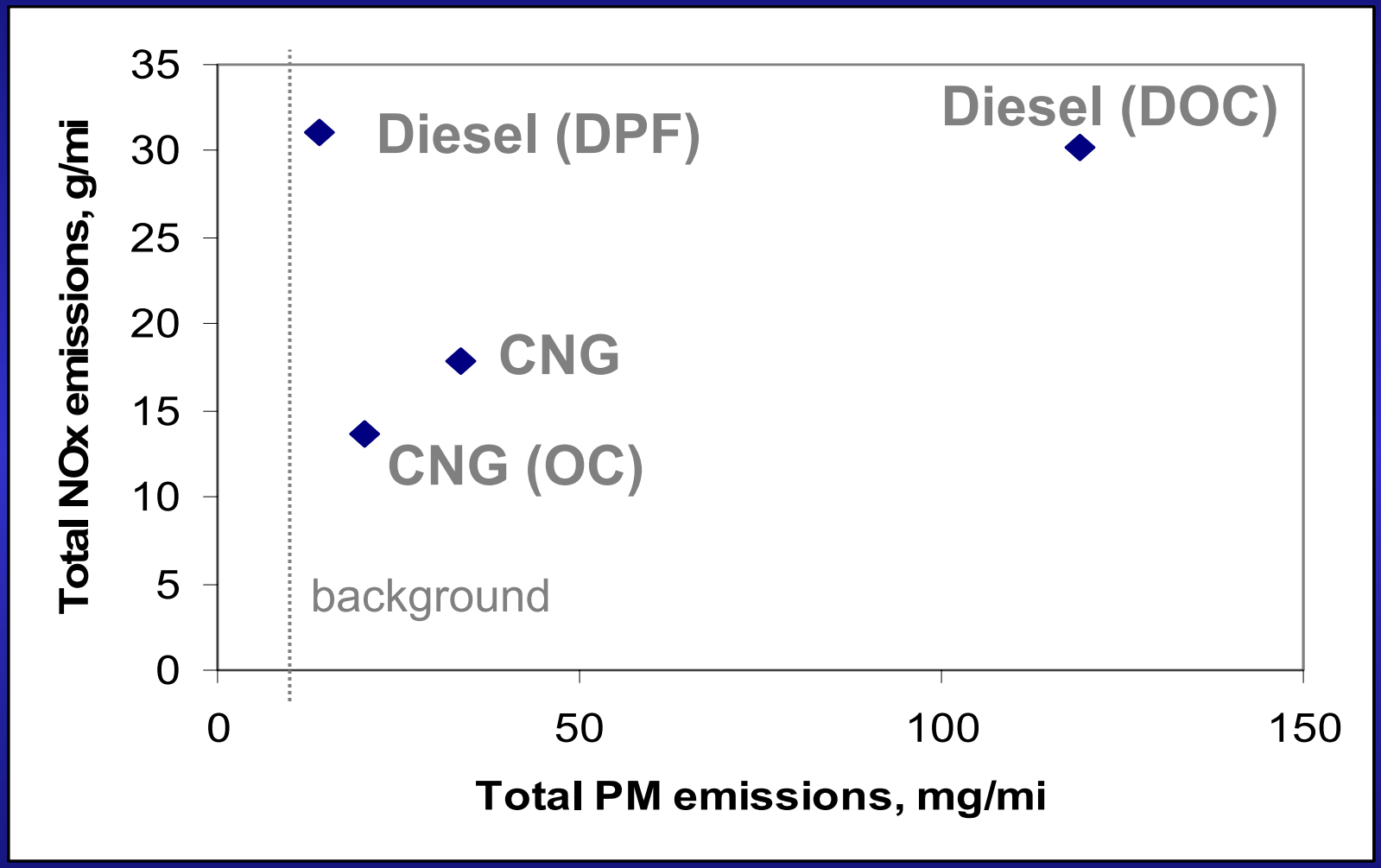
California Environmental Protection Agency

Air Resources Board

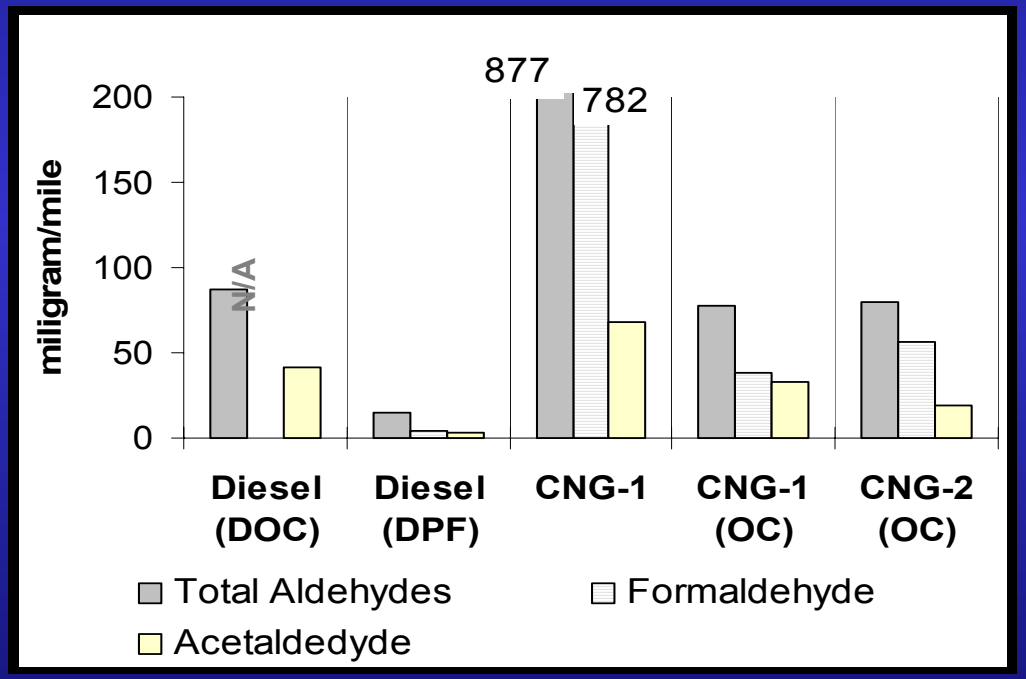
NO_X and PM Emissions (CBD)



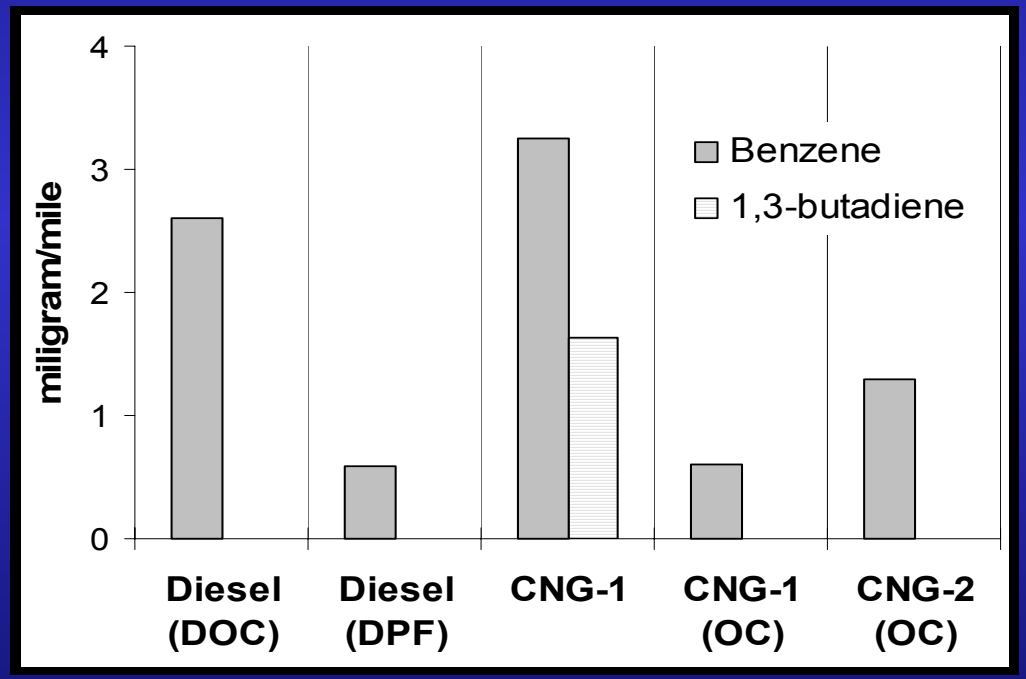
www.arb.ca.gov/research/cng-diesel/cng-diesel.htm

Non-regulated Emissions (CBD)

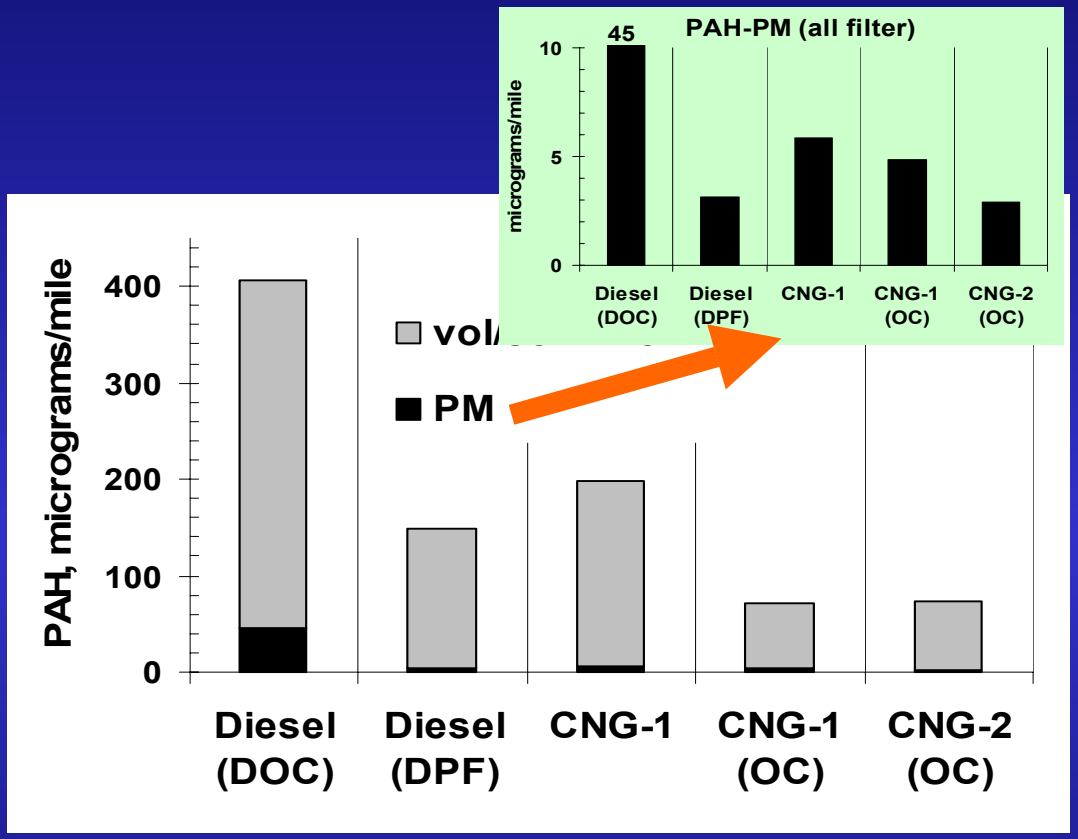
Carbonyls

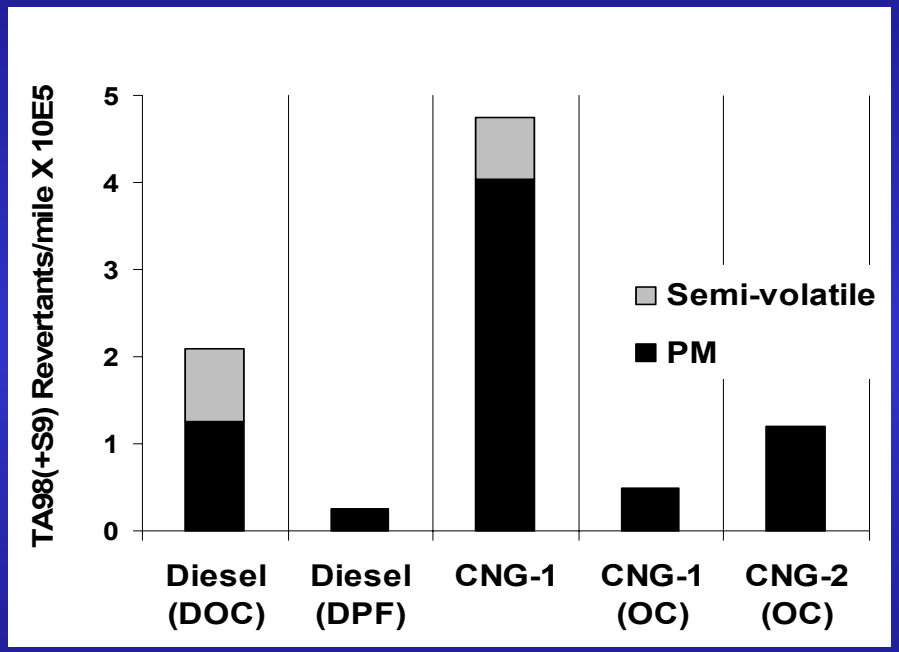


VOCs



Non-regulated Emissions (CBD), cont'd



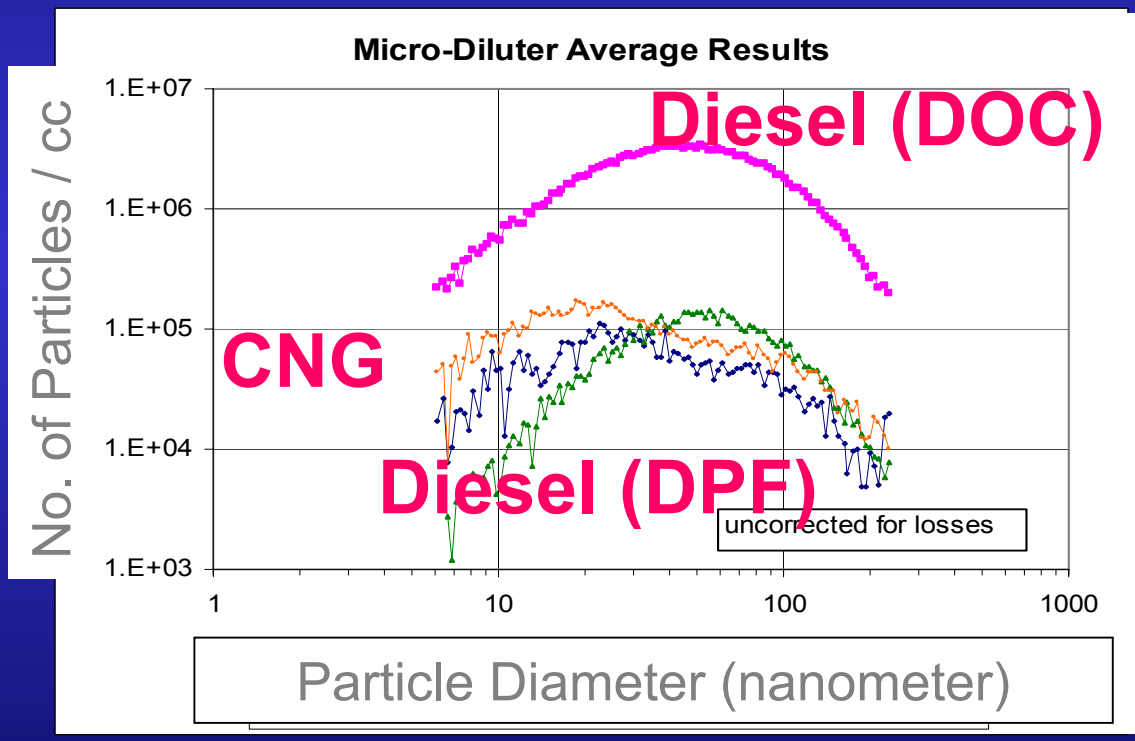


Polycyclic Aromatic Hydrocarbons

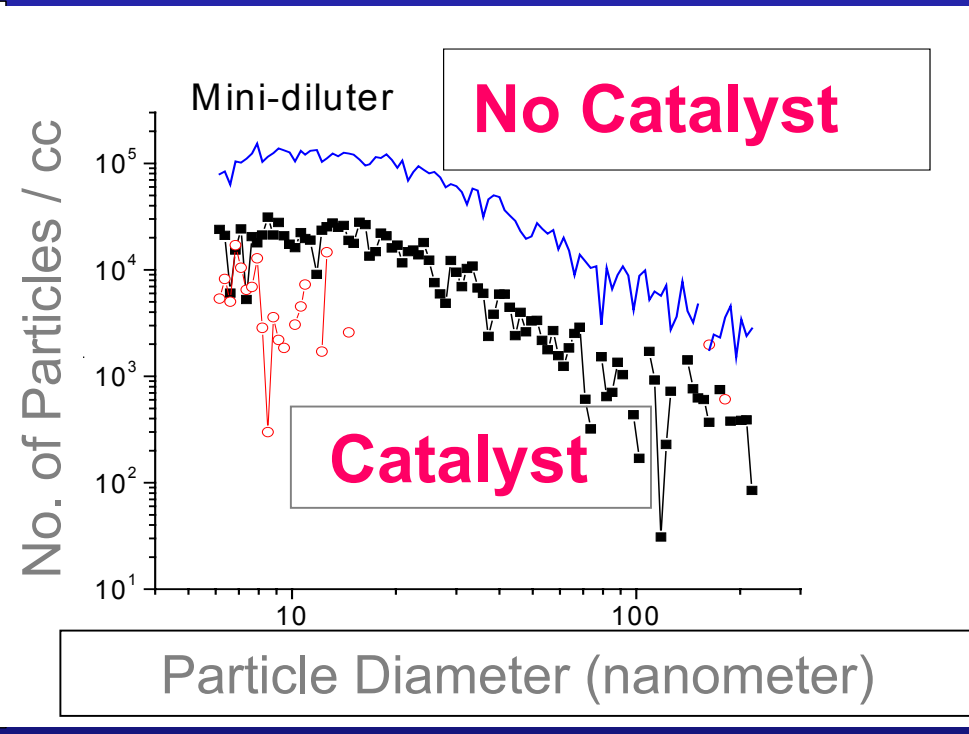
Mutagenicity

Ultrafine PM Size Distribution (55 mph Cruise)

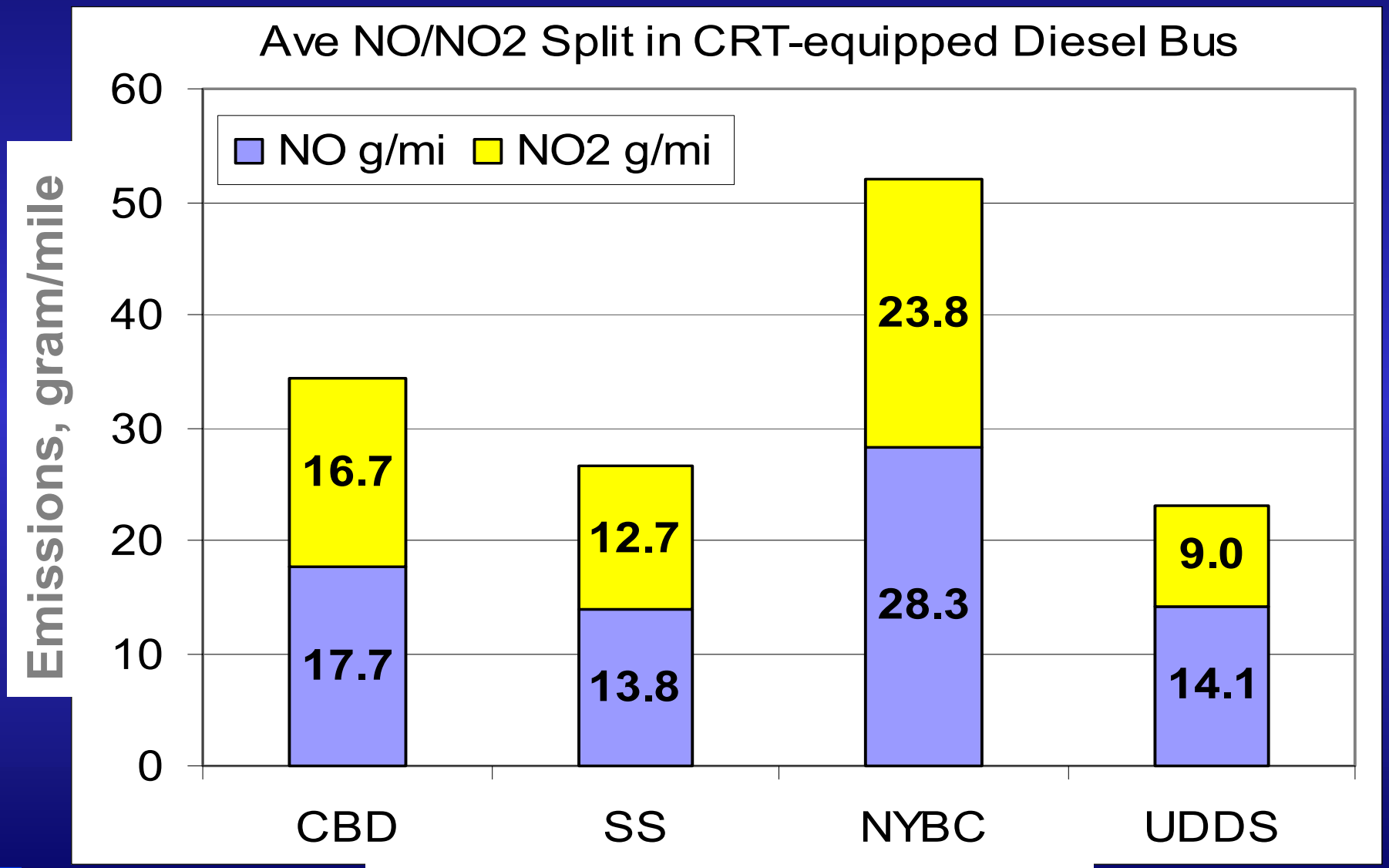
Diesel and CNG



CNG Oxidation Catalyst



NO and NO_2 Emissions



Directly-emitted NO_2 Accelerates Photochemistry

- Ozone function of NO_2/NO ratio and sunlight

- NO $\longrightarrow$ NO_2
  a) Tailpipe (~5%)
  b) Exhaust Plume (~5%) – NO > 1 ppm, low T
  c) Ozone Mixing – limited by available ozone, temporarily destroys ozone
  d) VOCs (remaining 90%)

- $NO_2 \longrightarrow HNO_3$ (nitric acid) $\longleftrightarrow NH_4NO_3$ (secondary PM2.5)

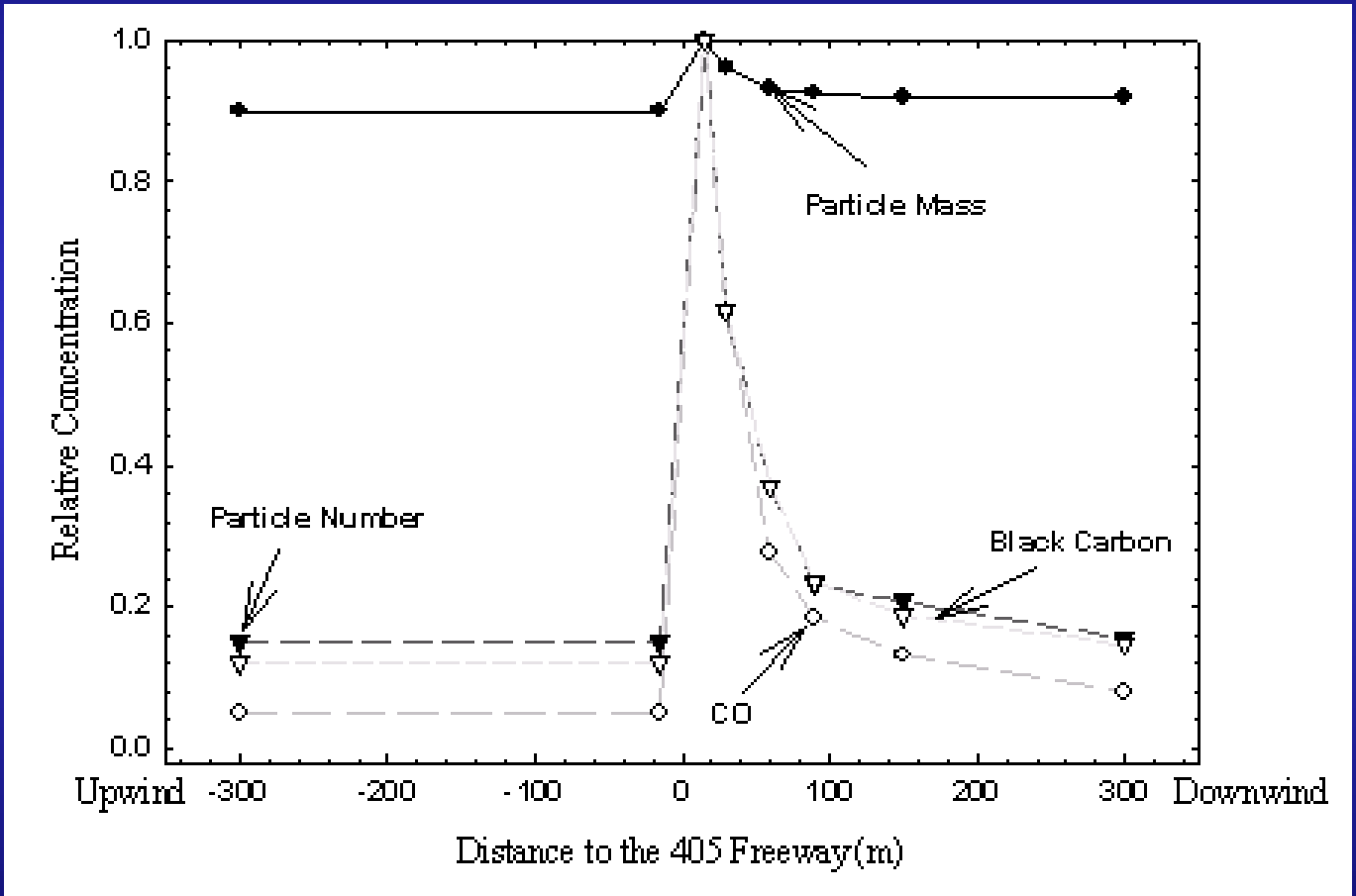
  (sunlight, ozone, VOCs) (NH_3, low T, high RH)

Photochemical Modeling Results

NO_2/NO_x (inc. 5% formation in exhaust plume)	15%	20%	25%	30%	50%
SUMMER	**% change** from baseline (diesel NO_2/NO_x = 10%)				
Peak 1-Hr O_3	**-1**	**0**	**0**	**0**	1
24-Hr O_3 Exposure > 90 ppb	**-3**	**-2**	**0**	2	5
Peak 24-Hr HNO_3	**0**	1	1	1	2
24-Hr HNO_3 Exposure	**0**	**0**	2	2	4
Peak 24-Hour $PM_{2.5}$	**-3**	N/A	N/A	**-2**	**-1**
24-Hour $PM_{2.5}$ Exposure > 65 ug/m^3	**-9**	N/A	N/A	**-8**	**-6**
FALL					
Peak 24-Hour $PM_{2.5}$	**-6**	N/A	N/A	**-5**	**-3**
24-Hour $PM_{2.5}$ Exposure > 65 ug/m^3	**-13**	N/A	N/A	**-13**	**-13**
WINTER					
Peak 1-Hr NO_2	1	6	12	18	41

Numbers in **light blue** represent simulated air quality benefits or no change

Is there a near-source NO_2 exposure problem?



Source: Zhu et al. (2002)

NO_2 Exposure Modeling and Screening Analysis

Modeling

- Assumptions
  - 40% NO_2
  - 90% penetration
  - Worst-case background
- Results (1-hour peak)
  - 0.180 ppm Freeway
  - 0.170 ppm 20 Idling School Buses

Measurement-based

- Assumptions
  - 20% NO_2
  - 90% penetration
  - Limited background analysis
- Results (15-minute peak)
  - 0.085 ppm Freeway
  - 0.028 ppm Self-pollution
  - 0.071 ppm Following
  - 0.184 ppm Total

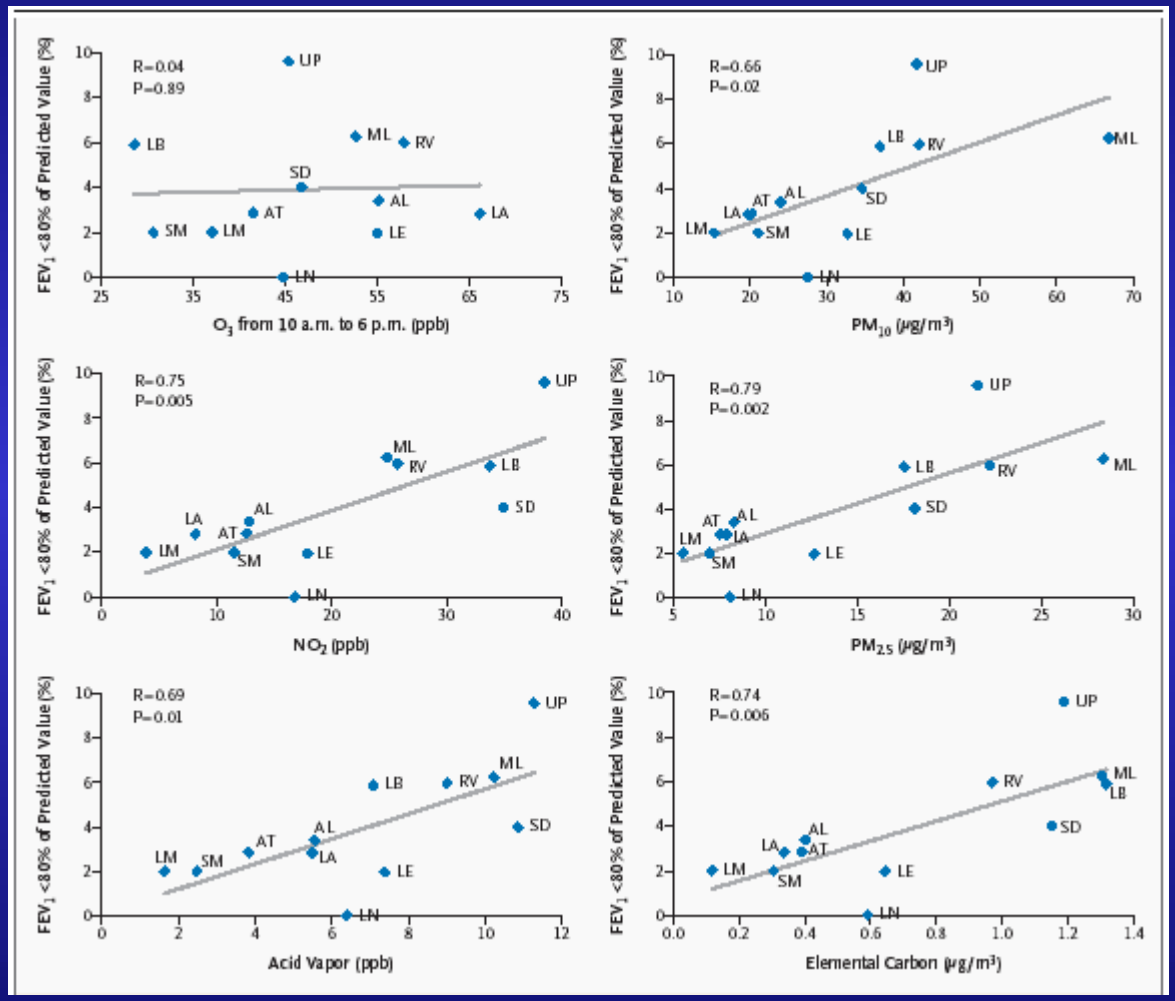
1-hour SAAQS = 0.25 ppm (0.37 ppm for 15 minutes)

Health Perspective

	Diesel PM	PM2.5	Ozone	NO_2
State Standard	no threshold	12 µg/m^3 (annual)	0.09 ppm (1-hour)	0.25 ppm (1-hour)
Exposure	1.8 µg/m^3 (avg. pop.)	18.5 µg/m^3 (avg. pop.)	0.19 ppm (2003 peak)	0.16 ppm (2003 peak)
Annual Health Impact	2000 deaths 250 cancers	6500 deaths	640 deaths (under review)	none

Sources: Lloyd and Cackette (2001), PM and Ozone Standard Reviews

CHS Lung Function Findings



Source: Gauderman et al. (2004)

Engine-out NO_2 Emissions

On-Road

Project/Lab	Test Vehicles / Engines	Average Engine-Out NO2
ECD Tech. Validation Project	21 vehicles '95-99 MY	5%
ARB	5 vehicles '87-00 MY	6%
Environment Canada	1 engine '01 MY	7%
Engine Mfr 1	1 engine '99 MY	6%
Highest Reported	1 engine '99 MY	21%

Engine-out NO_2 Emissions

Off-Road

Project/Lab	Test Vehicles / Engines	Average Engine-Out NO2
Engine Mfr 2	14 engines, elec. ctrl '99-01 MY	5%
Engine Mfr 2	4 engines, mech. ctrl. '00 MY	12%
Engine Mfr 3	3 engines "newer" MY	9%
SwRI (for ARB)	2 engines '99 MY	13%
Highest Reported	1 engine '99 MY	17%

Conclusions

- Catalyst-based diesel PM filters provide 80-95% reductions in PM, toxic VOCs and ultrafine PM, but increased NO_2/NO_X fraction
- NO_2 accelerates ozone, nitric acid and secondary PM2.5 formation
- Photochemical modeling shows 15% NO_2 (over 5% baseline) offset by 90% VOC reduction
- No near-source NO_2 exceedances expected with 20% limit
- 5% NO_2 baseline representative – higher values observed, but not typical