Global Trends in Motor Vehicle Pollution Control

Where We Are
Where We Are Going

Global Trends In Motor Vehicle (Cars, Trucks & Buses) Production

Motorcycle Production in Selected Countries

In 2000, ~20 Million
12 Million in China Alone

Global Trend In Motor Vehicles
Trends in People and Vehicles in New Zealand
(Normalized to 1951)

Combustion Emissions
- Lead
- Hydrocarbons
- Carbon Monoxide
- Oxides of Nitrogen
- Carbon Dioxide
- Particulates
- Other toxic pollutants
- Water Vapor

Ozone Isopleth Plot (EKMA Diagram)
- Area of effective HC control
- Area of effective NOx control
- 10:1 “Ridge”
- Correlated Ozone Concentration

Other Emissions
- Refueling Losses: displaced vapors
- Evaporative Emissions: diurnal, running losses, hot soak
- Crankcase Losses: due to "blow-by"
- Other Emissions: brake linings, tire wear, fluid leaks
What pollutants are of concern?

- Carbon monoxide (CO)
- Ozone (ROG + NOx)
- Haze
- Particles (PM10/PM2.5)
- Toxics
  - Diesel particles
  - Benzene
  - Chromium
  - Asbestos
- Greenhouse Gases
  - CO2, methane

Health Impacts of Air Pollution

- Premature Deaths
- Cancer
- Developmental Effects
- Hospitalization
- Asthma Attacks and Bronchitis

Health Effects

- Different Pollutants have Different Effects
  - Carbon Monoxide*: circulatory system, heart
  - Ozone: respiratory system, lung
  - Nitrogen Dioxide*: respiratory system
  - PM*: lung, potential effects on heart
  - Diesel, Air Toxics: cancer, respiratory effects
- There are potential effects of the Mixture
- Some Populations more sensitive than others
  - elderly
  - people with heart and lung disease

* Healthy Levels Exceeded in Auckland
Special Population Exposures

- Average Annual Levels Can Be Misleading
- In Urban Areas, there are Hot Spots:
  - Street canyons, roadsides, urban centers
  - Exposure levels for PM, diesel, CO, air toxics can be 2 to 10 times higher than average
- In these settings, vehicle contribution will be higher

Diesel PM Inside School Bus

Real-Time Bus and Car Comparisons

Brunekreef, Epidemiology 1997; 8: 298-303

PM - The Epidemiology Studies

A Number of Epidemiology Studies

- Europe Studies
- Harvard 6 Cities Study
Increased Risk of Premature Mortality Due To 10$\mu$g/m$^3$ PM$_{2.5}$

JAMA, March 2002

Diesel Cancer Studies in Railroad Workers (HEI, 1995)

Relative Cancer Risks

Based on ARB monitoring data 1995 - 1997

Major Risk Factors in Regional Burden of Disease & Mortality (000)

WHO 2002

New Zealand ~399/970
Auckland ~253/436
Greenhouse Gas Effect

- Some of the infrared radiation passes through the atmosphere.
- Some infrared radiation is absorbed and re-emitted in all directions by GHG.
- The effect is to warm Earth.
- Most radiation is absorbed by the Earth and makes it warm.
- Some infrared radiation is absorbed and re-emitted in all directions by GHG.
- Earth and atmosphere reflect 30%.

Global Warming Concerns

- IPCC - 1995
  - "the balance of evidence suggests a discernible human influence"
- IPCC - 2000
  - "there has been a discernible human influence on global climate"

Share of worldwide CO2 emissions from the combustion of fuel, by sector -- 1998

- Transport: 42%
- Production of Energy: 40%
- Manufacturing and Construction: 19%
- Residential: 8%
- Commercial and other: 4%

Transport contributes 42% of New Zealand's CO2

Elements of a Comprehensive Vehicle Pollution Control Strategy

- Clean Vehicle Technology
- Appropriate Maintenance
- Clean Fuels
- Transportation & Land Use Planning
California’s Goal: “Zero” Emissions

US Tier 2 Standards

United States and California On-road Truck Engine Standards, Beginning with the 1988 Model Year

Results of the British Columbia I/M Program Audit
Results of the British Columbia I/M Program Audit

HC (g/km)

Before Repair  | After Repair
---|---
Pre-1981 | 4
1981-87 | 3
Post 1987 | 2

NOx (g/km)

Before Repair  | After Repair
---|---
Pre-1981 | 3.5
1981-87 | 2.5
Post 1987 | 1.5

Emissions From Gasoline Cars In Europe

% reduction

Europe

ITALY GREECE BULGARIA ROMANIA HUNGARY SERBIA AUSTRIA FRANCE SPAIN PORTUGAL GERMANY POLAND SLOVAKIA CZECH REPUBLIC SWITZERLAND NETHERLANDS BELGIUM CROATIA SLOVENIA BOSNIA UNITED KINGDOM IRELAND NORWAY SWEDEN FINLAND ICHELAND ALBANIA MACEDONIA DENMARK LUXEMBOURG ANDORRA MALTA MONACO
Emissions From Diesel Cars In Europe

Heavy-duty Vehicles Emission Reduction In Europe
On ETC Test Cycle

European Fuel Sulfur Levels (PPM)

Cabin Air Quality
Gasoline and LPG

Comparison of Particle Emissions from SMPS 7: All Vehicles and Fuels - 50km/h

Conventional Diesel
Direct Injection
Gasoline
Trap Equipped Diesels
(MPI and LPG Gasoline)

European Agreement (g CO₂/km)
- Some 120 g/km Cars in 2000
- Target Range of 165-170 g/km in 2003
- Review Feasibility of 120 g/km for Average car by 2012

ACEA’s CO₂ Reduction

Penetration of Diesel Cars in Europe (% of New Sales)
Diesel PM Emissions Must Be Very Low For Diesels To Provide A Net Greenhouse Benefit

Source: Jacobson, "Control of Fossil-Fuel Particulate Black Carbon and Organic Matter: Possibly The Most Effective Method of Slowing Global Warming"

Japan

New Standards For Japanese Vehicles (October 2005)

50 PPM Maximum Sulfur Being Phased in 2003/4

New Japanese Fuel Economy Regulations

Source: Japan Ministry of Transport
New Vehicle Standards In Asia

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South America
Sales of Lead Free Gasoline
By End of 2002

- Lead Free
- Still Some Leaded

Don’t Replace One Harmful Substance With Another

California Civic 600
cpsi catalyst - 49,000 miles
No MMT

Canadian Civic 600
cpsi catalyst - 49,000 miles
With MMT

Diesel Fuel Specifications Around The World

- US
- EU 2005
- Japan 2004
- Germany 2003
- EU 2005/9
- HK Tax Scheme

The Three-way Catalytic Converter: A Familiar Technology Re-Engineered for High Performance in Close-coupled and Underfloor Applications

- Layered washcoat architectures and support materials with high thermal stability
- Integrated HC adsorption functions
- Mounting materials with improved durability
- High cell density ceramic or metallic substrates
- Insulation schemes for heat management
Diesel Particulate Filters

- Trapped PM
- Cell Plugs
- Exhaust (PM, CO, HC) Enter
- Ceramic Honeycomb Wall

Reductions:
• ~80 to 95% PM
• ~80-100% HC, CO
• ~80%+ toxins

Issues to balance:
• Sulfate formation
• Regeneration and back pressure
• Fuel Economy

Diesel Passenger Car Standards In The US, EU and Japan

Fuel Economy Reductions:
• ~80 to 95% PM
• ~80-100% HC, CO
• ~80%+ toxins

NOx Emissions (G/Km)

PM Emissions (G/Km)

EU Current
Japan Current
US Current
EU 2005
Japan 2005
US Tier 2 SULEV

Current and Future Heavy Duty Diesel Standards in US, EU & Japan

PM G/AWh

Recent and Projected World Transportation Fuel Demand

Source: EIA/DOE (2001)

Other
Bunker
Jet Fuel
Diesel
Gasoline

Source: EIA/DOE (2001)
Hybrid Vehicle Commercialization

- Toyota Prius: Small car, 2000
- Honda Civic: Small car, 2002
- Ford Escape: Small SUV, 2003
- Dodge Durango: Large SUV, 2003
- GM Sierra: Large Pickup, 2004
- GM: Medium SUV, 2004
- Toyota: Minivan, ?

Potential Future AFV Technology

- Hydrogen Fuel Cell Vehicles
- Direct Methanol Fuel Cell Vehicles
- High Efficiency Direct Injection Engines for Light- and Heavy-Duty Vehicles

Swedish Retrofit Program
All Trucks Above 3.5 Tons

New York City Retrofit Experience

- Very Low Sulfur Fuel Dominates The Market
- NOx, PM, CO, HC, CO2, NOx, T, HC, CO, PM, CO2, NOx, T, HC, CO, PM

OE M Catalyst / ULSD (50 ppm S) fuel
CRT Catalyst / ULSD (50 ppm S) fuel
Retrofit Reduction Required For Consideration in Tokyo

Diesel PM Inside School Bus

Diesel Exhaust Concentrations on Bus - Windows Open or Closed

Diesel Exhaust in the Back and Front of a Bus With Windows Closed

2WD tractor
130 hp

4WD tractor
250 hp

Combine
300 hp

Square baler
60 hp

Square bale wagon
150 hp