Vulnerability of Children to Air Pollution

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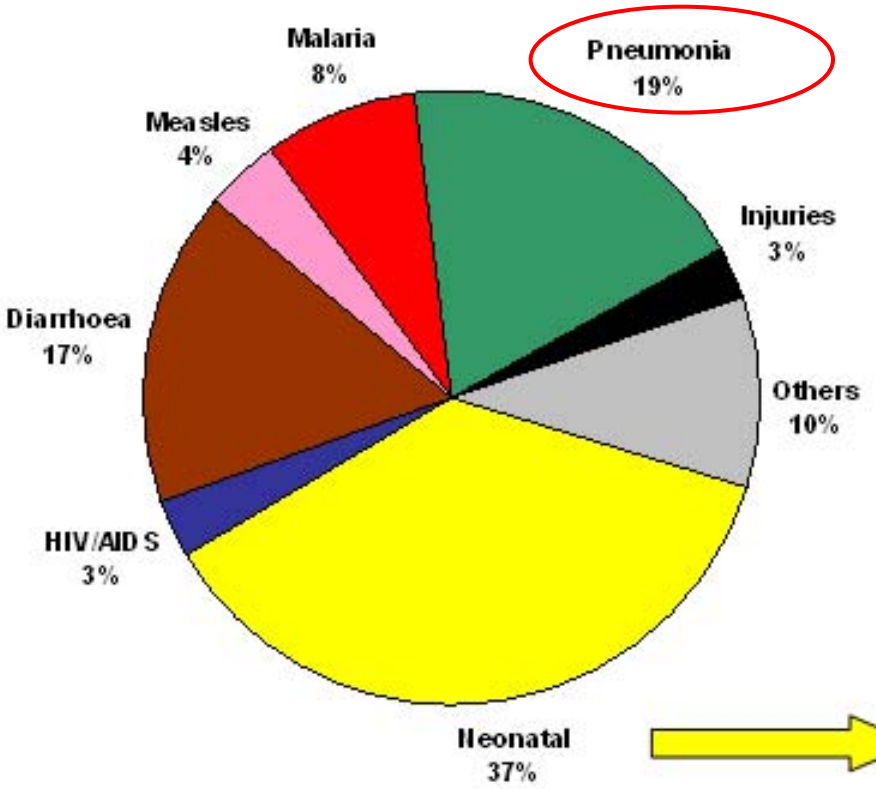
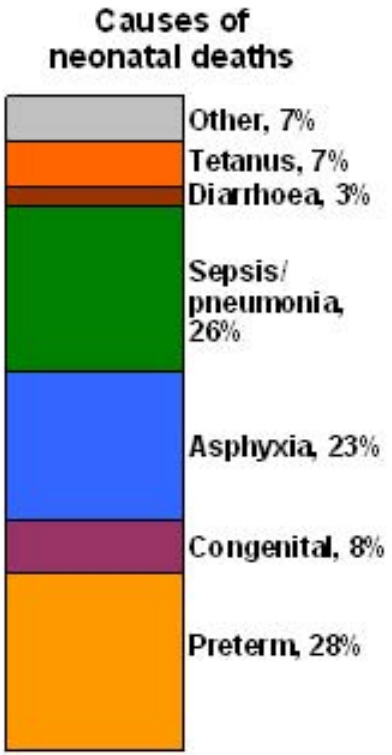
Air pollution and respiratory health in children

Outline

- Global burden of respiratory diseases
- Vulnerability of children to environmental exposures
  - Exposure pathways
  - Physiological differences
- Environmental impact on respiratory diseases
  - Lung growth
  - Respiratory infections
  - Asthma

Major causes of death among children under 5 years of age and neonates in the world, 2000-2003



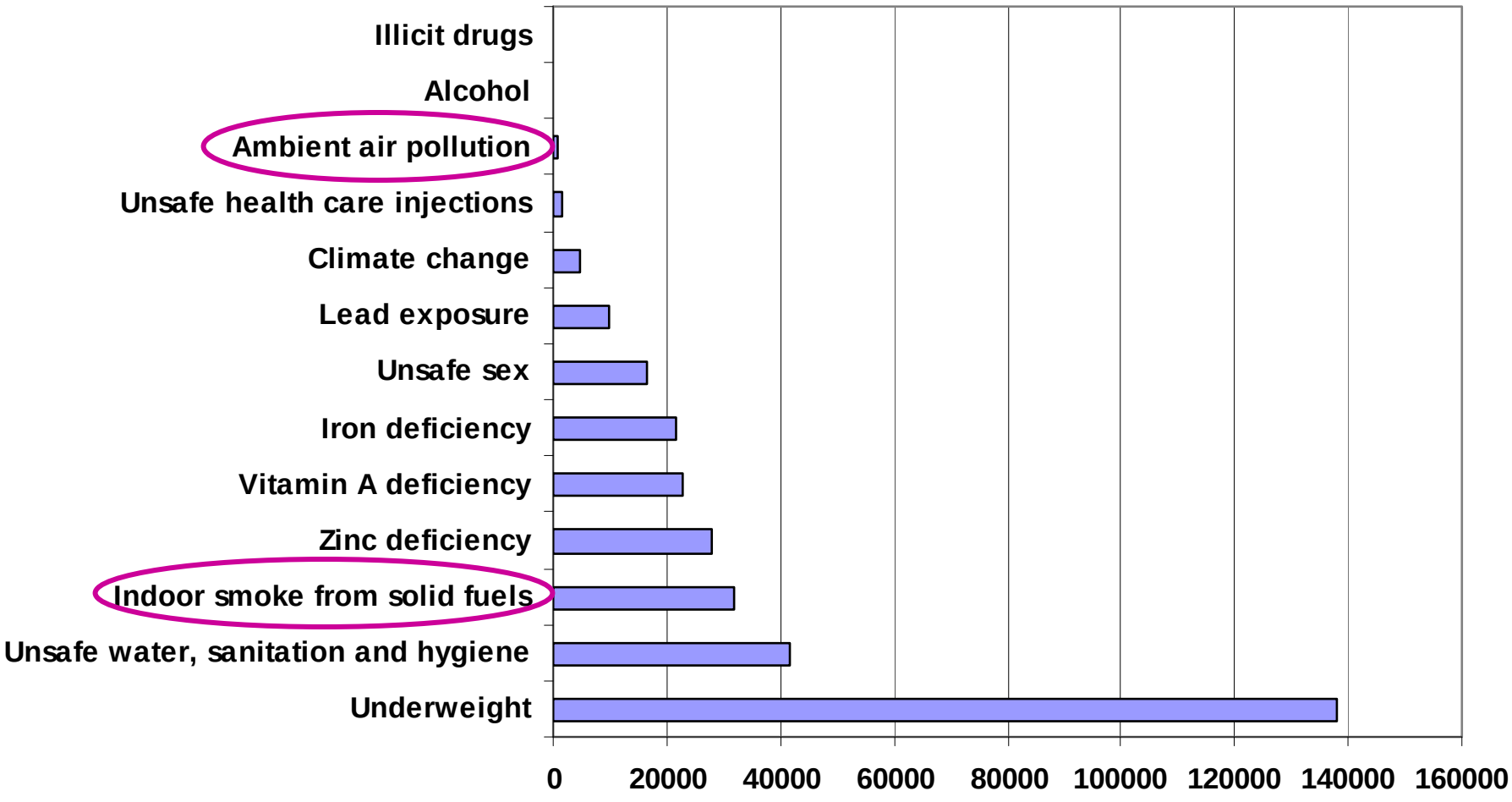


Undernutrition is an underlying cause of 53% of deaths among children under five years of age.

Mortality from Respiratory causes in children

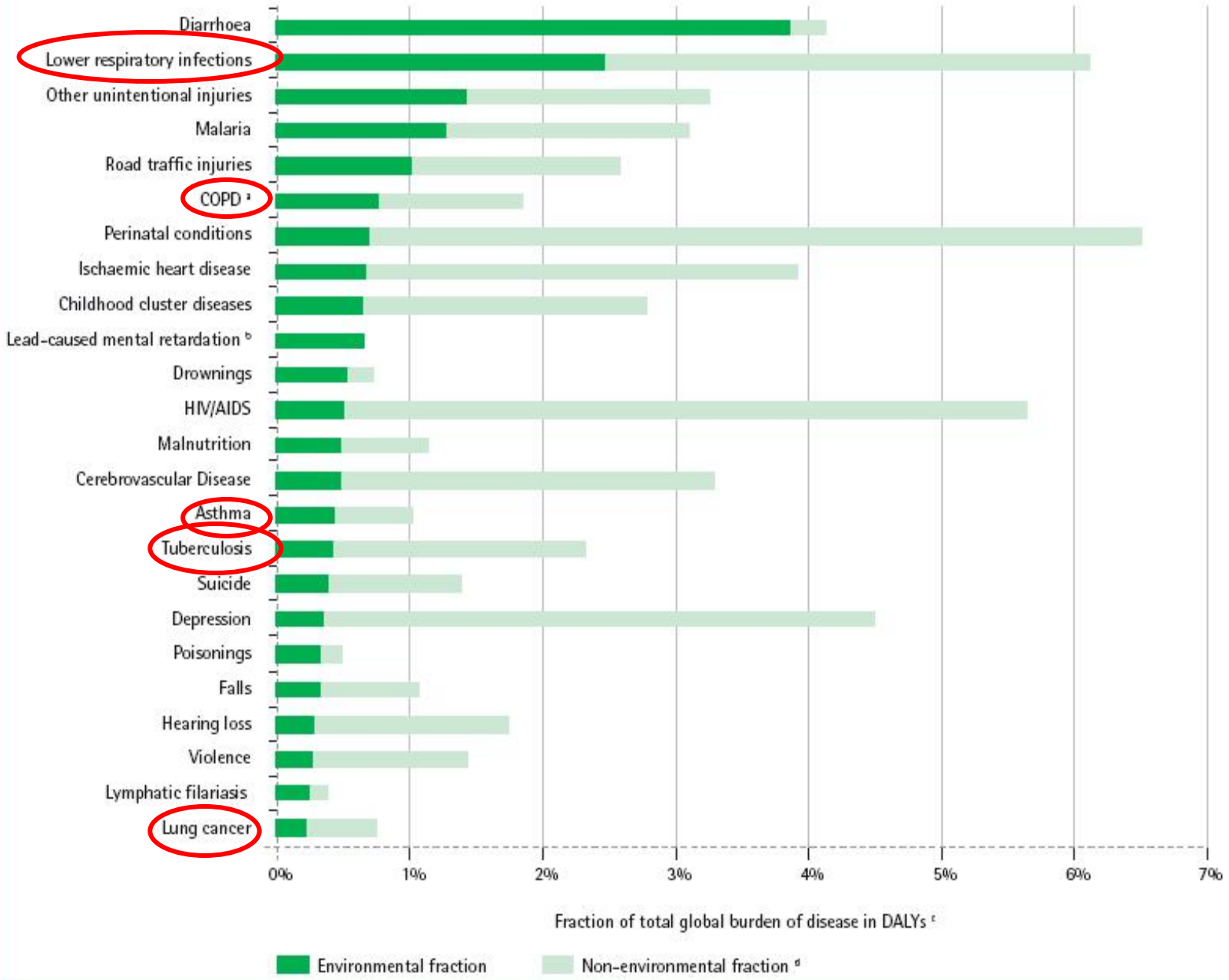
- **Acute respiratory illness**
  - **(1000000 deaths in <5, 2003)**
- **Acute otitis media**
  - **(541 deaths in <5, 2002)**
- **Asthma / bronchospasm**
  - **(4350 deaths in <5, 2002)**

Attributable burden of disease 0-4 years



World Health Report, 2002, www.who.int/whr/2002/en/

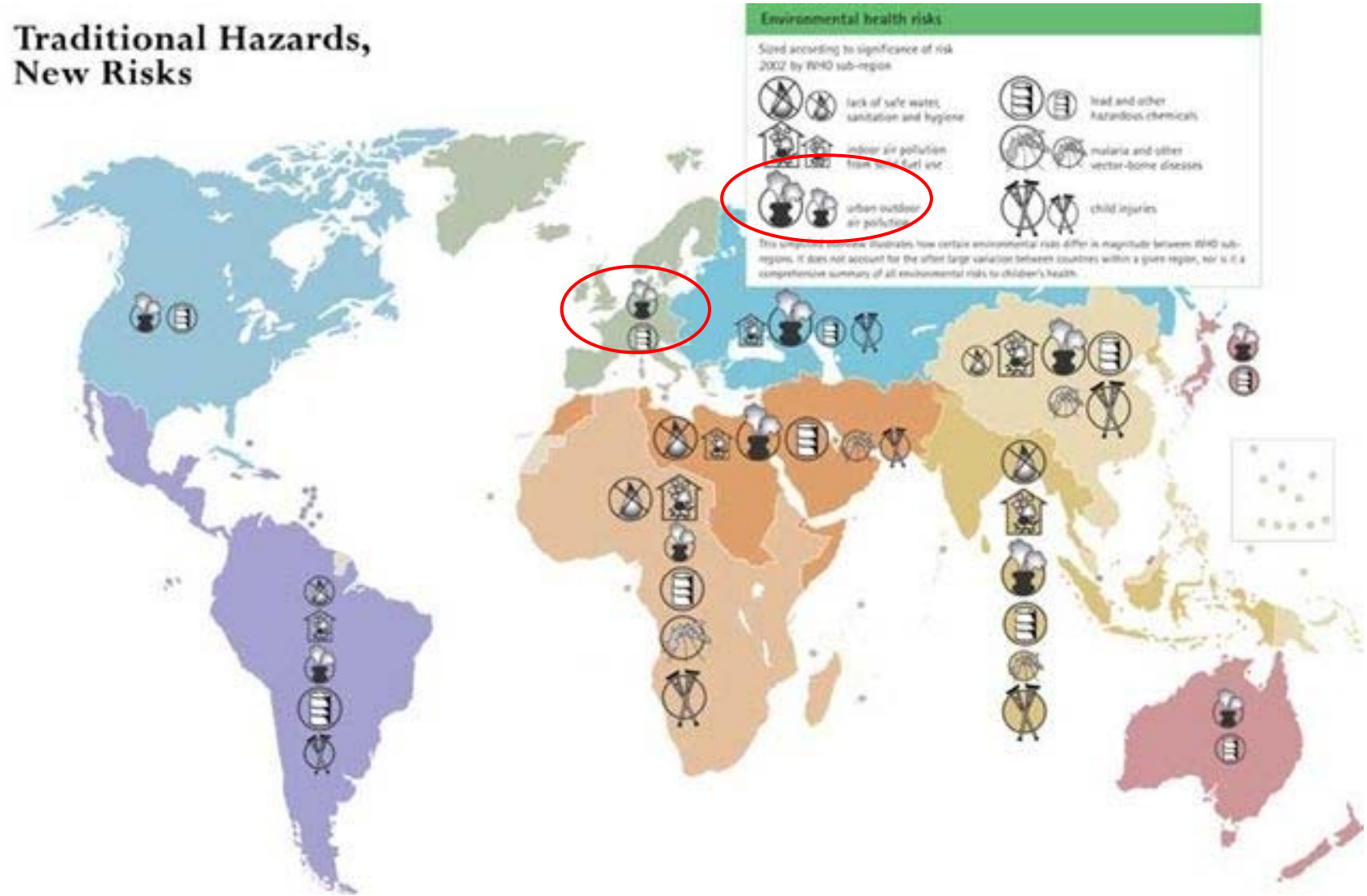
Diseases with the largest environmental contribution



Environmental contributions to respiratory diseases

	Environmental Fraction
ALRI	41%
COPD	42%
asthma	40%
tuberculosis	18%
lung cancer	25%

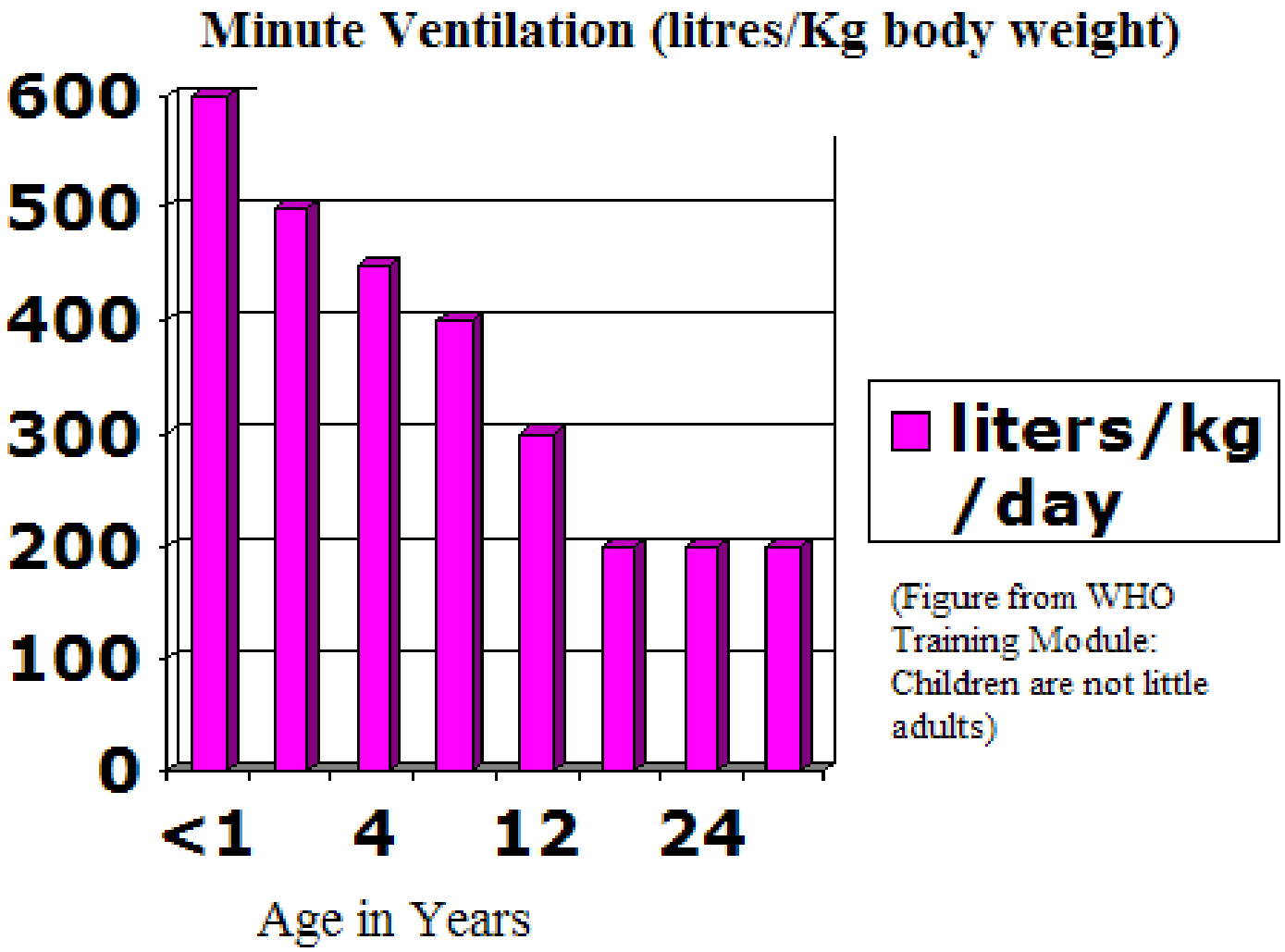
Environmental hazards vary in different parts of the world; Air pollution is a problem everywhere



Dynamic Developmental Physiology

- Anabolic state (growth)
  - ↑ energy, water, oxygen requirements
    - Breathe more, eat more, drink more per Kg
- More active absorption
- Immature detoxification enzymes early
- Blood-brain-barrier immature in infancy
- Elimination ↓ in early life

Children breathe more air than adults relative to body size



(Figure from WHO Training Module: Children are not little adults)

Exposure pathways

Children are shorter and spend time closer to the floor

- "child zone" ~ 25 cm; "adult zone" ~ 100-150cm
- Pollutant concentrations often higher near the floor, eg pesticides
- Higher ventilatory requirements increase exposure

Dynamic Developmental Physiology

- Many organs immature at birth
- Respiratory, Immune and CNS systems mature slowly
  - Pre and Post-natal “Windows of Susceptibility”

Developmental Milestones

- Respiratory system
  - Prenatal
    - airway branching to terminal bronchioles by 16w
    - functional smooth muscle by 8-10w, to respiratory bronchioles by 26w
    - cartilage complete by 28w
    - blood vessels complete by 17w
    - lamellar bodies in type II cells by 24w
    - 30-50% of alveoli present by term

Developmental Milestones

- Respiratory system
  - Postnatal
    - increase in airway size parallels growth
    - rapid increase in smooth muscle early
    - alveolarisation continues till ≈2y
    - pulmonary vasculature grows with alveoli
    - maturation of microvasculature during 2nd stage of alveolar development

Windows of Susceptibility

- Prenatal
  - Exposures may cause structural abnormalities
    - Smoking → small airways, lower lung function
    - PM → growth restriction
  - Exposures may cause functional abnormalities
    - PCBs, smoking → low IQ

Windows of Susceptibility

- Postnatal
  - Exposures may cause structural abnormalities
    - Air toxics, smoking → decreased lung growth
  - Exposures may cause functional abnormalities
    - Delayed immune maturation → ↑ risk of asthma

Major Outdoor Pollutants

- Particulate matter
- Ozone
- Nitrogen oxides
- Carbon monoxide
- Sulfur dioxide

WHO

Deposition of Pollutants in Respiratory Tract

Water Solubility	Initial Level of Impact	Compounds
High	Eyes Nose Pharynx Larynx	Aldehydes Ammonia Chlorine Sulfur dioxide
Medium	Trachea Bronchi	Ozone
Low	Bronchioles Alveoli	Nitrogen dioxide Phosgene

CDC

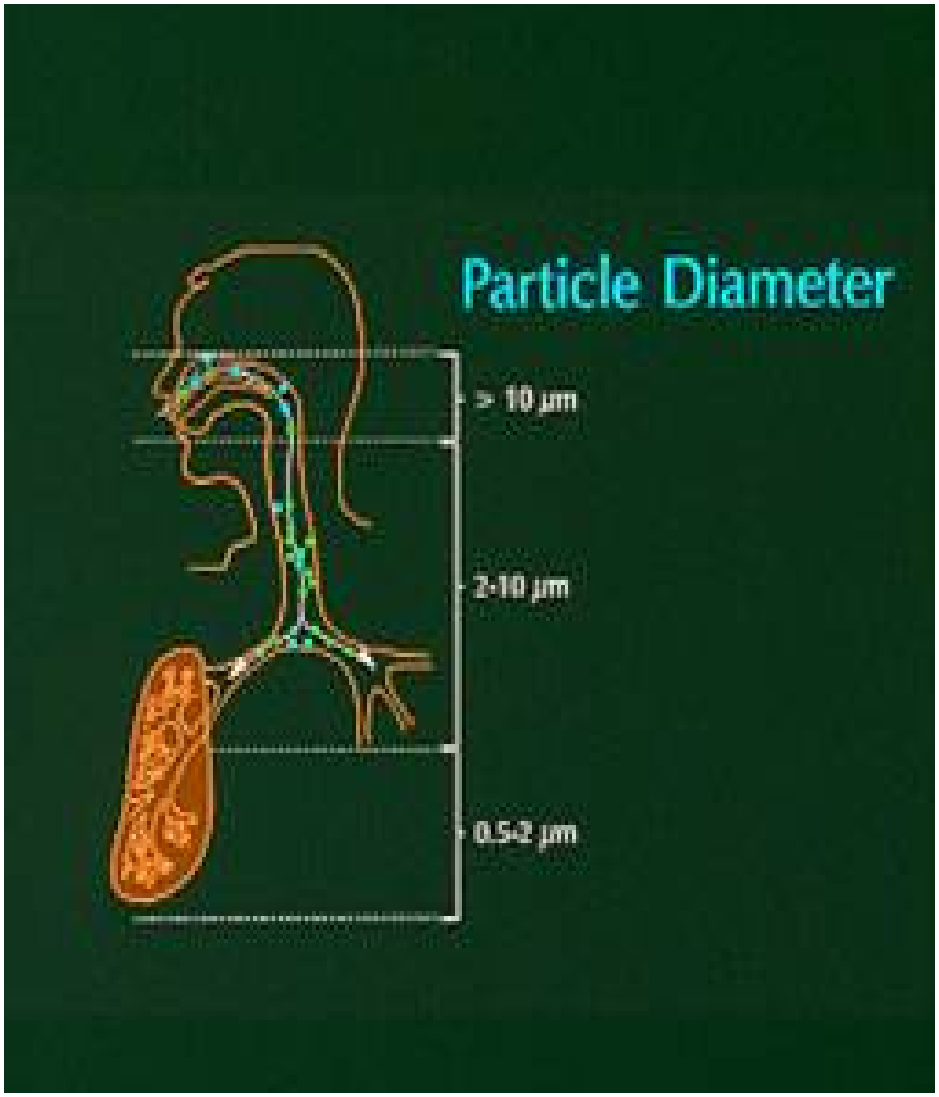
Particulate Matter

- Complex heterogeneous mixture of solid and liquid components

- Sources:
  - Power plants and industry
  - Motor vehicles, domestic coal burning
  - Natural sources (volcanoes, dust storms)
  - Small particles form surface for acid aerosol formation

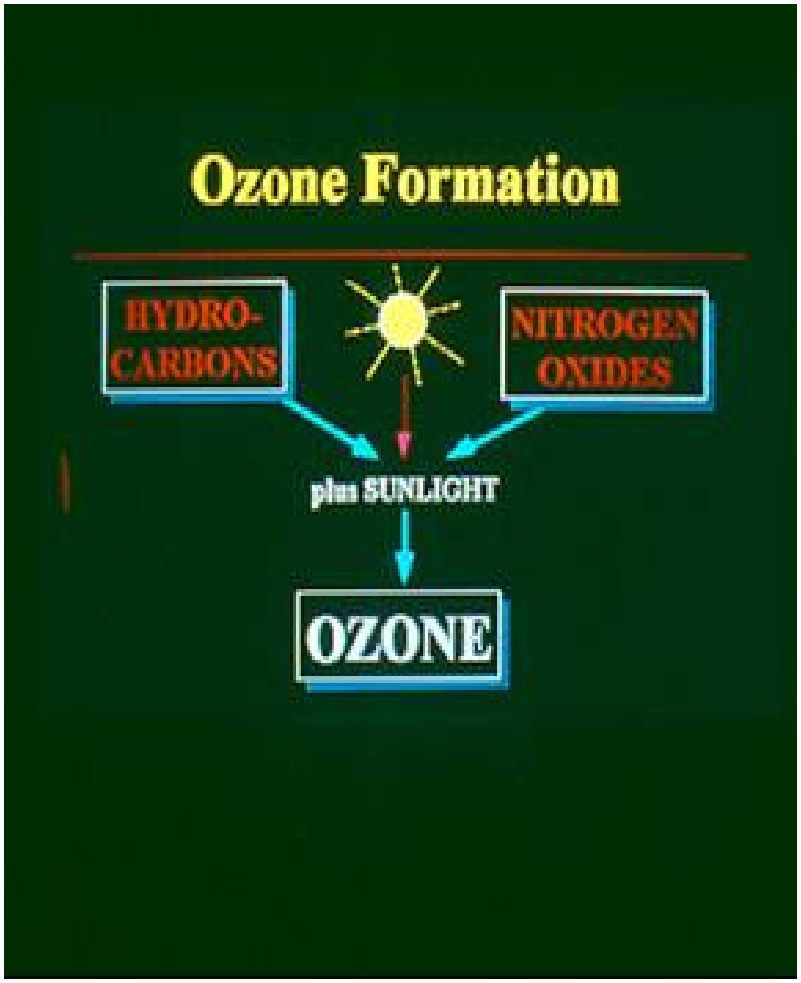
Size Matters

- **Coarse particles** (2.5–10 μm) deposited in the upper respiratory tract and large airways
- **Fine particles** (< 2.5 μm) may reach terminal bronchioles and alveoli
- **Ultrafine** (<1.0 μm) reach alveoli and may penetrate into blood stream



Ozone (O_3): "Secondary Pollutant"

- **photochemical reaction, VOCs, NO_2 + O_2**
  - Peaks late afternoon
  - Maximum in hot, stagnant air
- **High concentrations increase asthma attacks in children**



Indoor air contaminants

- **Sources of contaminants**
  - Combustion (cooking, heating)
  - Cigarettes
  - Building materials
  - Furnishings, carpets, paints, etc
  - Household chemicals/insecticides
  - Personal care products
  - Contaminated work clothes
  - Ambient air

Indoor air contaminants

- **Contaminants**
  - Combustion related products (PM, CO, NO_2)
  - Tobacco smoke
  - VOCs, HCHO
  - Bioaerosols (bacterial & fungal products, pollens, allergens)
  - Pesticides
  - Ambient air pollutants (PM, CO, NO_x, SO_x, O_3)

Health effects of air pollution

- ↓ **fetal growth** (Hansen C, Environ Health Perspect 2008)
  - US 13-26w gestation, ambient monitoring
  - ↓ abdominal circumference with:
    - O_3 d31-60, SO_2 d61-90, PM_{10} d91-120
  - ↓ biparietal diameter with:
    - SO_2 d0-30
  - ↓ head circumference with:
    - PM_{10} d91-120
  - ↓ femur length with:
    - PM_{10} d0-30 & d91-120

Health effects of air pollution

- ↑ **Mortality** (Romieu JOEM 2002;44:640-649)
  - ↑pneumonia mortality with ↑particulate exposure (Brazil)
  - 30%↑ resp mortality with NO_2 of 127 ppb (Brazil)
  - ↑ resp mortality with
    - ↑ SO_2 (8.6% for 20 $\mu g/m^3$),
    - ↑ CO (8.6% / 5ppm)
    - ↑ O_3 (5.7% for 126 $\mu g/m^{3)}$
  - ↑ total mortality 0.6% per 10 $\mu g/m^3$ PM_{10} (Thailand)
  - ↑ infant mortality with ↑ $PM_{2.5}$, O_3, NO_2 (Mexico)

Health effects of air pollution

- **Respiratory Symptoms/Infections**
  - Perth (Rodriguez Int J Environ Health Res 2007;17:1-10)
    - Air pollutants (O_3, NO_2, PM2.5) assoc with more severe ARI (fever, cough, wheeze)
  - Europe (Gehring ERJ 2002;19:690-698)
    - Traffic pollutants (pm2.5, NO_2) assoc with increased cough
  - Indonesia (Hong JOEM 2004;46:1174-79)
    - Pollutant exposure →↑respiratory symptoms

Health effects of air pollution

- **Environmental tobacco smoke**
  - ↑ pneumonia, LRI, wheeze in 1st year of life
  - ↑ ear infections in early childhood
  - Adverse effects on lung growth
  - ↑ BHR and persistent asthma

Health effects of air pollution

- **Lung growth**
  - ETS exposure associated with ↓ lung growth & lower lung function throughout childhood
  - Allergens (HDM) & irritants (Ozone) result in altered airway growth (Plopper et al)
    - Decreased branching, thickened walls
  - Strict allergen reduction (Woodcock et al)
    - Greater lung function at 3y

AMBIENT AIR POLLUTION AND LUNG FUNCTION DECREMENTS IN CHILDREN

- **Longitudinal studies**
  - Frischer et al, AJRCCM 1999; 160: 390
  - Jedrychowski et al, Environ Health Perspect 1999; 107: 669
  - Hovak et al, Eur Respir J 2002; 19: 838
  - Gauderman et al, AJRCCM 2000; 162: 1383
  - Avol et al, AJRCCM 2001; 164: 2067

- **Cross sectional studies**
  Ware et al, ARRD 1986; 133: 834
  - Dockery et al, Environ Health Perspect 1996; 104: 506
  - Peters et al, AJRCCM 1999; 159: 768

No studies in infants during rapid lung growth

IMPACT OF AMBIENT AIR POLLUTION ON LUNG GROWTH

n = 1759

- 10-18 yr old children 1993 - 2001
- 12 communities from S. California
- Daily ambient levels of O3, NO2, elemental carbon, PM2.5
- Spirometry conducted every year
- Comparisons between most polluted to least polluted areas

(Gauderman WJ et al, NEJM 2004; 351: 1057-1067)

Impact of air pollution on lung function

	FEV_1, ml [95% CI]	p
NO_2	-10.4 [-164.5, -38.4]	0.005
Acid Vapour	-105.8 [-168.8, -42.7]	0.004
Elemental carbon	-87.9 [-146.4, -29.8]	0.007
$PM_{2.5}$	-79.9 [-153.0, 6.4]	0.04
Ozone (1 hr max)	-44.5 [-138.9, -50.0]	0.32

(Gauderman WJ et al, NEJM 2004; 351: 1057-1067)

Summary

- Children are more vulnerable to adverse environmental exposures
  - Unique exposure pathways
  - Increased “dose” for give exposure
  - Physiological differences
  - Windows of susceptibility
- Developmental stage of exposure determines outcome
- Respiratory health adversely effected by air pollution

Tobacco smoke exposure, especially during pregnancy remains the **single greatest preventable risk factor** for respiratory disease in children

THE ROANOKE TIMES
Monday, September 20, 2004

STEPHANIE KLEIN-DAVIS | The Roanoke Times

[redacted] a Bullitt Avenue resident, worries about the effect on her unborn child from the sound of jackhammers.

TRAFFIC: Official says wait for end result