RAPIDC
Regional Air Pollution In Developing Countries

SEI STOCKHOLM ENVIRONMENT INSTITUTE

Exposure, measurement and estimation of health impacts

Presentation
by
Dieter Schwela
Stockholm Environment Institute, University of York

Malé Declaration: Workshop on
Air Quality and Health Impacts

19-22 February 2007, Bangkok, Thailand

Learning objectives

Understanding

- **Direct and indirect impacts on health**
- **Interrelationship between sources and pathways**
- **Elementary concepts of exposure**
- **Deposition of particles in the air ways**
- **Classification of air pollution health effects**
- **Overview of the current status of health impacts of key air pollutants**

The Problem

Urban air pollution poses a significant threat to human health and the environment throughout the Asia Region

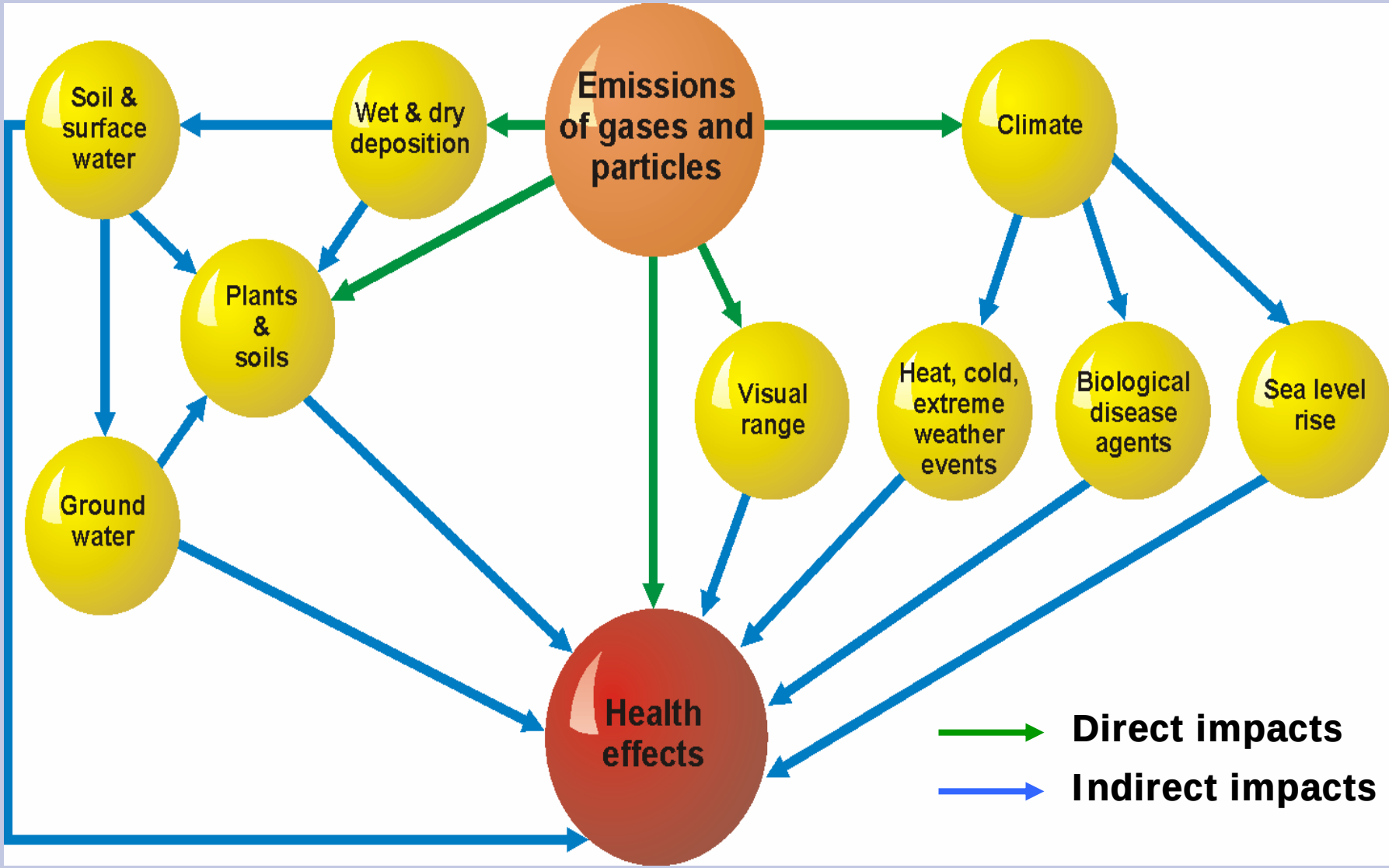
The issue of urban air quality:

- **Receiving more attention (increasing share of the Asian population living in urban centres and demanding a cleaner urban environment)**
- **Increased economic development is leading to rapid and unplanned urbanization**
- **Urban air pollution contributes to regional and global air pollution (acidification, regional haze, global climate change)**

Impacts of air pollution at different scales

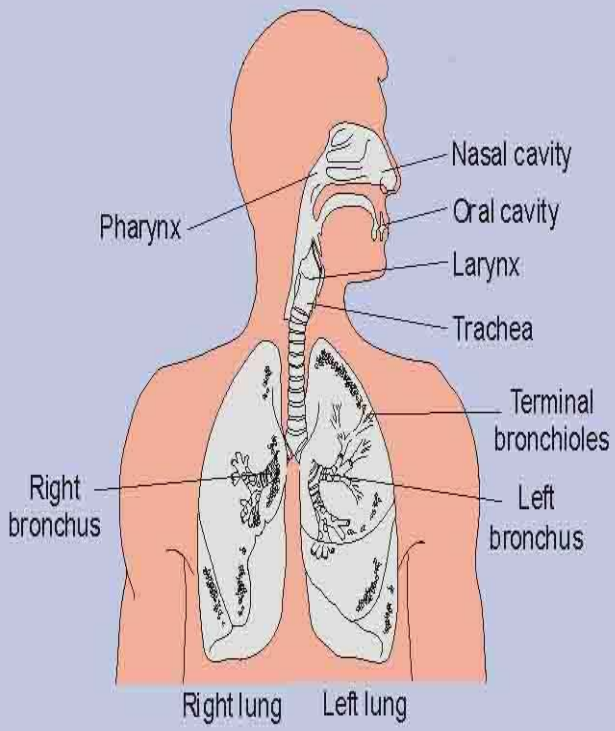
Household Urban Peri-urban Regional Global

The direct and indirect impacts of air pollution on health



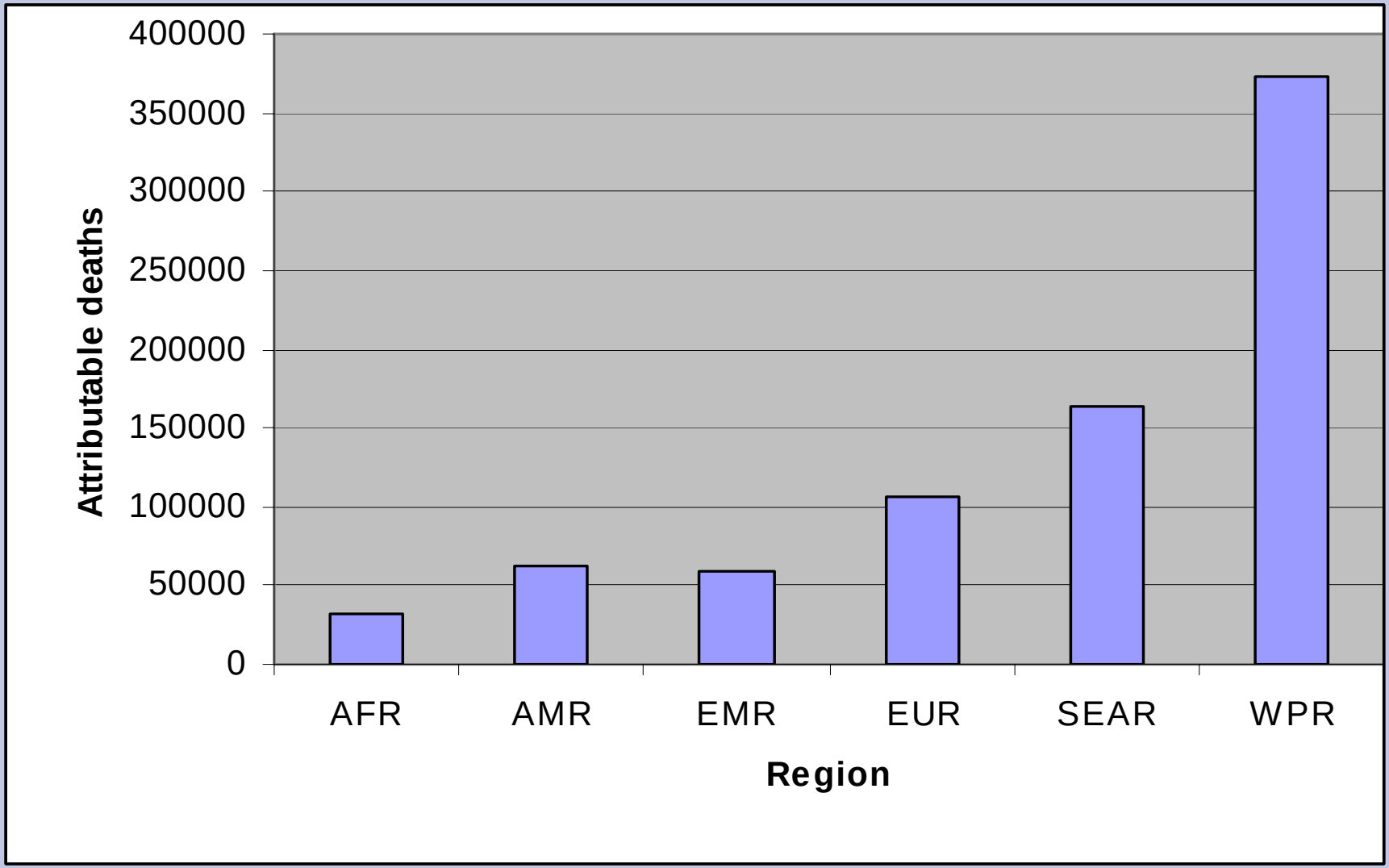
Health effects

- Respiratory System
- Immune System Allergies
- Skin and on Mucosal Tissues
- Sensory Effects
- Central Nervous Syster
- Cardiovascular System
- Carcinogenic Effects

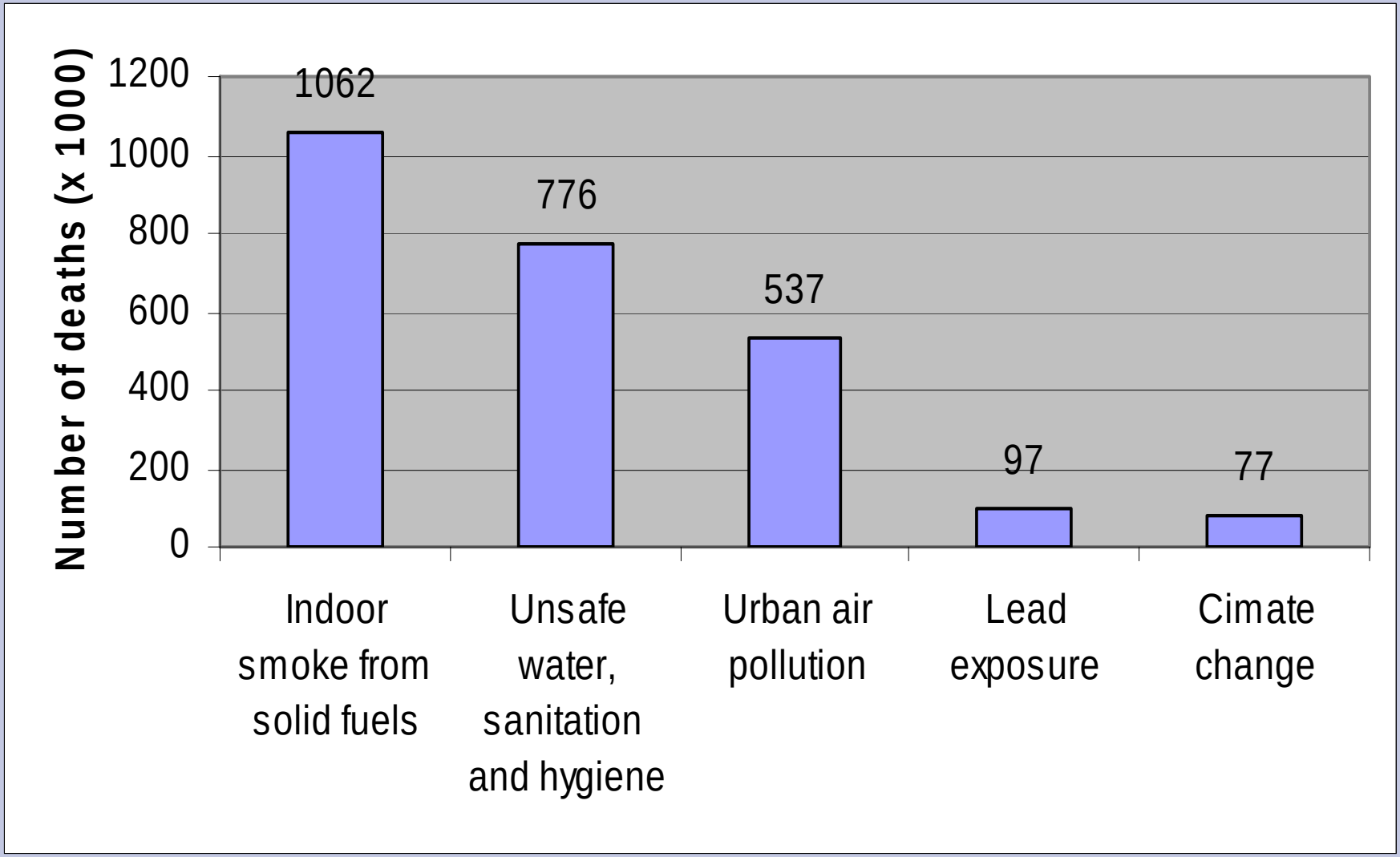


Economic impacts

Number of annual deaths attributable to outdoor air pollution by region



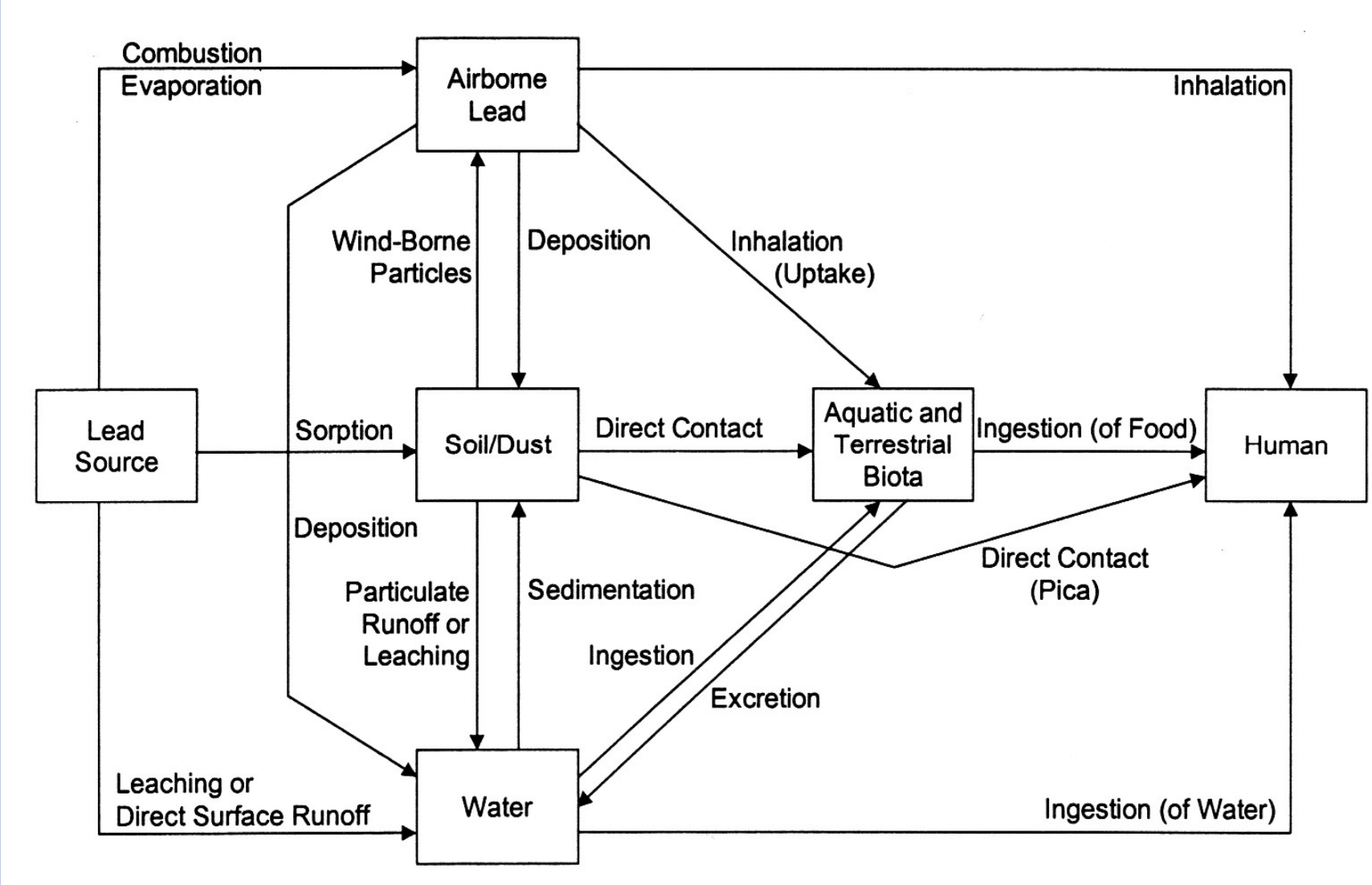
Annual mortality attributable to environmental risks in South East Asia and Western Pacific



Impacts of air pollution at different scales

Household Urban Peri-urban Regional Global

Interrelationships between sources and pathways of airborne lead

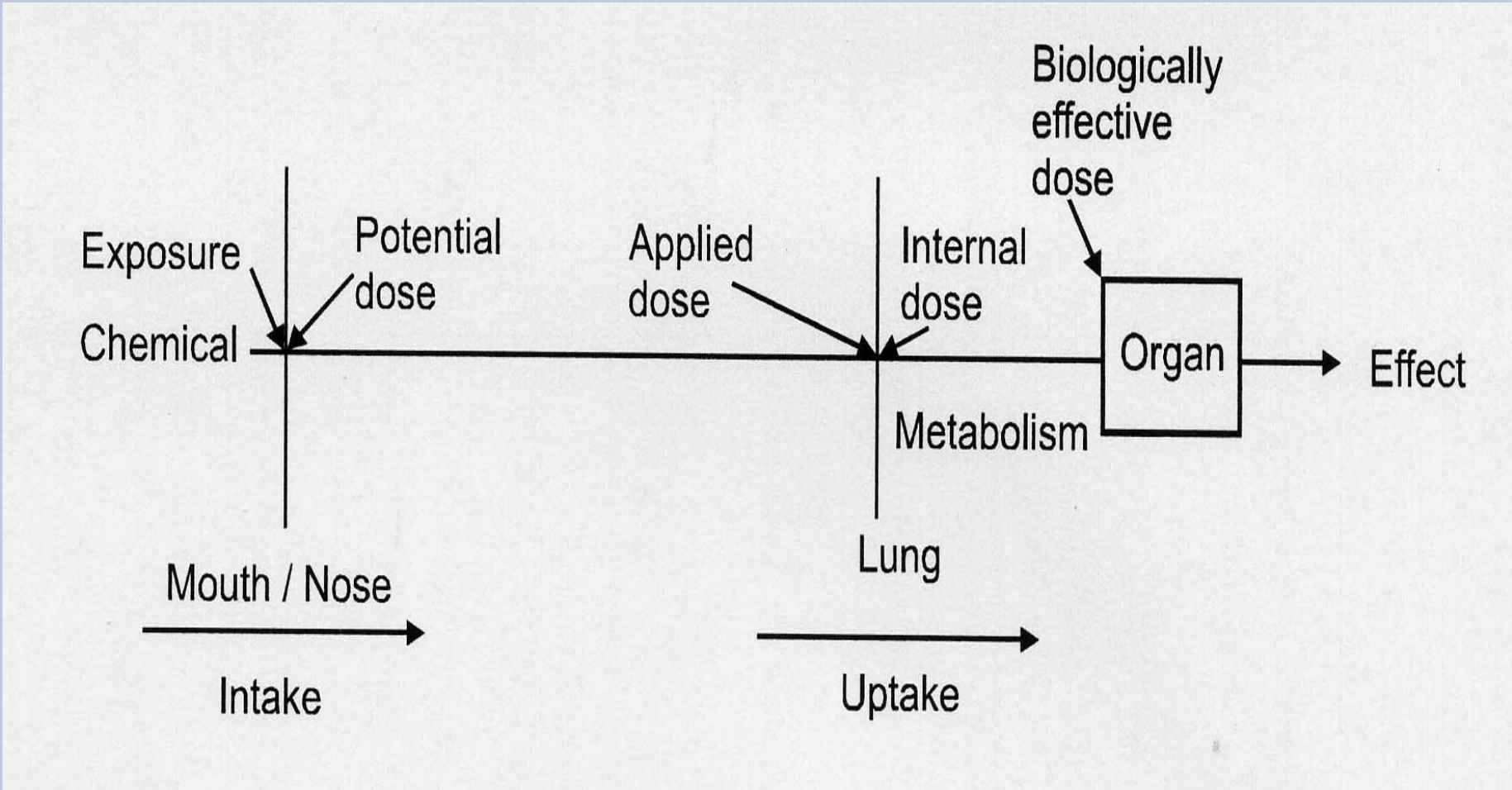


Concepts of exposure, intake, uptake, and dose

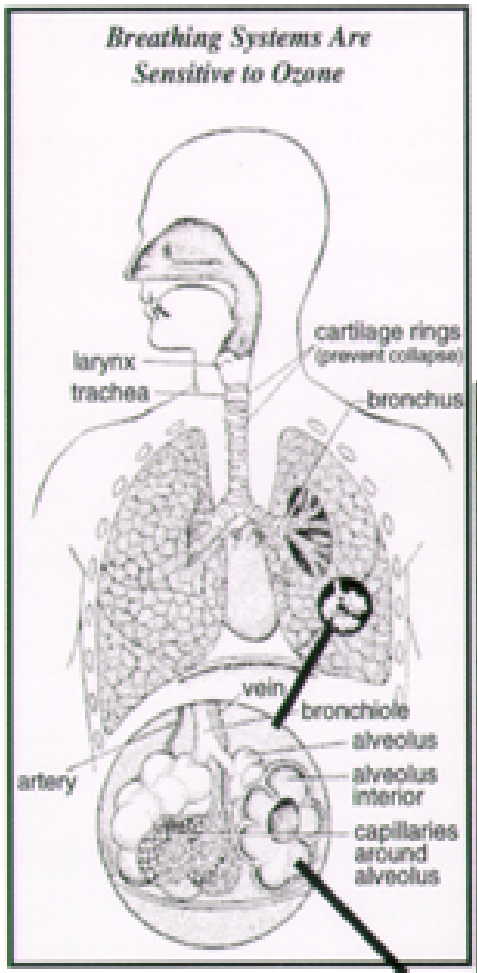
Two-step process of a chemical entering the body

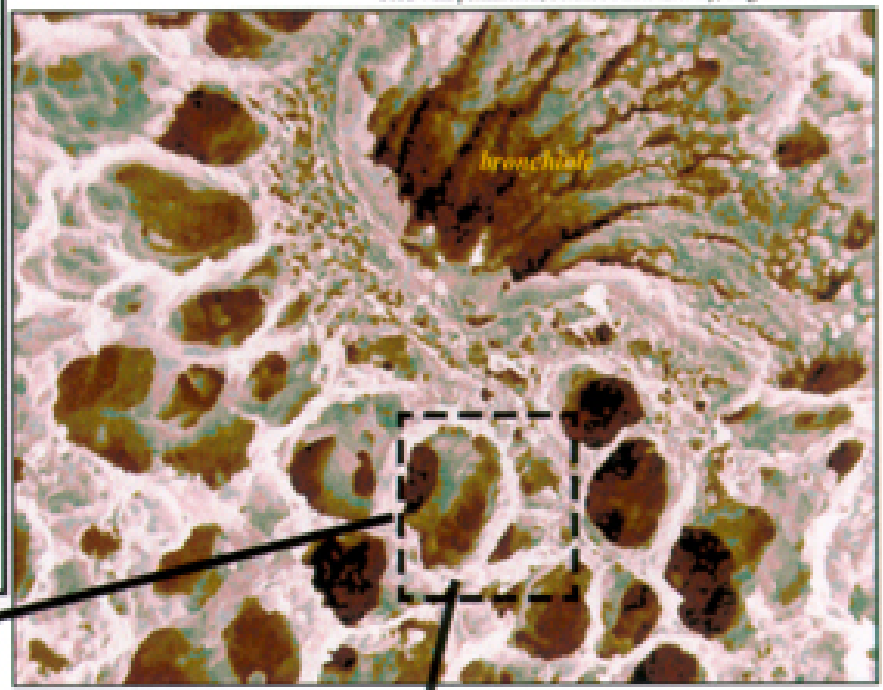
- Contact (simple)
- Crossing the boundary (more complex)
  - Intake (physically moving the chemical through nose or mouth)
  - Uptake (absorption of the chemical)
    - Potential dose (amount of the chemical inhaled)
    - Applied dose (amount of a chemical at the absorption barrier, e.g. lung)
    - Internal dose (amount of the chemical that has been absorbed and is available for interaction with biologically significant receptors
    - Biologically effective dose (amount that actually reaches cells, sites, or membranes where adverse effects occur)

Respiratory route



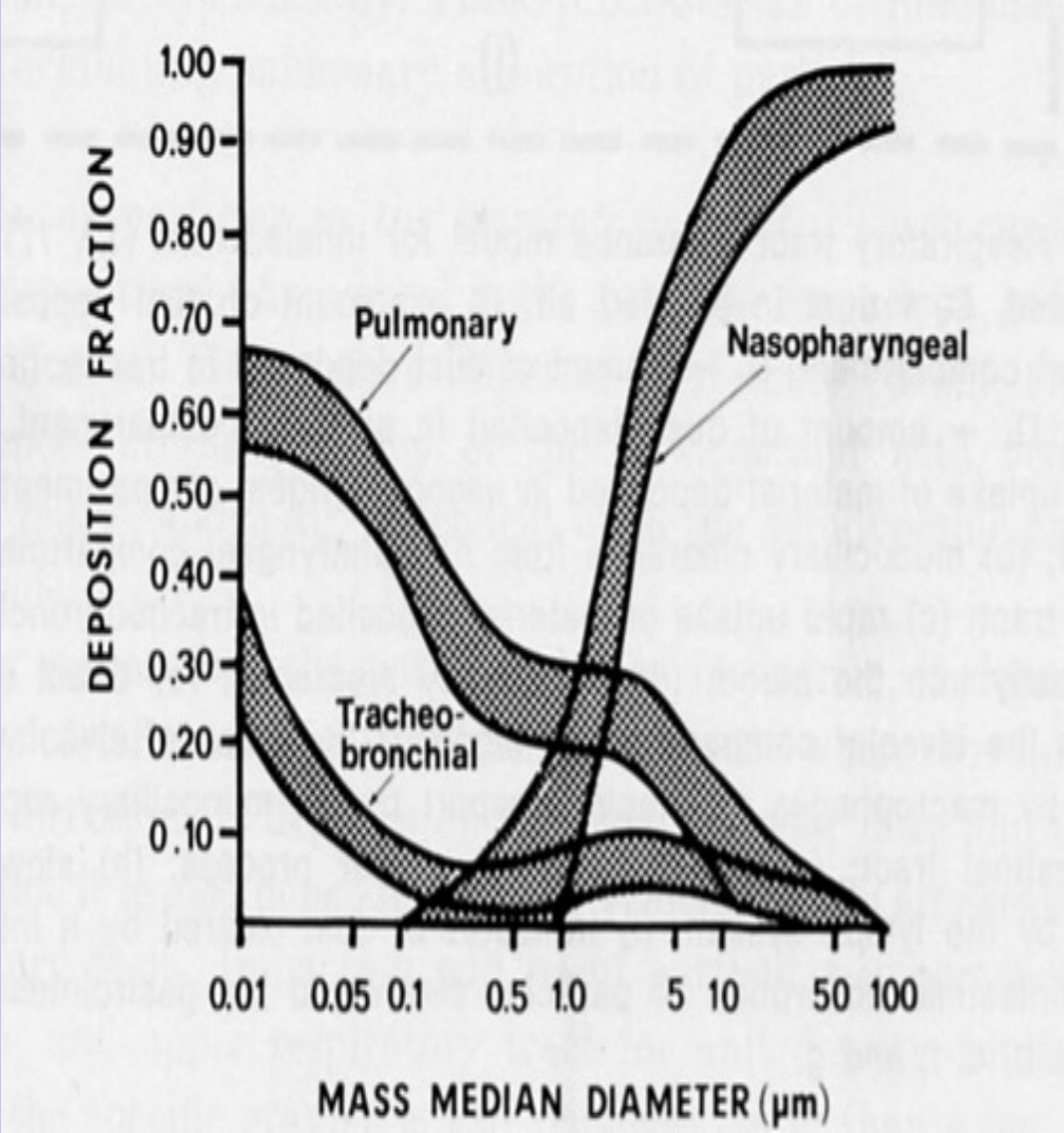
Exchange of gases (oxygen and carbon dioxide) occurs in air sacs (alveoli); our lungs contain some 700 million alveoli which have a total surface area comparable to that of a tennis court.





alveolus with accompanying capillaries

The respiratory tract is essentially a system of branching tubes which convey air from the mouth and nose to the sites in the lungs where exchange of gases takes place.



Deposition of particles in the respiratory tract

Impaction

Sedimentation

Diffusion

Classification of health effects of air pollution

Respiratory System

Immune System Allergies

Skin and on Mucosal Tissues

Sensory Effects

Central Nervous System

Cardiovascular System

Carcinogenic Effects

Effects of AP on the Respiratory System

A) Health Effects

Acute and chronic changes in pulmonary function

Increased incidence and prevalence of respiratory symptoms

Sensitization of airways to allergens present in the indoor environment

Respiratory infections (rhinitis, sinusivitis, pneumonia, alveolitis, legionnaires´ disease)

B) Principal Agents

Combustion Products: NO_x , SO_2 , CO, PM_{10}, $PM_{2.5}$

ETS : PM

Formaldehyde

Infectious Organisms

Effects of AP on the Immune System Allergies

A) Health Effects

- Allergic Asthma
- Allergic Rhinoconjunctivitis
- Extrinsic Allergic Alveolitis / Hypersensitivity Pneumonitis
- Permanent Lung Damage in Sensitized Individuals
- Pulmonary Insufficiency

B) Principal Agents

- House Mite Dust, Cockroaches, Pets, Insects and Moulds
- Outdoor Allergens
- High Humidity

Effects of AP on the Central Nervous System

A) Effects

Toxic Damage of Nerve Cells

Hypoxic / Anoxic Damage of Nerve Cells

Changes in neurophysiological behaviour

B) Principal Agents

VOC (Acetone, Benzene, Toluene, Formaldehyde)

CO, Pb

Pesticides

Effects of AP on the Cardiovascular System

A) Effects

- Reduced Oxygenation
- Increased Incidence and Prevalence of CVD
- Increased Mortality due to CVD
- Myocardiac Infarction

B) Principal Agents

- CO, PM
- ETS

Carcinogenic Effects of AP

A) Effects

Lung Cancer

Leukemia

Other ???

B) Principal Agents

Arsenic

Asbestos Fibres

Chromium

Nickel

Cadmium

Benzene

PAH

TCE

ETS

Radon

Synergism ?

Short-term exposure studies

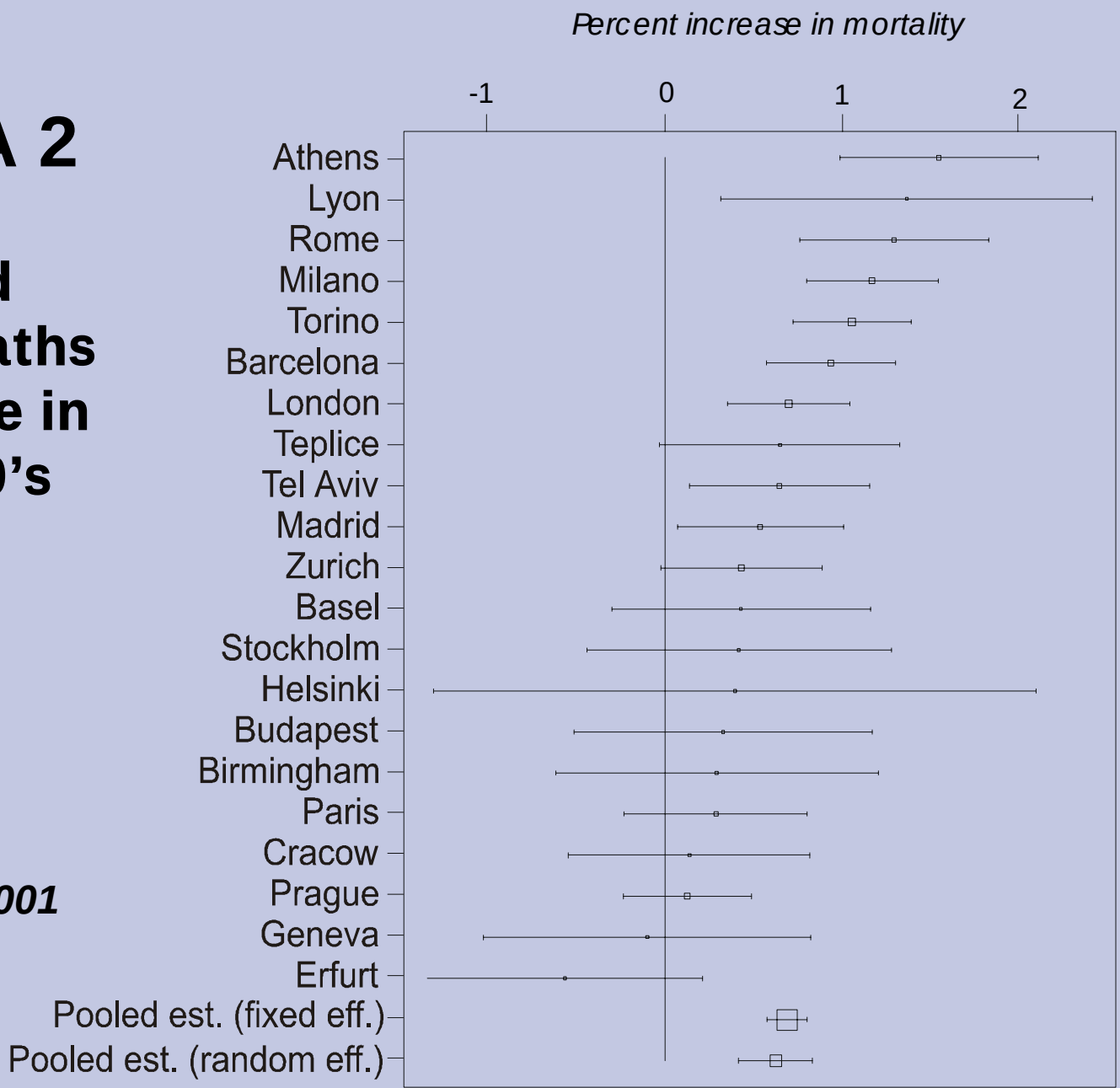
Time-series study

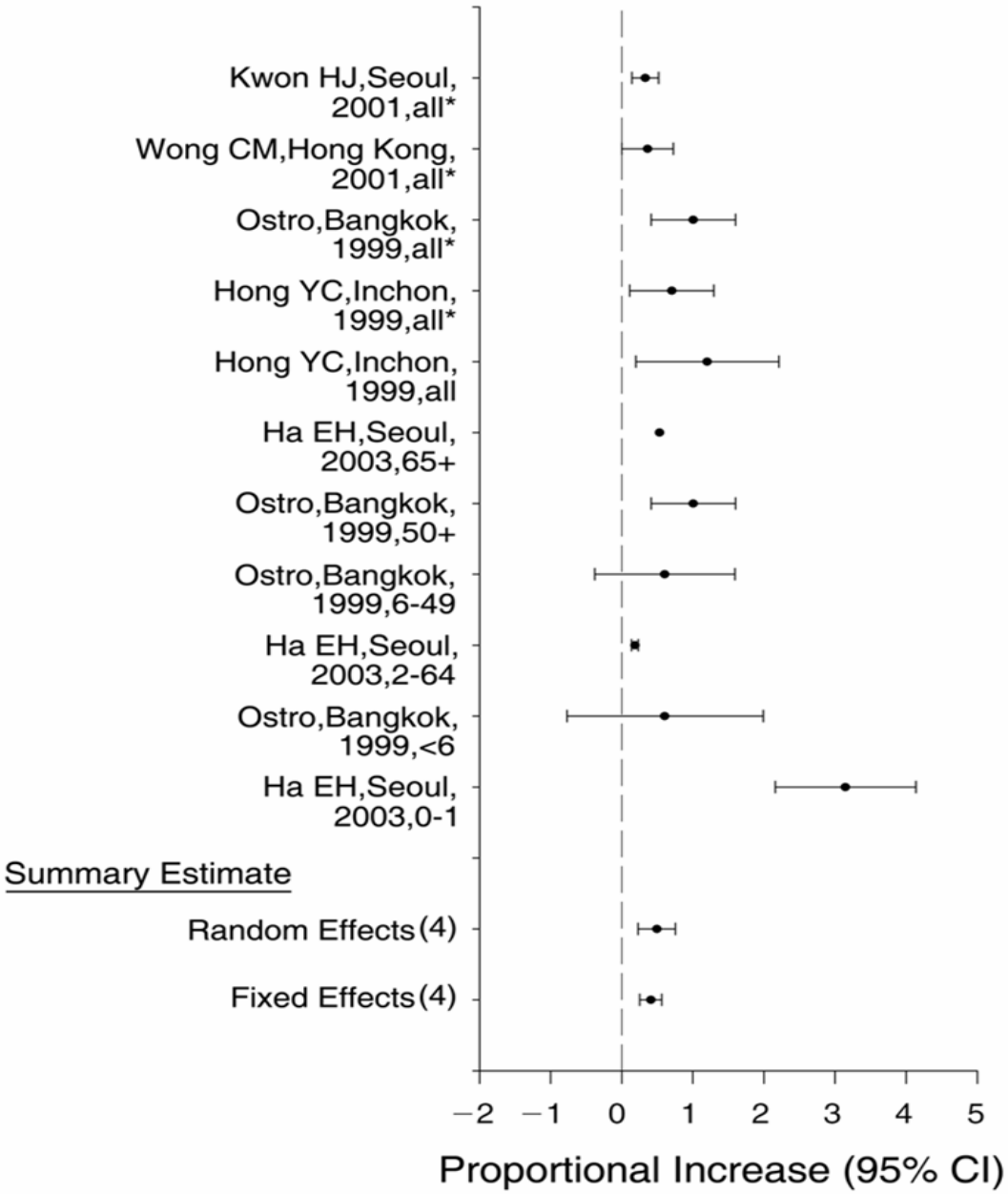
Case cross-over study

APHEA 2

PM_{10} and daily deaths in Europe in the 1990's

Katsouyanni 2001



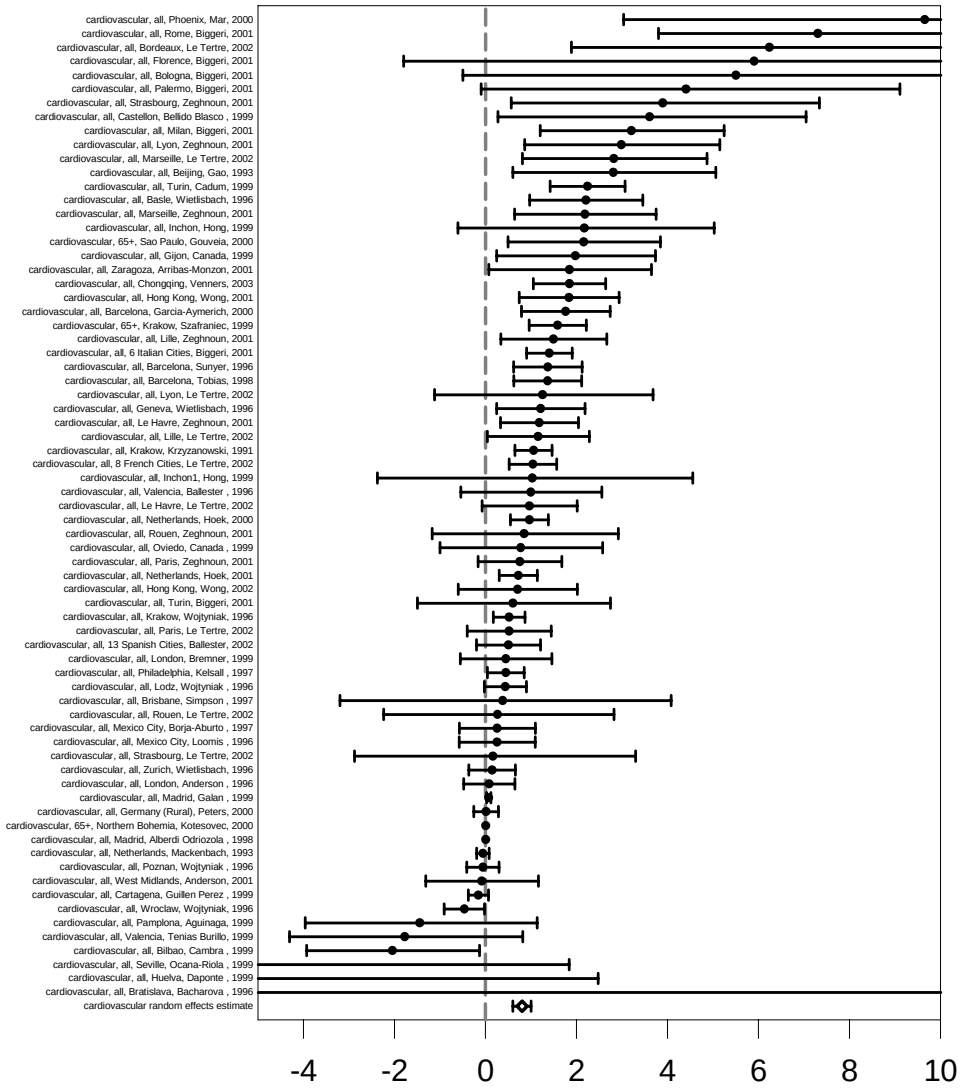


PM_{10} and daily all cause mortality in 4 Asian cities.

% change and 95% confidence intervals for 10 µg/m3 increase.

(HEI 2004)

Cardiovascular mortality and SO_2

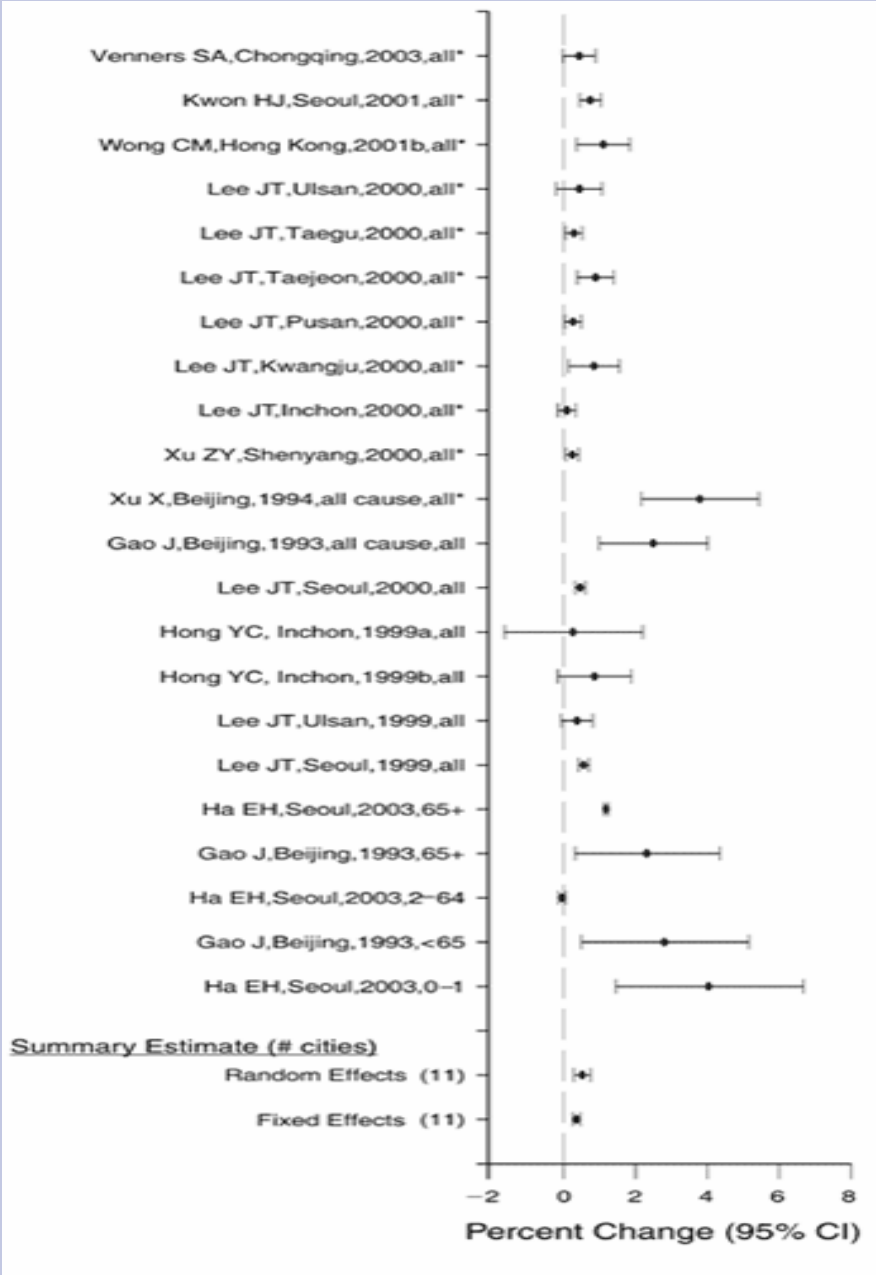


Percentage change 10 unit increase

SO_2 and cardiovascular mortality

% change (95% confidence intervals) for 10µg/m³ change

UK Department of Health 2005



SO_2 and daily mortality in 12 Asian cities.

% change and 95% confidence intervals for 10 µg/m3 increase.

(HEI 2004)

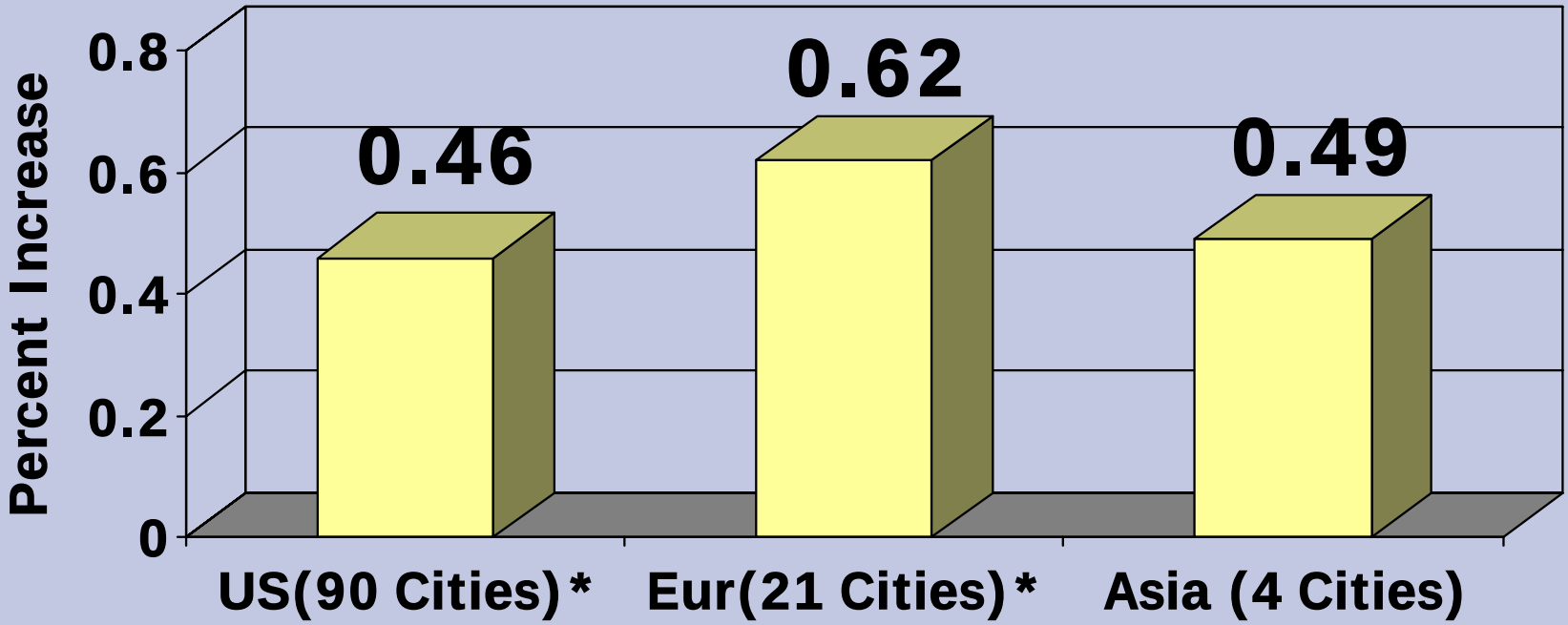
Time-series studies on NO_2 & daily mortality

- **NO_2 daily concentrations significantly associated with increased total, cardiovascular & respiratory mortality**
- **A meta-analysis on 109 studies:**
  - **2.8% increase of total mortality per 24ppb (45μg/m³) NO_2 increase**
  - **After adjusting for PM, 0.9% increase of total mortality per 24ppb NO_2 increase**
- **APHEA study:**

  effects of PM on daily mortality is greater in areas with high NO_2 levels
- **Shanghai study**

  1.04%, 1.05%, 1.43% increase of all-cause, cardiovascular & respiratory mortality per 10μg/m³ NO_2 increase (Song GX et al, 2005)

Comparison of Asian, North American and European results for PM_{10} and daily mortality. % increase for 10 µg/m³ (HEI 2004)



Long-term exposure studies

$PM_{2.5}$ long-term exposure and all-cause, lung cancer, cardiopulmonary mortality

ACS (American Cancer Society), Cancer Prevention Study II (CPS-II)

Prospective cohort study, 500,000 adults linked with air pollution data, 1982-1998

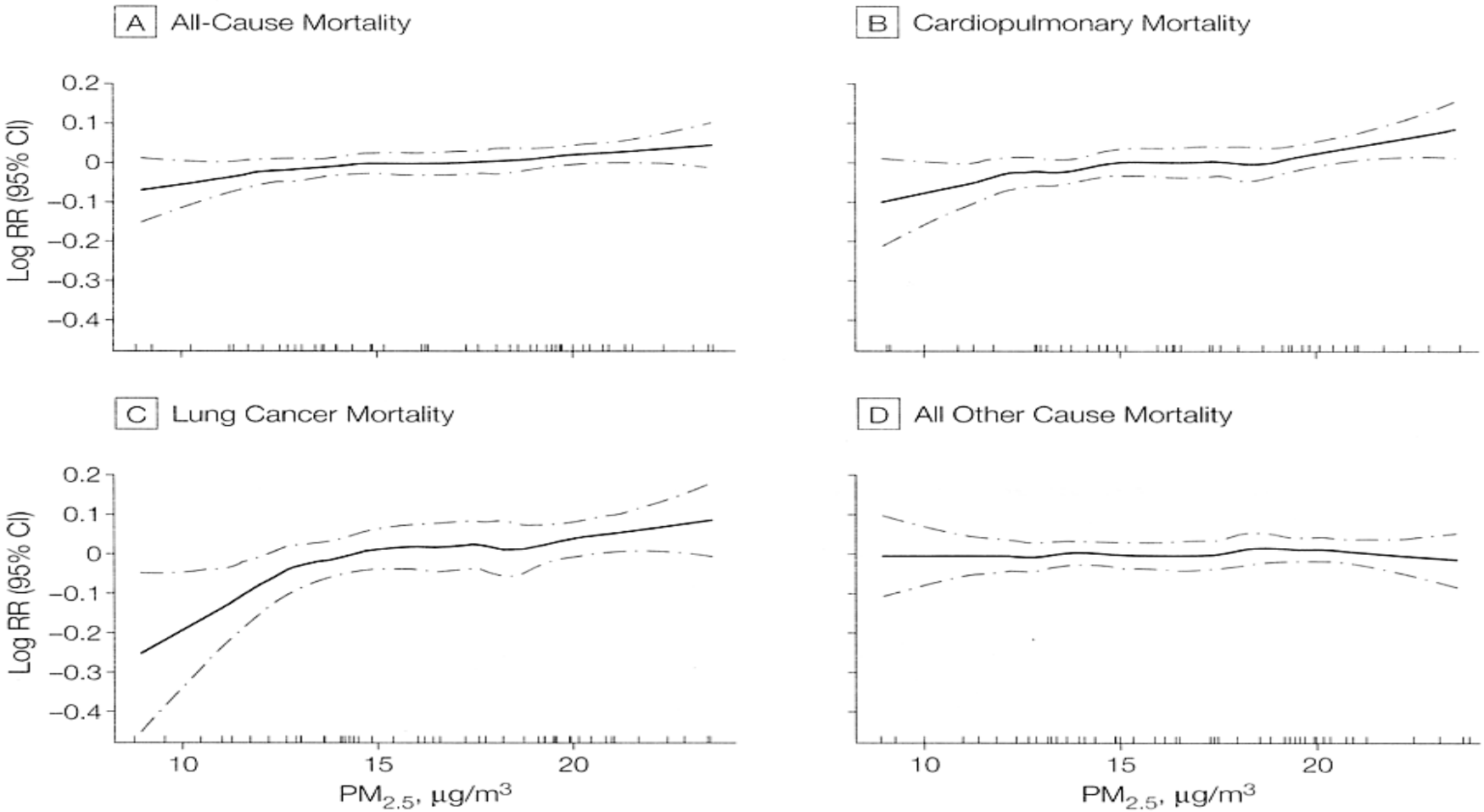
Confounders controlled: cigarette smoking, BMI, diet, occupational exposure, age, sex, race, education, alcohol

A 10 $\mu g/m^3$ increase of $PM_{2.5}$ was associated with approximately a 4%, 6% and 8% increase risk of all-cause, cardiopulmonary, and lung cancer mortality, respectively

Coarse particle fraction ($PM_{2.5-15}$) and TSP were not consistently associated with mortality

(Pope III et al, JAMA, 2002)

Figure 2. Nonparametric Smoothed Exposure Response Relationship



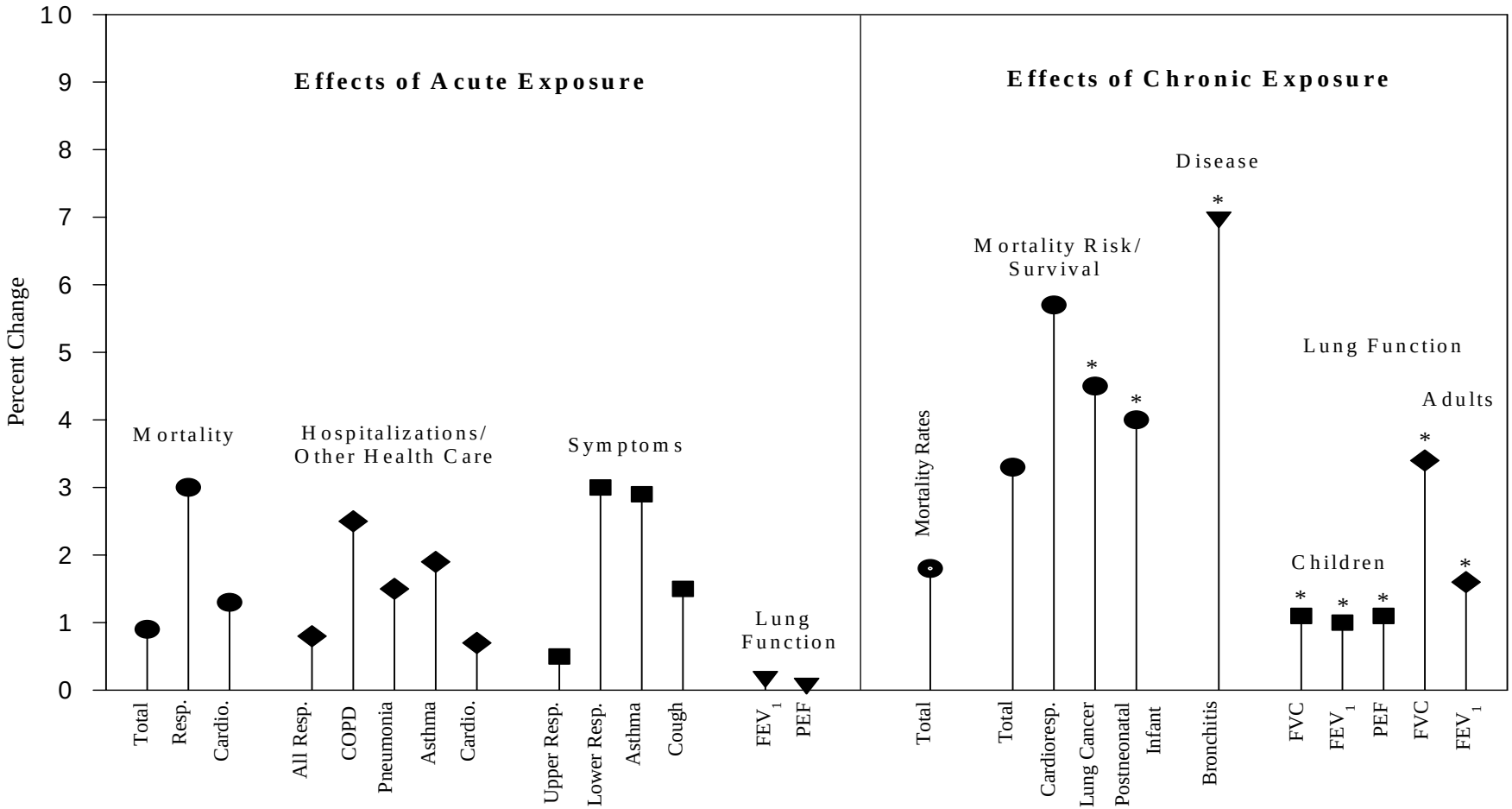
Vertical lines along x-axes indicate rug or frequency plot of mean fine particulate pollution; $PM_{2.5}$, mean fine particles measuring less than 2.5 µm in diameter; RR, relative risk; and CI, confidence interval.

Table 2. Adjusted Mortality Relative Risk (RR) Associated With a 10-μg/m³ Change in Fine Particles Measuring Less Than 2.5 μm in Diameter

	Adjusted RR (95% CI)*		
Cause of Mortality	1979-1983	1999-2000	Average
All-cause	1.04 (1.01-1.08)	1.06 (1.02-1.10)	1.06 (1.02-1.11)
Cardiopulmonary	1.06 (1.02-1.10)	1.08 (1.02-1.14)	1.09 (1.03-1.16)
Lung cancer	1.08 (1.01-1.16)	1.13 (1.04-1.22)	1.14 (1.04-1.23)
All other cause	1.01 (0.97-1.05)	1.01 (0.97-1.06)	1.01 (0.95-1.06)

*Estimated and adjusted based on the baseline random-effects Cox proportional hazards model, controlling for age, sex, race, smoking, education, marital status, body mass, alcohol consumption, occupational exposure, and diet. CI indicates confidence interval.

Long-term exposure to fine particulate and sulfur oxide-related air pollution is an important environmental risk factor for cardiopulmonary and lung cancer mortality.



Stylized summary of observed health effects. Approximate percent change in epidemiologic health endpoints per 5 μg/m³ increase in $PM_{2.5}$.

Consistent and coherent cascade of cardiopulmonary health effects?

Intervention study in Hongkong

July 1990, HK, a restriction over one weekend: all power plants & vehicles used fuel oil with a sulfur content <0.5% by weight

After intervention, SO_2 levels declined 50%: from 44 to 21μg/m³

- **A reduction in SO_2 leads to an immediate reduction in death**
  - **All causes decrease 2.1% (about 600 deaths per year associated with 10268 person-years of life per year)**
  - **Respiratory causes decrease 3.9%**
  - **Cardiovascular causes decrease 2.0%**
- **Average gain in life expectancy per year of exposure to the lower SO2 concentration level:**
  - **Females: 20days**
  - **Males: 41days**
  - **SO_2 consistently associated with mortality, PM_{10} associated with mortality only marginal**

---Hedley AJ et al. Lancet 2002, 360: 1646-1652

Hong Kong air quality intervention 1990

Before **After**

Kwai Tsing

On July 1st 1990 the Environmental Protection Department restricted the sulfur content of fuel to 0.5% by weight

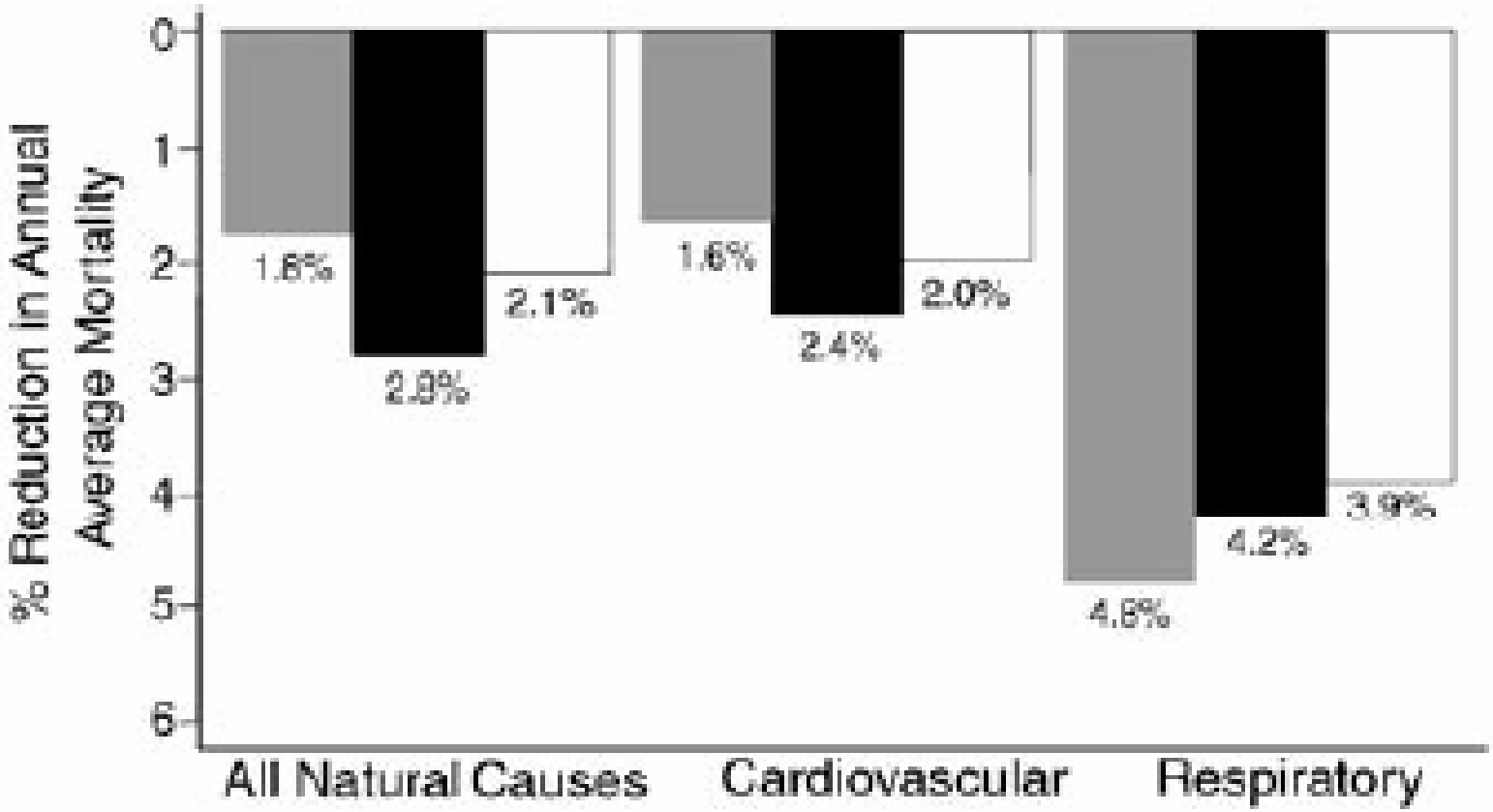
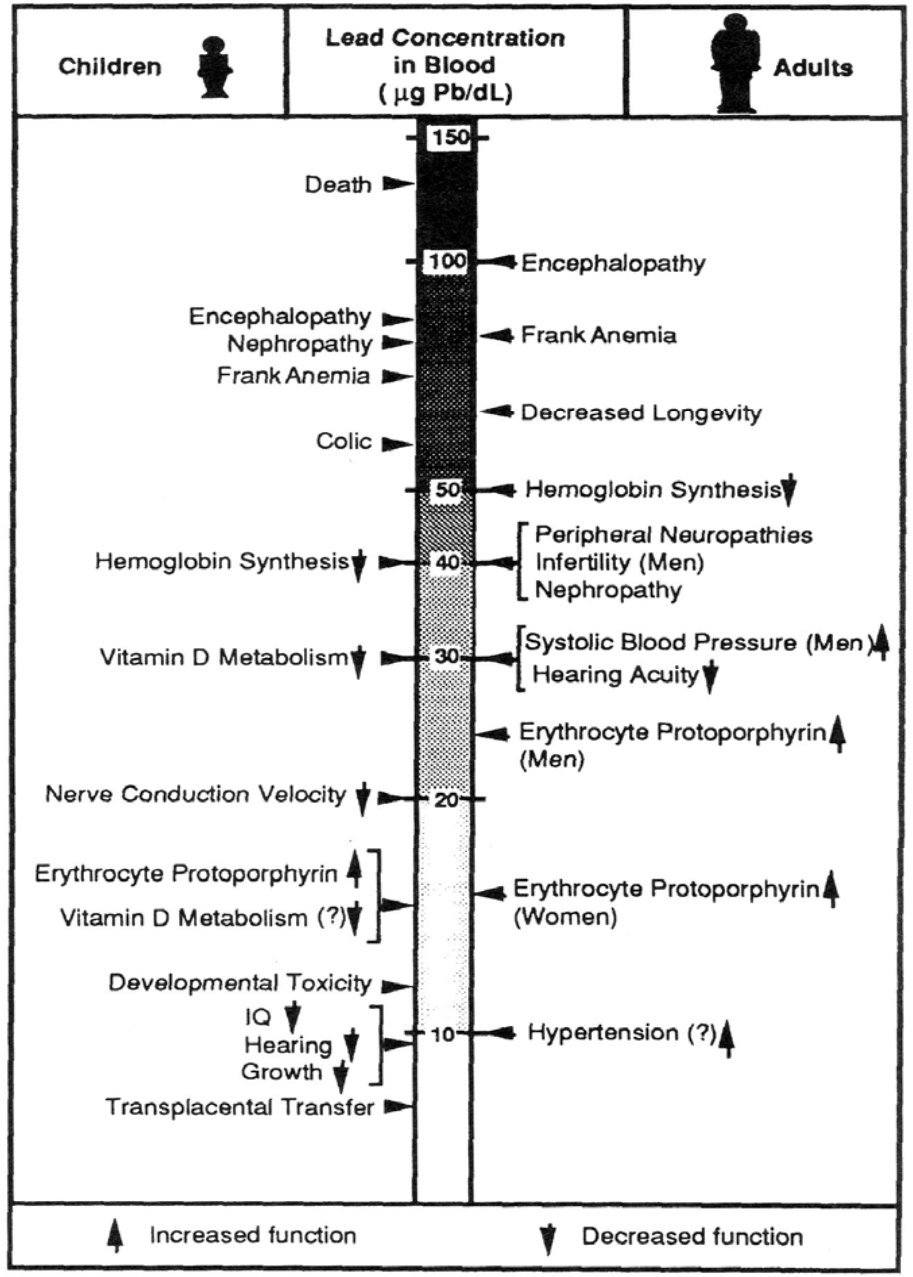


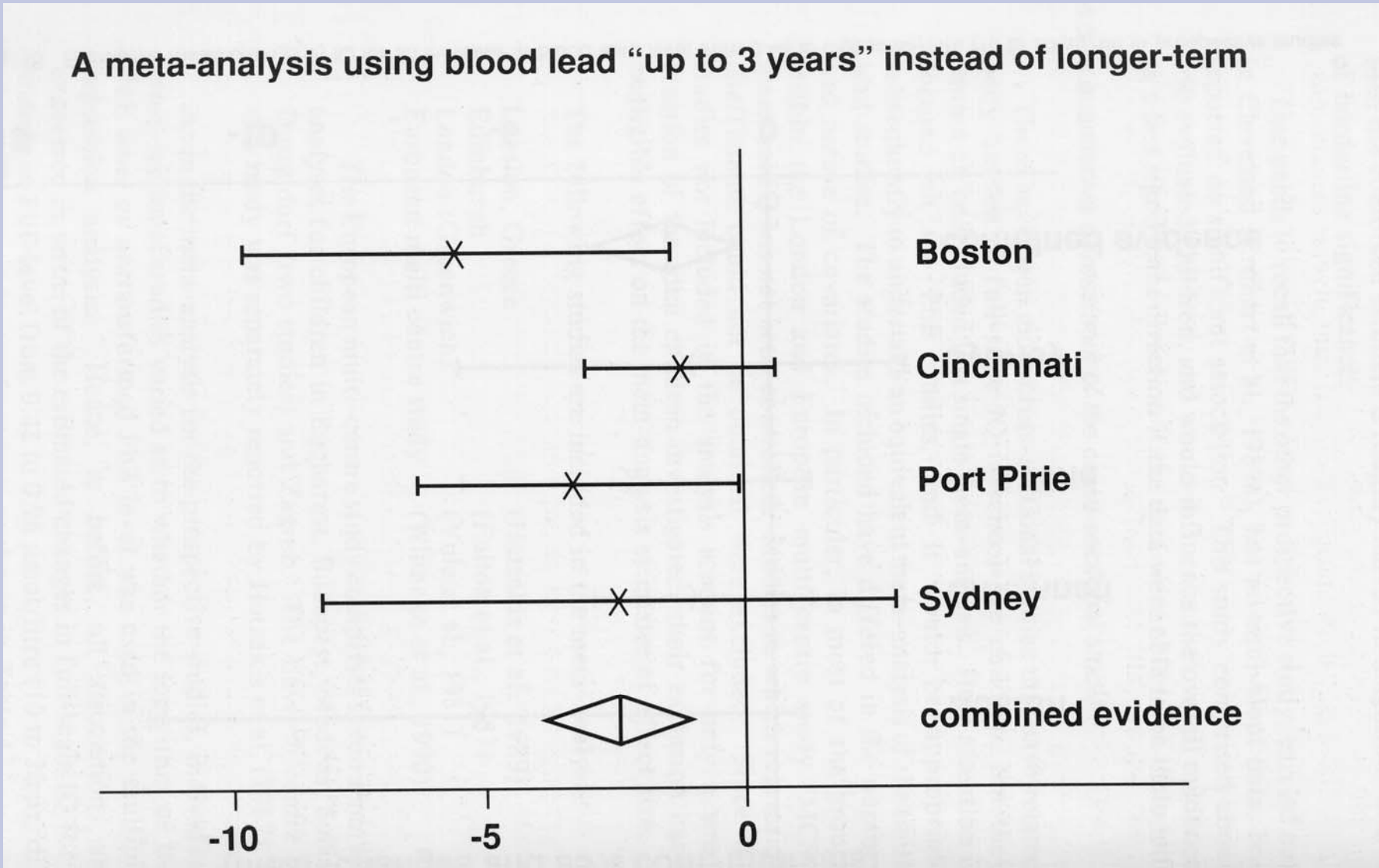
Figure 6. Percent reduction in annual average mortality due to all causes, cardiovascular disease, or respiratory disease after intervention to reduce sulfur content of fuel oil. Gray bars indicate people 15 to 64 years of age; black bars indicate people 65 years of more of age; white bars indicate people of all ages. Data from Hedley et al 2002.

Lead

Effects of inorganic lead in children and adults –lowest observed adverse effect levels (LOAELs)



Estimated mean change in IQ with 10-20 mg PbB/dl



Criteria for establishing causality

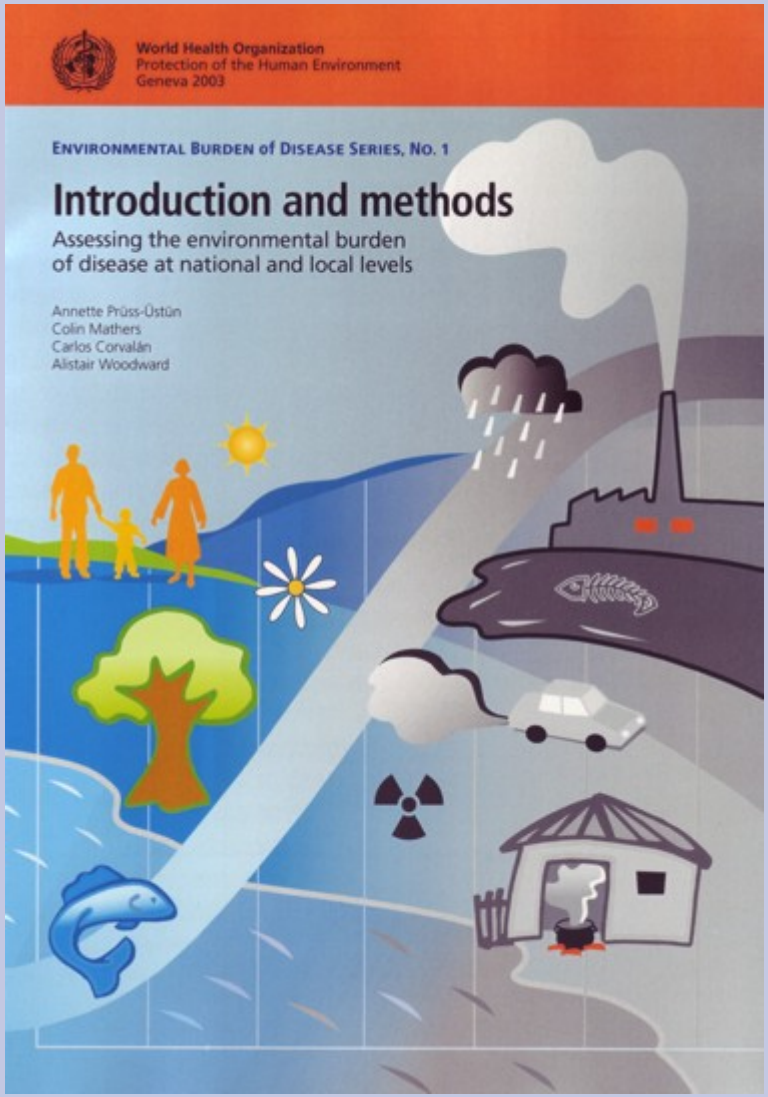
- **Strength of the association as measured by RR**
- **Consistency of the association**
- **Temporal relationship between cause & effect**
- **Biological gradient of the association**
- **Specificity of the association**
- **Biological plausibility of the association**
- **Effects of intervention**

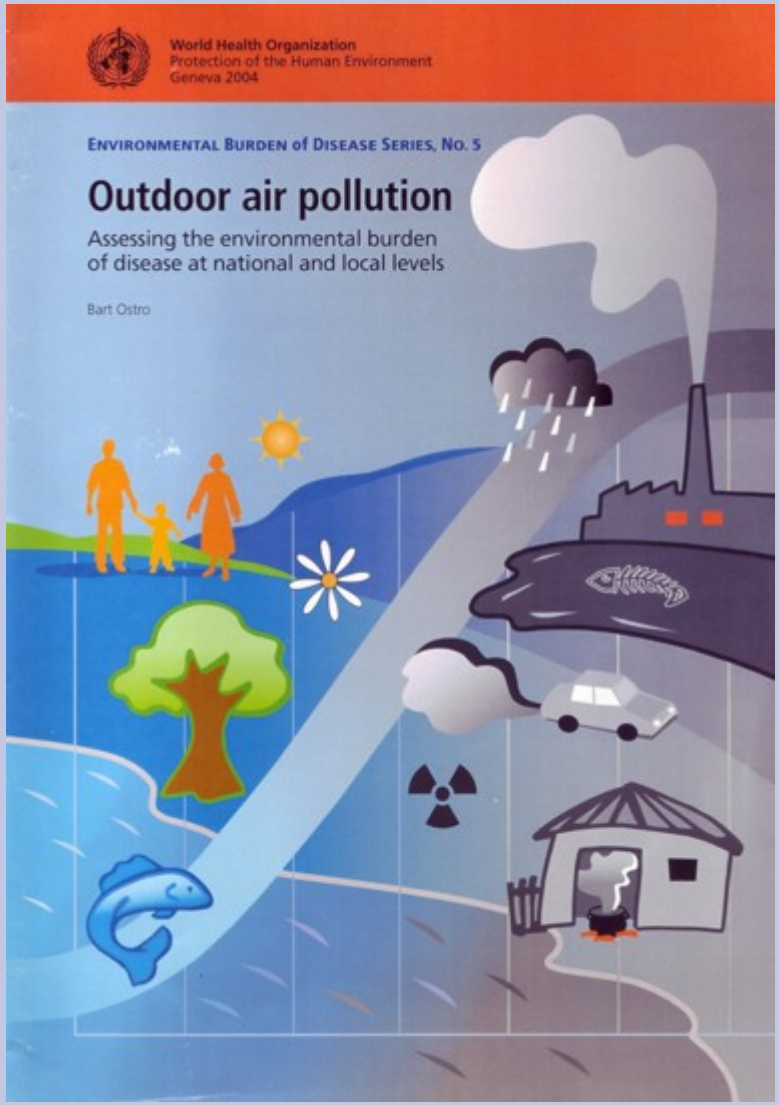
WHO/ IPCS, 1999

Conclusions and Recommendations

- **Ambient air pollution is a health hazard**
  - **Strong evidence shows association between ambient air pollution and adverse health effects in populations**
  - **Supported by toxicological and clinical experiments**
- **Ambient air pollution is relatively more important in Asia**
  - **Air pollution in Asia causes health effects similar to those reported from western countries**
  - **Higher pollution levels in Asia**
  - **Use of fossil fuels**
  - **Rapid urbanisation and development**
- **Improving air quality has substantial, measurable, and important public health benefits**

Resources


World Health Organization
Protection of the Human Environment
Geneva 2003
ENVIRONMENTAL BURDEN of DISEASE SERIES, NO. 1
Introduction and methods
Assessing the environmental burden of disease at national and local levels
Annette Prüss-Üstün
Colin Mathers
Carlos Corvalán
Alistair Woodward


World Health Organization
Protection of the Human Environment
Geneva 2004
ENVIRONMENTAL BURDEN of DISEASE SERIES, NO. 5
Outdoor air pollution
Assessing the environmental burden of disease at national and local levels
Bart Ostro