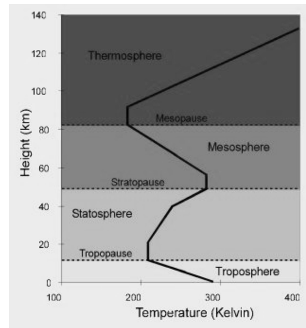
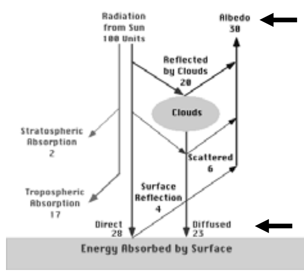
Overview

- **The natural atmosphere**
- **Outdoor pollutants and their sources**
- **Indoor air pollution**
- **Health effects of air pollution**
- **Climate change**

Vertical structure of the atmosphere

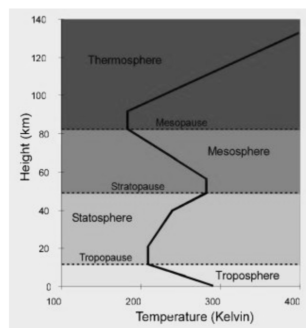


Distribution of incoming solar radiation



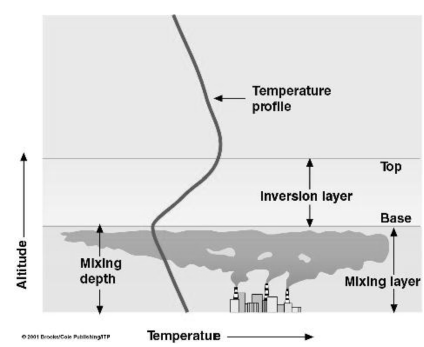
30% reflected back to space

About half absorbed by surface



As a warm parcel rises, it expands and cools, resulting in the "normal lapse rate" (– 6.5 ºC/km) of troposphere depicted here.

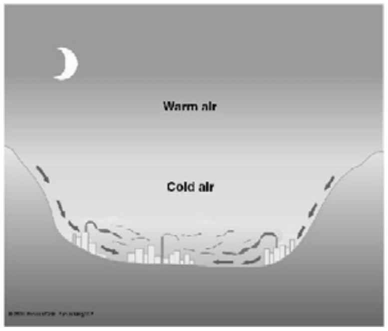
When the temperature lapse rate becomes "inverted" near the surface in urban areas, high pollution levels are likely to result



A Typical Morning in Denver, Colorado

Photo: David Parsons

Worst Case: Inversion in a Valley

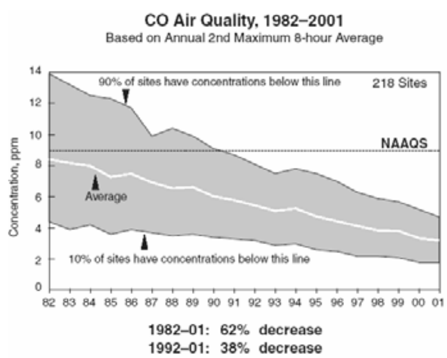


Air Pollutants of Human Health Concern

- **Carbon monoxide**
- **Sulfur dioxide**
- **Nitrogen dioxide**
- **Volatile organics**
- **Ozone**
- **Particulate matter**
  - **Sulfates, nitrates, organics, elemental carbon, lead and other metals**

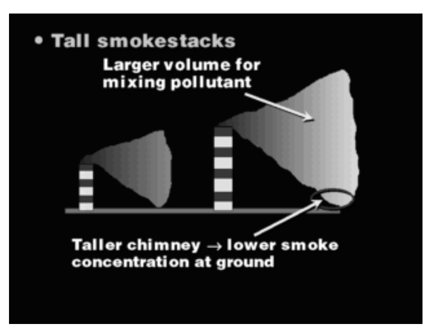
Carbon Monoxide - CO

- **Colorless, odorless gas**
- **Primary pollutant, emitted by incomplete combustion of biomass or fossil fuels**
- **Binds strongly with hemoglobin, displacing oxygen**
- **Emissions reduction by higher temperature combustion and use of catalytic converters on motor vehicles**

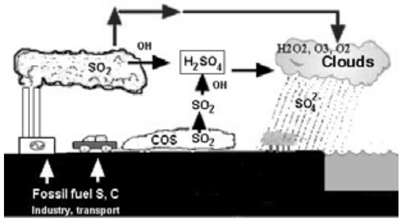


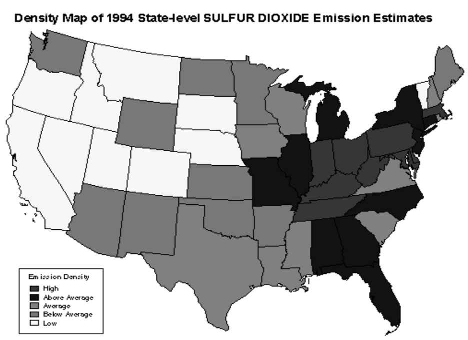
Sulfur Dioxide – SO_2

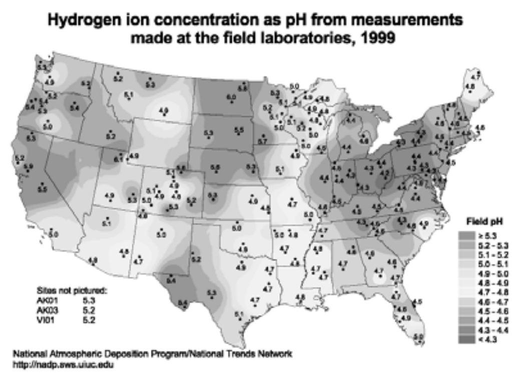
- **Primary pollutant, emitted by combustion of fuels containing sulfur; also metal smelting**
- **Irritates upper respiratory tract**
- **Converted in atmosphere to acid sulfates**
- **Emissions reductions by building taller smoke stacks, installing scrubbers, or by reducing sulfur content of fuel being burned**



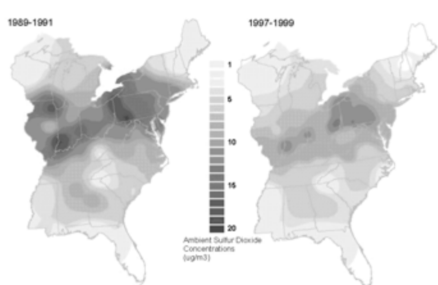
Acid Precipitation Formation





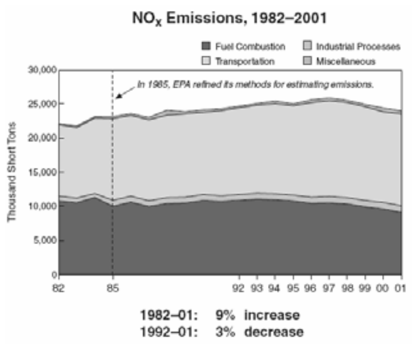


Progress in reducing SO2 concentrations



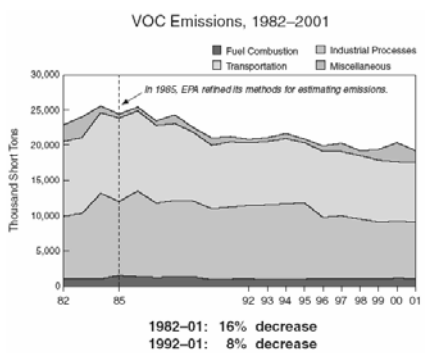
Nitrogen Dioxide – NO_2

- **Formed by oxidation of NO, which is produced with high temperature combustion (NO_2 is a secondary pollutant)**
- **Oxidant that can irritate the lungs and hinder host defense**
- **A key precursor of ozone formation**
- **Emissions reductions by engine redesign and use of catalytic converters**



Volatile Organic Compounds VOCs

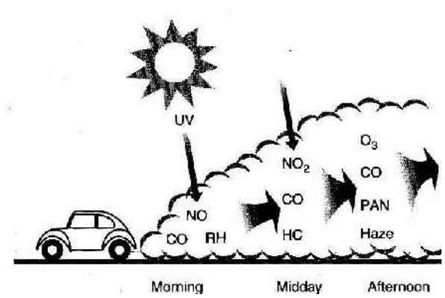
- **Products of incomplete combustion, evaporation of liquid fuels, atmospheric reactions, and release from vegetation (both primary and secondary)**
- **Wide range of compounds with varying health effects**
- **Another key ozone precursor**
- **Emissions reductions by high temperature combustion and control of evaporation, e.g., during refueling of cars**

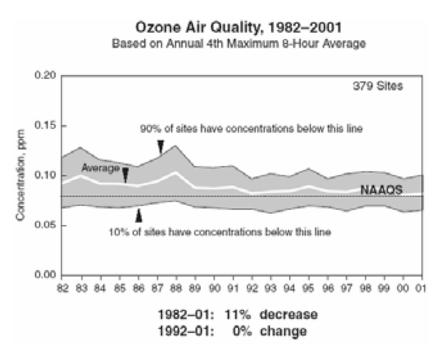


Ozone – O_3

- **Secondary pollutant, formed via photochemical reactions in the atmosphere from NOx and VOC in the presence of sunlight**
- **Strong oxidant that damages cells lining the respiratory system**
- **Concentrations often highest downwind of source regions**
- **Emissions reductions by control of NOx and VOC emissions, especially from motor vehicles**

Mechanisms of Ozone Formation

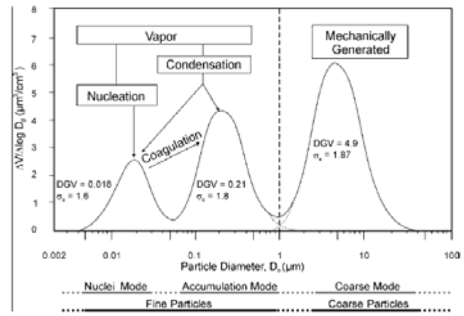


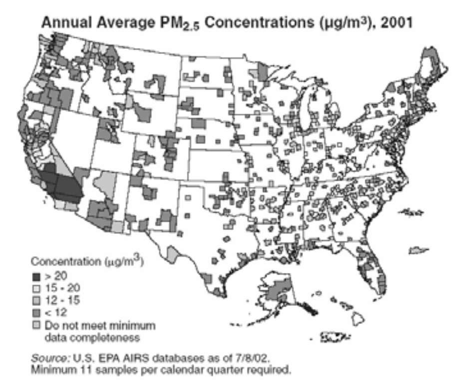


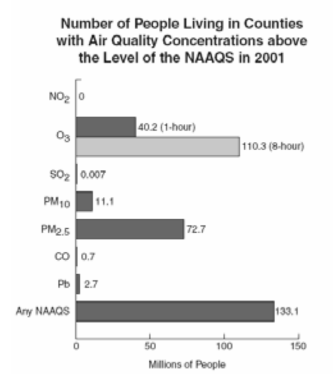
Particulate Matter - PM

- **Products of combustion, atmospheric reactions, and mechanical processes**
- **Wide range of particle sizes**
- **Wide range of physical/chemical properties**
- **Wide range of health impacts, including premature death**
- **Control by filtration, electrostatic precipitation, and reduction of precursor gases**

Distribution of particle mass at various particle diameters for a typical urban air sample



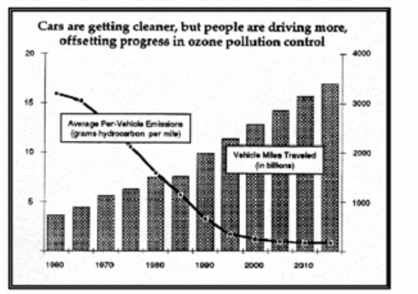




Motor Vehicles represent a major source category for several air pollutants (CO, NO_2, VOCs, O_3, PM)

Transportation emissions occur in close proximity to people

FIGURE 1. TRENDS IN VEHICLE EMISSIONS AND VEHICLE MILES TRAVELED[8]



Role of Diesel

30-200% more fuel efficient, 50-300% more durable than gasoline engine

Fuel Economy, Durability, Power

10x more particles / mile than gasoline engines, 30-70x more than engines with catalytic converters

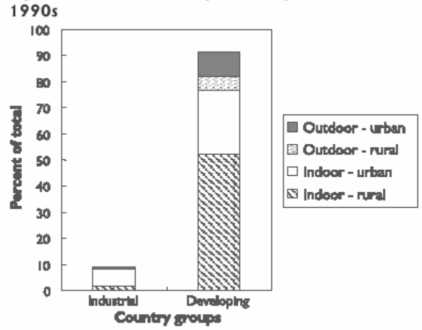
High PM, NOx, Toxics

Indoor Air Pollution

- **Combustion is principal source: cooking, smoking, heating**
- **Dilution and dispersion are limited, especially nearest the source**
- **Pollutants of greatest importance include: CO, NO2, PM, VOCs**
- **Indoor concentrations often far higher than outdoors, even in urban areas**
- **Those who spend the most time indoors near the source will be most impacted**

The most local form of air pollution: indoor combustion of biomass in India

Figure 2 — Worldwide exposure to particulates: Mid-1990s



Note: Exposure = concentration x population x duration.
Source: Smith 1998a.

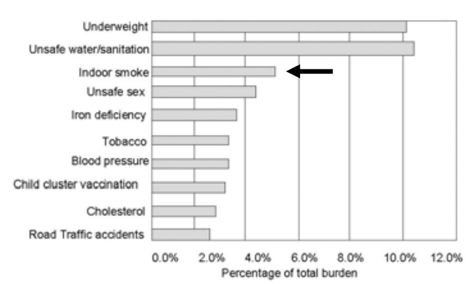


Fig. 2. Estimates of the impacts of ten largest risk factors for ill-health in poor South Asia. The impact of indoor air pollution is mainly on ALRI in children, with smaller contributions from COPD and lung cancer in adult women.
Source: World Health Organization, 2002, 2001.

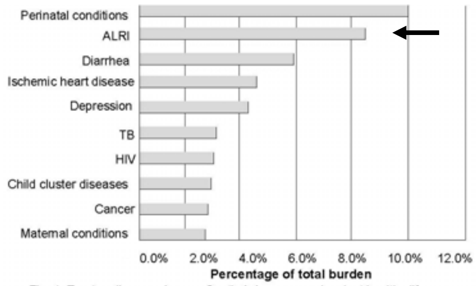
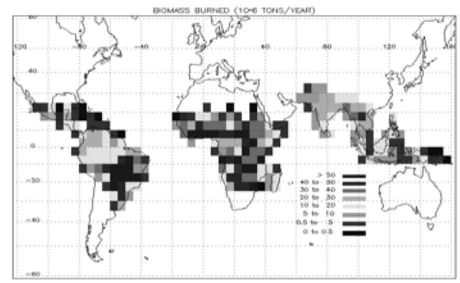
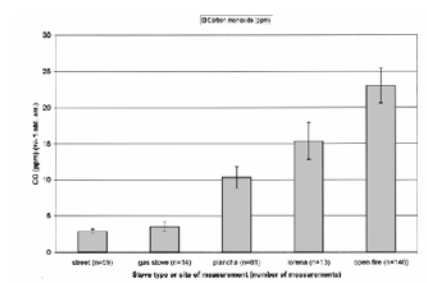


Fig. 1. Top ten diseases in poor South Asia measured as lost healthy life-years (DALYs). Includes India, Bangladesh, Myanmar and Nepal.
Source: World Health report, 2002, 2001.



- About half the world 's households use unprocessed solid fuels for cooking,ranging roughly from near zero in developed countries to more than 80%in China,India,and Sub-Saharan Africa (Holdren et al.,2000).
- In simple small-scale devices,such as household cookstoves, solid fuels have rather large emission rates of a number of important health-damaging airborne pollutants including respirable particulates,CO,dozens of PAHs and toxic hydrocarbons,and, depending on combustion and fuel characteristics, nitrogen and sulfur oxides.
- A large,although uncertain,fraction of such stoves are not vented,i.e.do not have flues or hoods to take the pollutants out of the living area.
- Even when vented to the outdoors,unprocessed solid fuels produce enough pollution to significantly affect local pollution levels with implications for total exposures (Smith et al.,1994).As cookstoves are essentially used everyday at times when people are present,their exposure effectiveness (or intake fraction)is high,i.e.the percentage of their emissions that reach people 's breathing zones, is much higher than for outdoor sources(Smith, 2002; Bennett et al.,2002).
- The individual peak and mean exposures experienced in such settings are large by comparison with WHO guidelines and national standards.

From: Kirk Smith, Indoor Air 2002;12:198 .207

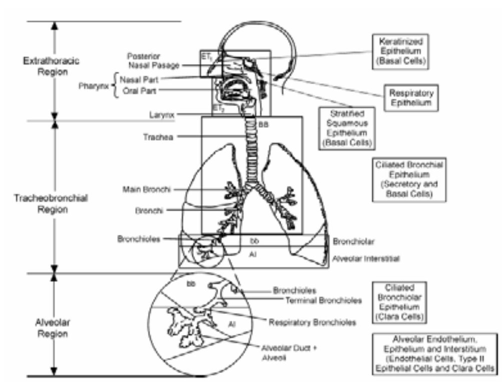


Indoor and outdoor $PM_{2.5}$ and CO in high- and low-density Guatemalan villages[1]

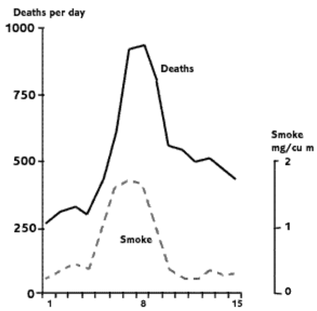
L.P. NAEHER,[a] K.R. SMITH,[b] B.P. LEADERER,[a] D. MAGE[c] AND R. GRAJEDA[d]

Health Effects of Air Pollution

- **Historical experience provides strong evidence for causal relationship between air pollution and premature death**
- **Modern epidemiology studies have consistently found significant associations**
- **Two primary epidemiologic study designs:**
  - **Time series studies of acute effects**
  - **Cohort or cross-section studies of chronic effects**
- **Let’s look at the evidence for particle health effects…**



London Killer Fog, December, 1952



London

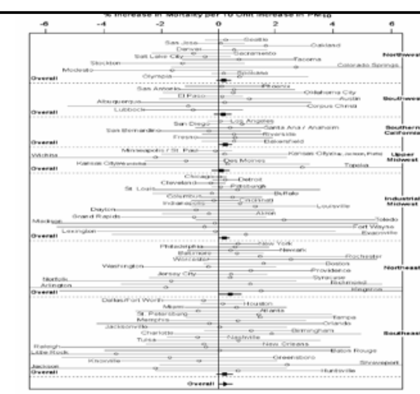
Mid-day in December 1952

Air Pollution Epidemiology

- **Provides most directly relevant results for policy makers**
- **Assesses effects of real mix of pollutants on human populations**
- **Pollutants tend to co-vary, making it hard to distinguish effects**
- **Can demonstrate associations between outcome and exposure, but not cause and effect**
- **Must control for confounding factors**
- **Exposure assessment is "ecologic"**

Time Series Epidemiology

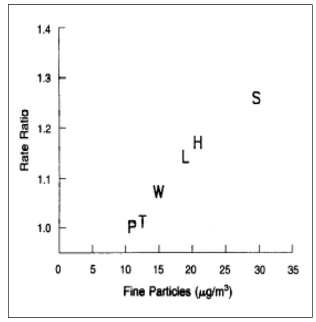
- **Addresses effects in narrow time window**
- **Involves multiple regression analysis of long series of daily observations**
- **Large number of studies have reported significant associations between daily deaths and/or hospital visit counts and daily average air pollution.**
- **Time series design avoids spatial confounding; however, temporal confounding due to seasons and weather must be addressed.**
- **Particles often appear most important, but CO, SO_2, NO_2, and/or ozone may also play roles.**
- **For example, NMMAPS Study**



Estimated excess risks for PM mortality (1 day lag) for the 88 largest U.S. cities as shown in the revised NMMAPS analysis.

Cohort Epidemiology

- **Address long-term exposure-response window**
- **Large populations in multiple cities enrolled and then followed for many years to determine mortality experience**
- **Must control for spatial confounders, e.g., smoking, income, race, diet, occupation**
- **Assessment of confounders at individual level is an advantage over cross-sectional, "ecologic" studies**



$PM_{2.5}$ associated with increases in daily CV mortality, CV-based hospital admissions, respiratory hospital admissions , mortality.

(Dockery, Pope, et al 1993; Schwartz 1994, Schwartz, Dockery 1996, Schwartz and Neas 2000)

Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution

Pope, C.A. et al., Journal of the American Medical Association: 287, 1132-1141, 2002

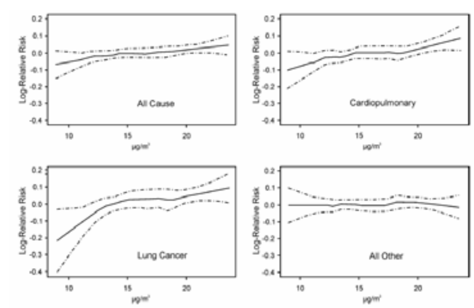
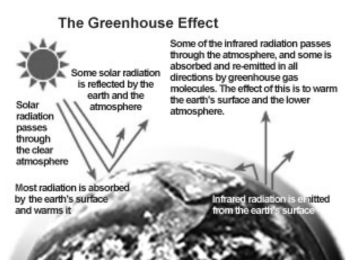


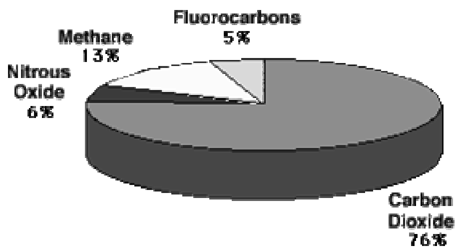
Figure 8-9. Natural logarithm of relative risk for total and cause-specific mortality per 10 μg/m³ $PM_{2.5}$ (approximately the excess relative risk as a fraction), with smoothed concentration-response functions. Based on Pope et al. (2002) mean curve (solid line) with pointwise 95% confidence intervals (dashed lines).

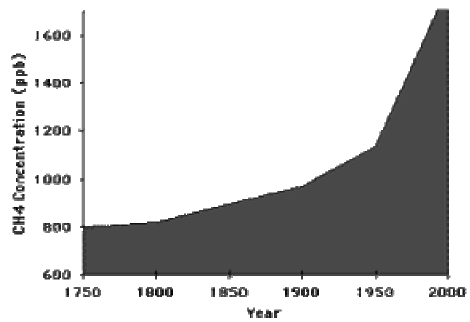
Conclusion

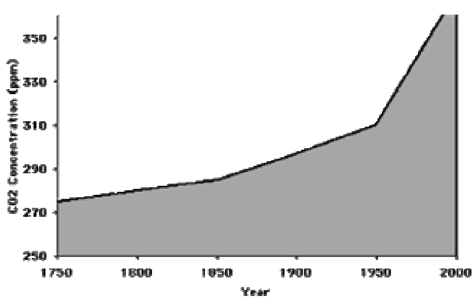
- **"Long-term exposure to combustion-related fine particle air pollution is an important environmental risk factor for cardiopulmonary and lung cancer mortality."**

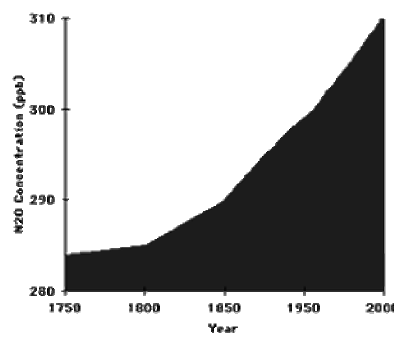


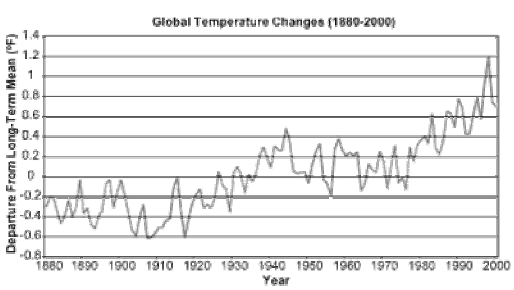
The Greenhouse Gases











Impacts of Climate Change

- General warming; greater at poles; greater in winter
- Sea level rise
- Changing rainfall patterns
- Greater variability and intensity of weather extremes
  - Longer and deeper droughts
  - More frequent and extreme storms

Climate Change and Public Health

- Changing patterns of rainfall will have profound effects on local agriculture, water supply, and well-being
- Heat-related mortality and morbidity
- Death and injury due to extreme storms
- Changing patterns of vector-borne diseases
- Air pollution
- Ability to adapt will vary with income level