

Diesel Exhaust Exposure and Lung Cancer In the Transportation Industry

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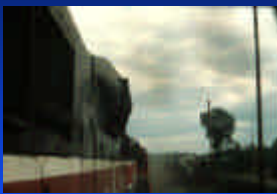
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Outline

- What is diesel exhaust?
- Past studies of lung cancer
- Air pollution health effects: is diesel unique?
- Recent lung cancer studies
 - Railroad worker studies
 - Trucking industry particle study

Diesel Exhaust Exposure Scenarios



Off road: Railroad Exposure



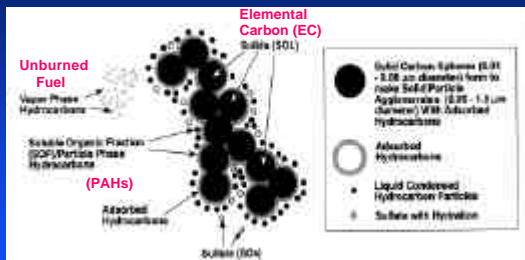
On road: Highway exposure

Diesel Exhaust Composition

- Vapor phase
 - Carbon monoxide
 - Carbon dioxide
 - Sulfur dioxide
 - Nitrogen oxides
 - Aldehydes
 - Hydrocarbons
 - PAH compounds
- Particulate phase
 - Elemental carbon
 - Sulfates
 - Hydrocarbons
 - PAH compounds

PAH = Polycyclic Aromatic Hydrocarbons

Diesel Particles



Carcinogenic agent(s)?

Health Effects Institute, 1995

Source Apportionment

- Each major combustion source has a characteristic organic "fingerprint" of emissions (numerous compounds on particles)
 - Diesel:** High concentration of PAHs and other organic compounds.
 - Wood:** High concentration of specific organic compounds.
 - Meat:** High concentration of specific organic compounds.
- Measure total $PM_{2.5}$, which is a combination of all sources.
 - Total:** A bar chart showing the total $PM_{2.5}$ as a combination of Diesel, Wood, and Meat emissions (equal amounts).
- Based on organic tracers (GC/MS), can determine the linear combination that accounts for the total → 33% from each source. Gas/diesel share fingerprint, but diesel produces more elemental carbon (15 to 40 times more).

How Big Are Combustion Particles?

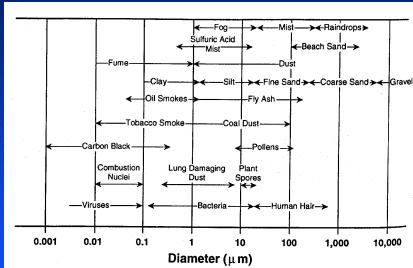


Fig. 14-1 Approximate size ranges for airborne inhalation hazards (from the Mine Safety Appliances Co., Pittsburgh, PA).

1 micron (μm) = $0.001 \text{ mm} = 10^{-3} \text{ mm}$

Size Determines Where Particles Deposit:

Tracheobronchial: $1 \mu\text{m}$ - $10 \mu\text{m}$ diameter particles
Alveolar: $< 1 \mu\text{m}$ diameter particles

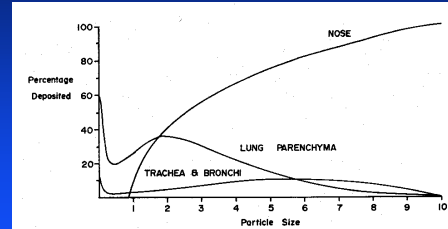


Figure 7-2. Regional deposition of particles as a function of their size in microns. This assumes a respiratory rate of 1.5 per minute and a tidal volume of 700 to 750 ml. (Based on data from Task Force Group on Lung Dynamics, Committee II ICRP, Deposition and retention models for internal dosimetry of the human respiratory tract. Health Phys., 12, 173, 1966.)

Particulate Matter (PM)

- Respirable particles: $\leq 10 \mu\text{m}$ (micron)
- Fine particles: $\leq 2.5 \mu\text{m}$ ($\text{PM}_{2.5}$)
 - ◆ Combustion particles
 - Motor vehicles
 - Burning of coal, fuel oil, wood, food
 - ◆ Crustal particles
 - Finely ground road dust and soils



EM of ambient PM on filter

Early Diesel Research- 1971

Odor and Irritant Effects



Lung Cancer Summary Of Results In Animals

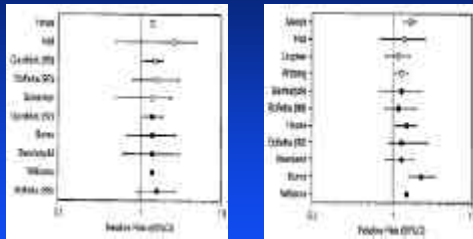
- Dose related increase in lung tumors at high levels of diesel exhaust exposure particles ($3500 \mu\text{g}/\text{m}^3$) in rats (1980's)
- Not observed in mice, hamsters
- Relevance to humans exposed at lower concentrations is uncertain
- Results can be reproduced by inhalation of other particles without organics (1990's)

Cancer Health Effects

- Lung cancer
 - ◆ USEPA (2002), CAEPA risk assessment (1998), HEI (1995) review
 - ◆ ~40 studies with 20% -50% risk in DE occupations
 - ◆ Unlikely to be explained by bias or confounding
 - ◆ EPA - likely to be a carcinogen (2002)
 - ◆ NTP - reasonably anticipated to be a human carcinogen
- Bladder cancer
 - ◆ Meta-analysis (2001) with 35 studies
 - ◆ Risk elevated 10% -30% in DE occupations
 - ◆ Confounding and bias can't be fully excluded

Occupational Exposure to Diesel Emissions and Lung Cancer

HEI Special Report 1995



Railroad workers

Truckers

(solid circle = smoking adjusted open circle = smoking unadjusted)

Exposure Assessment In 39 Lung Cancer Studies

- Single job title or usual job – 18 studies
- Yearly job listing or years of employment – 21 studies
- Source of information
 - ◆ Self-report, census, next-of-kin, death certificate - 21 studies
 - ◆ Union or work record – 17 studies
- Measurement of current exposure - 3 studies
 - ◆ Respirable particles adjusted for smoking (2 railroad worker studies, Garshick et al 1987 – case control, 1988 - cohort)
 - ◆ Limited measurements of elemental carbon (1 case-control study, Steenland et al, 1990)
- Estimation of lifetime dose inaccurate

Can Exposure to Urban Traffic Cause Lung Cancer?

Nyeberg et al (1999)

- Case-control study of 1,042 men with lung cancer in Stockholm 1985-1990
- Next-of-kin smoking/occupational history
- Exposure model developed based on 1993 NO₂ (linked to road network) and SO₂ values (home heating oil) using GIS
- Extrapolated to 1960 based on traffic counts, oil consumption
- Elevated cancer risk related to NO₂ levels with 20 years lag, but not SO₂.

Nafstad et al (2003)

- 16,209 men age 40-49 in Oslo in 1972/73
- Lung cancer mortality assessed through 1998
- NO₂ and SO₂ exposure models
- Risk related to NO₂, greatest with 1974-1978 levels, not SO₂

Particulate Air Pollution and Lung Cancer

	Six Cities PM _{2.5}	ACS PM _{2.5}
Lung cancer	1.37 (0.81-2.31)	1.14 (1.04-1.23)

- Harvard six city study: RR of most vs. Least polluted city (Dockery et al. 1993)
- American cancer society cohort: RR per 10 µg/m³ rise in PM (pope et al. 2002)

VA Boston/ BWH/HSPH Diesel Cohort Studies

- US railroad worker studies
 - Case-control (1987), retrospective cohort (1988, 2000)
 - Exposure assessment (1988)
 - RR worker cohort mortality update (2004)
- US trucking industry particle study
 - NCI funding 2001-2006
 - Motor-freight carrier association companies and IBT
 - Retrospective cohort study and exposure assessment

Railroad Worker Cohort Study: Design

- Railroads converted to diesel during 1950's
- By 1959 – 96% diesel
- 54,973 workers age 40-64 in 1959
- Yearly work history – RR retirement board
- 43,593 total deaths
- 4,351 lung cancer deaths
- Exposed workers: train crews
- Unexposed: clerks, station agents, Signal maintainers



Railroad Worker Study: Results

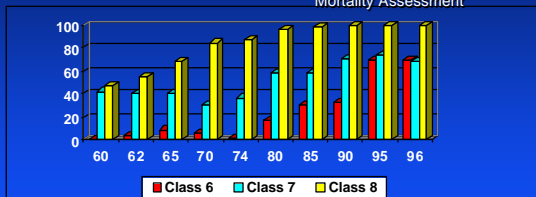
- Lung cancer risk in diesel exposed jobs
 - 1.40 (95% confidence interval=1.30-1.51)
 - Garshick E et al. Lung Cancer in Railroad Workers Exposed to Diesel Exhaust Environ Health Perspect 2004; 112: 1539-43.
- Smoking adjustment
 - Indirect adjustment – work in progress
 - Significantly elevated relative risk approximately 1.24
- Workers exposed to older diesels in 1950's and 1960's
- Modern RR diesels in 1970's to mid 1980's
- Not able to estimate dose

Trucking Industry Particle Study

- Teamster cohort
- 56,000 unionized workers employed in 1985
- Lung cancer mortality through 2000
- Stable workforce with computerized records
 - Job titles, work locations (terminals)
- Can link job title and work location to epidemiologic data
- Exposure assessment to define relationship between job and terminal activities
- Estimate exposure based on models
- Local and long-haul drivers, dockworkers, shop

% Diesel Vehicles Sold in the US By Weight Class And Year

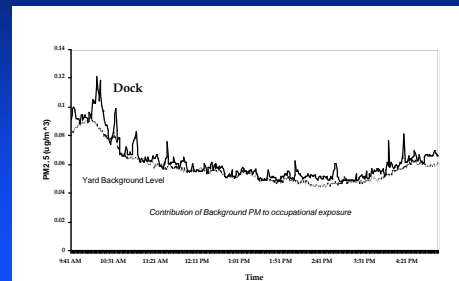
1985-2000
Mortality Assessment



Adapted from the American Automobile
Manufacturer's Association (1968,1975,1996,1997).

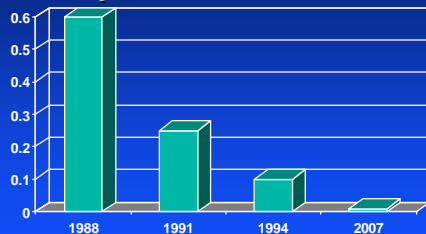
Variation in Real-time $PM_{2.5}$ in Dock Area and Upwind of an Urban Atlanta Terminal.

Garshick E et al. in Diesel Epidemiology Working Group. 2002.
Health Effects Institute, Boston, MA.



Heavy Duty Diesel On Road Regulations

grams/brake-hp



Low sulfur fuel in 2006