

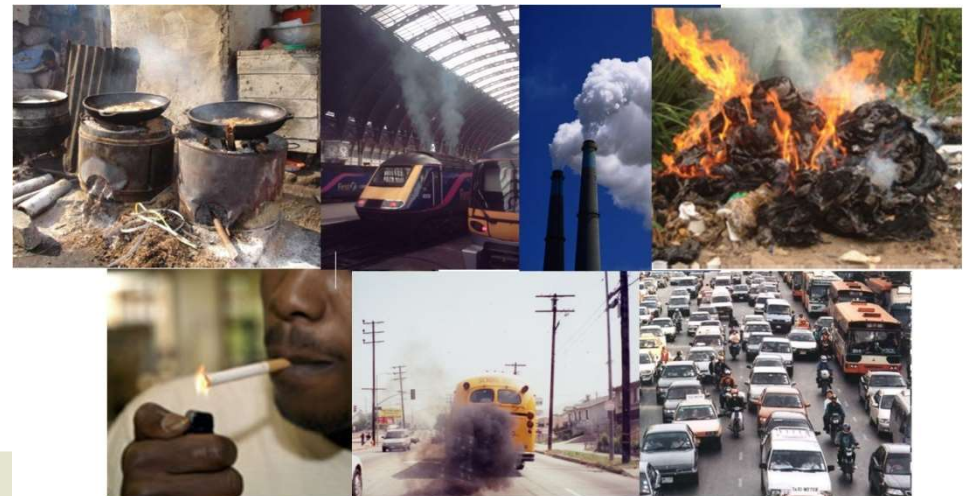
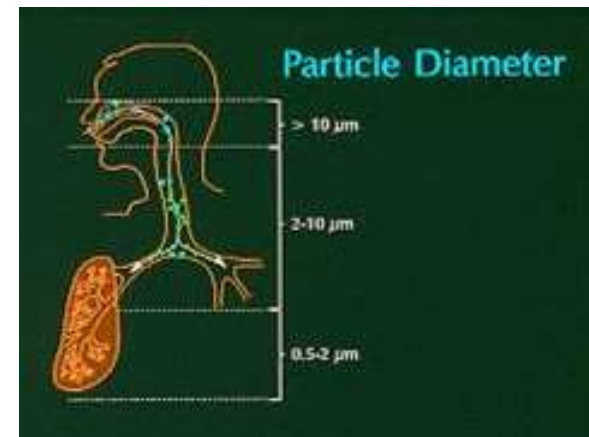
## Module B:

# Air Quality

Sources, Distribution, Impacts,  
Monitoring, Modeling, Control

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# Goal !

**You will be able to explain key concepts of air pollution and air quality management**

## **Expectation:**

- To memorize key concepts and definitions
- To describe physico-chemical phenomena, and
- To apply the understanding on current air quality problems

# Learning Objectives !

1. To learn about the criteria air pollutants, air quality regulations, and their impact on human health and climate
2. To understand sources of air pollutants & their spatial and temporal variability
3. To understand particle composition & size distribution
4. To learn about monitoring methods and thus able to quantify pollutants' concentrations
5. To explain effects of meteorology and the physics of dispersion of pollutants in the atmosphere
6. To learn about air quality modeling methods
7. To learn about air pollution control methods from mobile and stationary sources

# Evaluation !!!

## When:

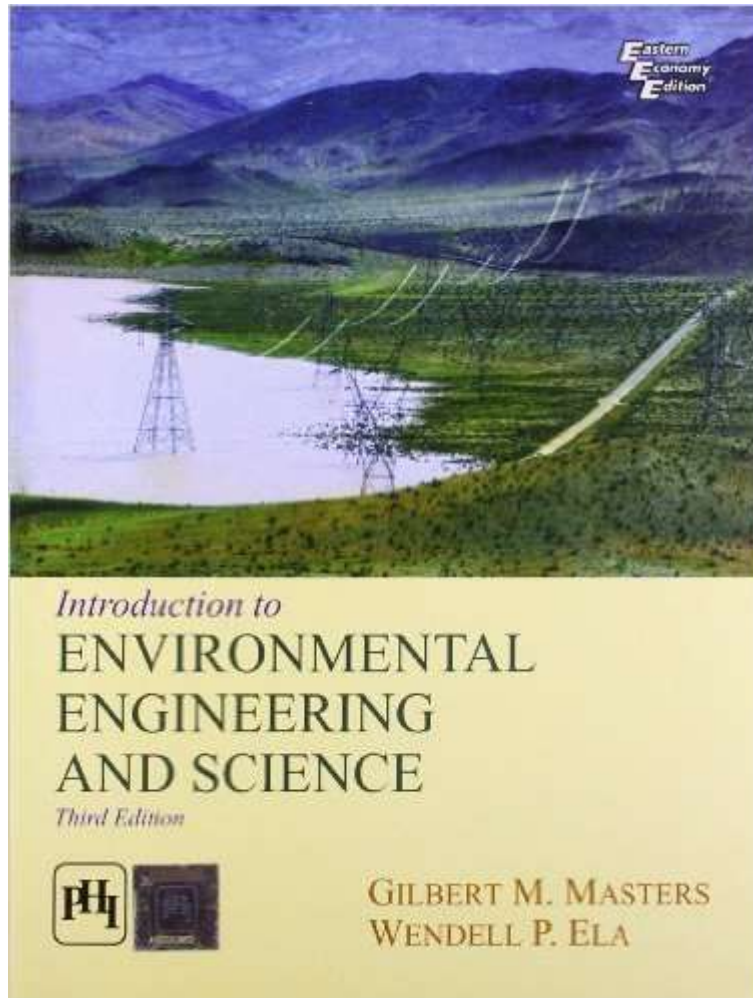
- This module starts from today...
- There will be a total of seven lectures

## Evaluation:

- Final Exam – 60%
- Quiz – 40%

**Quiz will be in the week of 21<sup>st</sup> Aug**

# Textbook

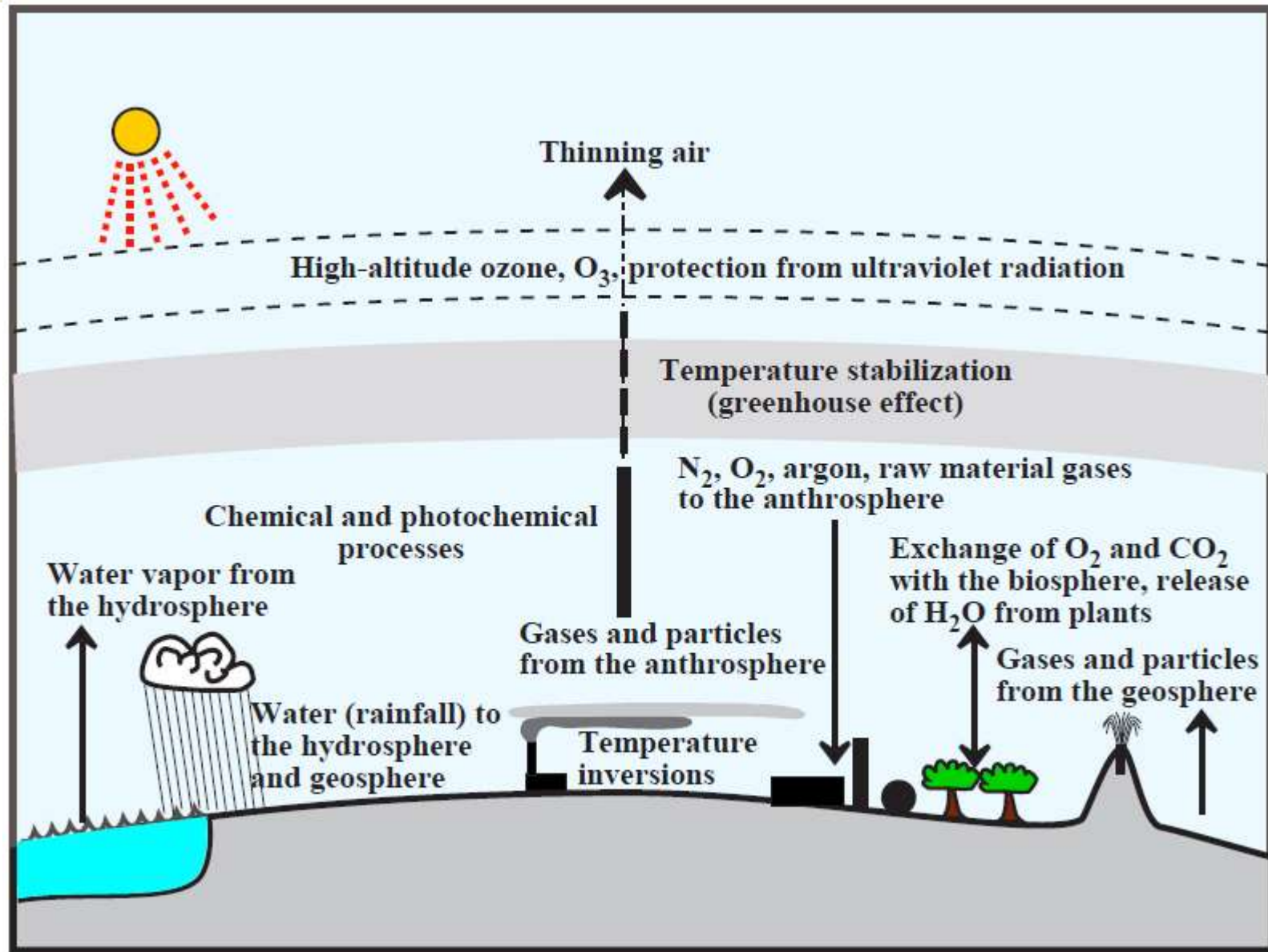


**Will provide relevant articles or chapters from other books, as necessary**

# Today's Learning Objective !

- To learn about the criteria air pollutants, air quality regulations, and their impact on human health and climate

# Atmosphere



# Air Pollution !

- Not a new phenomena: Smoke from Burning of Coal
- Problems in many urban areas in late 1800s and early 1900 due to coal use
- 1000's of deaths attributed to **air pollution episode** in London (Great Smog) in December 1952
  - large emissions of pollutants
  - restricted air volume
  - failure to recognize problem
- Photochemical smog:  $\text{CO} + \text{NO}_x + \text{HC} + \text{Light} \rightarrow \text{VOCs} + \text{O}_3 + \text{PAN}$  (Peroxyacetyl nitrate)
- **Bhopal gas tragedy**: 2–3 December 1984

<https://www.youtube.com/watch?v=UH5LPwdVnqI>



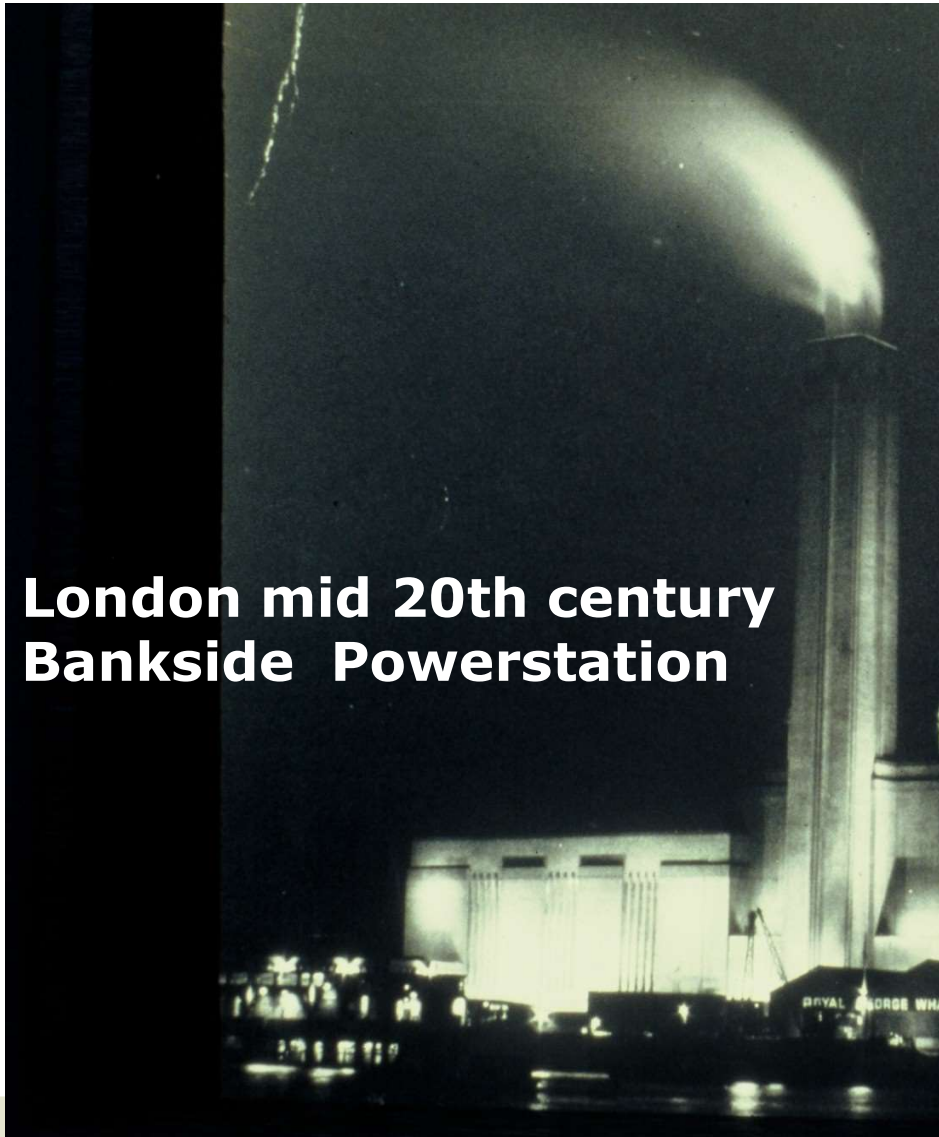
# London Smog, December 1952



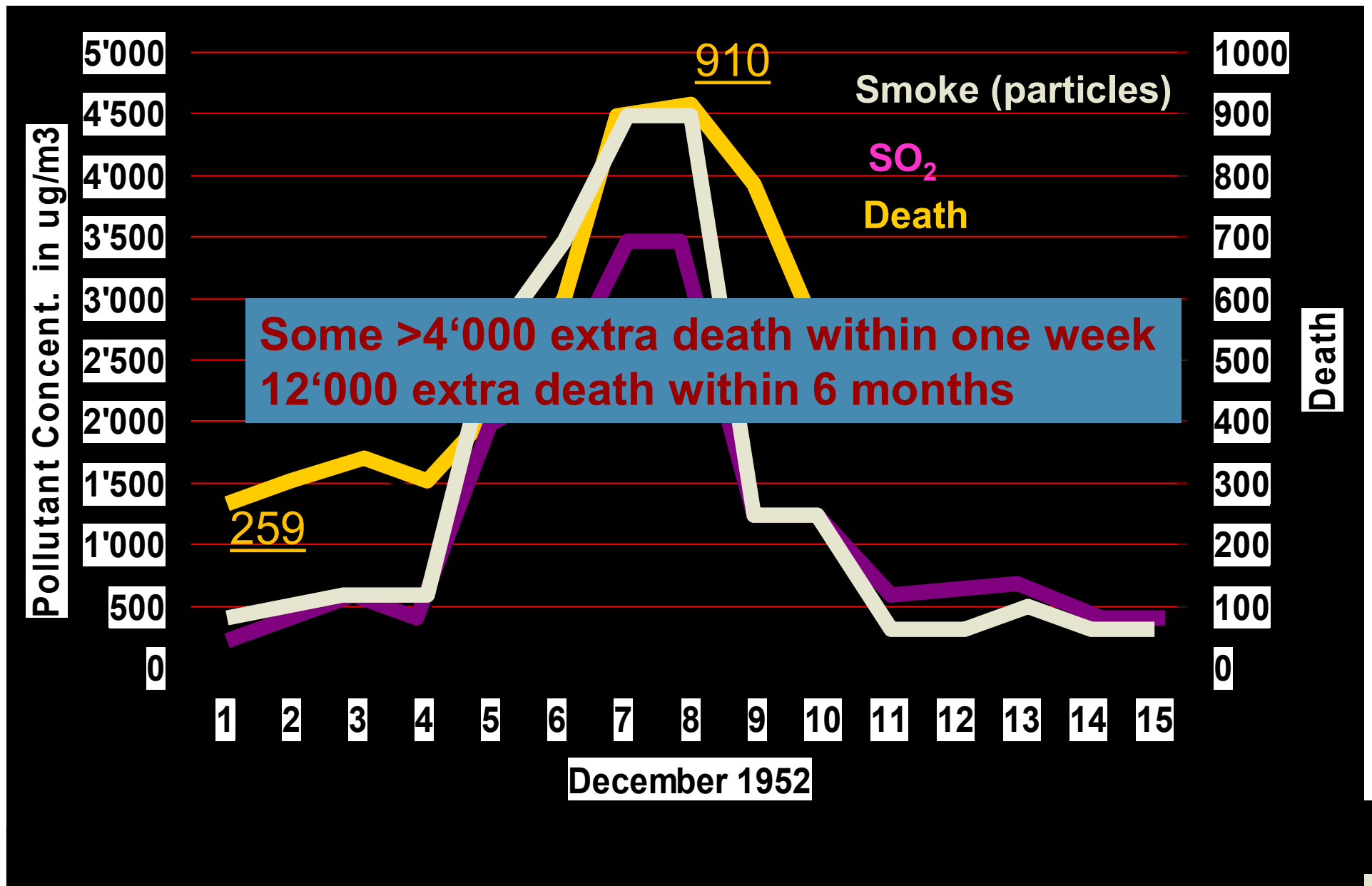
Watch the London Smog 1952 "Killer Fog"  
<http://www.youtube.com/watch?v=eUQ9tPc8YbM>

# London smog, 1952

**London mid 20th century  
Bankside Powerstation**



# London-Smog, December 1952



# Why study/assess air quality?

That was 20<sup>th</sup> century, ...with advancement in technology and preventive measures and enforced regulations, the question is:

**Is air pollution still a relevant problem?**

# Health effects of air pollution



The NEW ENGLAND  
JOURNAL of MEDICINE

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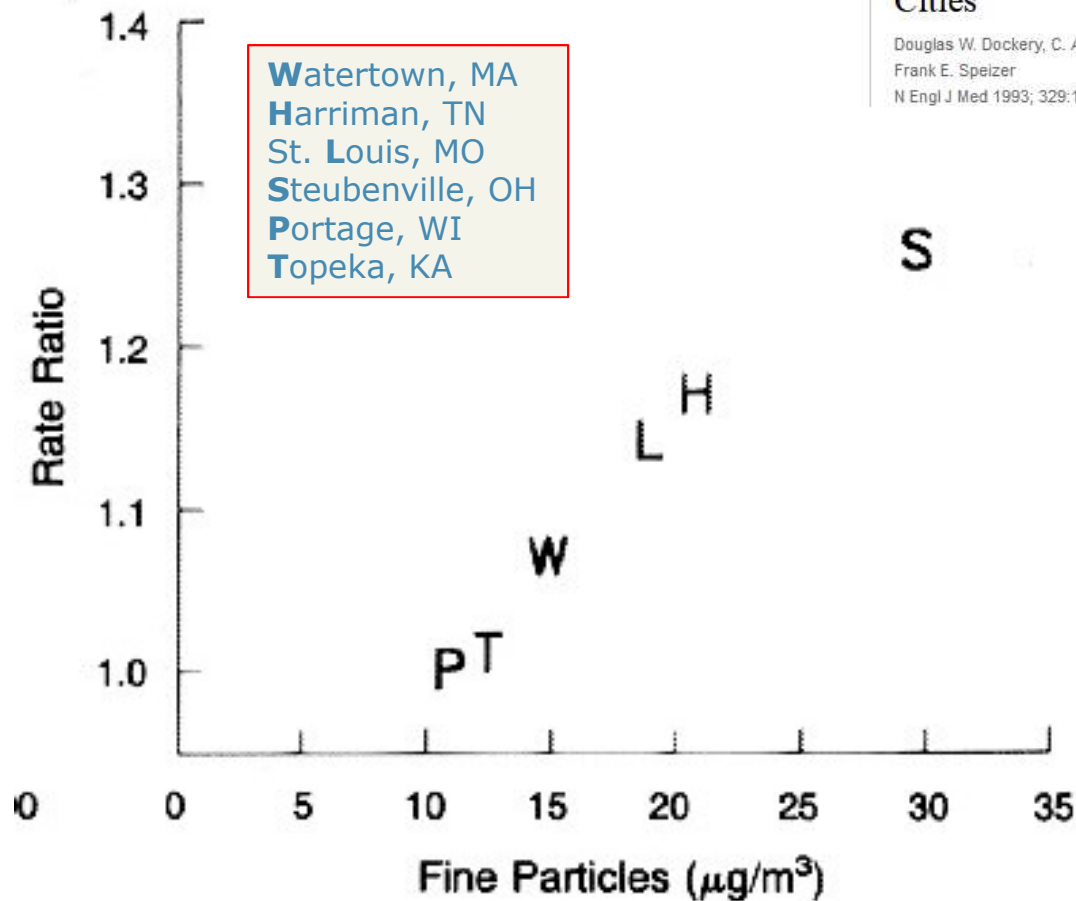
CME >

## ORIGINAL ARTICLE

### An Association between Air Pollution and Mortality in Six U.S. Cities

Douglas W. Dockery, C. Arden Pope, Xiping Xu, John D. Spengler, James H. Ware, Martha E. Fay, Benjamin G. Ferris, Jr., and Frank E. Speizer

N Engl J Med 1993; 329:1753-1759 | December 9, 1993 | DOI: 10.1056/NEJM199312093292401

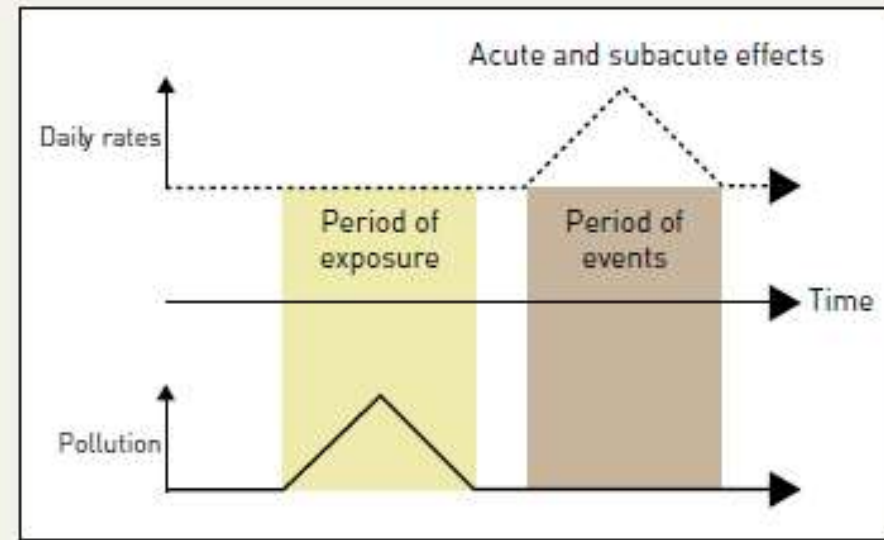


- 1974 – 1991 prospective cohort study of effect of air pollution on mortality in six cities in USA
- Mortality was most strongly associated with the levels of inhalable, fine and sulfate particles
- Air pollution was positively associated with mortality due to lung cancer and cardiopulmonary disease

# Health effects assessment?

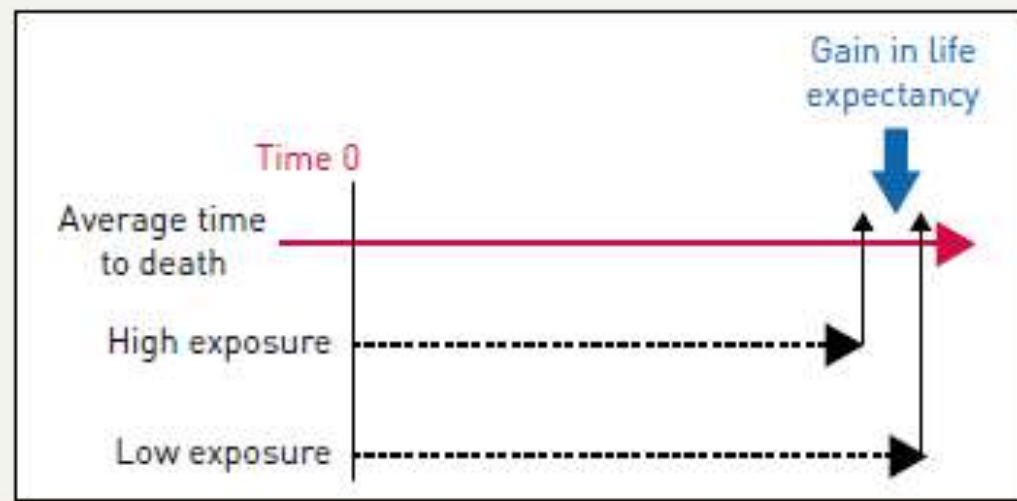
## Acute health effects

**Figure 5a.1. Schematic representation of epidemiological short-term studies in air pollution.** Short-term studies attempt to find associations between changes in concentrations during some time period and changes in outcome rates the same day or a few days after exposure. Modified from [14].



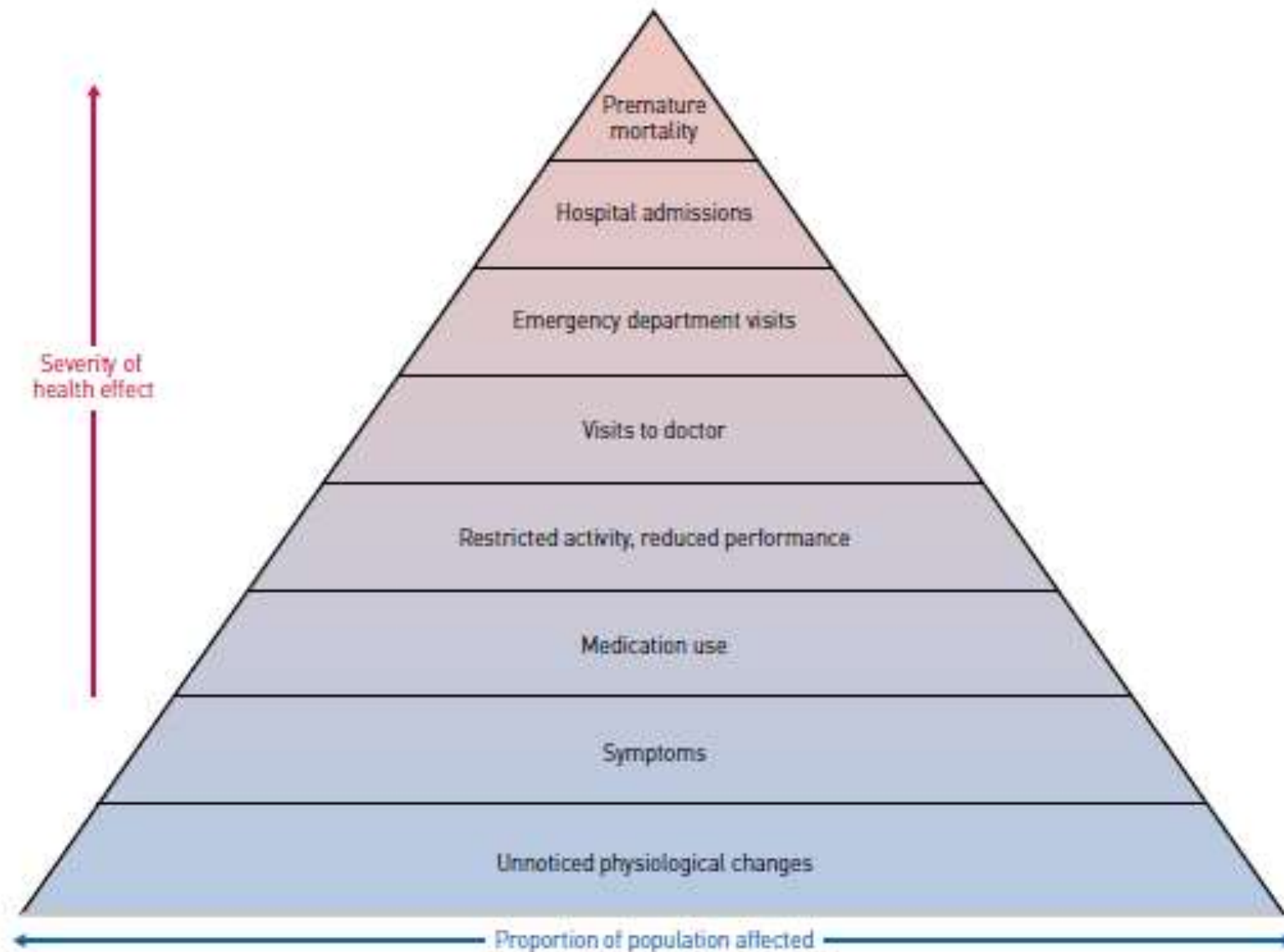
## Chronic health effects

**Figure 5b.1. Schematic representation of epidemiological long-term studies in air pollution.** Cohort studies follow a population through time and compare outcomes (e.g. time to death) among people with different levels of exposure





# Health effects of air pollution



# Health effects of air pollution:

## Acute effects

Daily mortality

Respiratory hospital admissions

Cardiovascular hospital admissions

Emergency room visits for respiratory and cardiac problems

Primary care visits for respiratory and cardiac conditions

Use of respiratory and cardiovascular medications

Days of restricted activity

Work absenteeism

School days missed

Self-medication

Avoidance behaviour

Acute symptoms

Physiological changes, e.g. in lung function



# Health effects of air pollution:

## Chronic effects

Mortality from chronic cardiorespiratory disease

Chronic respiratory disease incidence and prevalence  
(asthma, COPD)

Chronic change in physiological function (e.g. lung function)

Lung cancer

Chronic cardiovascular disease

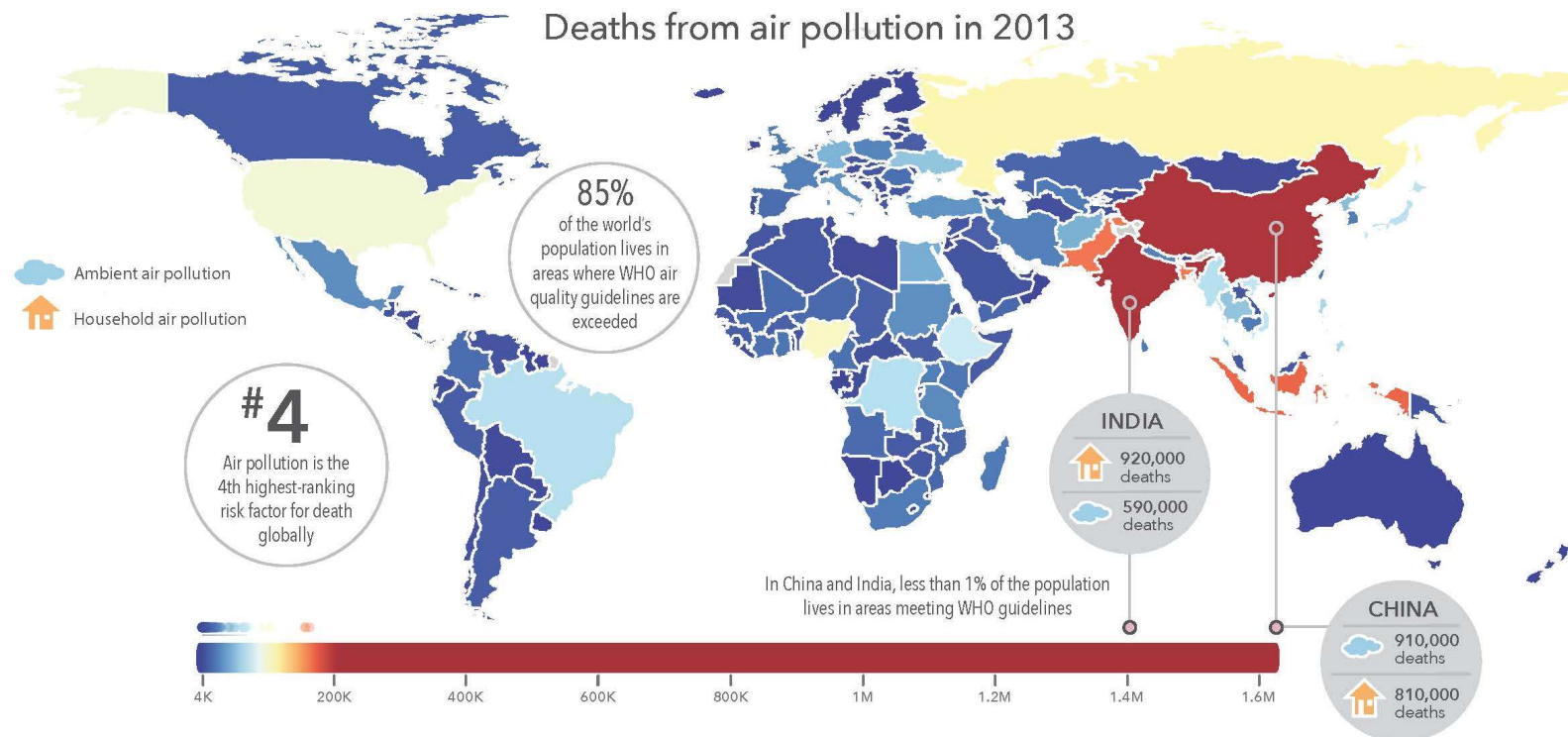
### Other effects

Low birth weight

Pre-term delivery

Adversely affected cognitive development in infants

# Global burden of air pollution

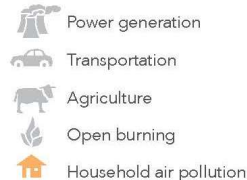


## Air pollution was responsible for 5.5 million deaths in 2013

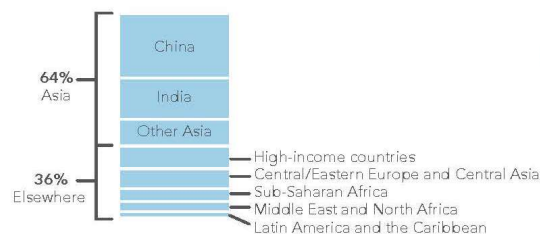
**Household air pollution**  
 Caused by burning solid fuels for heating and cooking, including:



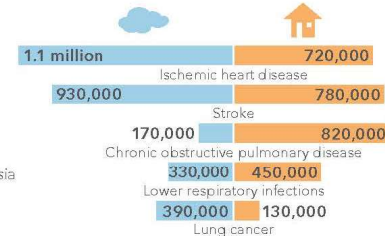
**Ambient air pollution**  
 Caused by emissions from things like:



2.9 million deaths from ambient air pollution in 2013



10% of all deaths were from air pollution in 2013



### Source:

1. Forouzanfar MH, et al. Global, regional, and national comparative risk assessment of 79 behavioral, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*. 2015 Dec 5;386(10010):2287-323.
2. Brauer M, et al. Ambient air pollution exposure estimation for the Global Burden of Disease 2013. *Environmental Science & Technology*. 2016 Jan 5;50(1):79-88.



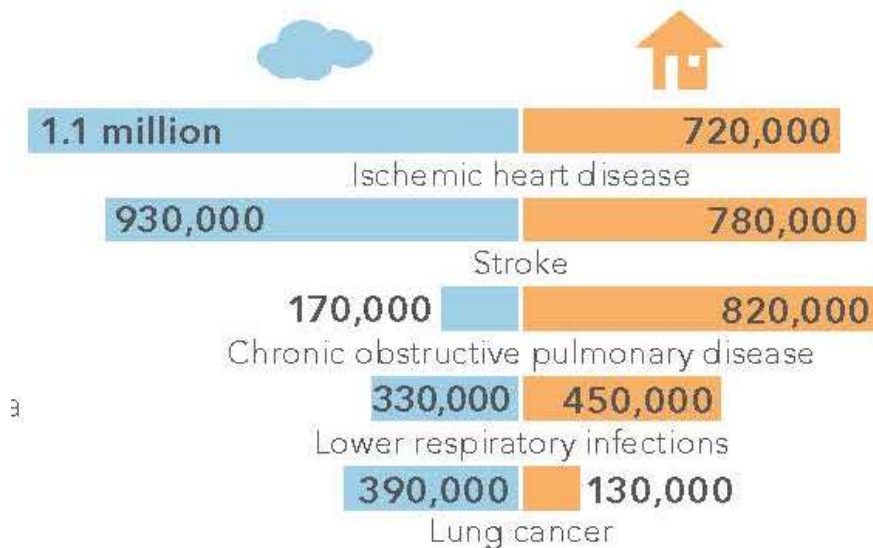
IHME | UNIVERSITY of WASHINGTON

ES 200/07 Aug 2017

<http://www.healthdata.org/news-release/poor-air-quality-kills-55-million-worldwide-annually>

# Global burden of air pollution

10% of all deaths were from air pollution in 2013



## Household air pollution

Caused by burning solid fuels for heating and cooking, including:



Coal



Wood



Dung



## Ambient air pollution

Caused by emissions from things like:



Power generation



Transportation



Agriculture



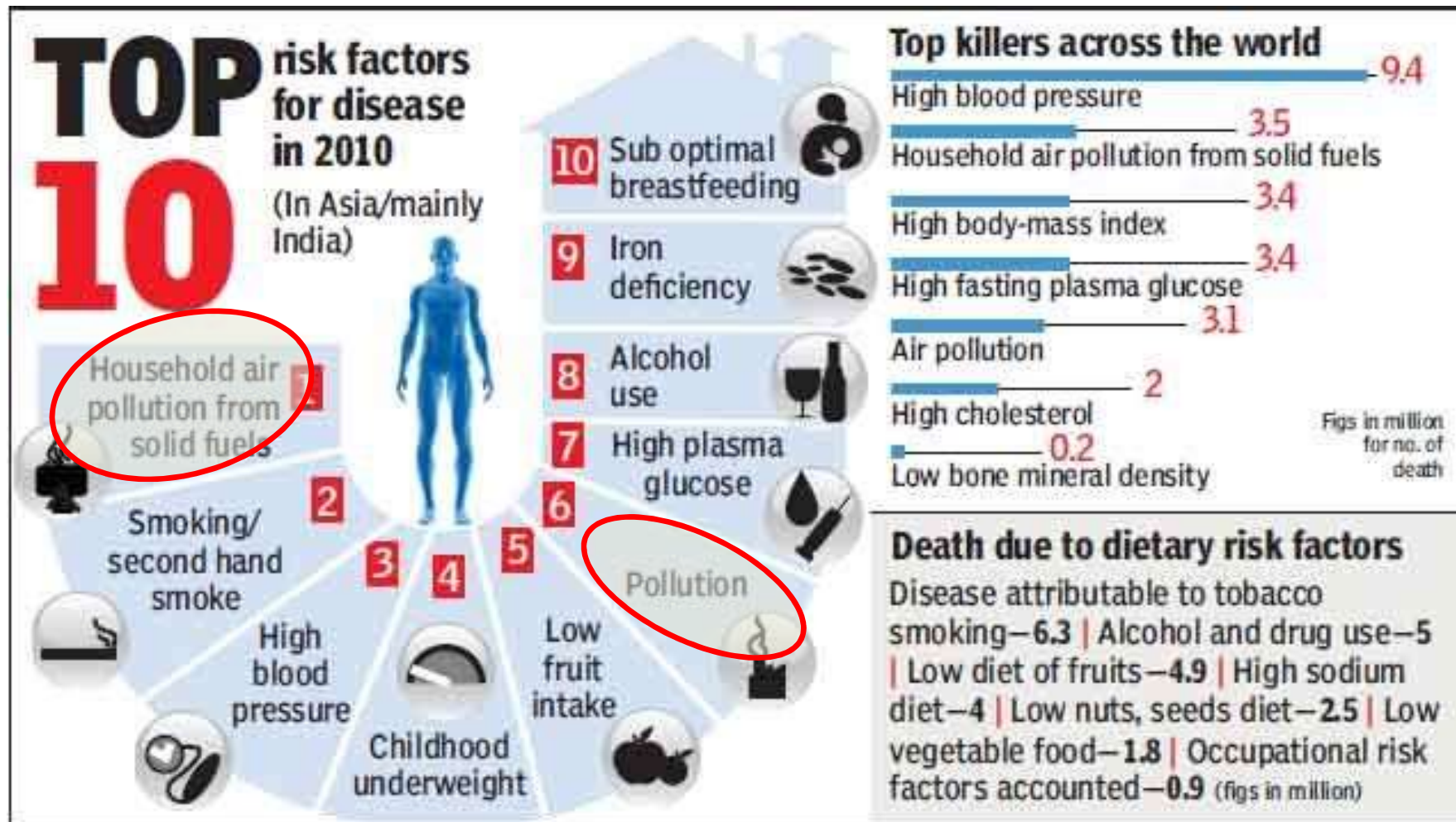
Open burning



Household air pollution



# Air pollution leading risk factor for diseases/deaths in India ...and worldwide



[http://urbanemissions.blogspot.in/2014\\_02\\_01\\_archive.html](http://urbanemissions.blogspot.in/2014_02_01_archive.html)

# Air quality and lung cancer in India

## Lung cancer cases peaked in '09-'11

**Kolkata, Delhi and areas around these two cities have most polluted air in country**



➤ Delhi, Jharkhand, West Bengal and Maharashtra have worst air quality

➤ Highest number of lung cancer cases during 2009-11 reported in Delhi, Mumbai and Kolkata

➤ Half of urban population breathes air that exceeds the accepted standard of PM10

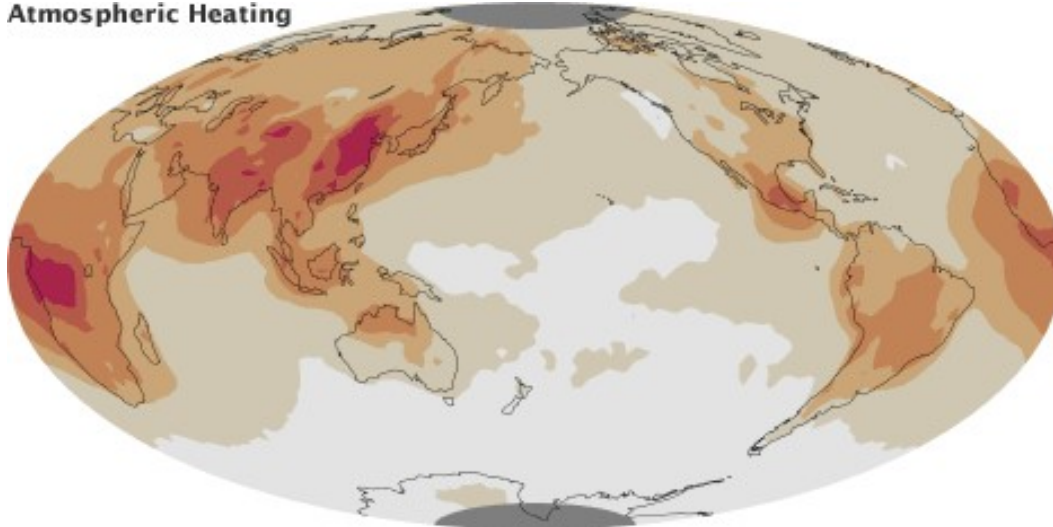
**Analysis of three pollutants (SO<sub>2</sub>, NO<sub>2</sub> and particulate matter) at 450 air monitoring locations in 190 cities/towns across the country shows**

**One-third of urban population lives in cities/towns with PM10 levels classified as 'critical'**

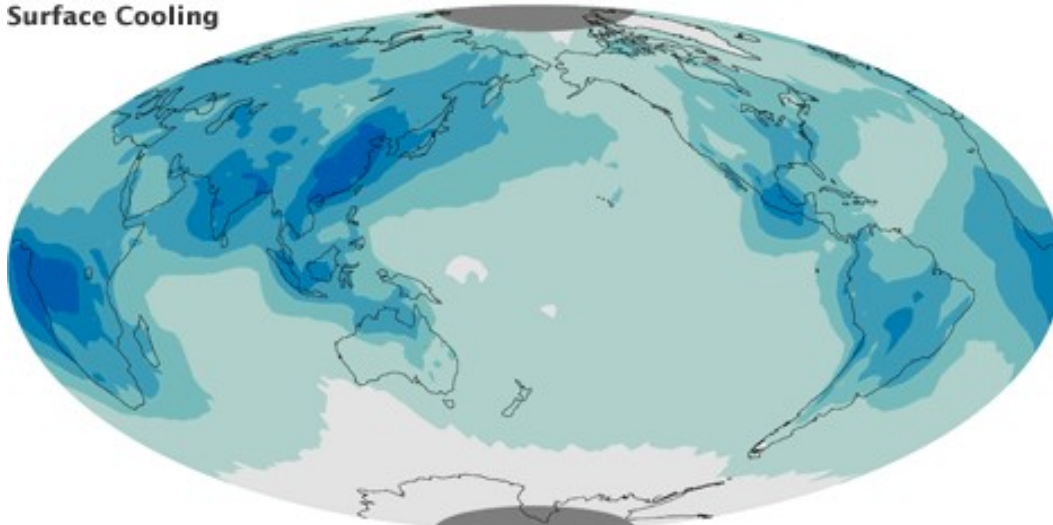


# Air pollution affects climate: Direct effects

Atmospheric Heating



Surface Cooling



Black Carbon Forcing (Watts/m<sup>2</sup>)

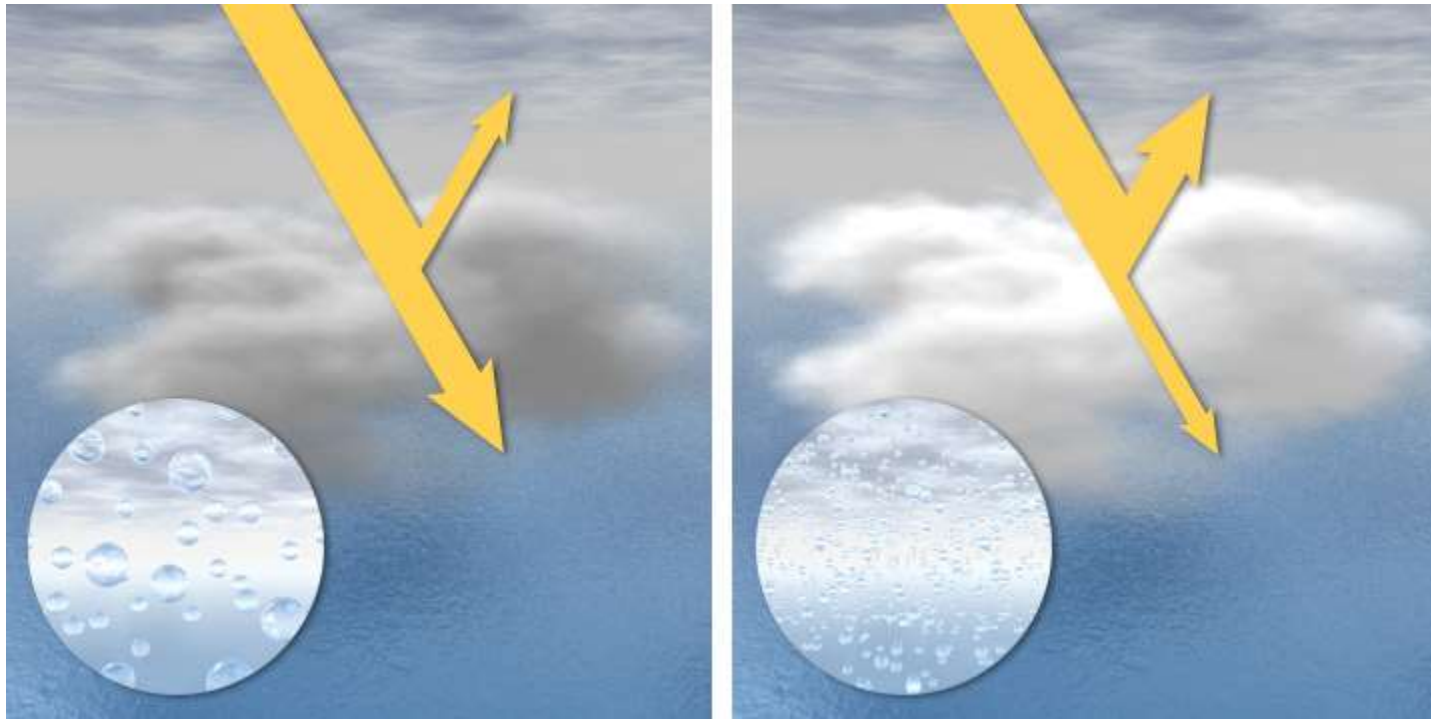


Sun provides the energy that drives Earth's climate, but not all of the energy that reaches the top of the atmosphere finds its way to the surface.

That's because aerosols—and clouds seeded by them—reflect about a quarter of the Sun's energy back to space.

Black carbon aerosols, similar to the soot in a chimney, absorb sunlight rather than reflecting it. This warms the layer of the atmosphere carrying the black carbon, but also shades and cools the surface below.

## Air pollution affects climate: Indirect effects



Whereas aerosols can influence climate by scattering light and changing Earth's reflectivity, they can also alter the climate via clouds. On a global scale, these aerosol "indirect effects" typically work in opposition to greenhouse gases and cause cooling

Brighter clouds, in turn, block sunlight from reaching Earth's surface, shading the planet and producing net cooling. This cloud brightening effect—called the "cloud albedo effect"—may have a big impact on the climate,

# **Air pollution affects visibility !**





# Air quality regulation in India

## Air Prevention and Control of Pollution Act (1981), Amended in 1987

A comprehensive legislation which makes provisions for:

- Central pollution control board (CPCB)
- State pollution control boards (SPCBs),
- power to declare pollution control areas,
- restrictions on certain industrial units,
- authority of the Boards to limit emission of air pollutants,
- power of entry, inspection, taking samples and analysis,
- penalties, offences by companies and Government, and
- cognizance of offences

# Air Act, 1981

## Air Prevention and Control of Pollution Act (1981), Amended in 1987

- The Act specifically empowers State Government to designate air pollution control areas and to prescribe the type of fuel to be used in these designated areas
- Air pollution sources such as industry, vehicles, power plants, etc. not permitted to release **criteria air pollutants** or other toxic substances beyond a prescribed level (called as **NAAQS**)
- The Air Act apparently adopts an industry wide “best available technology” requirement for abiding the emission requirements

# Criteria Air Pollutants

- US EPA, EEA and other national regulatory agencies use **six** "criteria pollutants" as indicators of **outdoor** air quality
- For each of them a maximum concentration above which adverse effects on human health may occur, is established - referred as NAAQS.

Source	SO <sub>2</sub> µg·m <sup>-3</sup>				NO <sub>2</sub> µg·m <sup>-3</sup>			PM <sub>10</sub> µg·m <sup>-3</sup>		PM <sub>2.5</sub> µg·m <sup>-3</sup>		Ozone µg·m <sup>-3</sup>	
	1 year	24 hr	1 hr	10 m	1 year	24 hr	1 hr	1 year	24 hr	1 year	24 hr	8 hr	1 hr
WHO [21]		20		500	40		200	20	50 <sup>a</sup>	10	25 <sup>a</sup>	100	
European Union (revised 2008) [50]		125 <sup>a</sup>	350 <sup>f</sup>		40		200 <sup>e</sup>	40	50 <sup>b</sup>	25		120 <sup>f</sup>	
Switzerland [51]	30	100 <sup>d</sup>			30	80 <sup>d</sup>		20	50 <sup>d</sup>				120 <sup>d</sup>
France [52]	50	125 <sup>a</sup>	350 <sup>f</sup>		40		200 <sup>e</sup>	40	50 <sup>b</sup>				
Sweden [53]		100	200		40	60	90	40	50				
UK [54]		125 <sup>a</sup>	350 <sup>f</sup>	266 <sup>b</sup>	40		200 <sup>e</sup>	40	50 <sup>b</sup>	25		100	
Japan [55]		105	262			113			100				118 <sup>c</sup>
USA [56]	78	366			100			50	150	15	65	157	
California [57]		105 <sup>c</sup>	655				470 <sup>c</sup>	20	50	12	65	137	180 <sup>c</sup>

# National Ambient Air Quality Standards: (NAAQS) India

Ambient Concentration

Type of area

Averaging interval /Exposure duration

S. No.	Pollutant	Time Weighted Average	Concentration in Ambient Air		
			Industrial, Residential, Rural and Other Area	Ecologically Sensitive Area (notified by Central Government)	Methods of Measurement
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulphur Dioxide (SO <sub>2</sub> ), µg/m <sup>3</sup>	Annual* 24 hours**	50 80	20 80	• Improved colorimetric method • Fluorimetric method
2	Nitrogen Dioxide (NO <sub>2</sub> ), µg/m <sup>3</sup>	Annual* 24 hours**	40 80	80	• Modified Jacob & Hoelheiser (Na-Arsenite) • Chemiluminescence
3	Particulate Matter (size less than 10µm) or PM <sub>10</sub> , µg/m <sup>3</sup>	Annual* 24 hours**	50 100	60 100	• Gravimetric • TOEM • Beta attenuation
4	Particulate Matter (size less than 2.5µm) or PM <sub>2.5</sub> , µg/m <sup>3</sup>	Annual* 24 hours**	40 60	40 60	• Gravimetric • TOEM • Beta attenuation
5	Ozone (O <sub>3</sub> ), µg/m <sup>3</sup>	8 hours** 1 hour**	100 180	100 180	• UV photometric • Chemiluminescence • Chemical Method
6	Lead (Pb), µg/m <sup>3</sup>	Annual* 24 hours**	0.50 1.0	0.50 1.0	• AAS /ICP method after sampling on EPM 2000 or equivalent filter paper • ED-XRF using Teflon filter
7	Carbon Monoxide (CO), mg/m <sup>3</sup>	8 hours** 1 hour**	02 04	02 04	• Non Dispersive Infra Red (NDIR) spectroscopy
8	Ammonia (NH <sub>3</sub> ), µg/m <sup>3</sup>	Annual* 24 hours**	100 400	100 400	• Chemiluminescence • Indophenol blue method

[http://cpcb.nic.in/National\\_Ambient\\_Air\\_Quality\\_Standards.php](http://cpcb.nic.in/National_Ambient_Air_Quality_Standards.php)

# Criteria air pollutants

## 1. Nitrogen Dioxide: $\text{NO}_2$

- brownish gas, irritates the respiratory system
- originates from combustion ( $\text{N}_2$  in air is oxidized)
- $\text{NO}_x$  sum of  $\text{NO}$  &  $\text{NO}_2$

## 2. Ozone: ground level $\text{O}_3$

- primary constituent of urban smog
- $\text{CO}/\text{HCs} + \text{NO}_x + \text{light} \rightarrow \text{PAN}$  (Peroxyacetyl nitrate)

Have you heard of LA smog?

## 3. Carbon monoxide: $\text{CO}$

- reduces blood's ability to carry  $\text{O}_2$
- product of incomplete combustion

# Criteria air pollutants

## 4. Lead: Pb

- cause learning disabilities in children , toxic to liver, kidney, blood forming organs
- tetraethyl lead – anti knock agent in gasoline; leaded gasoline has been mostly phased out

## 5. Particulate Matter: PM<sub>10</sub> (and PM<sub>2.5</sub>)

- respiratory & cardiovascular disorders

## 6. Sulfur Dioxide: SO<sub>2</sub>

- formed when fuel (coal, oil) containing sulfur is burned and metal smelting
- precursor of acid rain along with NO<sub>x</sub>

**At least now you know about London smog !**