# STUDY OF CNG AND DIESEL TRANSIT BUS EMISSIONS

April 22, 2004

Air Resources Board
California Environmental Protection Agency

# Presentation Outline


- Project goals
- Description of emissions testing
- Highlights from study results
- Final remarks

# Project Status

- Testing : 2001 - 2002
- Results reported at various venues:
  - publications
  - technical presentations
- Information in website:
  - http://www.arb.ca.gov/research/cng-diesel/cng-diesel.htm

# Acknowledgements


- ARB multi-division effort:
  - Research Division
  - Stationary Source Division
  - Mobile Source Control Division
  - Monitoring and Laboratory Division
- Collaborators:
  - University of California, Davis
  - University of Connecticut
  - Clean Air Vehicle Technology Center
  - South Coast AQMD (co-funding)
  - The Gas Company (co-funding)
  - CA Natural Gas Vehicle Coalition
  - BP (fuel donation)
  - Los Angeles County Metropolitan Transit Authority

# PROJECT GOALS

- Compare “clean” technology options for HD transit buses
- Fill research data gaps:
  - Evaluation of fuel and after-treatment
  - Assessment of driving cycle effects
  - Measure exhaust components of toxic risk significance
  - Investigation of ultrafine (<0.1μm) particle tailpipe emissions

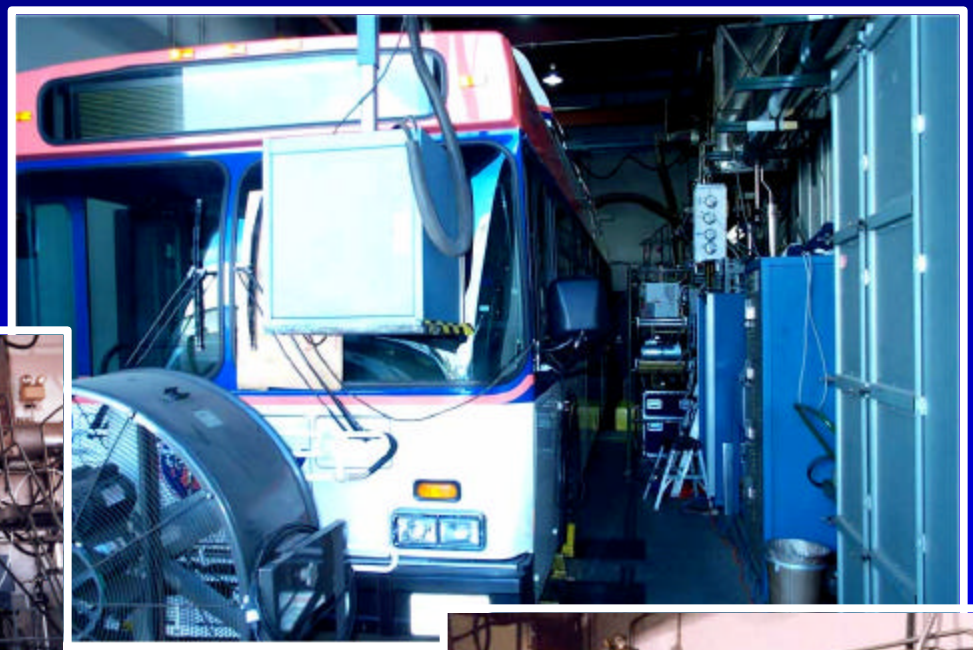
# Three Test Buses*

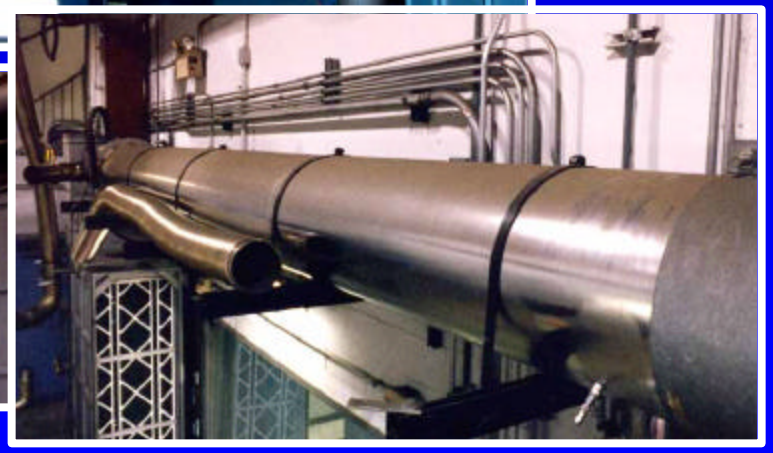
| | Model Year | Engine Make | After-treatment | Fuel |
|---|---|---|---|---|
| **Diesel** | 1998 | DDC-S50 | DOC<br>CB-DPF | ULSD |
| **CNG-1** | 2000 | DDC-S50G | none<br>OC | CNG |
| **CNG-2** | 2001 | Cummins-Westport C-Gas Plus | OC | CNG |

***All 40 passenger, New Flyer chassis from So.Cal. public fleets tested "as-is"**

# Test Facility

## CARB Heavy- duty Emissions Testing Laboratory
## Los Angeles





# After-treatment for Transit Buses


## DIESEL TRAP

**Catalyst-based DPF (CRT™ by JMI)**

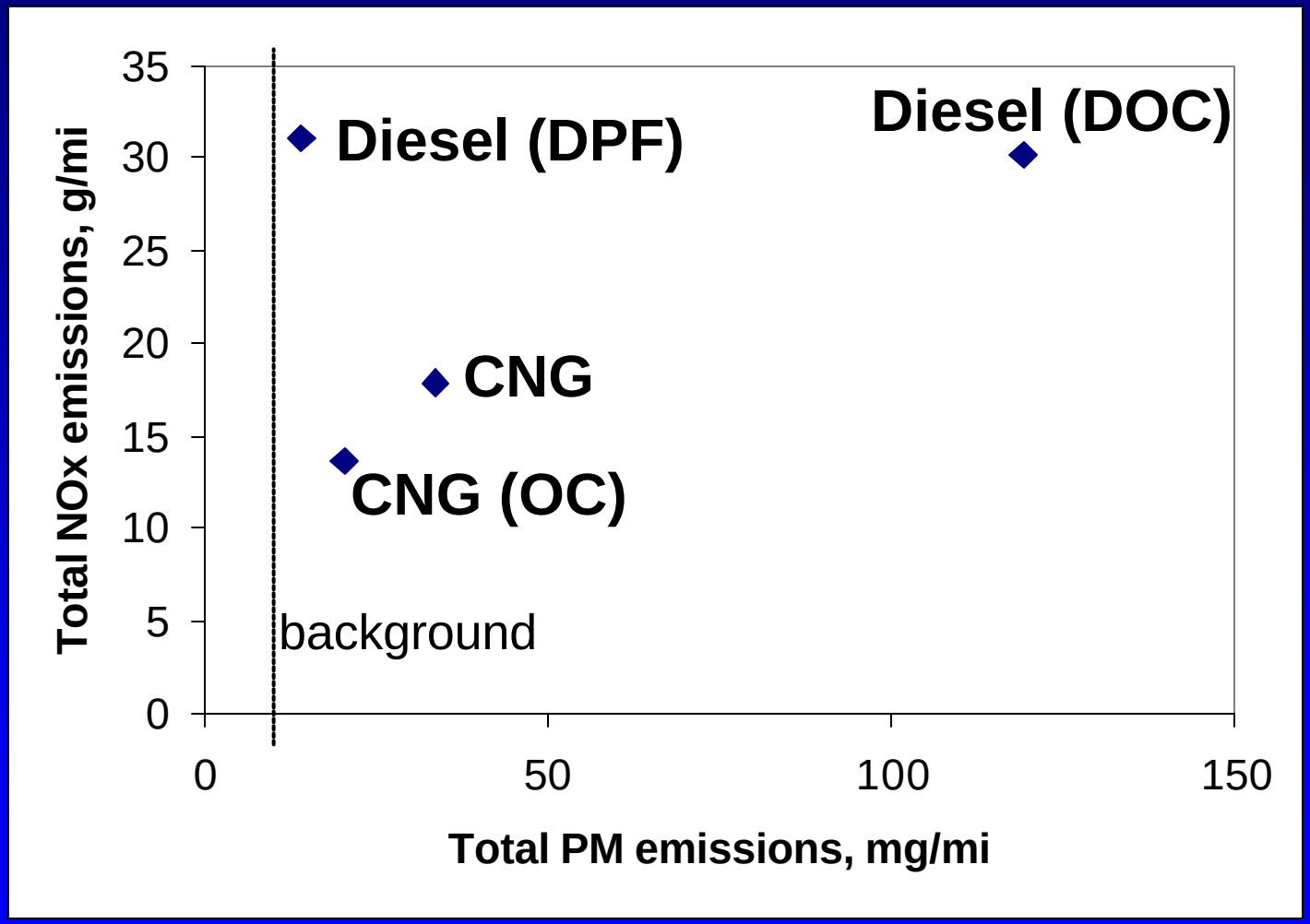
## CNG

**Oxidation Catalyst**

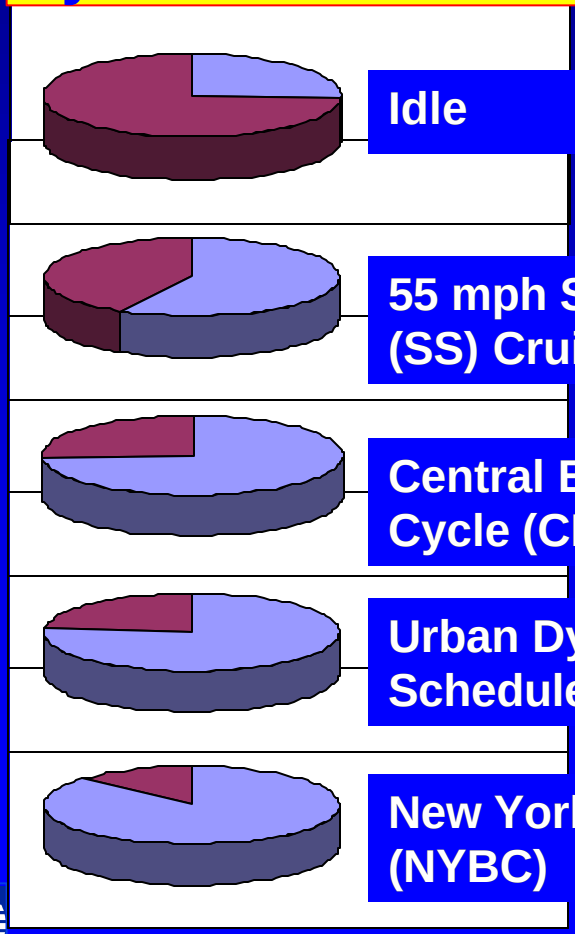
# Experimental Approach

- Focus on criteria emissions and other pollutants of toxic significance
- Gaseous emissions:
  - $NO_X$, $NO_2$, CO, $CO_2$,
  - Total Hydrocarbons, $CH_4$/NMHC, and VOCs
- Particulate matter emissions:
  - Total PM, metals, and elemental and organic carbon
  - Ultrafine particle number and size
- Phase distribution (PM / volatile / semi-volatile) of:
  - Mutagenicity via bioassay (modified Ames Assay)
  - Polycyclic aromatic hydrocarbons

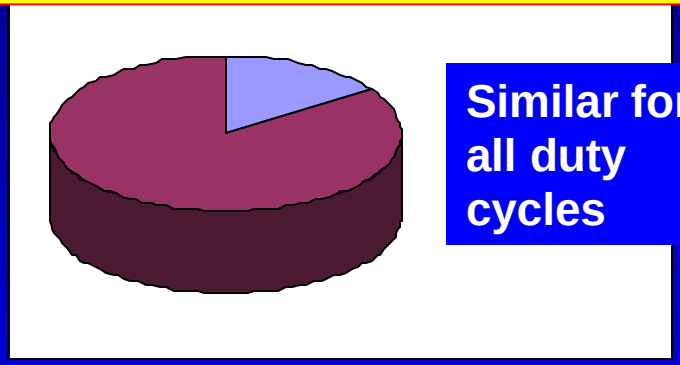
# $NO_x$ and PM Emissions (CBD)



## Diesel PM composition depends on duty cycle



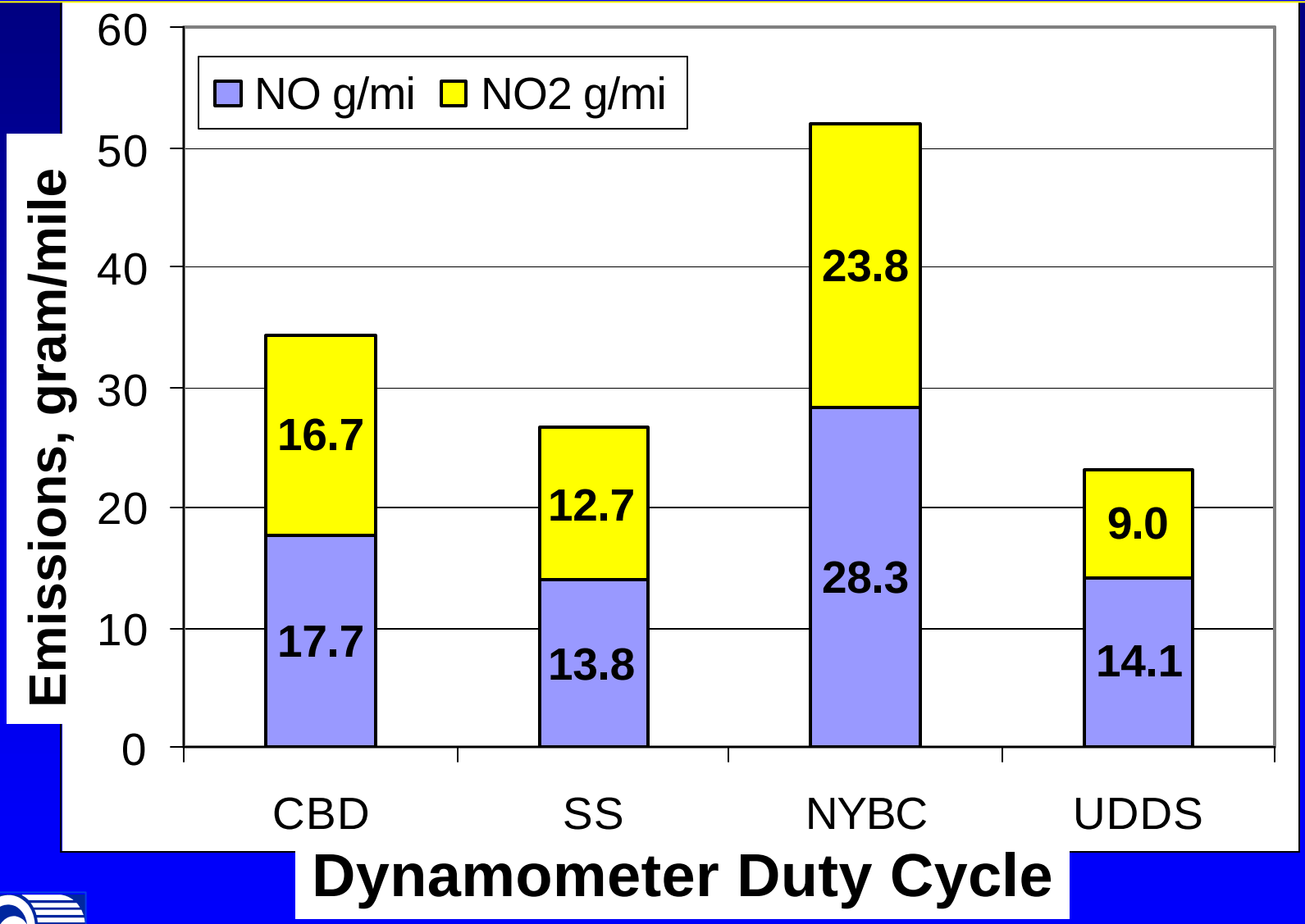

## Diesel trap PM and CNG PM composition less dependent on duty cycle




Elemental Carbon

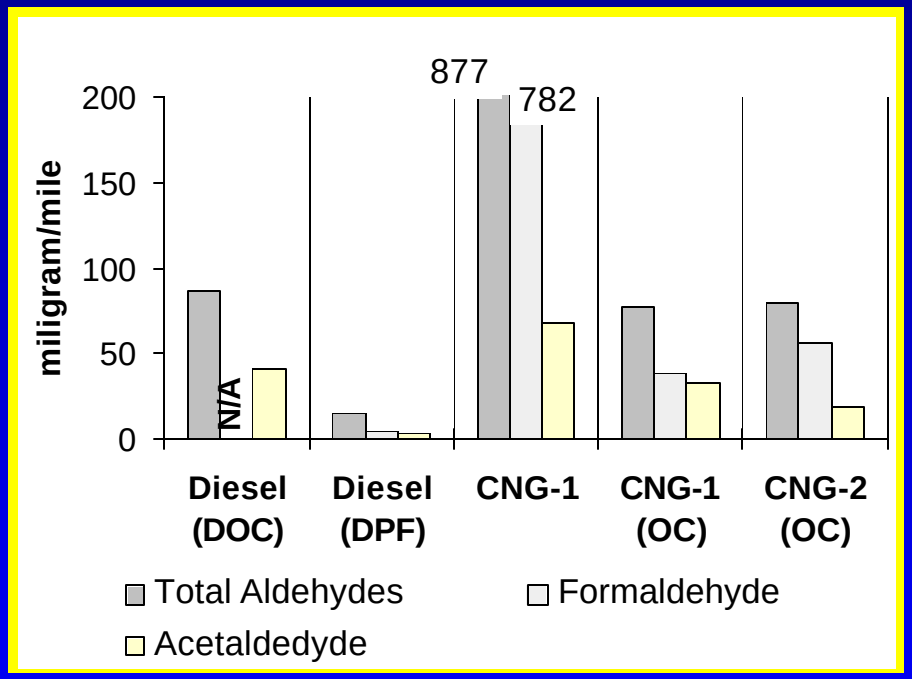
Organic Carbon

# NO & $NO_2$ Emissions from Trap-equipped Diesel

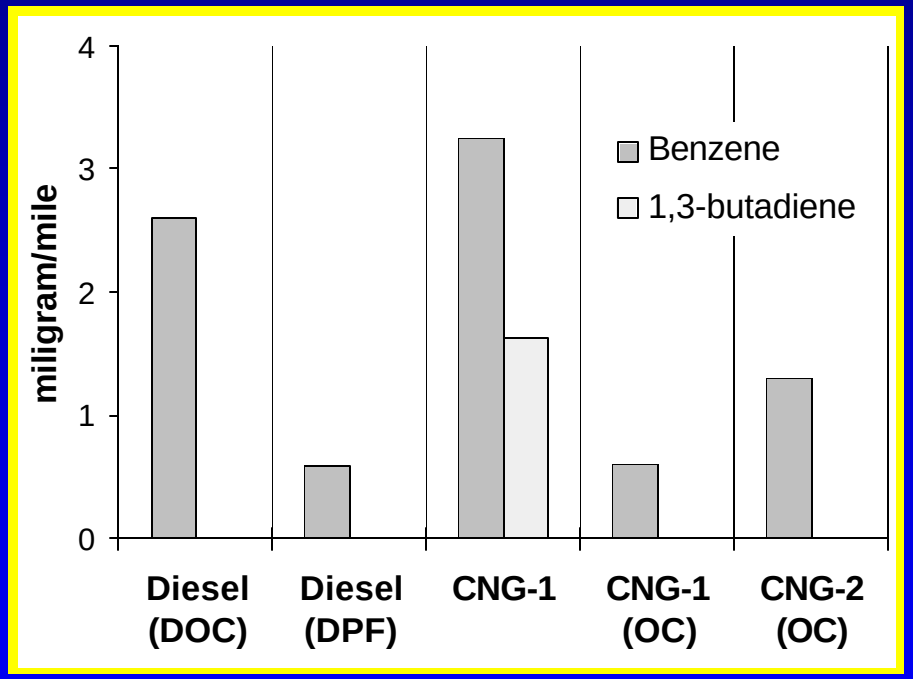


# Non-regulated Emissions (CBD)

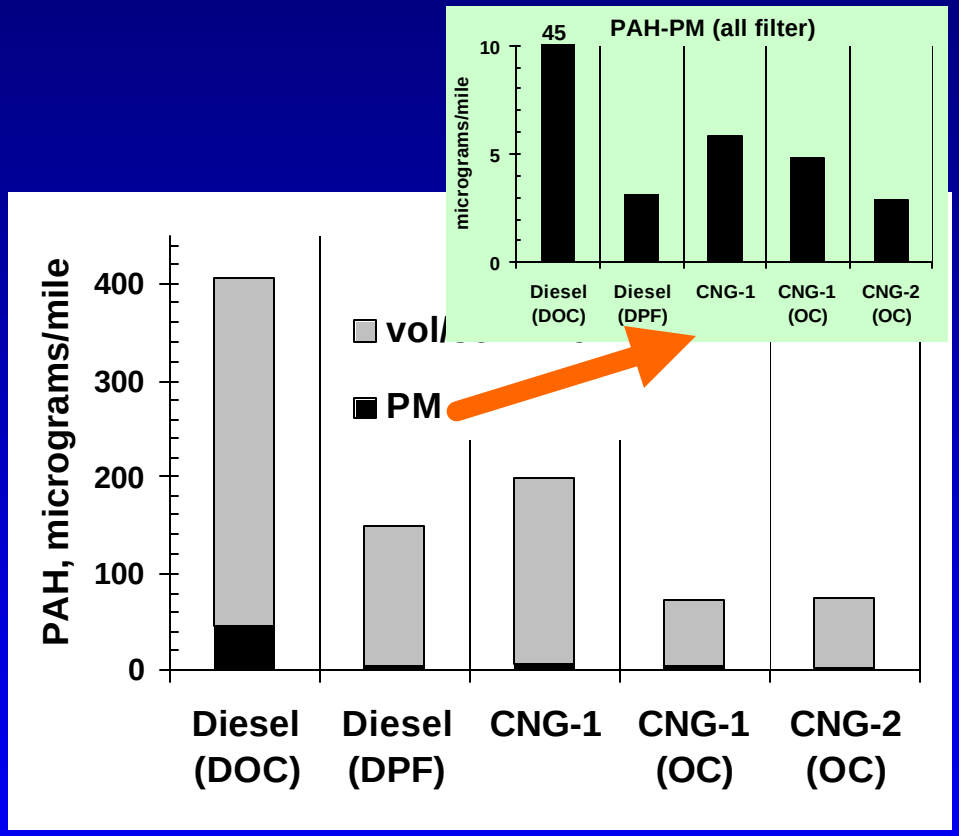
## Carbonyls

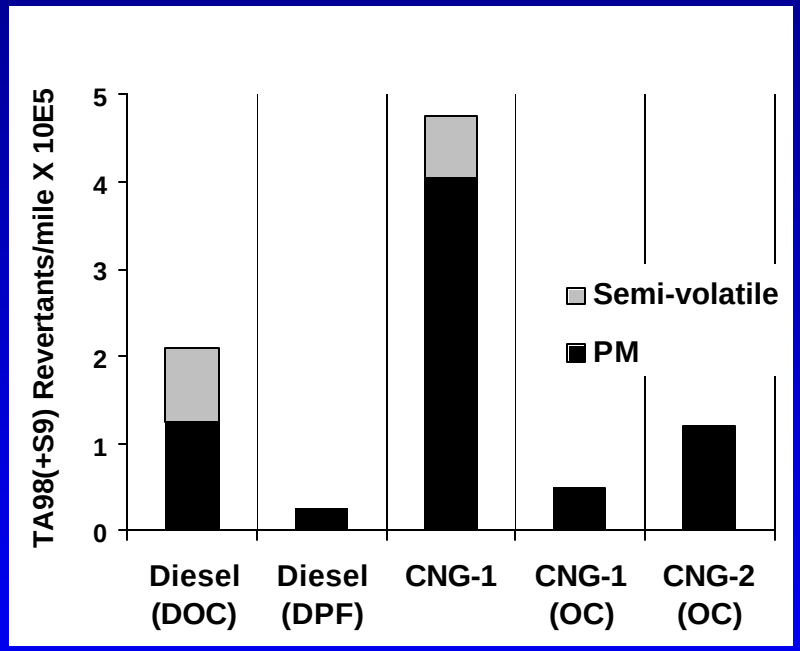



## VOCs



# Non-regulated Emissions (CBD) – cont'd



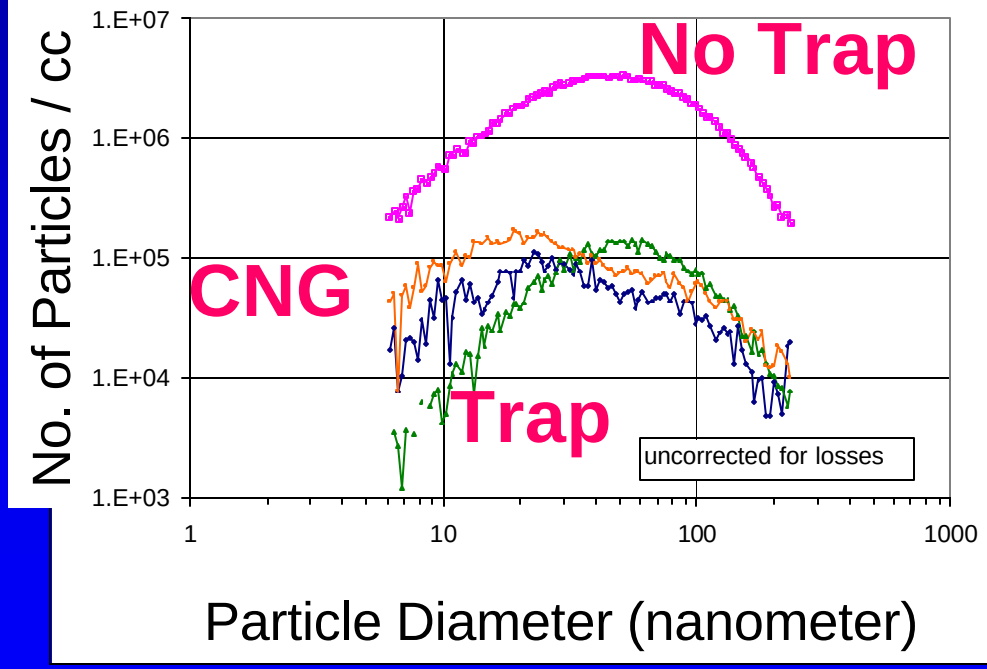




**Polycyclic Aromatic Hydrocarbons**

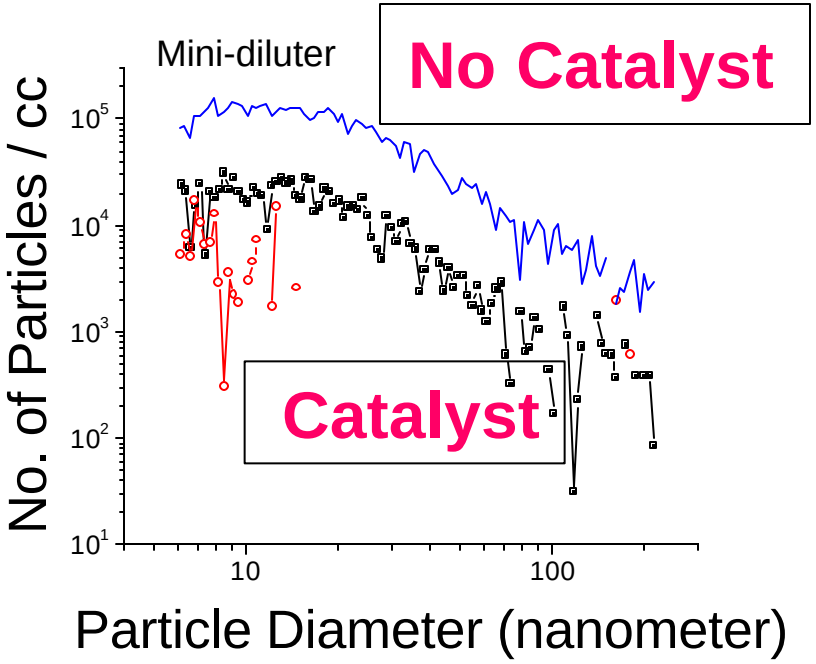
**Mutagenecity**

# Ultrafine Particle Size Distribution

## Trap Diesel and CNG Comparison




## Oxidation Catalyst for CNG



# Final Remarks

- "Clean" alternatives can benefit from additional control and improvement
- Diesel trap changes PM composition, reduces toxic emissions, but emits high $NO_2$
- CNG emits lower $NO_X$, but higher formaldehyde. Catalyst reduces formaldehyde
- Lubricating oil most likely plays a key role in PM toxicity
- When comparing results, difficulty arises because diesel PM is a TAC whereas CNG PM has no such designation
- ***Durability, deterioration, and maintenance were not evaluated***