Diesel Exhaust and Human Health

Presented to the
Regional Science Council
June 7, 2006

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Overview

- Composition of Diesel Exhaust
- Health Effects, Cancer Dose-Response
- Ambient Monitoring
- Diesel Impacts in Region 9
- Control Technologies
- Impacts of Rules
- Ongoing Research Needs

Composition of Diesel Exhaust

Gas-Phase:

- Carbon Dioxide,
- Water Vapor,
- Carbon Monoxide,
- Nitrogen compounds,
- Sulfur compounds,
- Hydrocarbons, and
- Air Toxics, including formaldehyde, acetaldehyde, acrolein, benzene, 1,3-butadiene, polcyclic aromatic hydrocarbons (PAHs) and nitro-PAHs

Particulate Matter:

- Central core of Elemental Carbon
- Adsorbed organic compounds,
- Sulfates,
- Nitrates, and
- Metals

- Composition varies significantly with different engine types (heavy duty, light duty), operating conditions (idle, accelerate, decelerate), and fuel formulations (high/low sulfur fuel)

Typical Diesel Particle Size Distribution

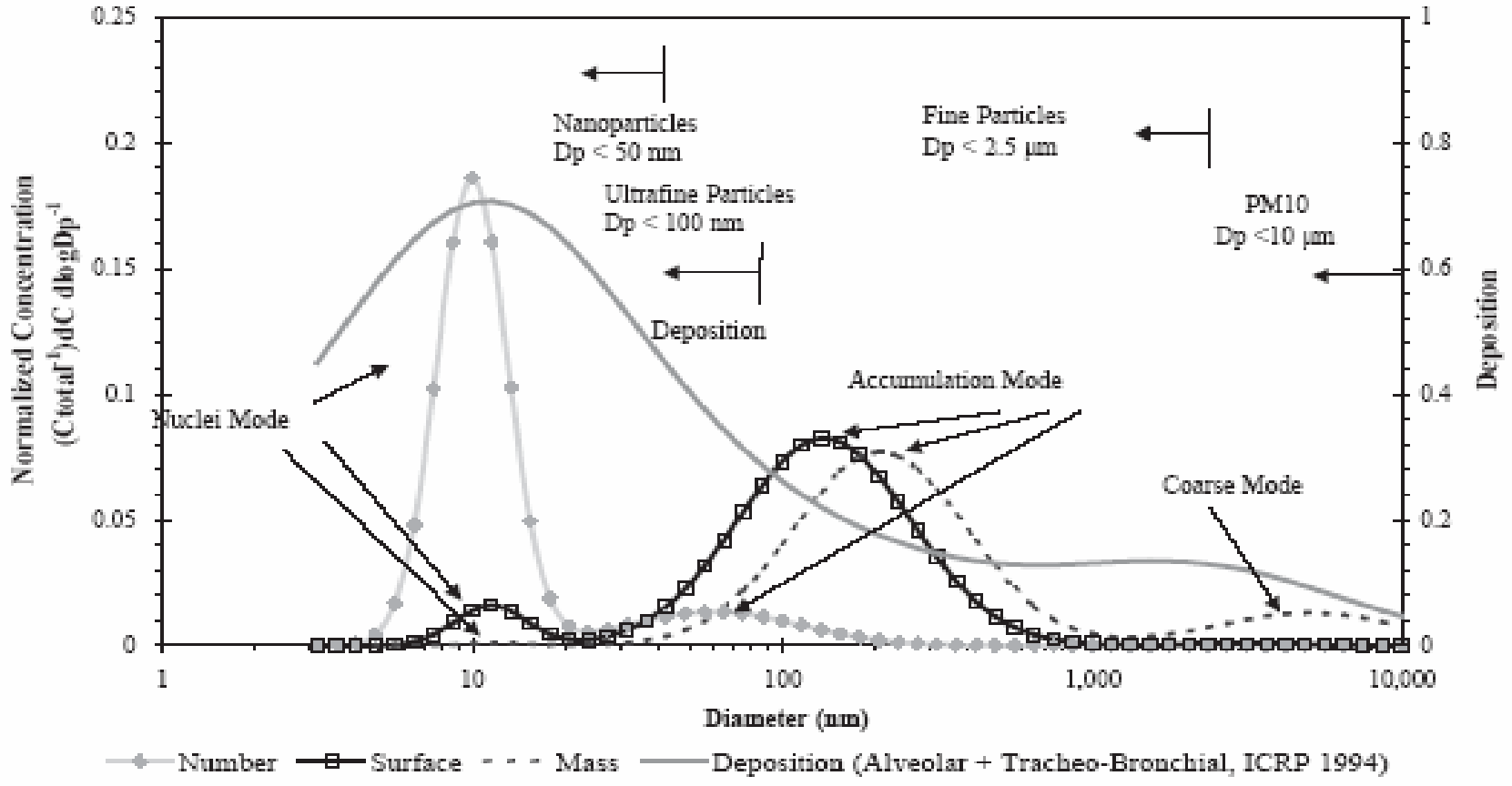
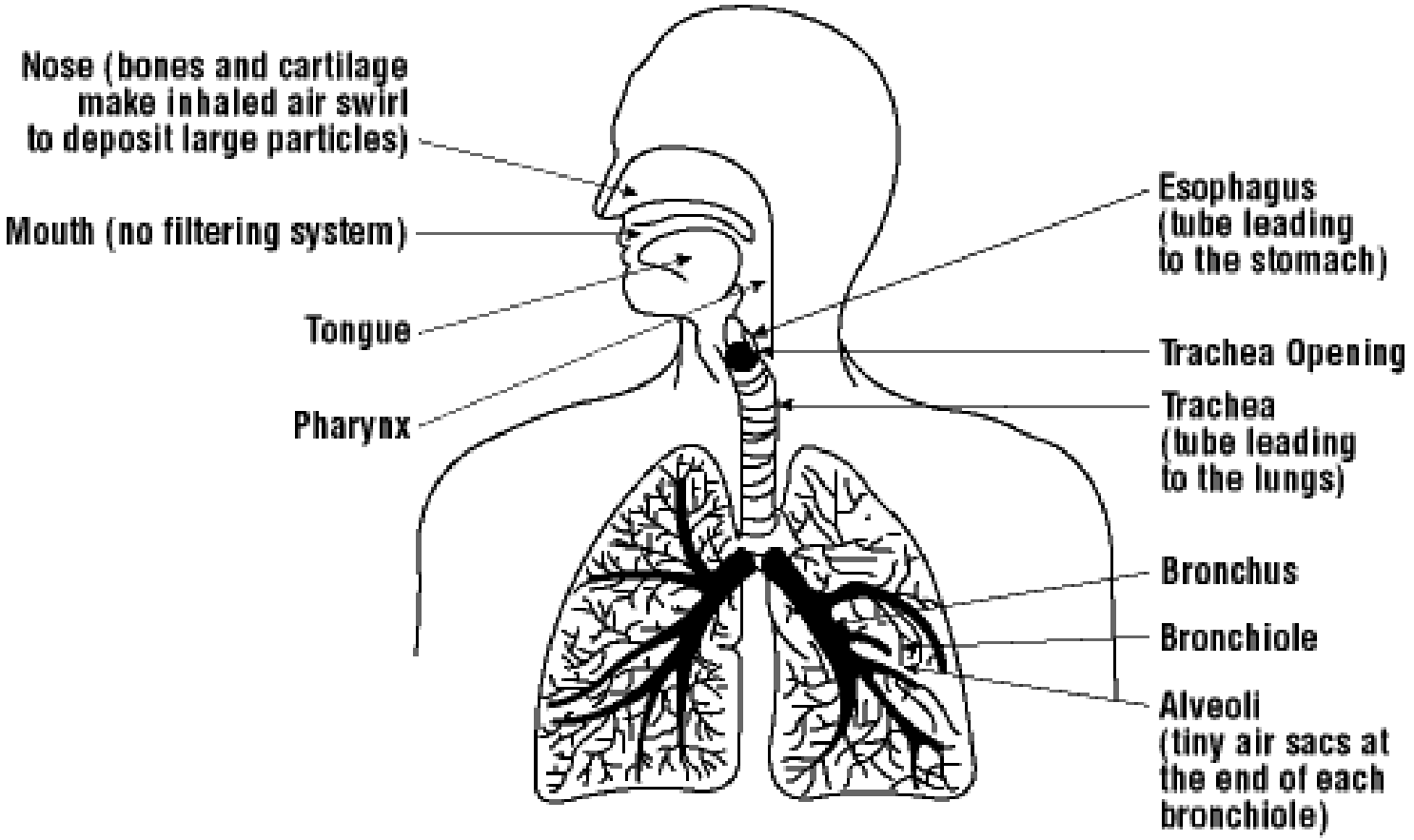


Fig. 1. Typical Diesel mass and number weighted size distributions shown with alveolar deposition.

Inhalation of Particulate Matter



- In general, larger (“course”) particles (5-30 μm) are deposited in the upper airways (nose, nasal cavity, and throat)
- Smaller (“fine”) particles (1-5 μm) are deposited in the trachea and upper bronchial tubes
- Smallest (“ultrafine”) particles (<1 μm) reach the alveolar region

Diesel Exhaust – Health Impacts

- Ozone (Formed through release of precursors: NO_x and VOCs): Ozone is a respiratory irritant, leading to reduced lung function, asthma aggravation, chronic bronchitis, emphysema.

- Particulate Matter (PM, released directly): Exposure may lead to premature mortality, chronic bronchitis, chronic obstructive pulmonary disease (COPD), asthma aggravation, pneumonia, and heart attacks.

- Air Toxics: Diesel exhaust as a whole is classified as a "likely human carcinogen" and respiratory irritant. Many of the components of diesel exhaust are "likely" or "known" (e.g. benzene) human carcinogens and also have respiratory, neurological, developmental, and immunological health endpoints.

EPA's Diesel Exhaust Health Assessment (September 2002)

Key Findings:

- Diesel exhaust is "likely to be carcinogenic to humans by inhalation," based on
  - epidemiologic evidence
  - rodent evidence
  - other supporting mode of action information
- "Dose-response information too uncertain to derive a confident estimate of cancer unit risk."
- Provided a "perspective on population impact"

EPA's Diesel Exhaust Health Assessment Human Data: Occupational

- 18 of 22 studies showed a positive correlation: observed increase of Lung cancer above background of 2-160%, or an average of ~40% (RR of 1.4)

- Exposure determined retrospectively is "Achilles heel." Most studies use surrogates: years worked, high/medium/low exposures based on job classification, vehicle miles traveled and fleet emission estimates for activity, etc.

EPA's Diesel Exhaust Health Assessment "Perspective" on the Hazard Impact

- Use crude approximations based on occupational data - estimate what risks might be in an exposed population
- Using average of RR 1.4, worker excess risk is about 2%
- High and lower-end exposure occupational concentrations - typical of epidemiologic settings
- Assume occupational concentrations can be converted into equivalent environmental exposures

“Perspective” on the Hazard Impact

- Adopt average environmental DE exposure of 0.8 ug/m^3

$$\frac{\text{general population risk}}{\text{environmental exposures}} = \frac{\text{occupational risk}}{\text{occupational exposures}}$$

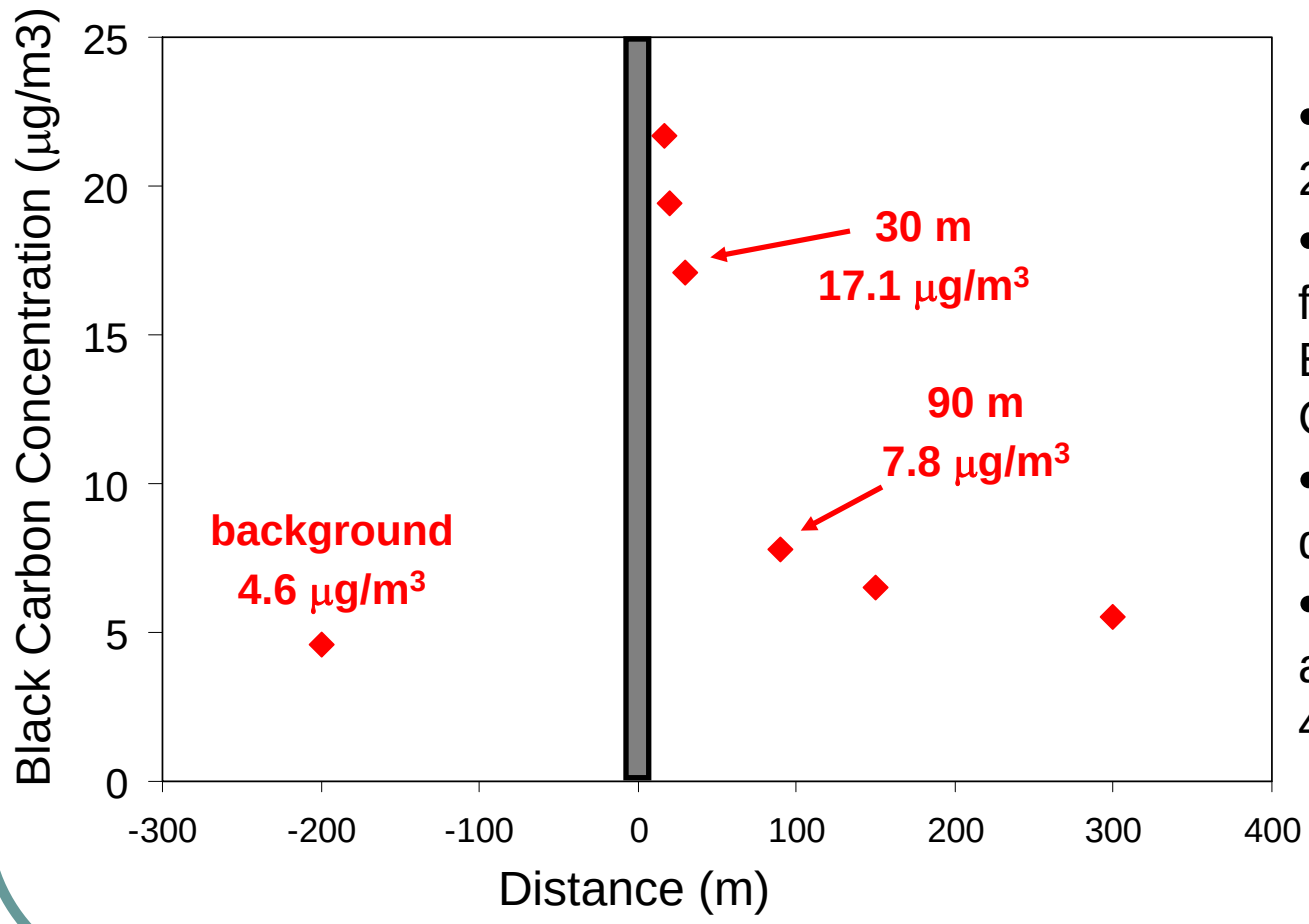
$$\frac{?}{0.8\ \mu g/m^3} = \frac{0.02}{\text{range of exposure}}$$

- Possible risk range could be 10^{-3} to10^{-5}
  - can’t rule out zero risk
  - general indicator of possible significance of the hazard . . .
  - not a definitive characterization of risk
  - not to be used to estimate exposure specific risk to a population

Ambient Monitoring of Diesel Exhaust

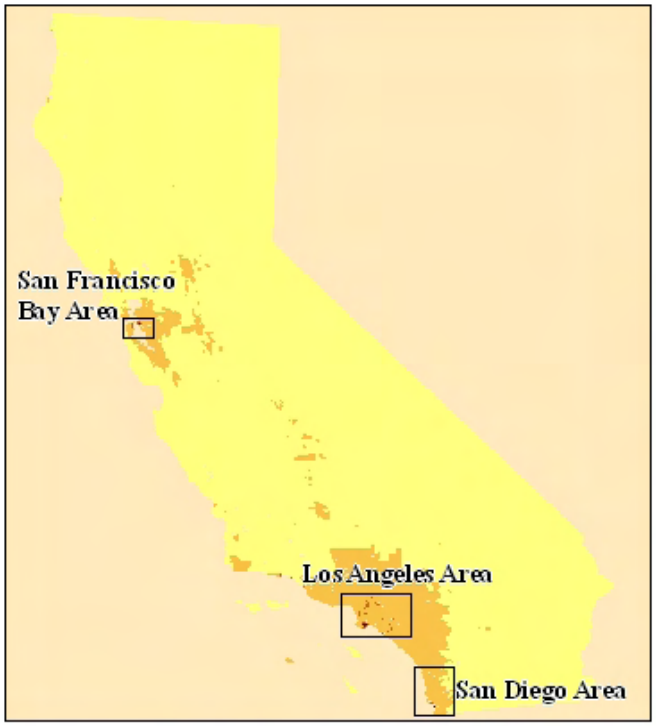
- Biggest uncertainty: There are no known compounds unique to diesel.
- Surrogates for diesel exhaust:
  - elemental/black carbon,
  - PAHs,
  - hopanes and steranes,
  - ultrafine PM
- All of these can be emitted by gasoline engines as well.

Diesel Exhaust – Near-Roadway Monitoring



- Source: Zhu *et al*. 2002
- Location: 710 freeway near Long Beach, Southern California
- Fleet mix: 30% diesel
- Duration: 2 month average, 10am - 4pm

1999 NATA for California
Modeled Ambient Diesel PM Concentrations



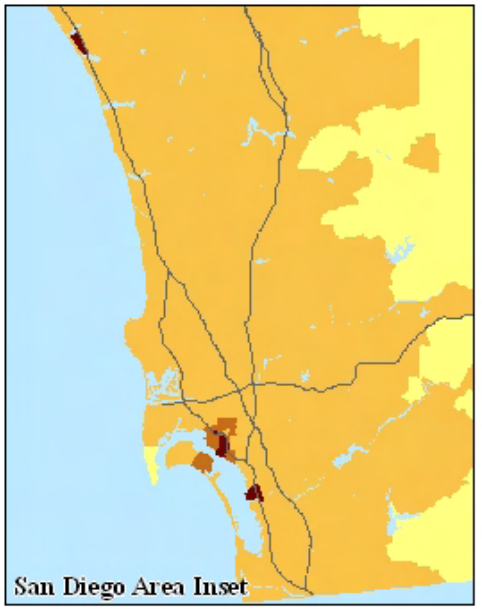
Modeled Diesel PM µg/m^3

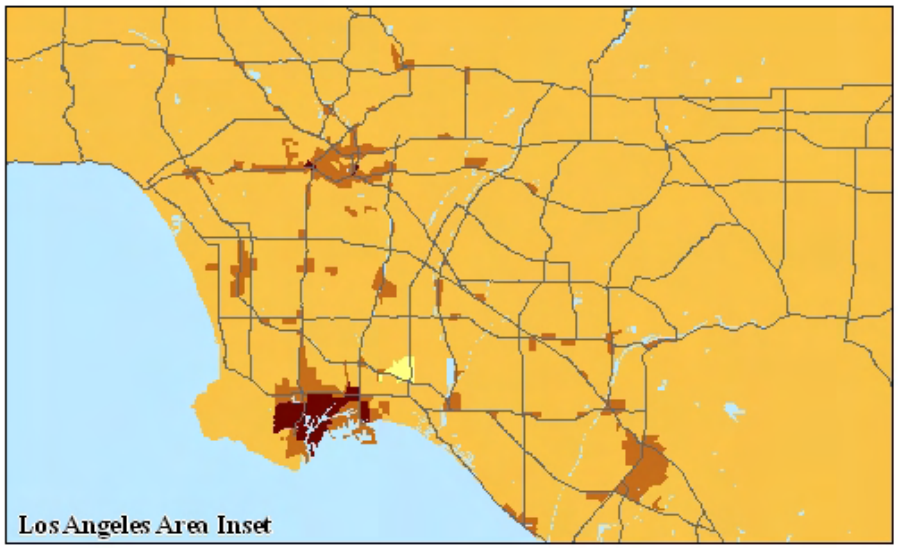
By Census Tract

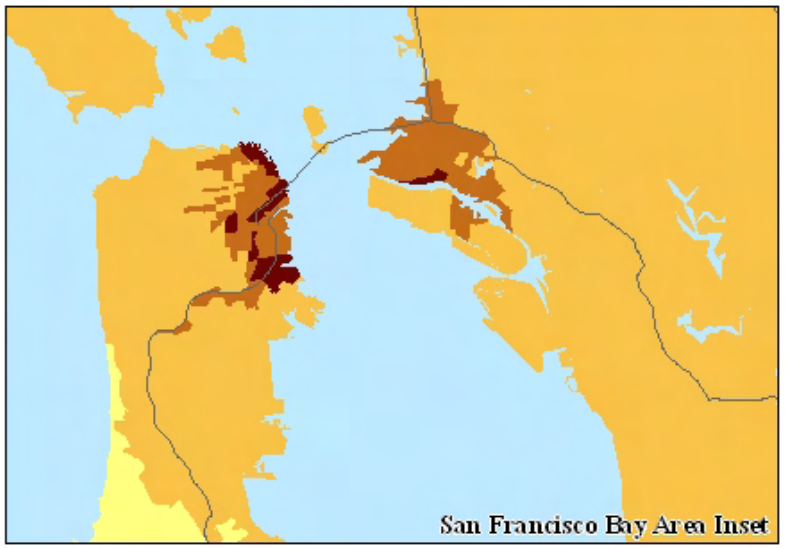
- 0.02 - 0.33
- 0.33 - 1.6
- 1.6 - 3.3
- 3.3 - 8.2

Source: EPA National-Scale Air Toxics Assessment December 2004

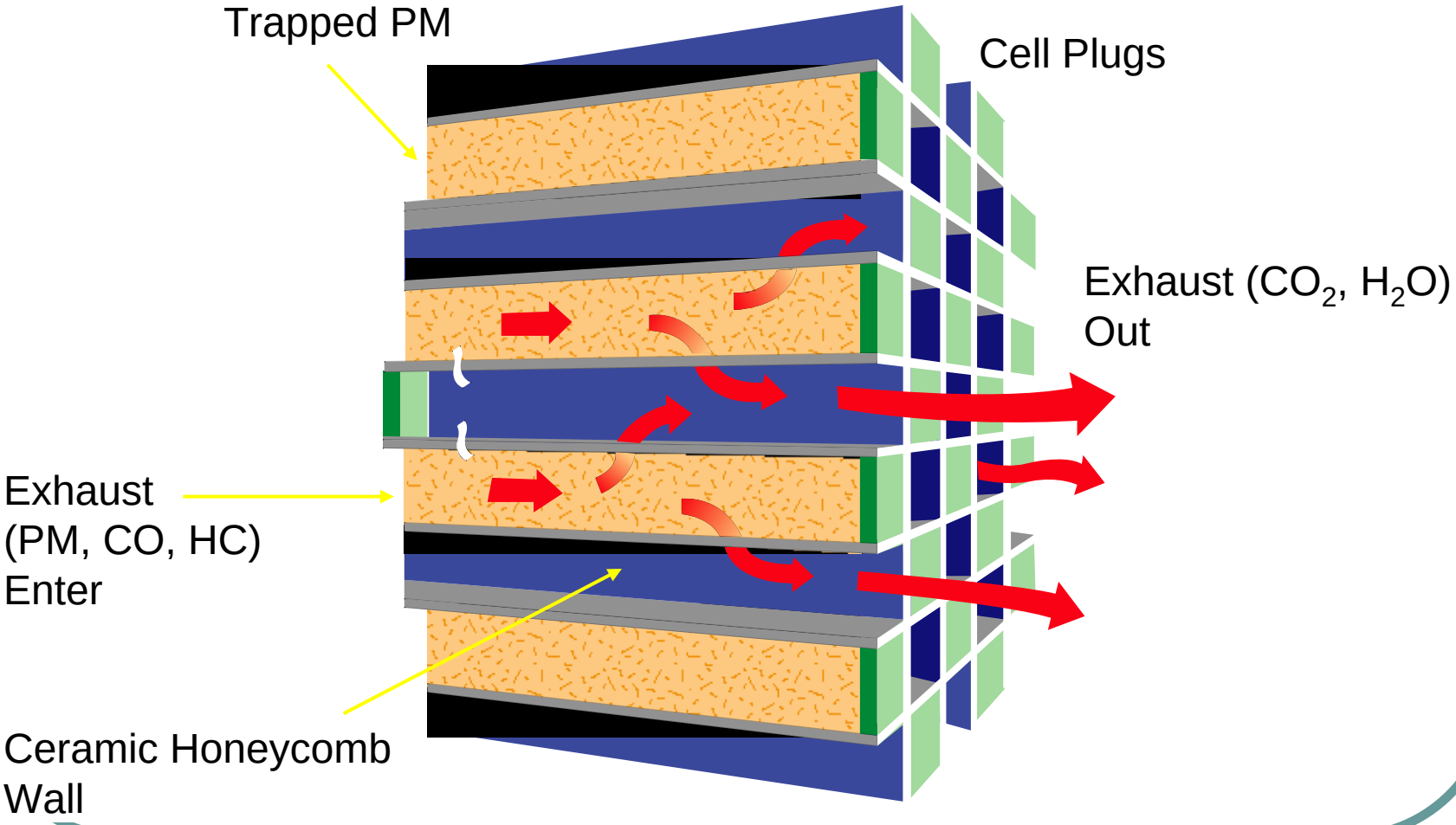
Interstate



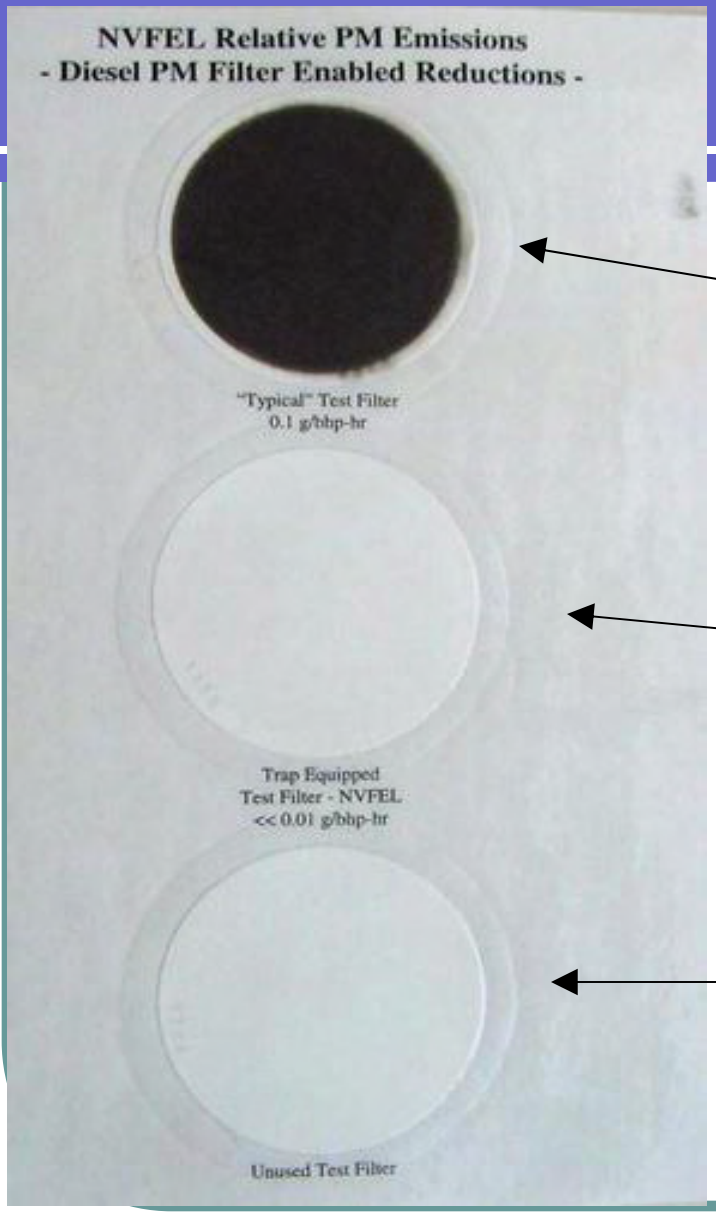




Control Technologies: Diesel Particulate Filters



Control Technologies



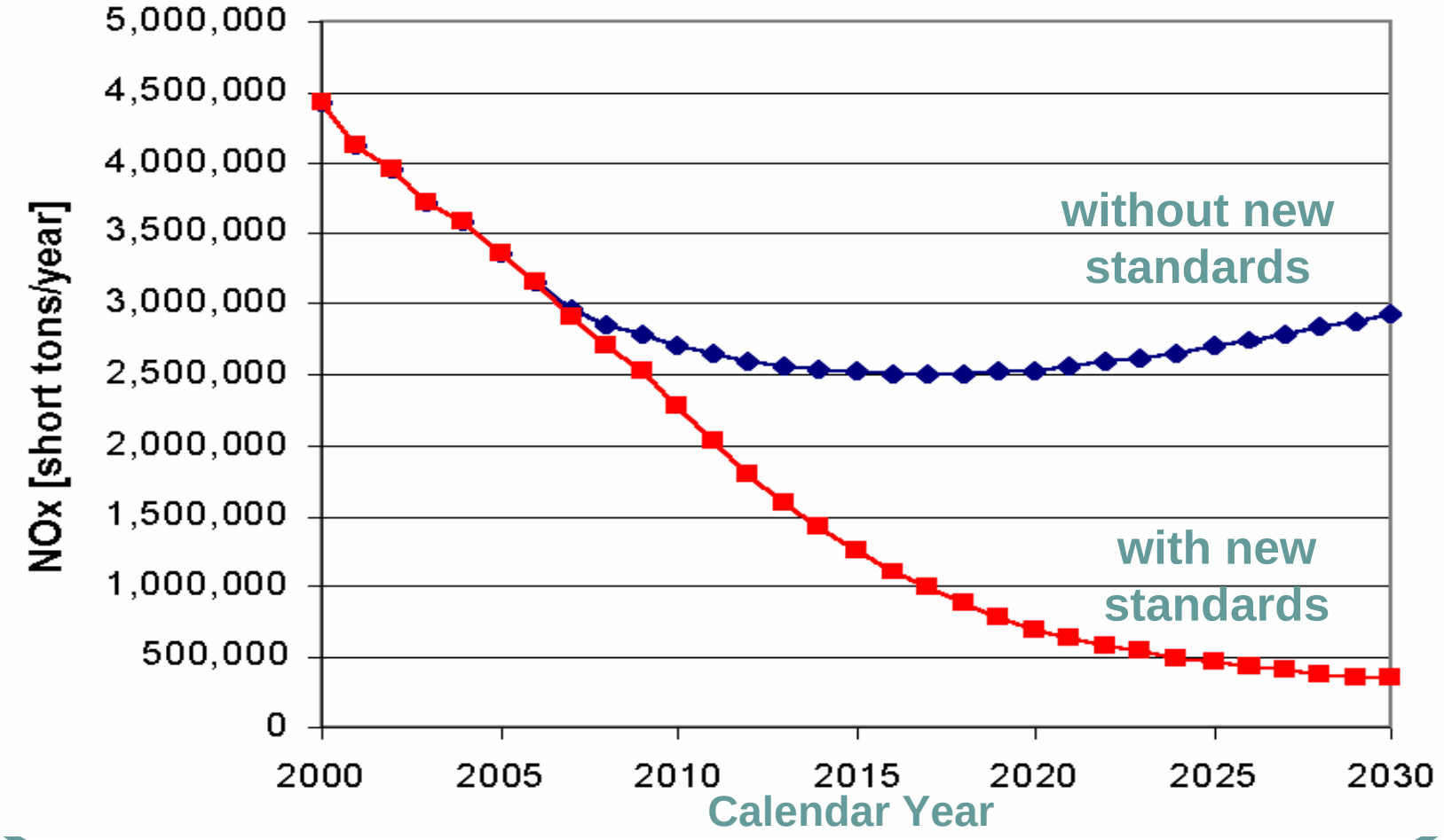
- Typical test filter – current standards
- Test filter – 2007 standards
- Unused test filter

EPA Rules

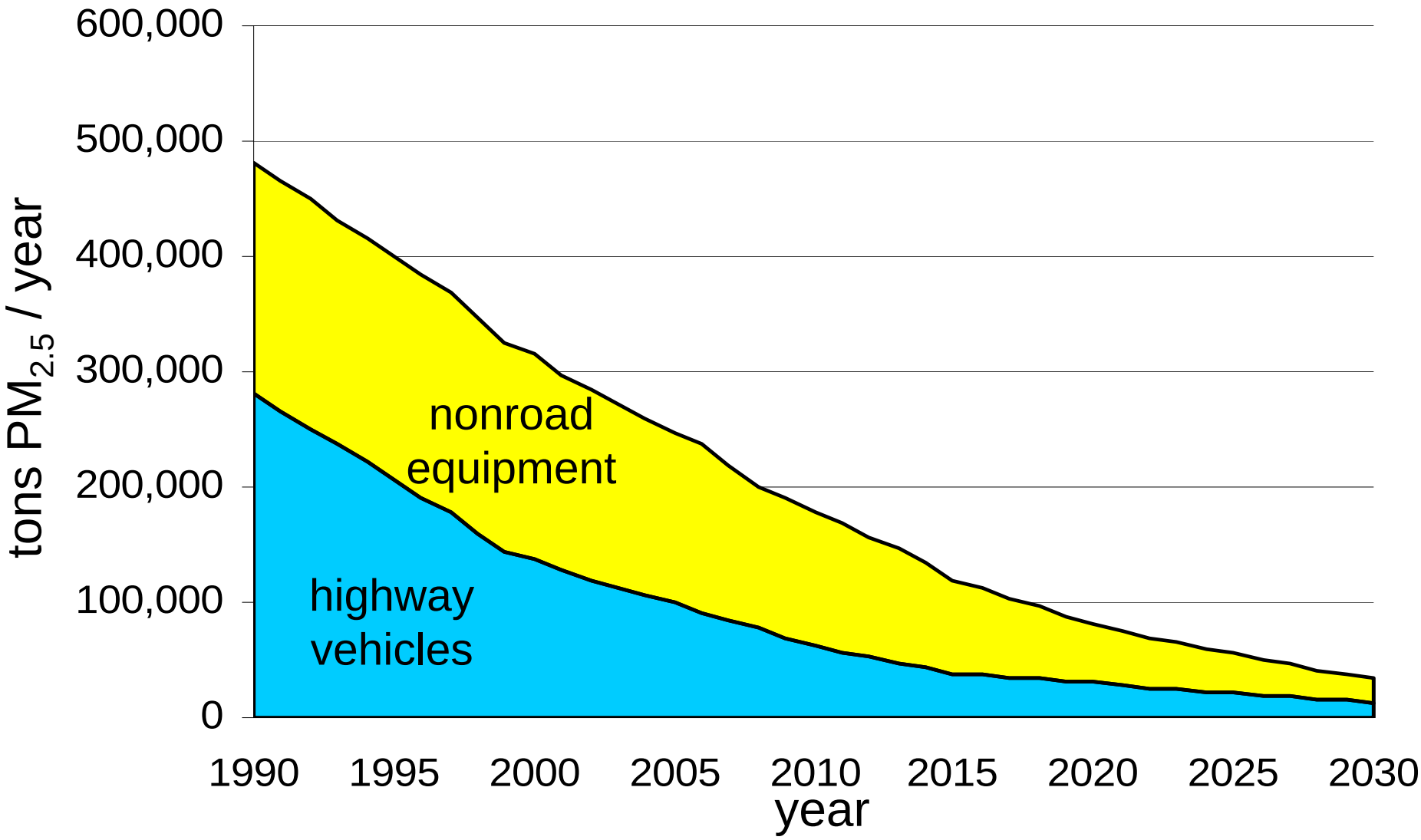
Heavy-Duty Highway Diesel (2000) and Clean Air Nonroad Diesel (2004) Rules:

- For fuels, require:
  - For highway engines, ultra-low sulfur diesel in 2006,
  - For nonroad engines, low sulfur diesel in 2007 and ultra-low sulfur diesel in 2010 (in 2012 for locomotives and marine engines)
- For engines, require advanced technologies, such as particle traps, phased-in for highway engines beginning 2007 and nonroad engines beginning 2011 (anticipated full fleet turnover by 2030)

Impact of Mobile Source Programs on NO_x Emissions



Impact of Mobile Source Programs on Diesel $PM_{2.5}$



EPA Rules: Air Quality & Health Benefits

Annual (2030)		HD2007	NRTier4
	Cost	$4 billion	$2 billion
	Net Benefits	$70 billion	$80 billion
Reduced	NO_x	2,600,000 tons	738,000 tons
Reduced	PM	110,000 tons	129,000 tons
Avoided	Premature Mortality	8,300	12,000
Avoided	Hospital Admissions	7,100	8,900
Avoided	Lost Work Days	1.5 million	1.0 million

Ongoing Research Needs

- Cancer dose-response
- Monitoring methods
- Control technologies
- Environmental tracking