Global Trends in Diesel Particulate Control: Current Trends & Remaining Challenges

Measurement and regulation trend of nano particles
Tokyo, Japan
March 20, 2003

Summary
- Review Concerns With Diesel Particles
  - Health Effects From Particles
  - Toxicity
  - Small Size (nano-particles)
- What is Being Done To Address The Concerns
- Remaining Challenges

Number of People Living in Areas Exceeding Air Quality Standards in 2000 in the US

- O₃-1 Hr
- O₃-8 Hr
- PM₁₀
- PM₂.₅
- CO
- Pb
- Any NAAQS

PM Health Effects
- High levels of PM (e.g. 500 µ/m³) known to cause premature death
  - e.g. London 1952
- Recent studies in US, Europe, Asia, South America have found association of PM with premature death at much lower levels
  - no evidence of a "threshold" (safe level)

The Role of Trucks in Japan

- Vehicles
  - Heavy Trucks 17.8%
  - Other 82.1%
- PM
  - Heavy Trucks 60.0%
  - Other 40.0%
- NOₓ
  - Heavy Trucks 10.5%
  - Other 89.5%
**PM - The Epidemiology Studies**

A Number of Epidemiology Studies

- Europe Studies
- Harvard 6 Cities Study

**PM10 Study in Europe**
(Lancet Medical Journal – September 2, 2000)

- ~6% of all deaths from PM10
- ~40,000 deaths per year in Austria, France, Switzerland; 2 times traffic fatalities
- Motor Vehicles Responsible For ~50%
- People in Cities Die ~18 Months Earlier Than They Otherwise Would
- Over 300,000 cases of chronic bronchitis; 500,000 asthma attacks; 16 million lost person days of activity
- Health Costs From Traffic Pollution ~1.7% of total GDP

**Increased Risk of Premature Mortality Due To 10μg/m³ PM2.5**

![Graph showing increased risk of premature mortality due to 10μg/m³ PM2.5](image)

*JAMA, March 2002*

**Brunekreef, Epidemiology 1997; 8: 298-303**

![Graph showing lung function and truck traffic density](image)

**Diesel Particulate Matter**

![Diagram of diesel particulate matter](image)

**Cancer Studies in Railroad Workers**
(HEI, 1995)

![Graph showing cancer studies in railroad workers](image)
**Relative Cancer Risks**

Based on ARB monitoring data 1995 - 1997

**Comparison of PM10, PM2.5, and Ultrafine PM**

**Combustion is the Major Source of Ultrafine PM in Los Angeles**

Source: Cass et al., 2000

**PM Emissions in the UK - 1996**

*Source: Apportionment of Exhaustable Particles in the United Kingdom*
Exposure Information is Limited in US

- Only existing ultrafine PM network is in southern California
- Freshly emitted ultrafine PM concentrations do not correlate well with PM10 or PM2.5 mass concentrations
- Freshly emitted ultrafine PM concentrations decrease rapidly with distance from source

1 Sioutas et al, 2002

Ultrafine Particle Dispersion and Coagulation

Source: Costas Sioutas, University of California

ARB In-Vehicle Study
Real-Time Fine Particle Counts

(L.A. Freeway; AM Rush Hour; Vent Open)

Intriguing Health-Related Findings

- Ultrafine PM exposure associated with mortality
  - Effects strongest for respiratory disease followed by cardiovascular disease
  - Individuals with airway obstruction receive greater dose of ultrafine PM than healthy individuals
  - Ultrafine particles pass rapidly into the circulatory system
  - Ultrafine PM is more potent than fine or coarse PM towards inducing cellular damage

1 Wichman et al, 2000; 2Brown et al., 2002; 3Nemmar et al., 2001; 4Li et al., 2002

Cabin Air Quality

Biologically Plausible Mechanisms of Ultrafine Toxicity
Concern Over Ultrafine PM Reinforced

- Daily Mortality in Erfurt Germany
- Health Effects of Ultrafine & Fine PM Comparable
- Effects of Ultrafines Depend on Number and Surface Area
- Since 91/92 PM Mass Has Declined
- Since 91/92 very small particles (.01-.03) increased

HEI Research Report 98, November 2000

Particle Size Distributions (Transit Buses, 55 mph Steady State)

<table>
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<tr>
<th>Bin #</th>
<th>NOx</th>
<th>NMOG</th>
<th>CO</th>
<th>HCHO</th>
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Bins for Tier 2/LEV2 (g/mile)

United States

United States and California On-road Truck Engine Standards, Beginning with the 1988 Model Year
New York City Retrofit Experience

California Diesel Risk Reduction Program
- Require PM Filters on All New & Most Existing Diesels (On & Off Road)
- Aiming for 90% Reduction in Total PM Emissions From 1.25 Million Engines
- Full Implementation By 2010
  - PM Traps
  - Low Sulfur Fuel
  - In Use Emission Testing
  - Alternative Fuels

Rest of the US
- EPA’s Target is Commitment For 100,000 Retrofits
- ~71,000 To Date
  - New York
  - Seattle
  - Texas
  - Others

Europe

Emissions From Diesel Cars In Europe

Heavy-duty Vehicles Emission Reduction In Europe On ETC Test Cycle
European Fuel Sulfur Levels (PPM)

Swedish Retrofit Program
All Trucks Above 3.5 Tons

Conclusions From Auto-Oil II

- Emissions From Road Traffic Will Likely Be Reduced by 80% From 1995 Levels by 2020
- Remaining Problems Will Require Further Actions To Address
  - PM From Diesel Vehicles
  - High Levels of Localized NO₂
  - Ozone

Penetration of Diesel Cars in Europe (% of New Sales)

PM-Emissions (kt/a) in Germany – TREMOD 2.0 (08/2000)

PM-Emissions (kt/a) in Germany – TREMOD 2.1 (10/2001)
Comparison of the Cancerogenous Potential of Otto- and Diesel Passenger Cars in Urban Traffic

Letter To Commission From France & Germany (29/1/2003)

- In Spite of Progress, Significant Problems From NOx and PM Emissions
- PM number in range 0.01-2.5 μM Remains High; Vehicles Major Source
- Diesel Registrations Have Doubled
- PM Filters Could Reduce By 99%; Current Standards Can Largely Be Met Without Filters
- US Standards 80% Lower Than Euro IV
- Request Tighter Standards Proposal by Mid 2004

PSA's DPF System for Diesel Passenger Cars

New Standards For Japanese Vehicles (October 2005)

Retrofit Reduction Required For Consideration in Tokyo
United States

Mobile Source PM

Engine Standards – 2 Step Fuel Program

Standards requiring high efficiency aftertreatment are shown in bold.

<table>
<thead>
<tr>
<th>Year</th>
<th>Tier</th>
<th>PM: 50% reductions using oxidation catalysts or engine-based control</th>
<th>PM: 100% reduction</th>
<th>NOx: 50% reduction</th>
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</tbody>
</table>

PM: 100% reduction | NOx: 100% reduction

- Inventories: significant
- Machine population: large (and growing)
- Personal exposures: very important due to where used and how designed
### Conclusions

- PM Remains A Major Concern
- Special Concerns With Diesel PM
  - Small Size
  - Toxicity
- Stringent New Diesel Standards and Low Sulfur Fuel Standards Spreading
- PM Filters Seen As Key To Control
- Europe Considering Additional Step
- Non Road & Retrofit – Unfinished Agenda

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**Thank You for Your Attention!**