

Reducing Black Carbon from On-and Off-Road Diesel Engines

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Black carbon is any combustion particle that strongly absorbs light

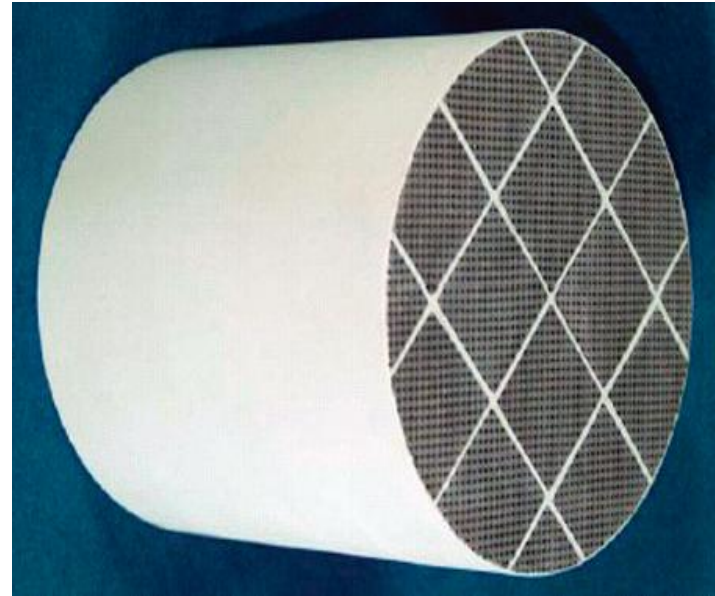
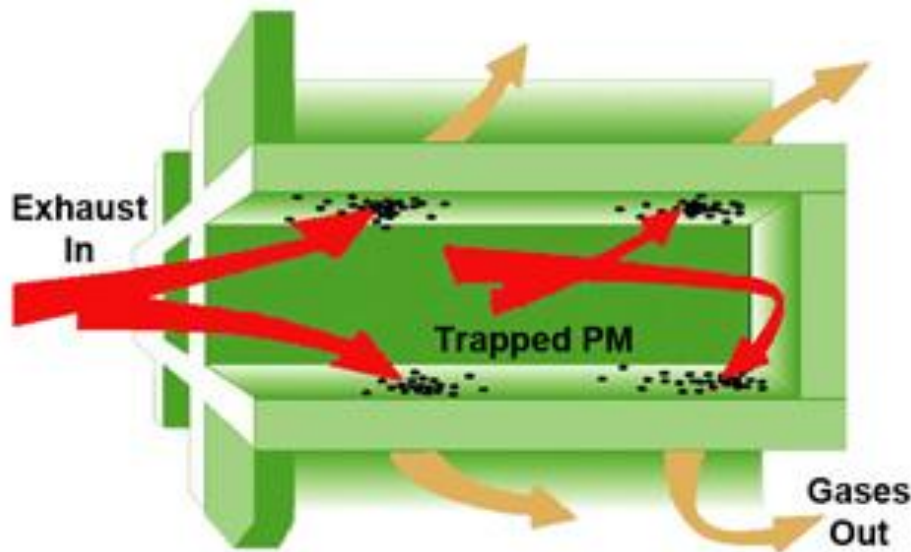
White smoke indicates low concentration of BC



Dark smoke indicates high concentration of BC

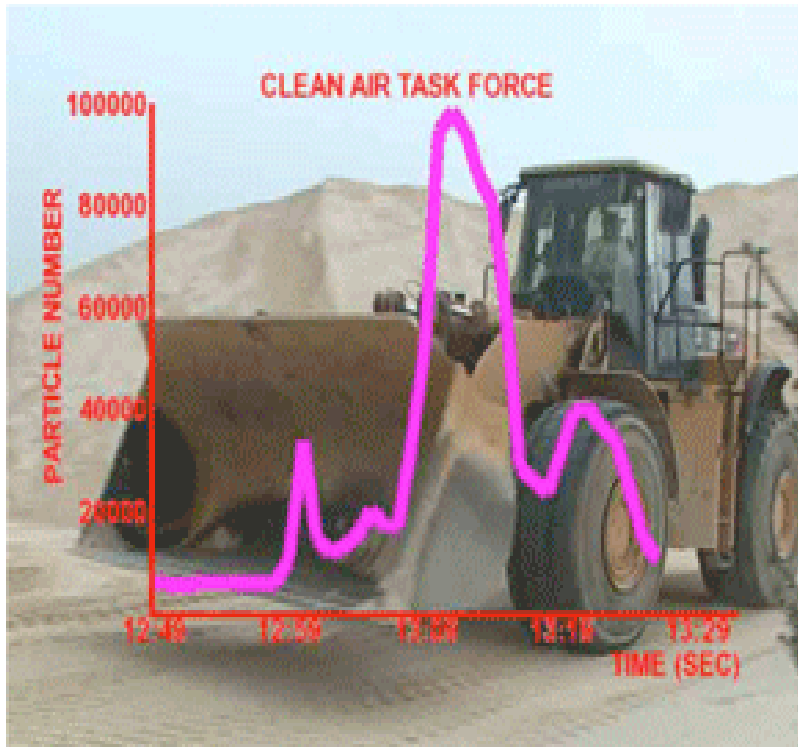


Diesel Particulate Filter

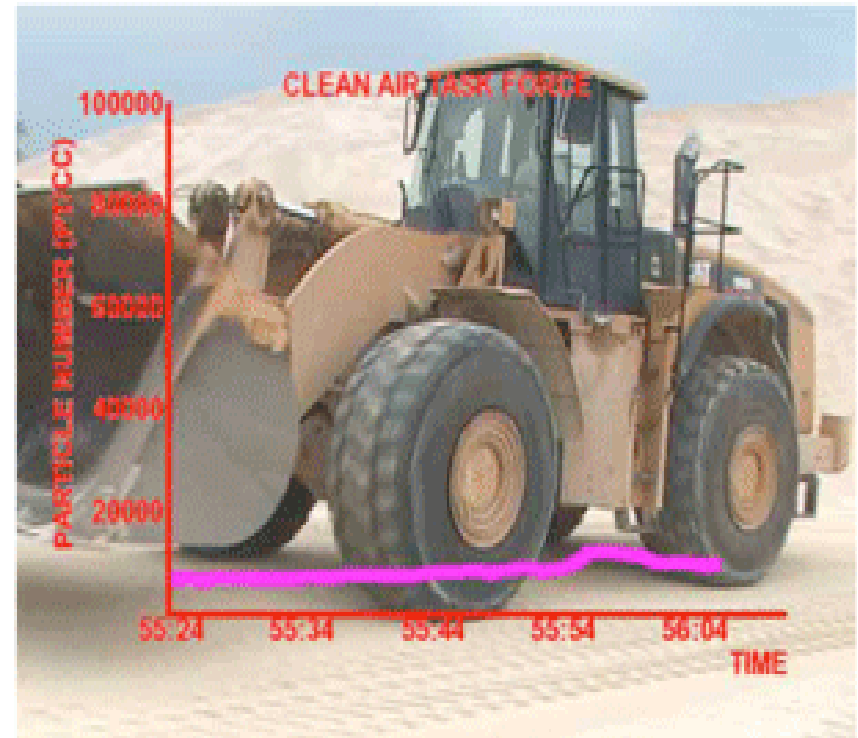


Removes 90+% BC, PM; also HC and CO
Requires Ultralow Sulfur Diesel (ULSD)

Wheel Loader Results



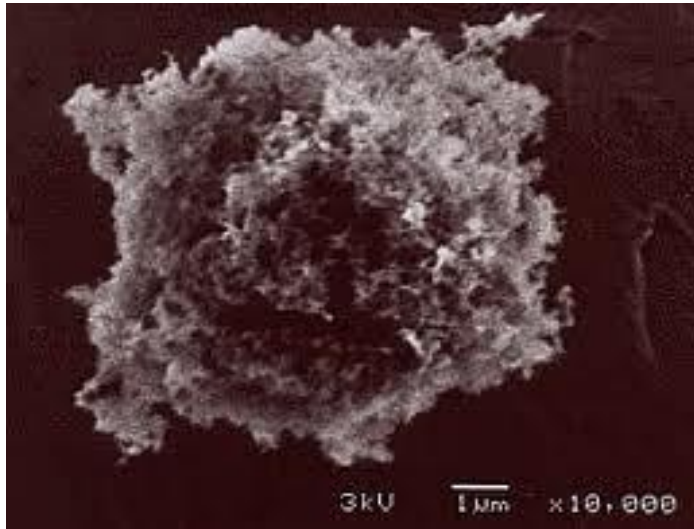
**Pollution exposure levels without
a tailpipe filter**



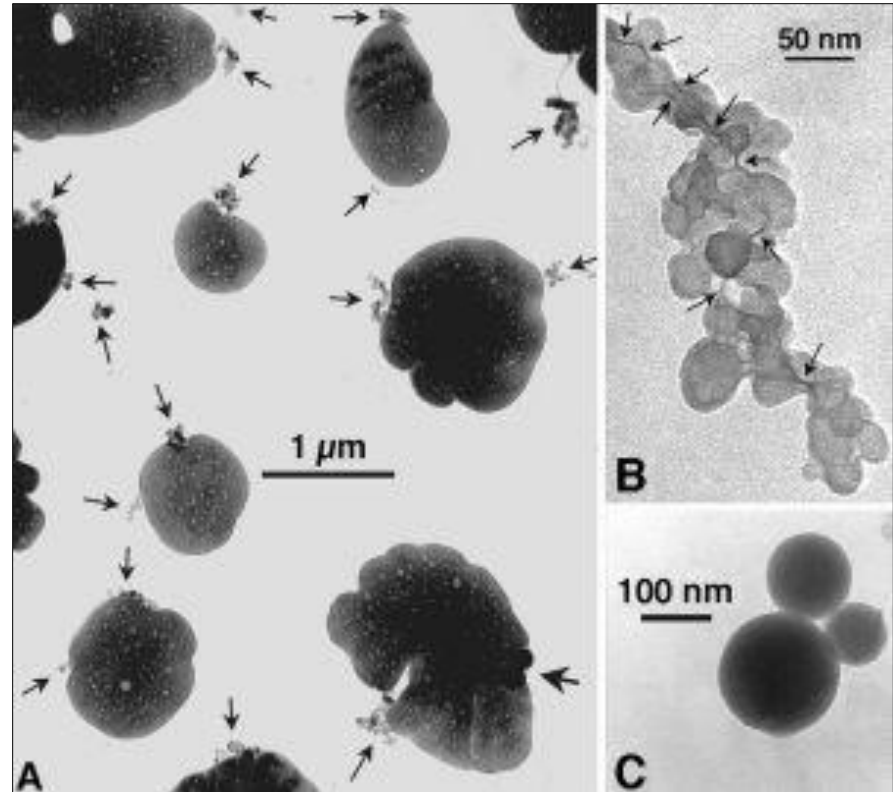
**Pollution exposure levels with
a tailpipe filter**

Health Effects of Black Carbon

Black Carbon Particles



Pure black carbon



A: Sulfates

B: Black carbon detail

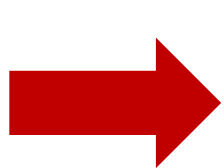
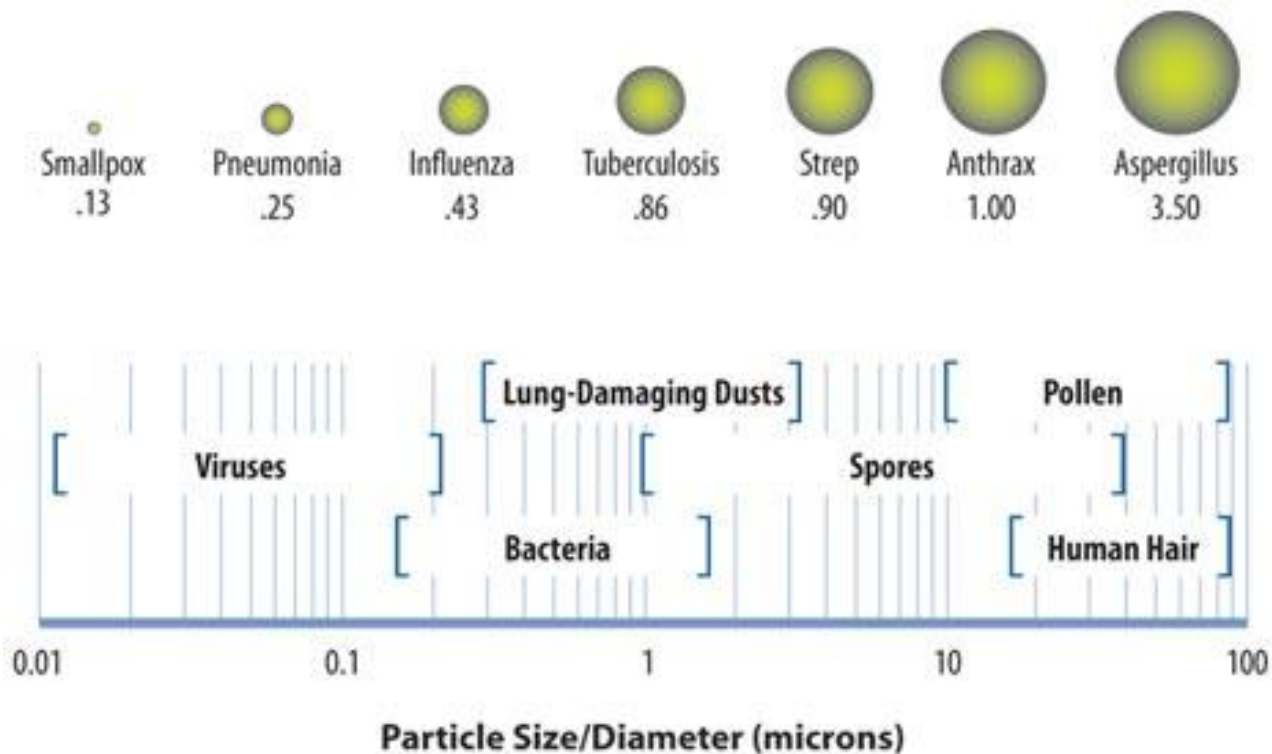
C: Fly ash from coal-combustion

Credit: Peter Buseck, Arizona State University

Note:

1 micrometer = 1,000 nanometers

Respirable Particles



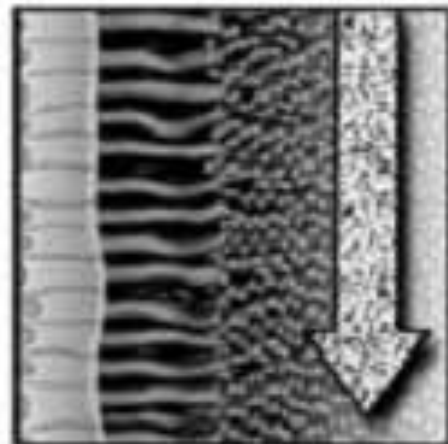
Diesel Exhaust
.05



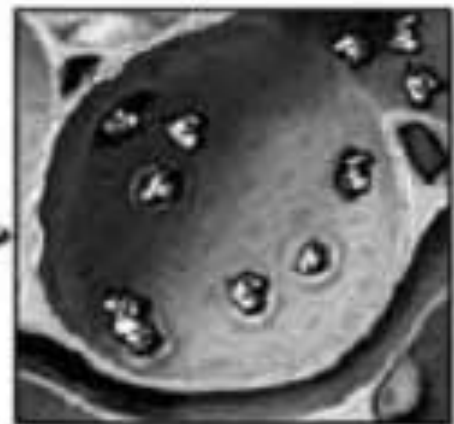
1. Particle pollution inhaled



2. Microscopic particles evade body's natural defenses



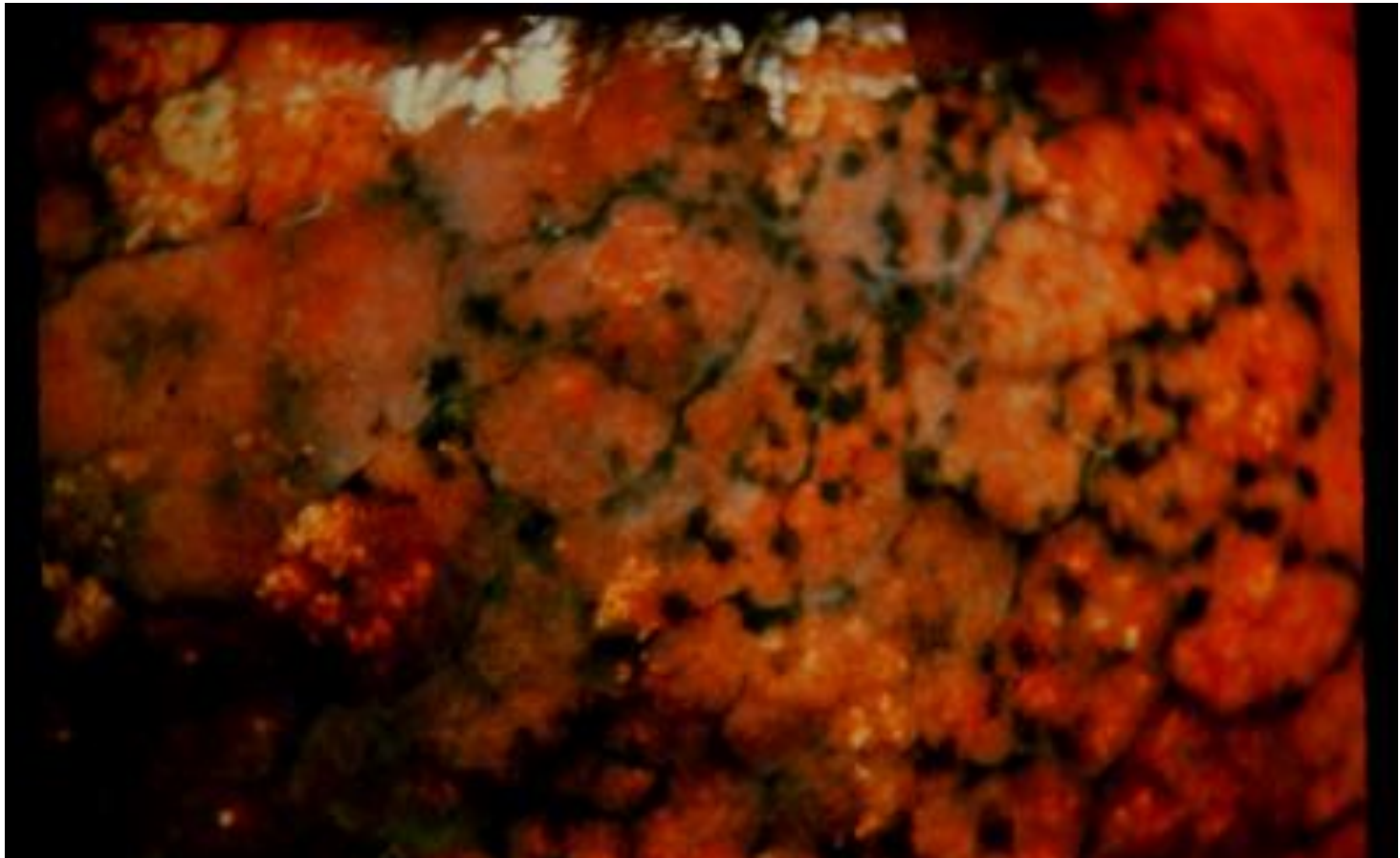
3. Particles lodge deep in lung's air sacs



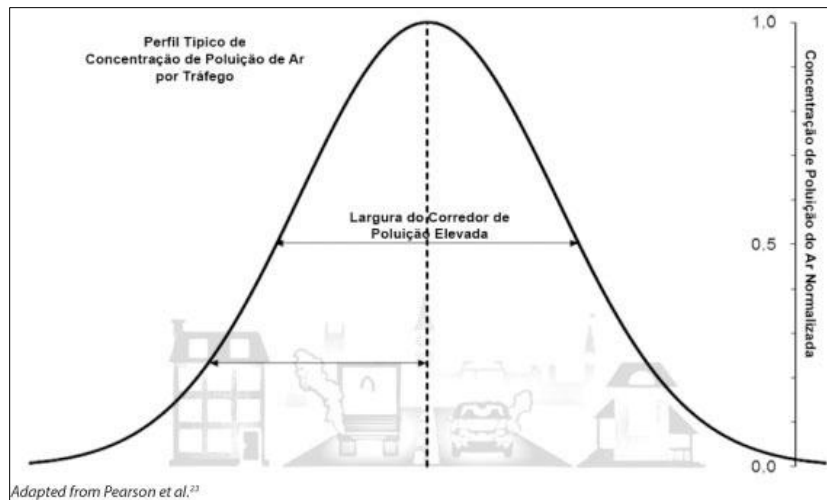
4. Particles damage the lungs



Lung Tissue from 50-Year Old Non-Smoker



Peak Exposure by Roadways



Figur1 1 – Profile of the concentration of pollutants emitted by vehicular traffic as the model of distance weighted traffic density



POLLUTION DISPERSION AROUND A BUSY ROAD

TYPES OF POLLUTANTS

ELEMENTAL CARBON



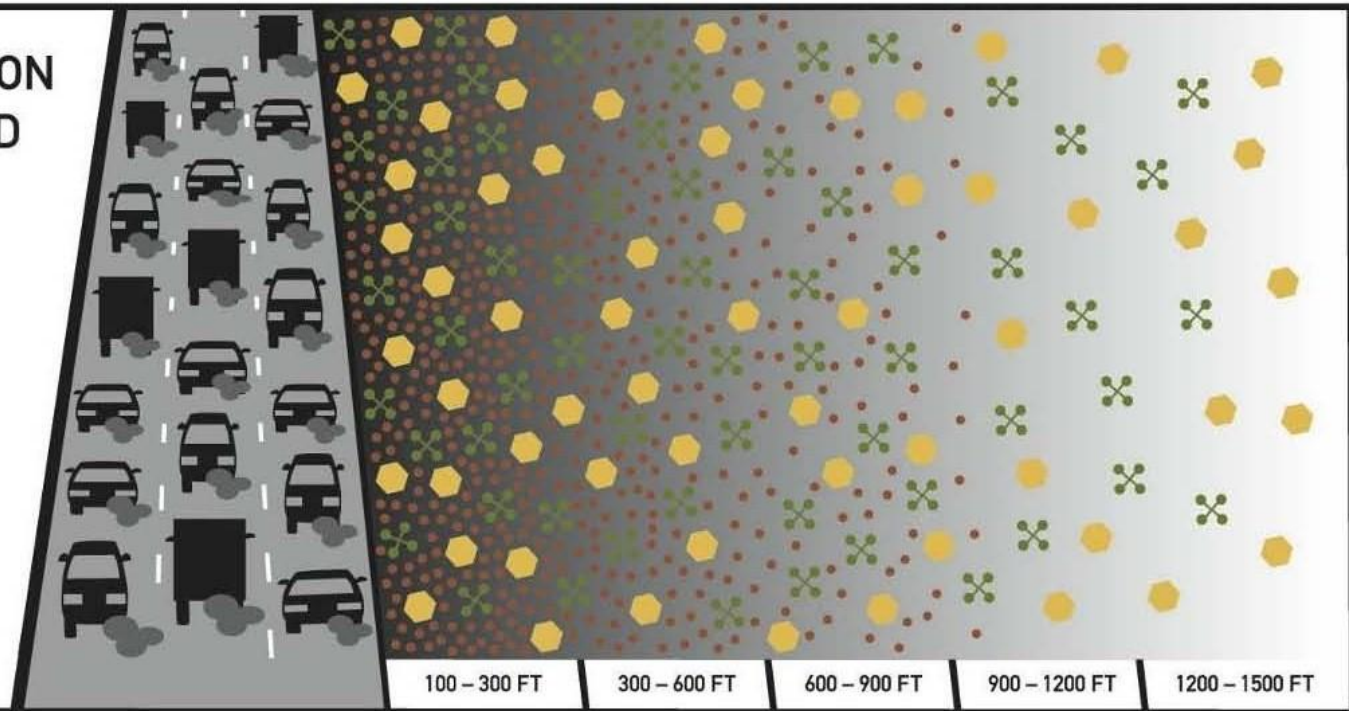
NITROGEN DIOXIDE



ULTRAFINE PARTICLES



DISTANCE FROM THE SOURCE



1500 FEET
LUNG DEVELOPMENT



500 – 1500 FEET
CHILDREN'S ASTHMA

EXAMPLE DISTANCES WHERE HEALTH EFFECTS ARE FOUND



400 FEET
CHRONIC HEART DISEASE



300 FEET
ADULT LUNG DISEASE



300 FEET
ACUTE HEART ATTACKS



What California Did and Why

Evolving Policy Goals

- In 1999, CA identified diesel exhaust as a “toxic air contaminant,” causing cancer
- In mid 2000s, CA recognized mortality impact of PM_{2.5}, which was 10 times worse
- More recently, CA has learned about the climate impacts of black carbon

CA Diesel Population

Type	2010
Heavy-Duty Trucks	650,000
Off-Road Equipment/Engines	525,000
Stationary & Portable Engines	70,000

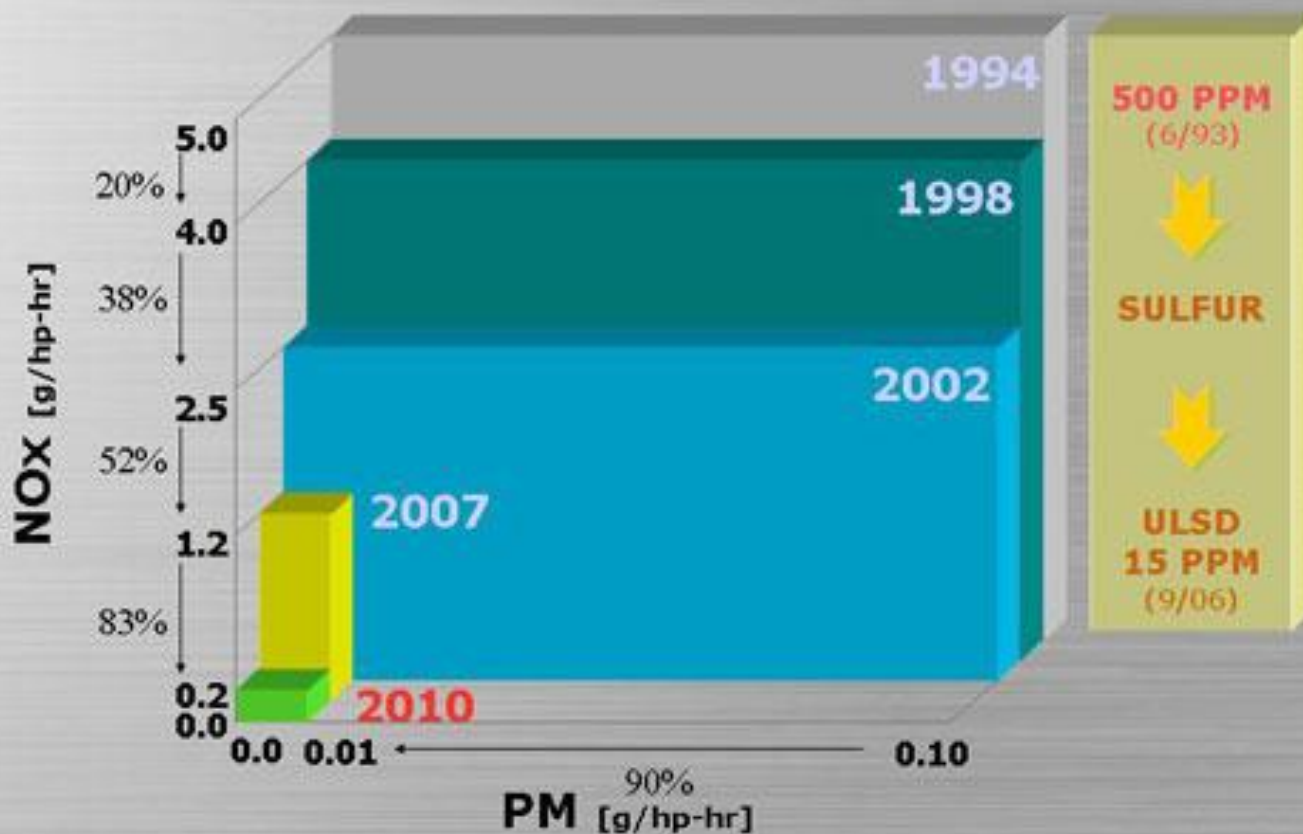
Diesel Risk Reduction Plan

- Goal: cut toxic risk
 - 75% by 2010
 - 85% by 2020
- Mix of strategies
 - Engine & fuel standards
 - Retrofit controls
 - Repowering
 - Fuel switching
 - Scrappage



CARB On-Road Diesel Standards

Emission Regulations

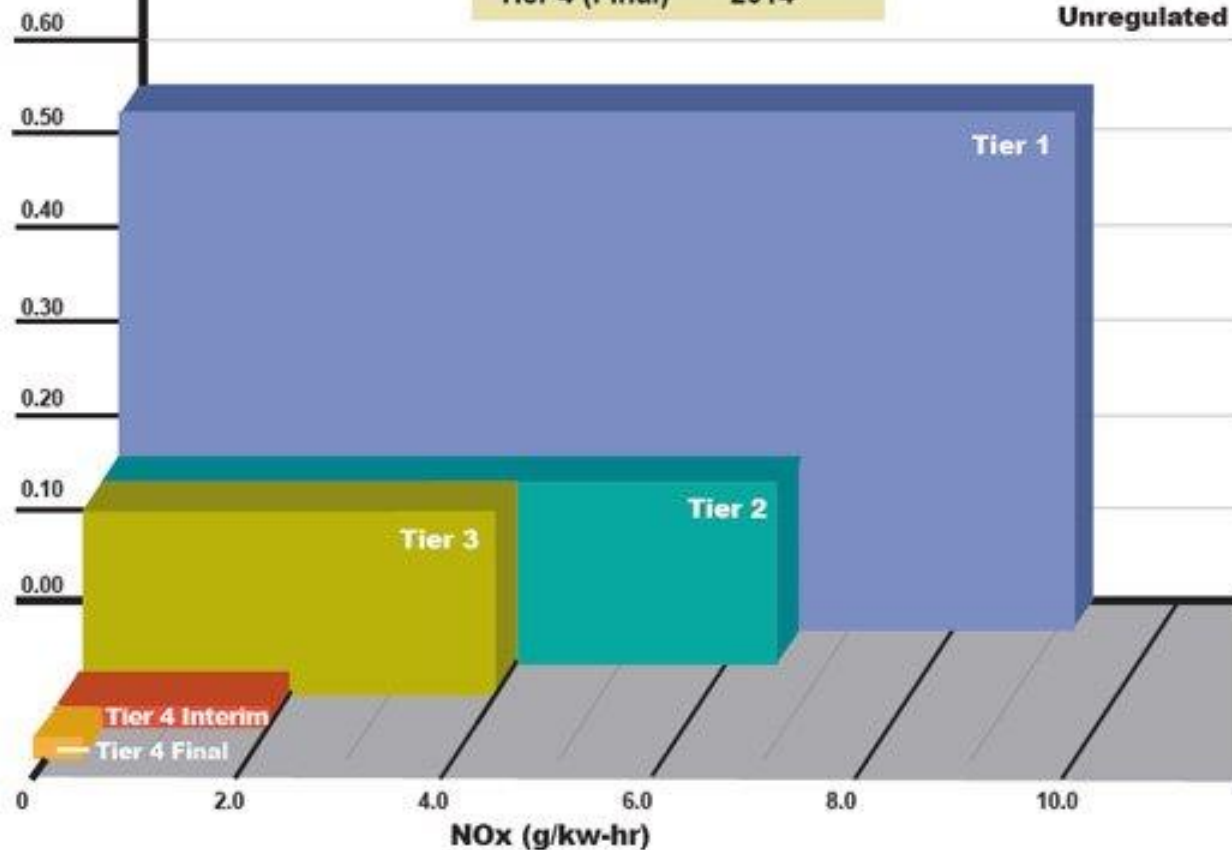


CARB & Federal Non-Road Diesel Standards

US EPA Non-Road Regulations (130-560kw)

Particulates (g/kw-hr)

Tier 1	1996
Tier 2	2001-2003
Tier 3	2005-2006
Tier 4 (Interim)	2011
Tier 4 (Final)	2014



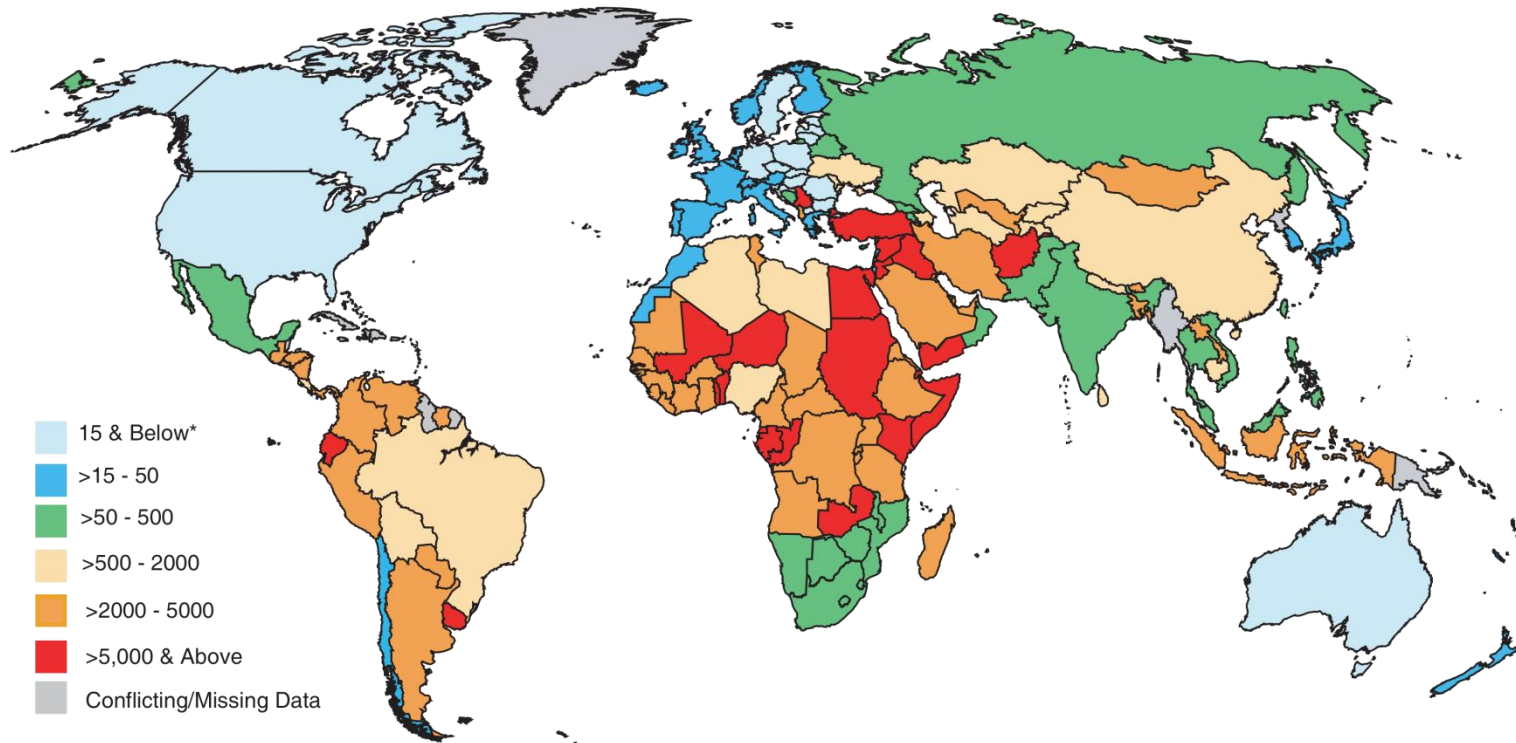
Low-Sulfur Diesel Fuel Adopted by CARB in 2003



Diesel Fuel Quality



Diesel Fuel Sulphur Levels: Global Status
September 2010



* Information in parts per million (ppm)

Sulphur levels are maximum allowable as of September 2010. For additional details and comments per country, visit www.unep.org/pcf.v.

Problem: Old Diesel Engines

In California:

- 53% of diesels >14 years old
- 21% of diesels >20 years old
- 7% of diesels >35 years old

⇒ Long life of diesel engines makes turnover alone an insufficient control strategy

Specific Regulations

- **On-Road Vehicles**

- Transit Buses (2000, 2004, 2005)
- Idling Limits (School Buses 2002, Trucks 2004)
- Garbage Trucks (2003)
- Public Utility Vehicles (2005)
- Port Drayage Trucks (2007)
- Line-Haul Trucks (2008)

- **Off-Road Vehicles**

- Cargo Handling Equipment (2005)
- Commercial Harbor Craft (2007)
- Construction and Mining Equipment (2007, 2010, 2011)

Specific Regulations, cont'd

- **Fuel Requirements**

- Off-Road Low Sulfur Diesel Fuel (2003)
- Locomotive Fuel (2004)
- Marine Auxiliary Engines (2005)
- Marine Main Engines (2008)

- **Stationary and Area Sources**

- Emergency Power Generators (2004)
- Transportation Refrigeration Units (2004)
- Agricultural Pumps (2006)
- Shore Power (2007)

Some Illustrations



Consumer Protection Provisions

- Pre-Verification of Retrofit Devices
- Durability Tests
- Minimum Warranties



Progress to Date

- 50% drop in ambient BC concentrations
 - 0.46 mg/m³ in 1989
 - 0.24 mg/m³ in 2008
- 25% drop in climate forcing
 - Regional cooling of 1.4 W/m²



What I'd Recommend Based
on California's Experience

Universal Prescription

- Adopt filter-based PM standards
- Limit diesel fuel sulfur to 15 ppm
- Align on-road and off-road rules
- Until low-S fuel is widely available
 - Scrap gross emitters
 - Retrofit centrally fueled fleets
 - Restrict vehicle idling