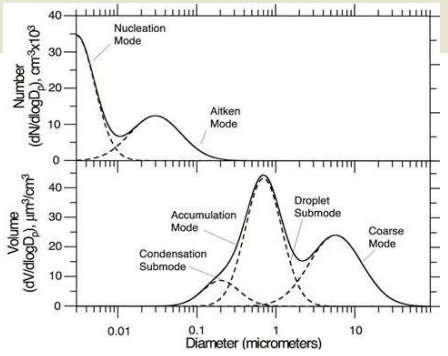
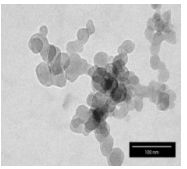




Complex Mixture



Lecture 3

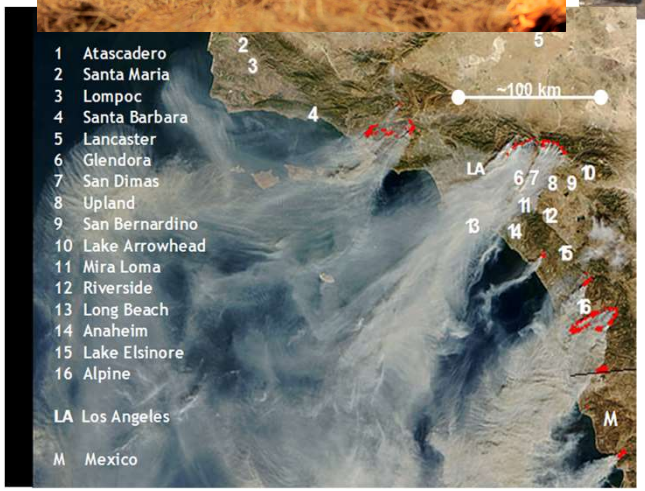
# Module B/Air Quality:

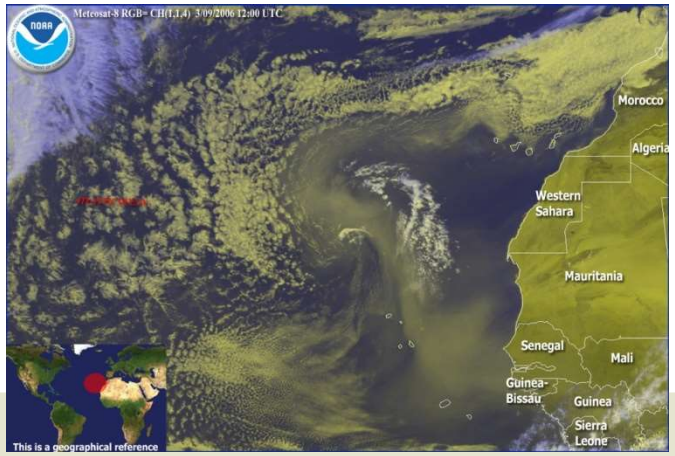
# Particles Size & Composition Measurement Methods

**Harish C. Phuleria**
CESE, IIT Bombay

Email: phuleria@iitb.ac.in

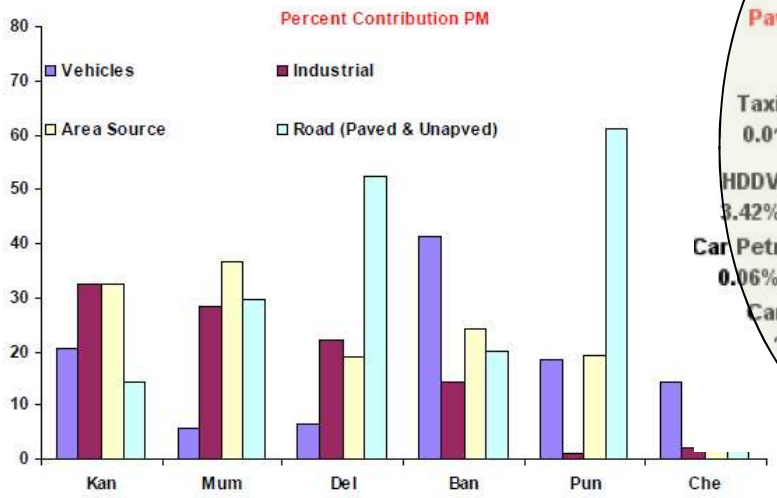
# Recap 1

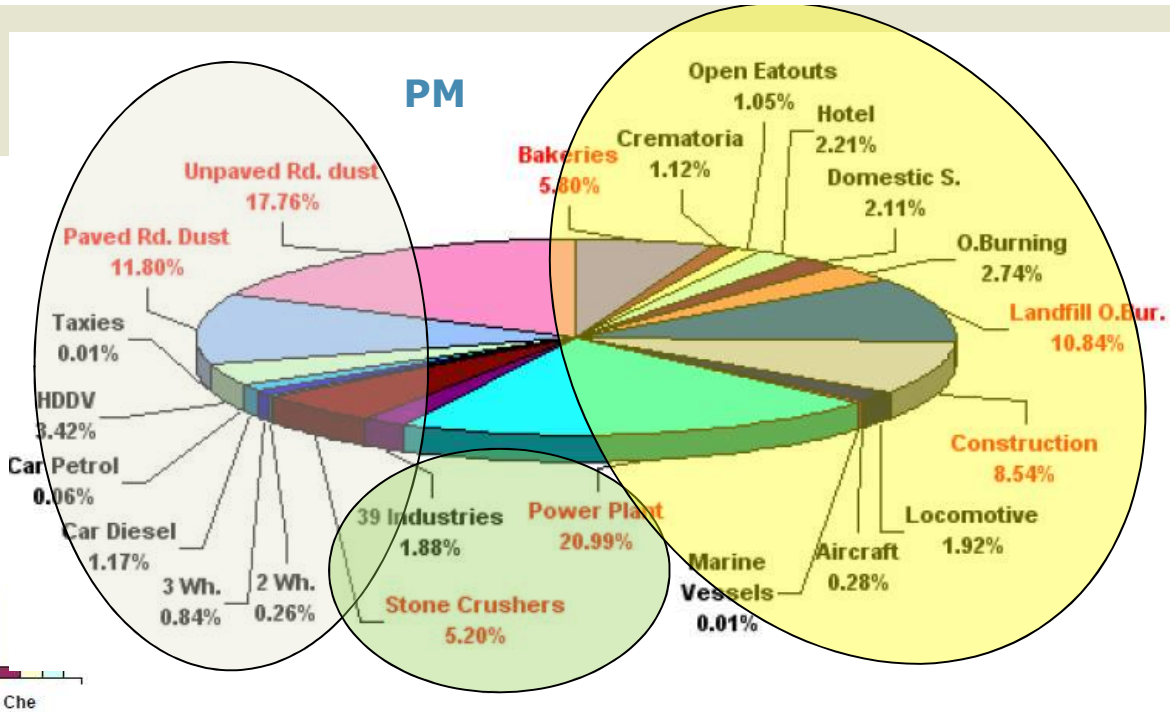


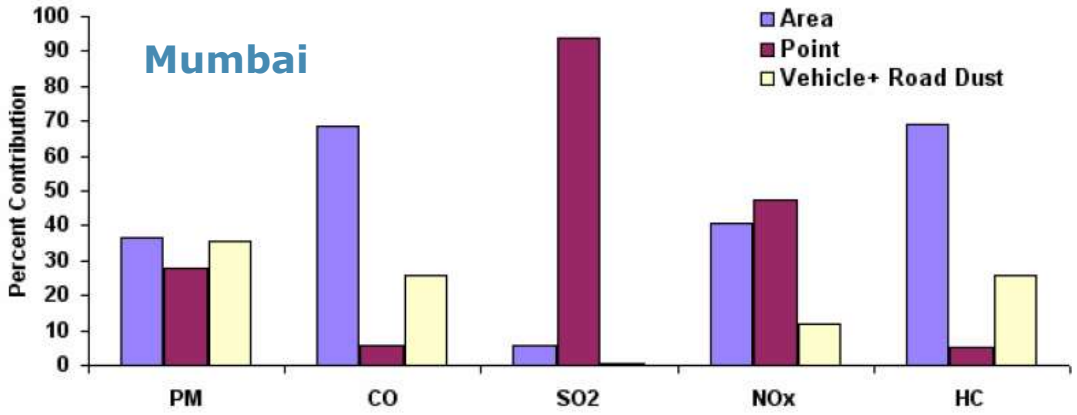



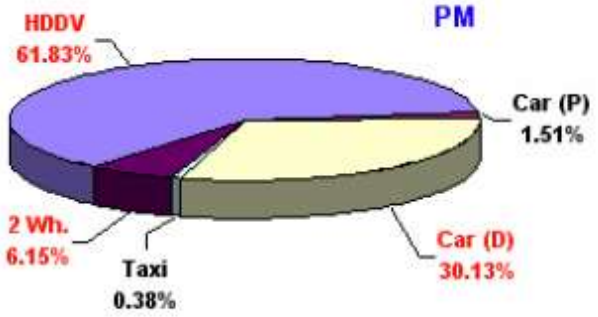

Prabir Mallik/The World Bank

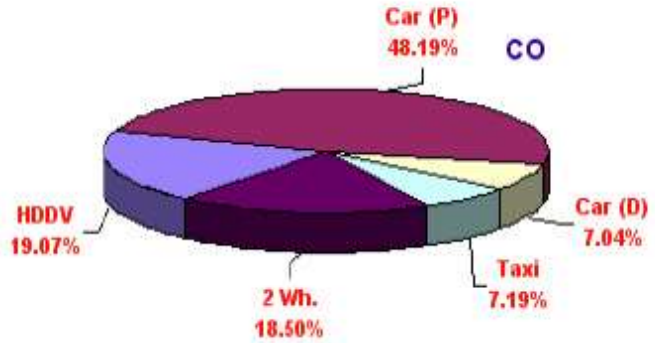
# Recap 2


Percent Contribution PM
Vehicles
Industrial
Area Source
Road (Paved & Unapved)
80
70
60
50
40
30
20
10
0
Kan
Mum
Del
Ban
Pun
Che


PM
Open Eatouts
1.05%
Hotel
2.21%
Crematoria
1.12%
Bakeries
5.80%
Domestic S.
2.11%
Unpaved Rd. dust
17.76%
O.Burning
2.74%
Paved Rd. Dust
11.80%
Landfill O.Bur.
10.84%
Taxies
0.01%
HDDV
3.42%
Car Petrol
0.06%
Construction
8.54%
Car Diesel
1.17%
39 Industries
1.88%
Power Plant
20.99%
Locomotive
1.92%
3 Wh.
0.84%
2 Wh.
0.26%
Marine
Vessels
0.01%
Aircraft
0.28%
Stone Crushers
5.20%

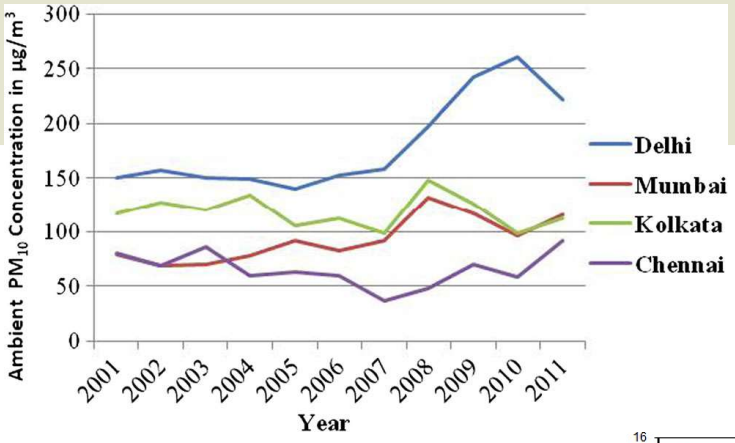

Mumbai
Area
Point
Vehicle+ Road Dust
Percent Contribution
100
90
80
70
60
50
40
30
20
10
0
PM
CO
SO2
NOx
HC

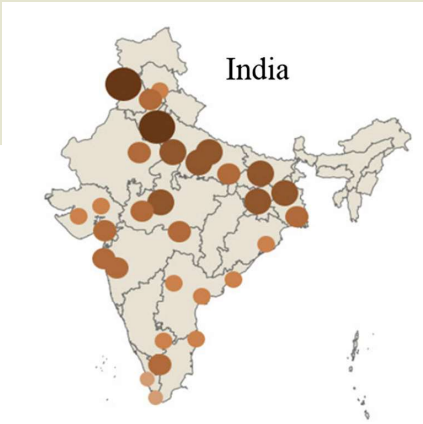

PM
HDDV
61.83%
Car (P)
1.51%
2 Wh.
6.15%
Car (D)
30.13%
Taxi
0.38%

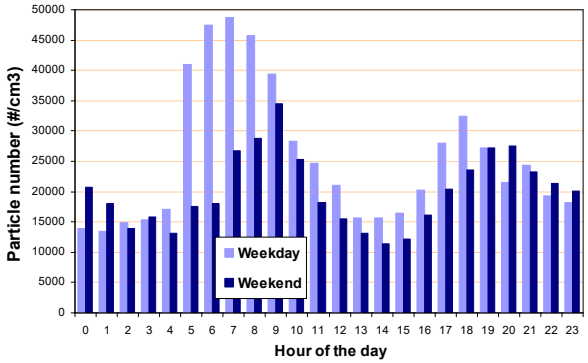

Car (P)
48.19%
CO
HDDV
19.07%
Car (D)
7.04%
Taxi
7.19%
2 Wh.
18.50%

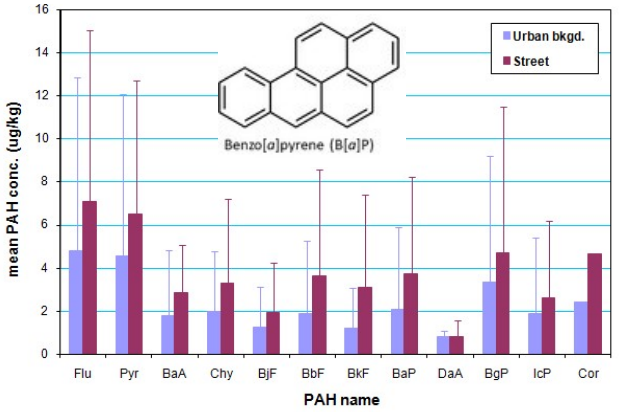
# Recap 3

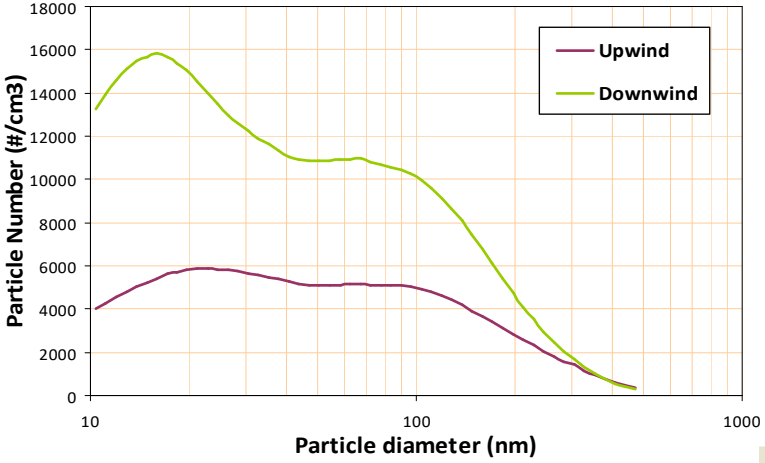
- **Spatial variation:**
  - Local/urban
  - state or national
  - regional or global
- **Temporal variation:**
  - hourly
  - daily
  - weekday
  - seasonal
  - annual
  - diurnal

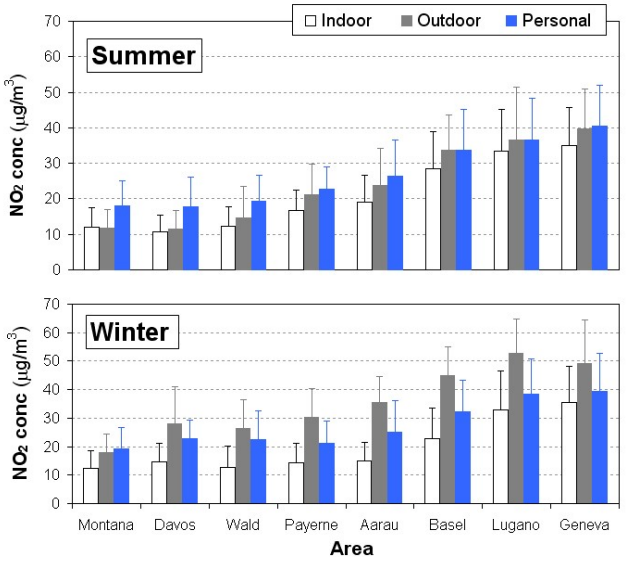


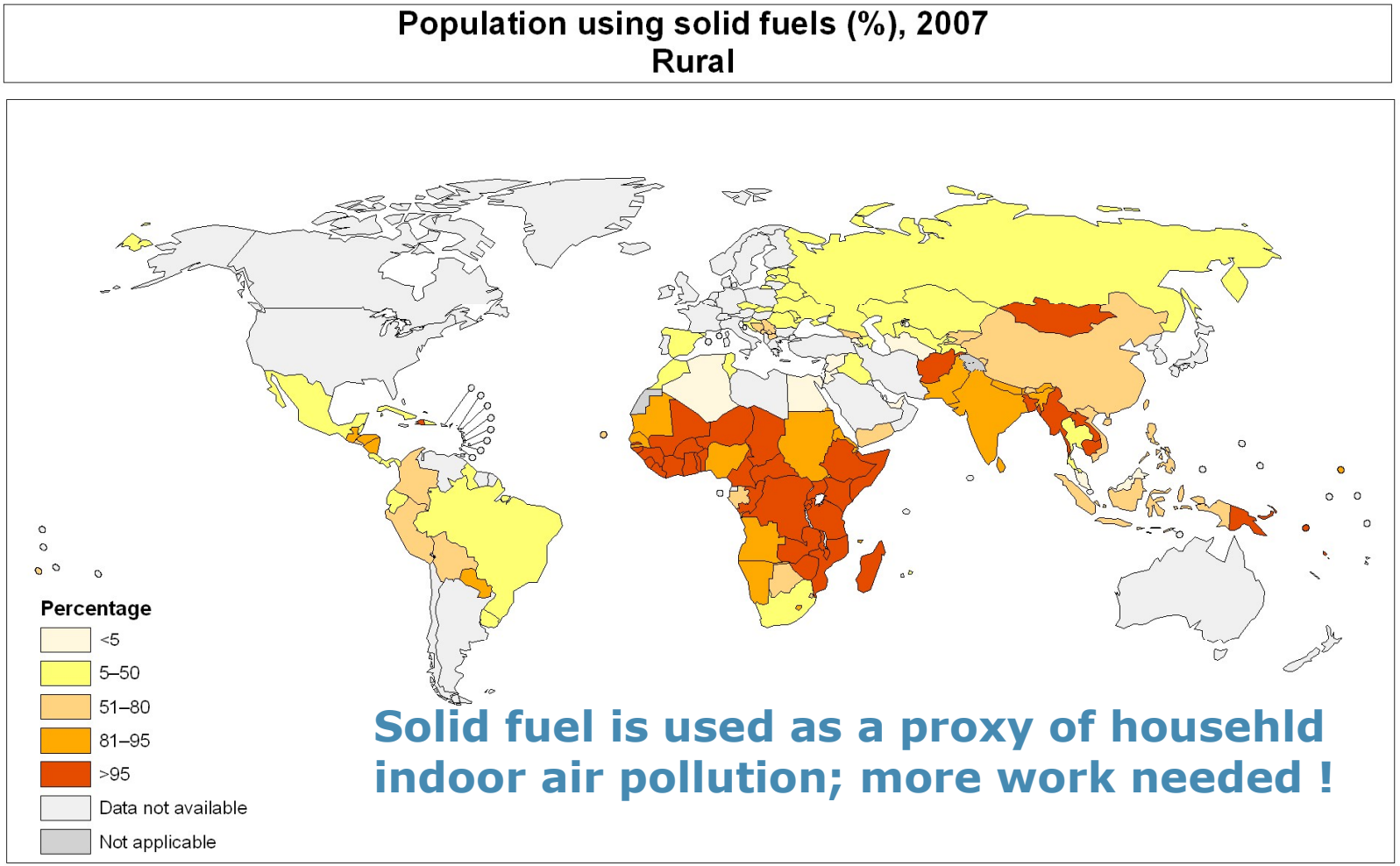



# Indoor air pollution across the globe

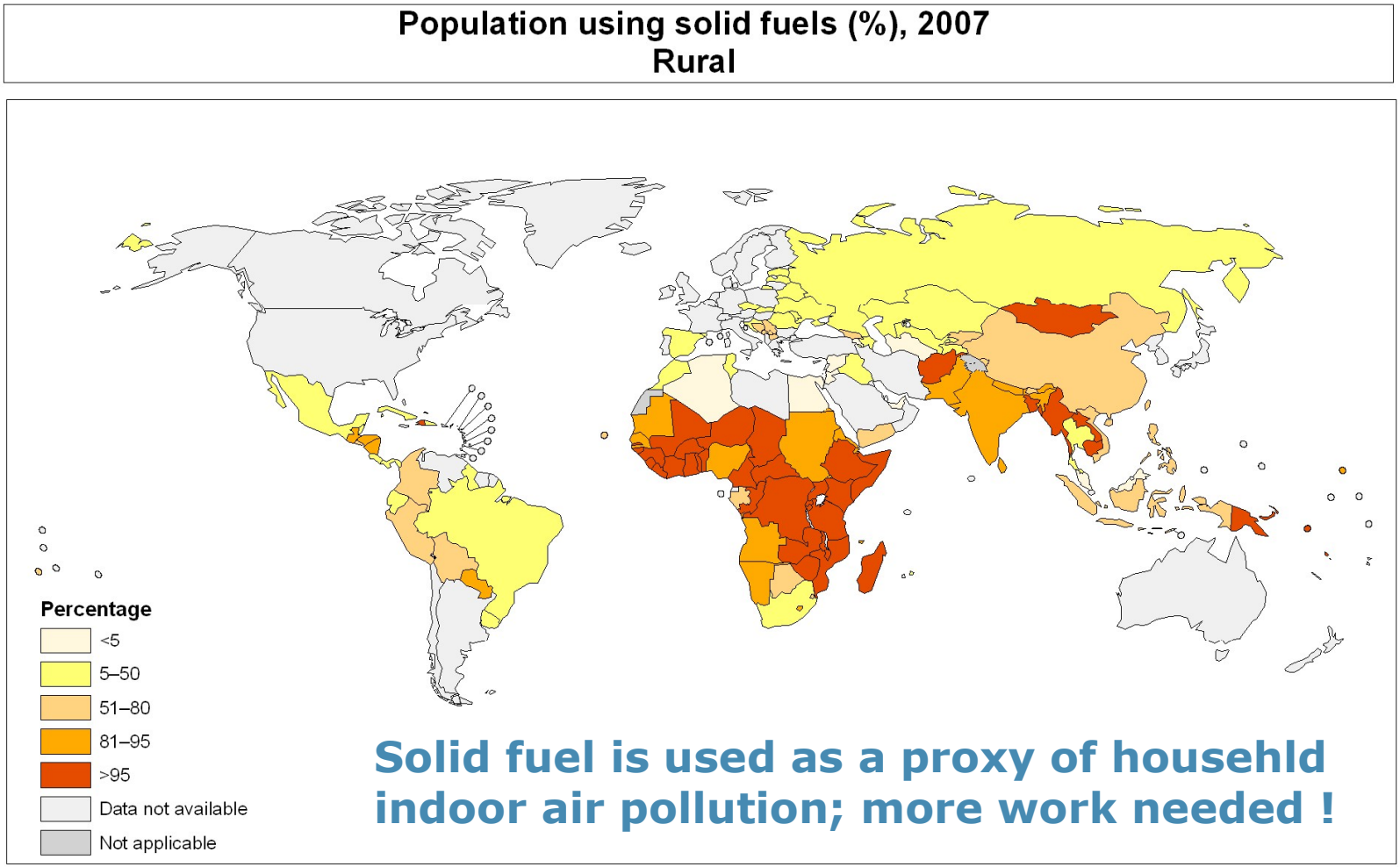
## Spatial distribution on global scale




(WHO, 2011)

# Indoor air pollution across the globe: Rural areas

## Spatial distribution on global scale




The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

Data Source: World Health Organization
Map Production: Public Health Information and Geographic Information Systems (GIS)
World Health Organization

World Health Organization





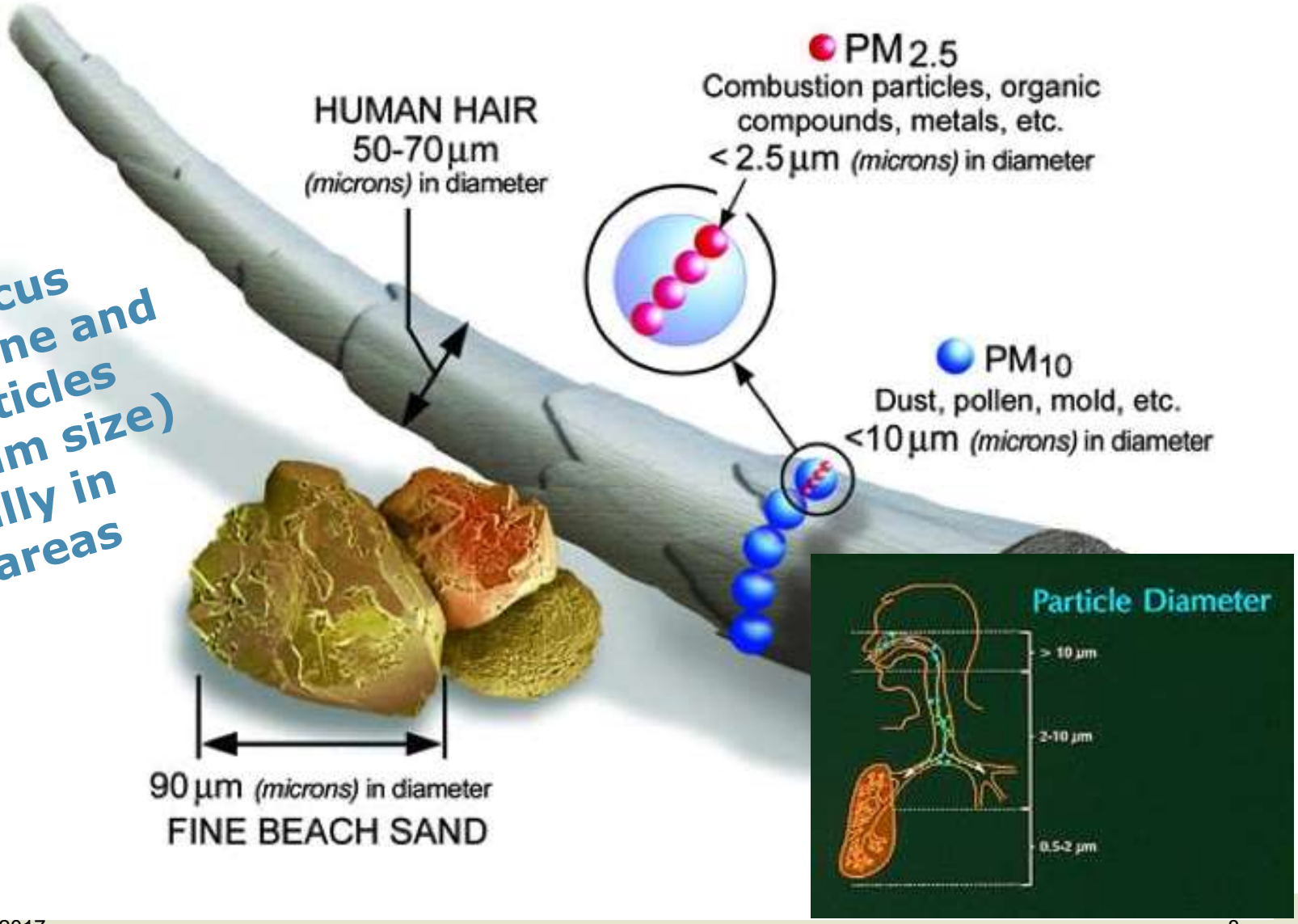
**(WHO, 2011)**

# Today's Learning Objectives !

- To understand particle composition & size distribution

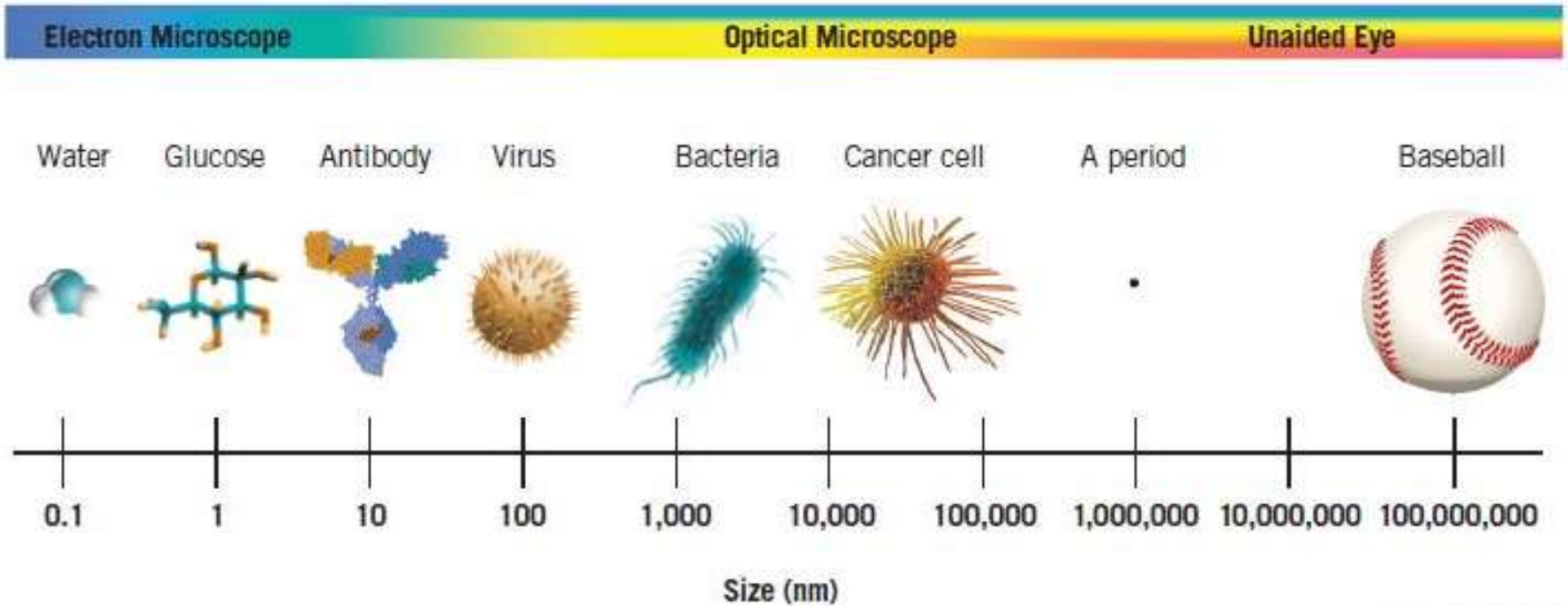
- To learn about monitoring methods and thus able to quantify pollutants' concentrations

# Particles – size matters !



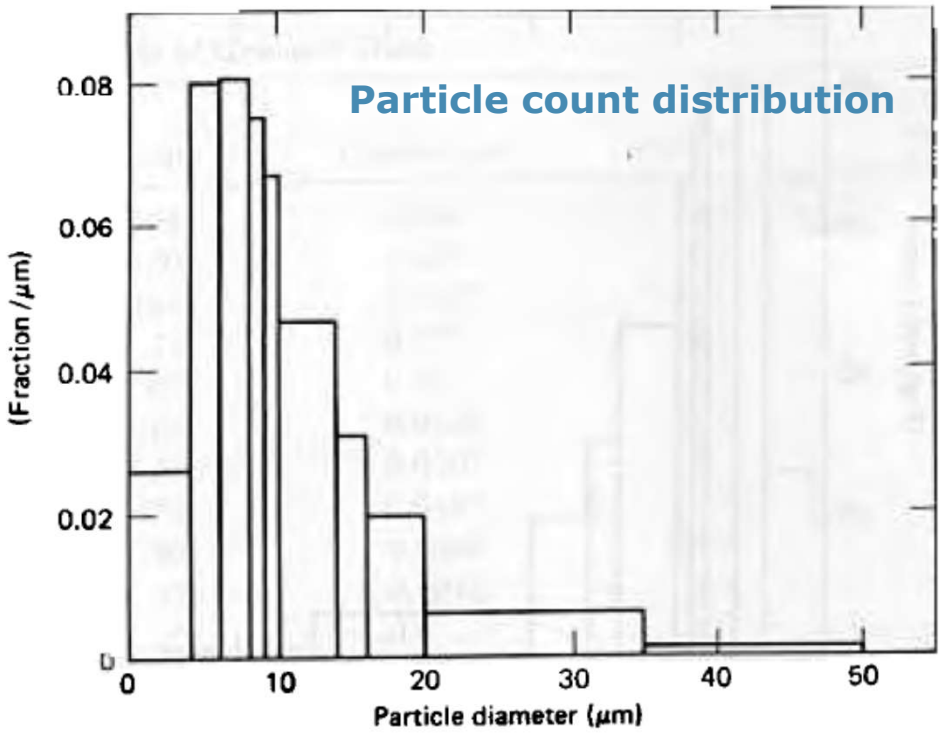

**Recent focus on ultrafine and nanoparticles (<100 nm size) especially in urban areas**

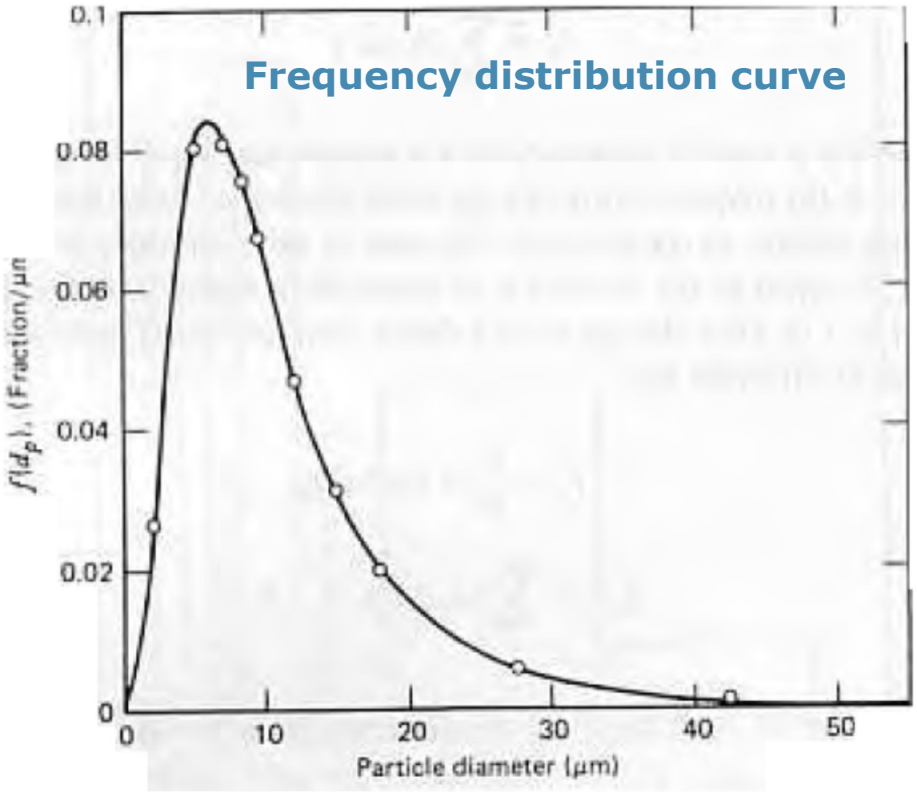
# Particles – size matters !




http://www.particlesciences.com/news/technical-briefs/2012/glossary-of-drug-nanotechnology.html

# Particle size distribution: Ambient aerosols

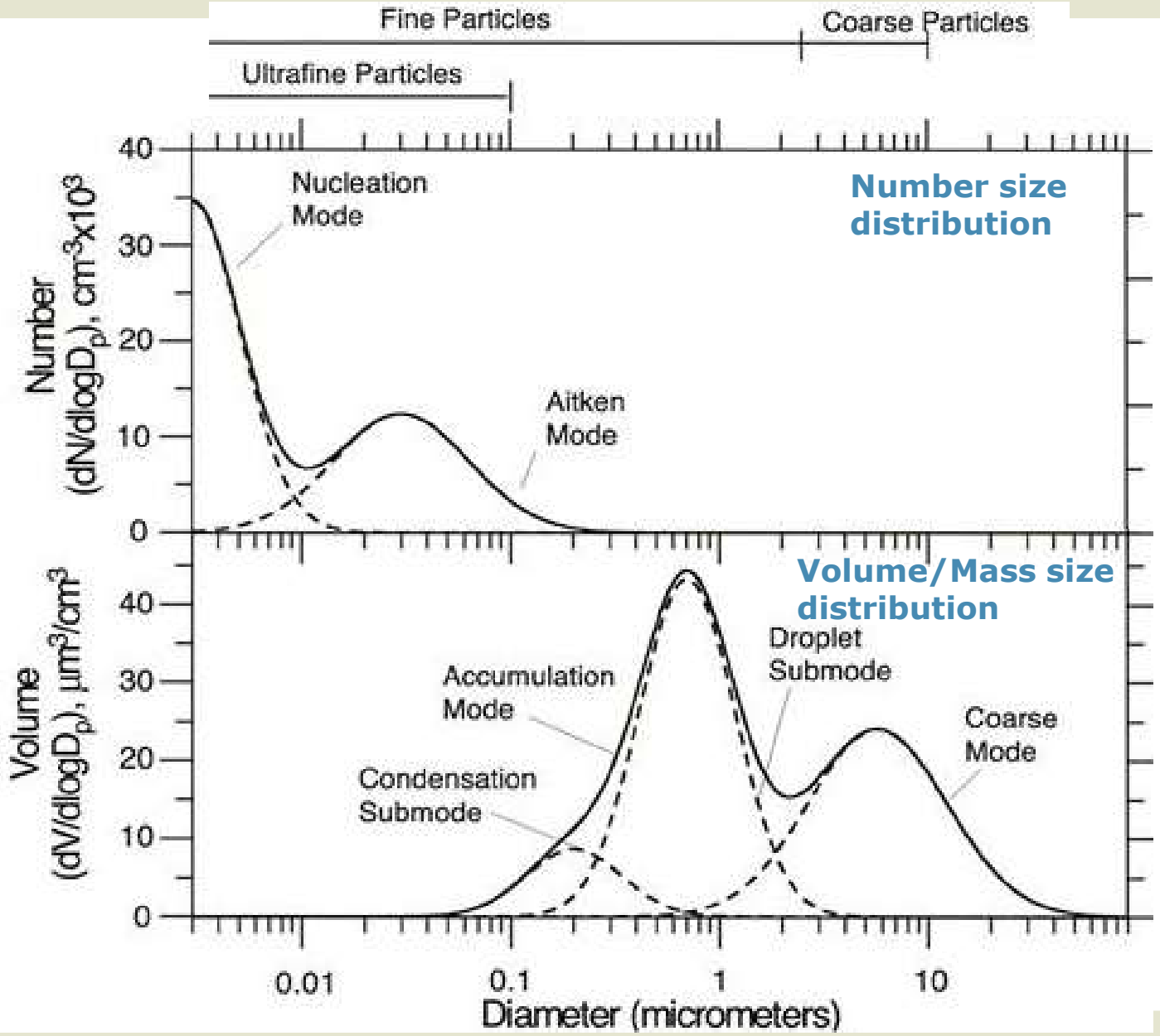




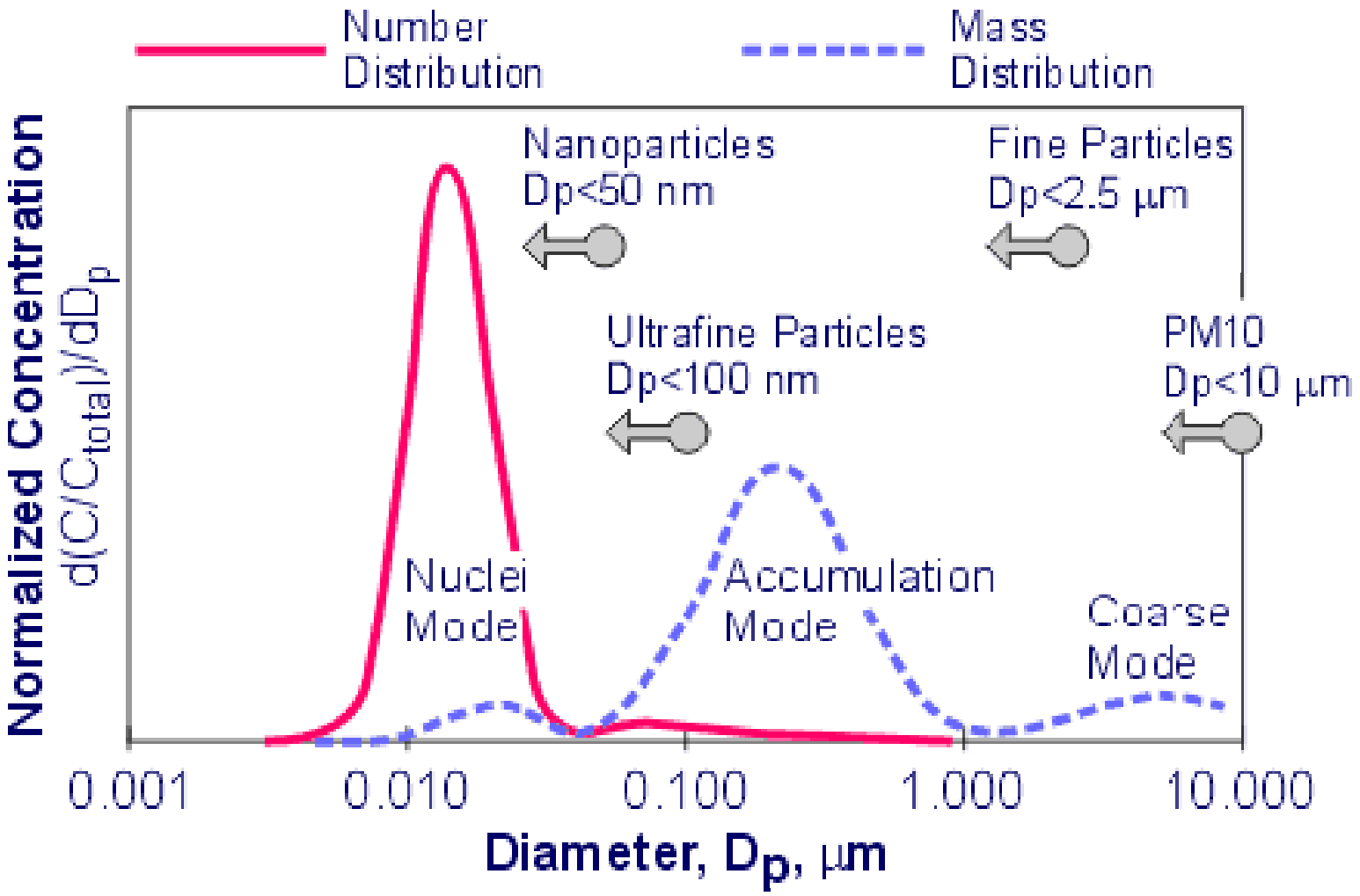

**Hinds, 1999**

# Particle size distribution: Ambient aerosols




NARSTO, 2004

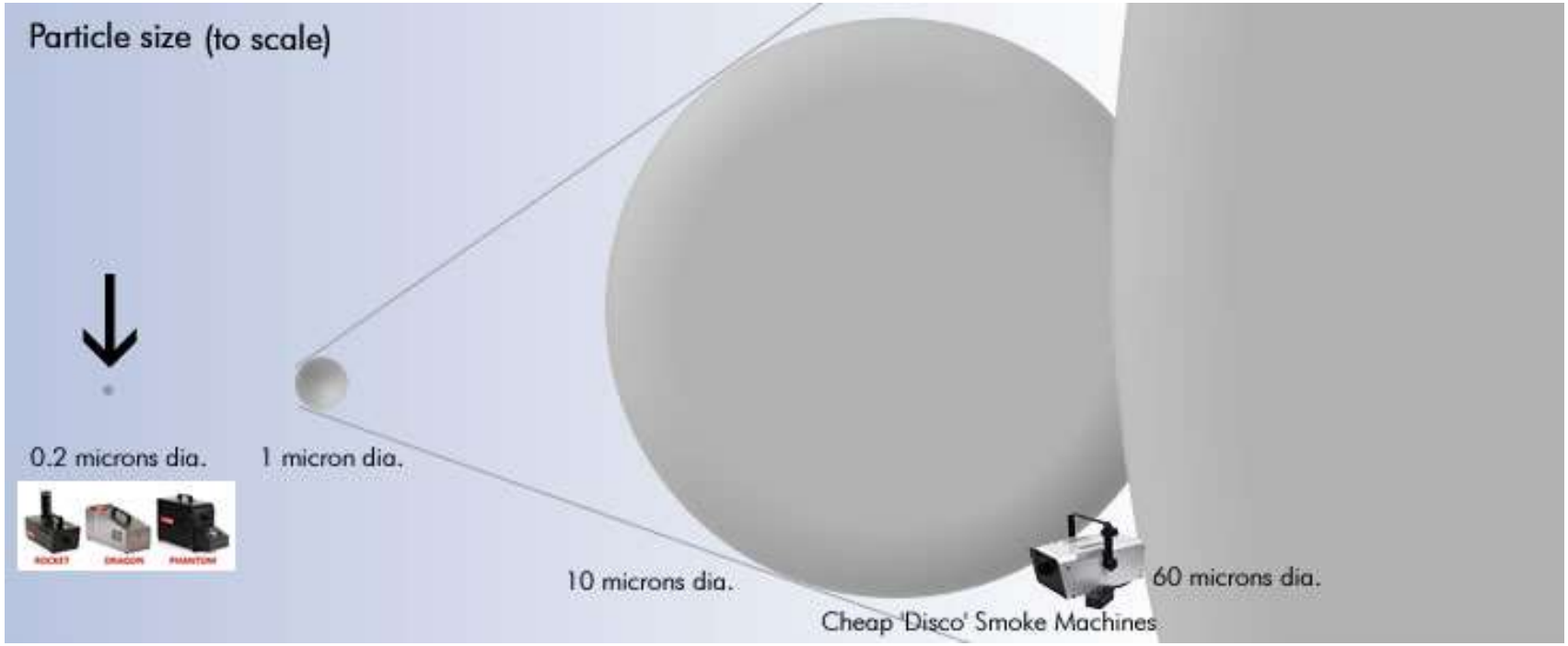
# Particle size distribution: Diesel exhaust




**https://www.dieselnet.com/tech/dpm_size.php**

# Class exercise !

**Q.** How many 0.2 μm particles will have the same mass as that of one 10 μm particle (assume same density)??




http://www.smokemachines.net/smoke-particle-size.shtml

# Particle deposition in lungs

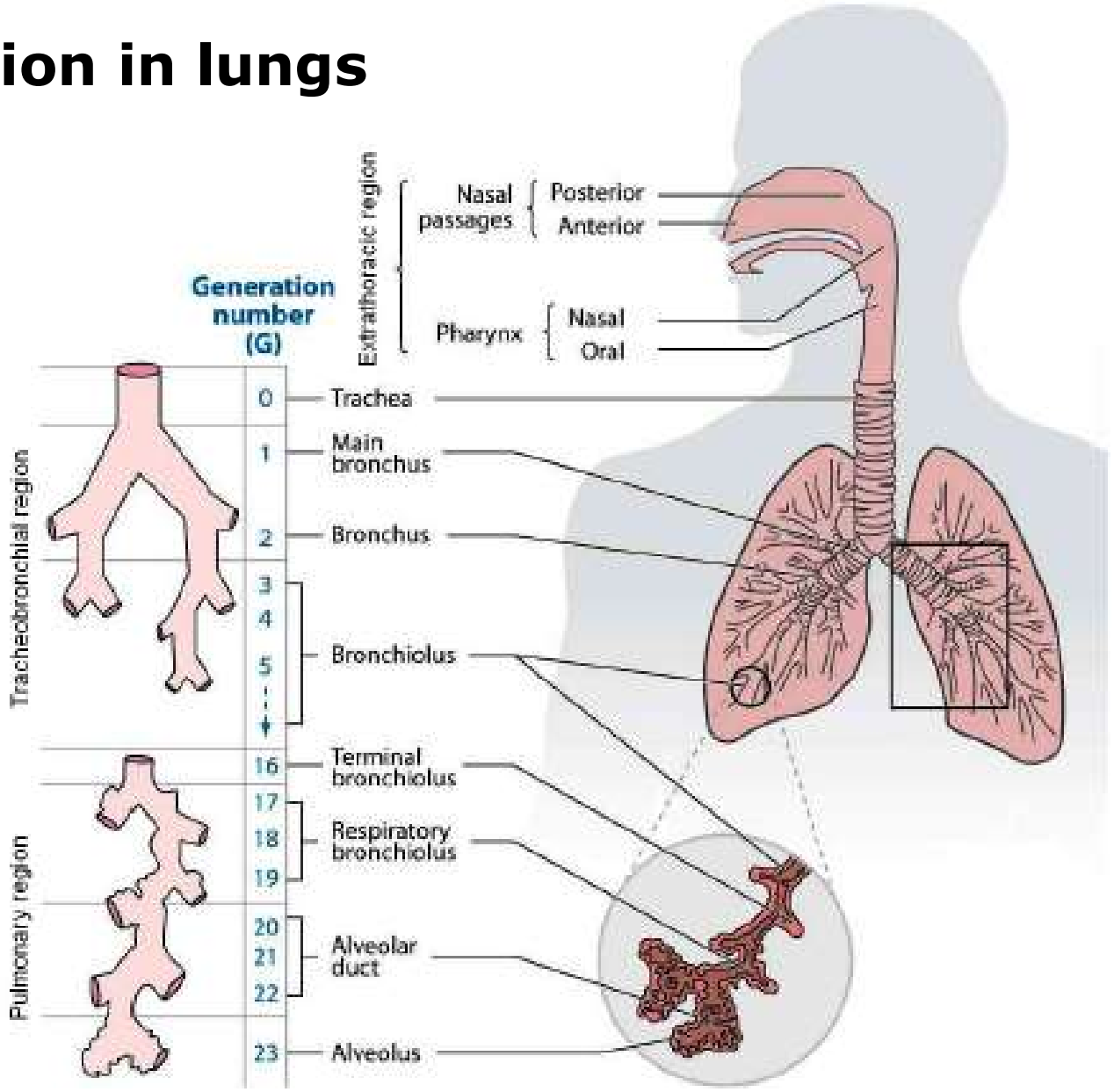



Figure 1: ICRP[1] anatomical regions and airway generation model; Tracheobronchial region (generations 0-16) and pulmonary region (generations 17-23). (modified 19)

**Husain et al., Health, 2011**

# Particle deposition in lungs

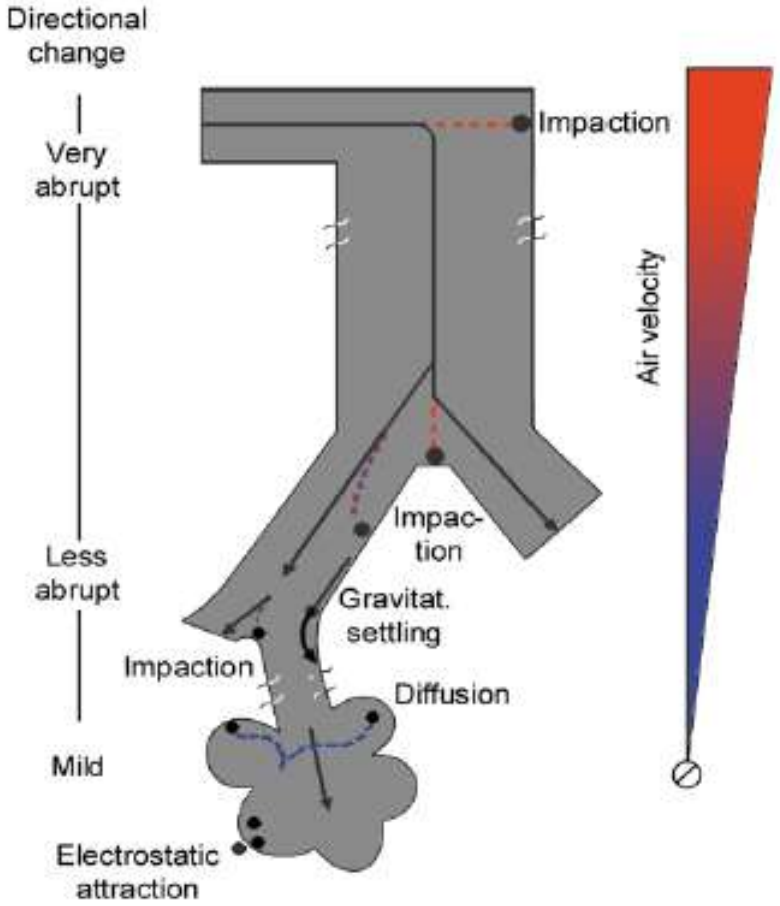



Figure 2: Major mechanisms of particle deposition in the respiratory tract. [20]

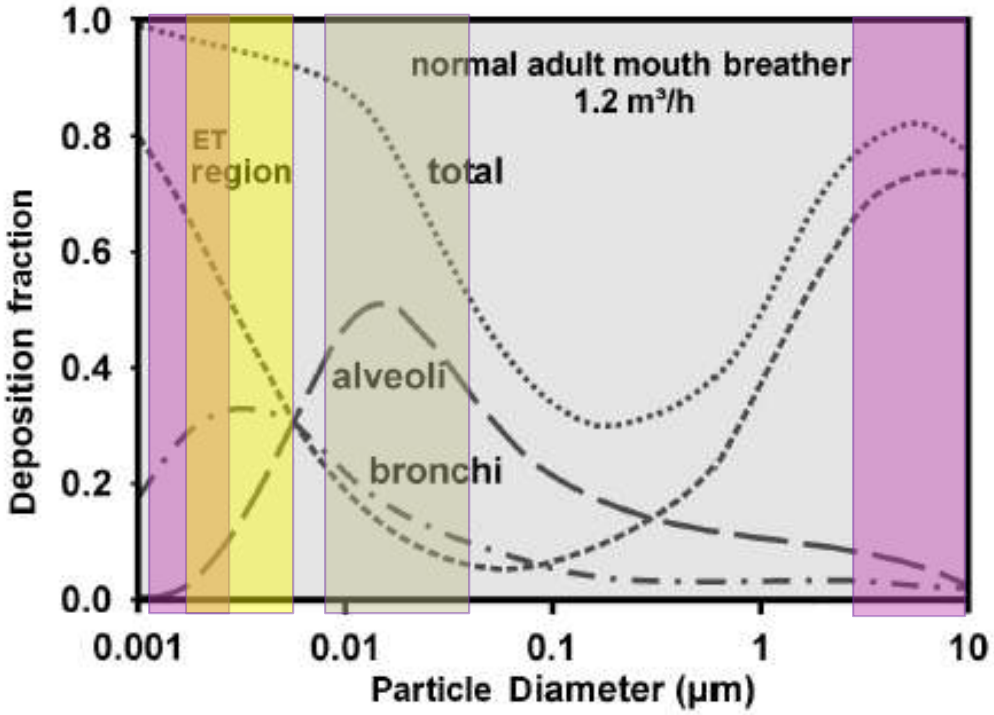



Figure 6: Average predicted total and regional lung deposition based on ICRP [1] deposition model for nose breathing for light exercise breathing condition. Highest deposition (ET region for 0.001 and 10 µm particles, bronchi region for 0.005 to 0.007 µm particles and alveolar region for 0.01 to 0.05 µm particles).

**Husain et al., Health, 2011**

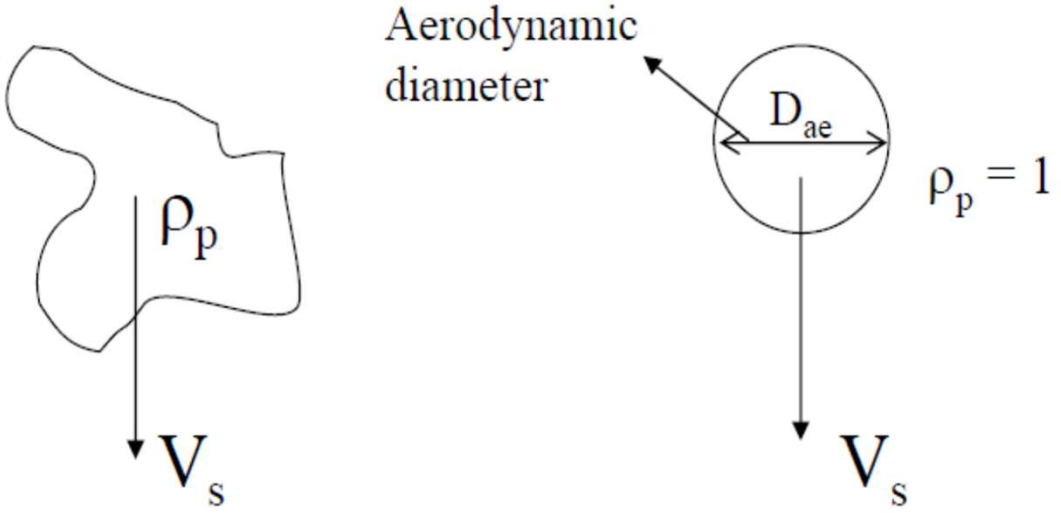
# Aerodynamic diameter

**$PM_{10}$ / $PM_{2.5}$** ?

Mass concentration of all particles having aerodynamic diameter $\leq$ 10 / 2.5$\mu$m

# Aerodynamic diameter

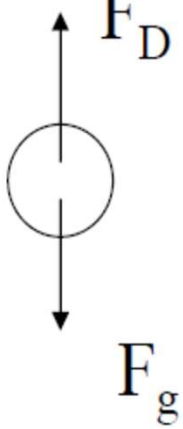
– Diameter of a unit density sphere (i.e., $\rho_p$=1, similar to a water droplet) with the same settling velocity as the particle in question




– Settling velocity of a spherical particle

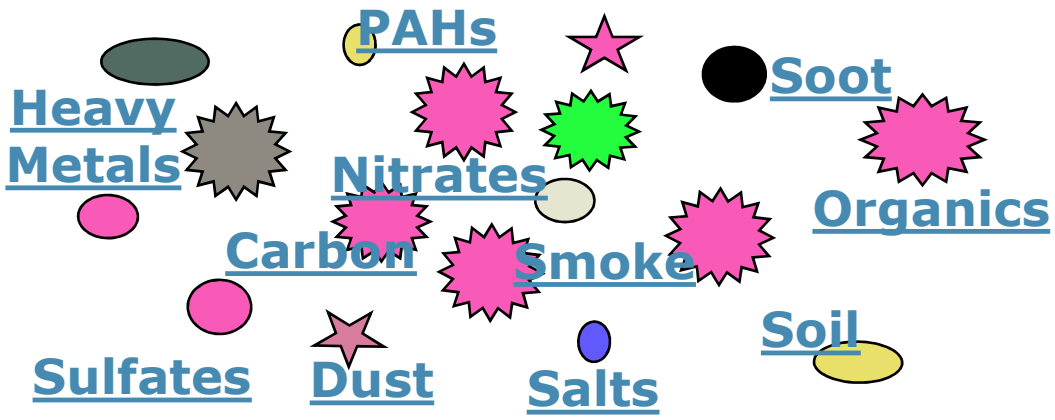
$$V_s = \frac{D_p^2 \rho_p C_c g}{18\eta}$$

$$F_D = 3\pi\eta V d_p$$




Aerodynamic size characterizes particle deposition in human lungs and filtration

# Particles composition

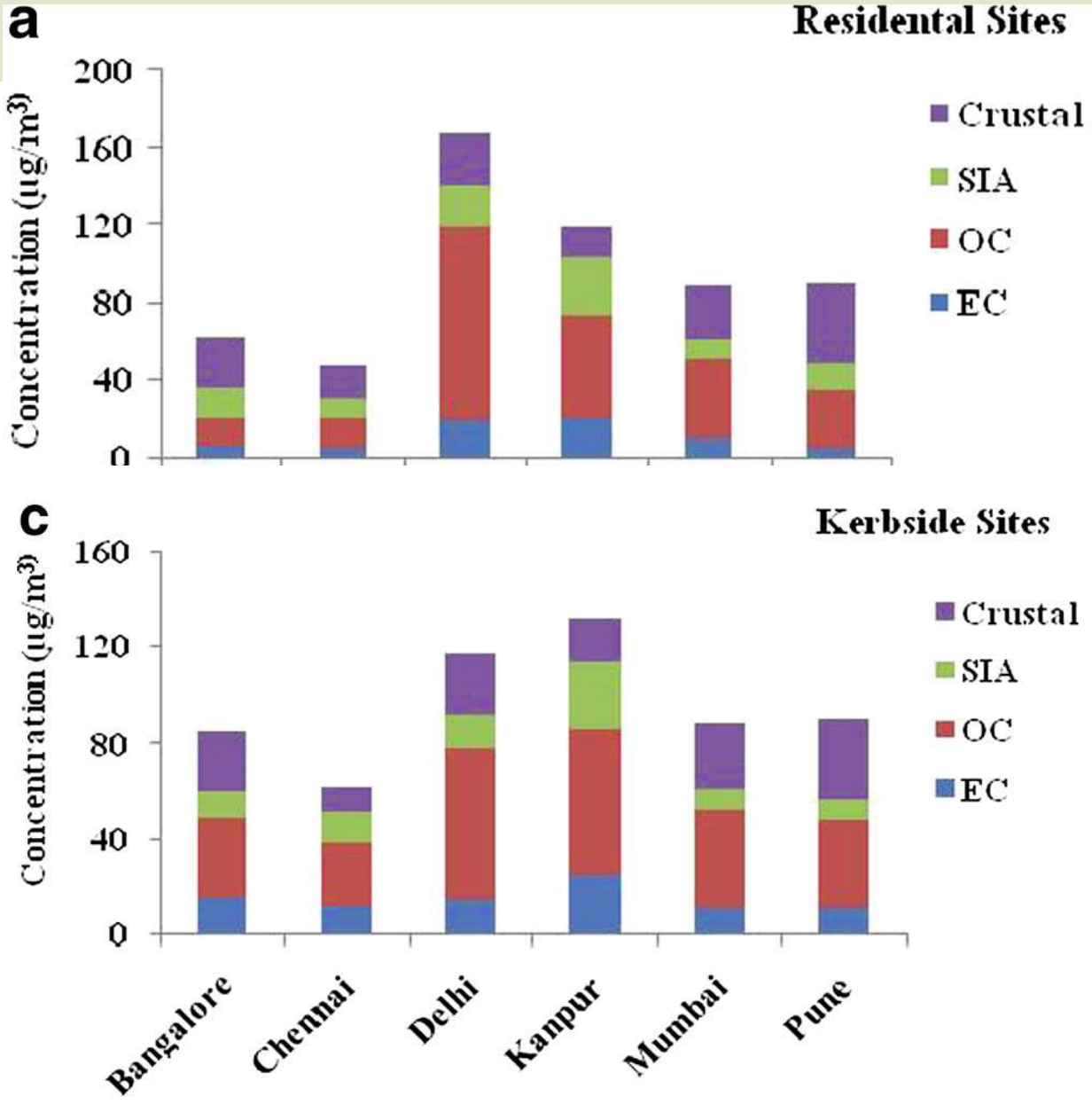



- PM a complex mixture of particles that can be solid/ liquid or both
- vary in size composition and origin

**Complex Mixture**

- **Bulk composition:** EC, OC, Nitrate, Sulfate, Ammonium, dust
- **Trace constituents:** Heavy metals, PAHs, …

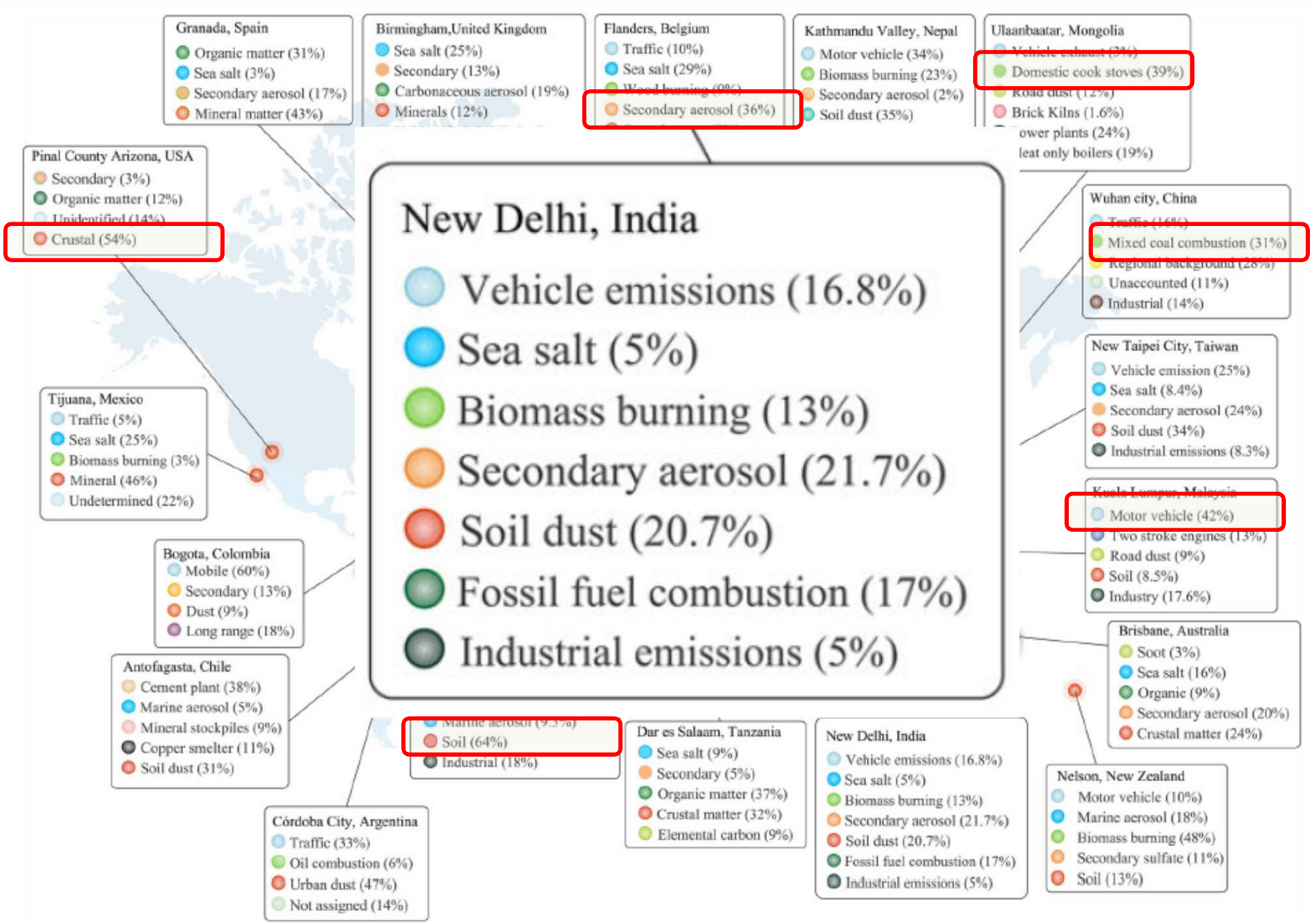
# $PM_{10}$ chemical composition across Indian cities






**(Gargava & Rajagopalan, 2016)**

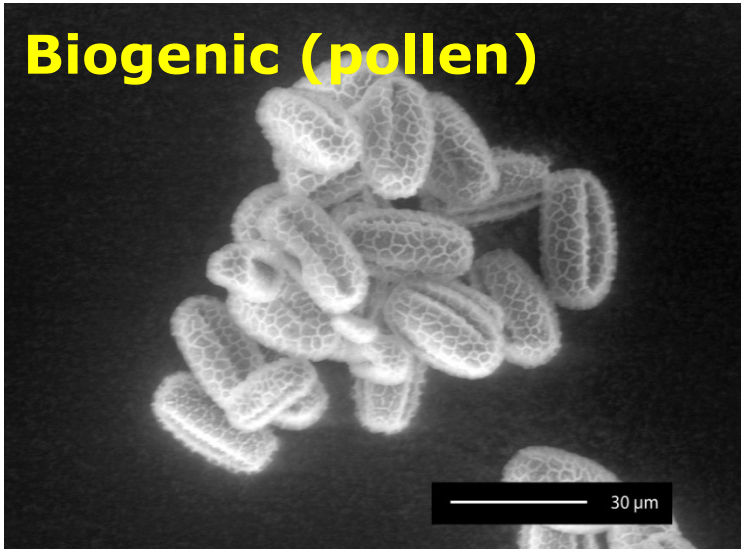
# $PM_{10}$ sources in cities across the globe

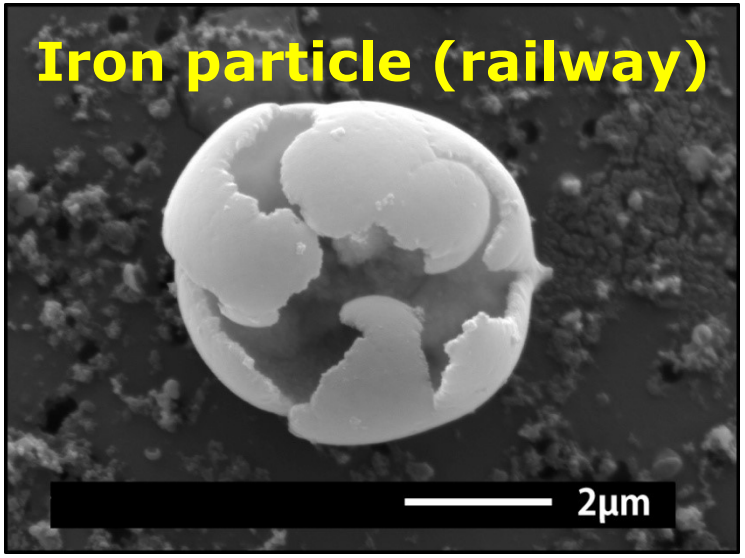


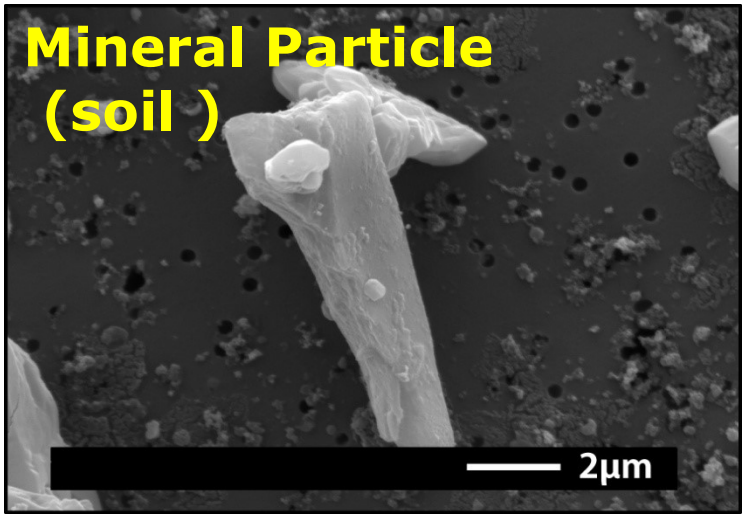


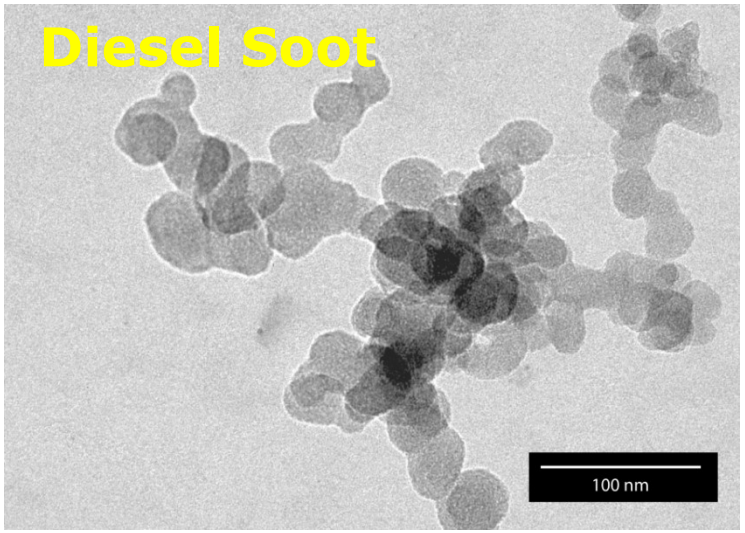

**(Mukherjee et al., 2017)**

# Particle shape & size



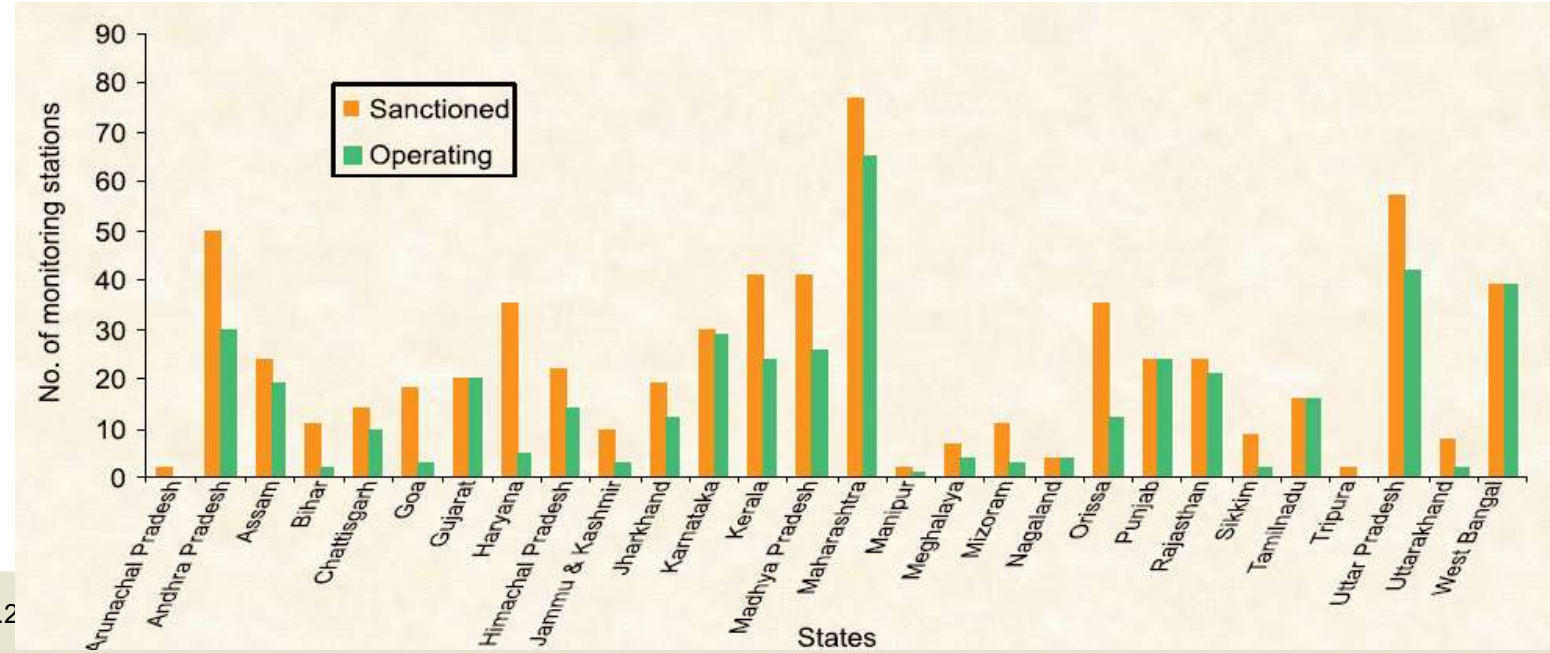



# Air quality monitoring network

How to manage air quality
… in a city, region or countrywide ???

- NAMP (National Air Monitoring Program): >680 stations in 300 cities/areas (http://www.cpcb.nic.in/air.php)
- Typically $SO_2$, $NO_2$, $PM_{2.5}$, $PM_{10}$ measured
- Monitoring is conducted twice a week for 24 hours (resulting in 104 daily measurements /year)

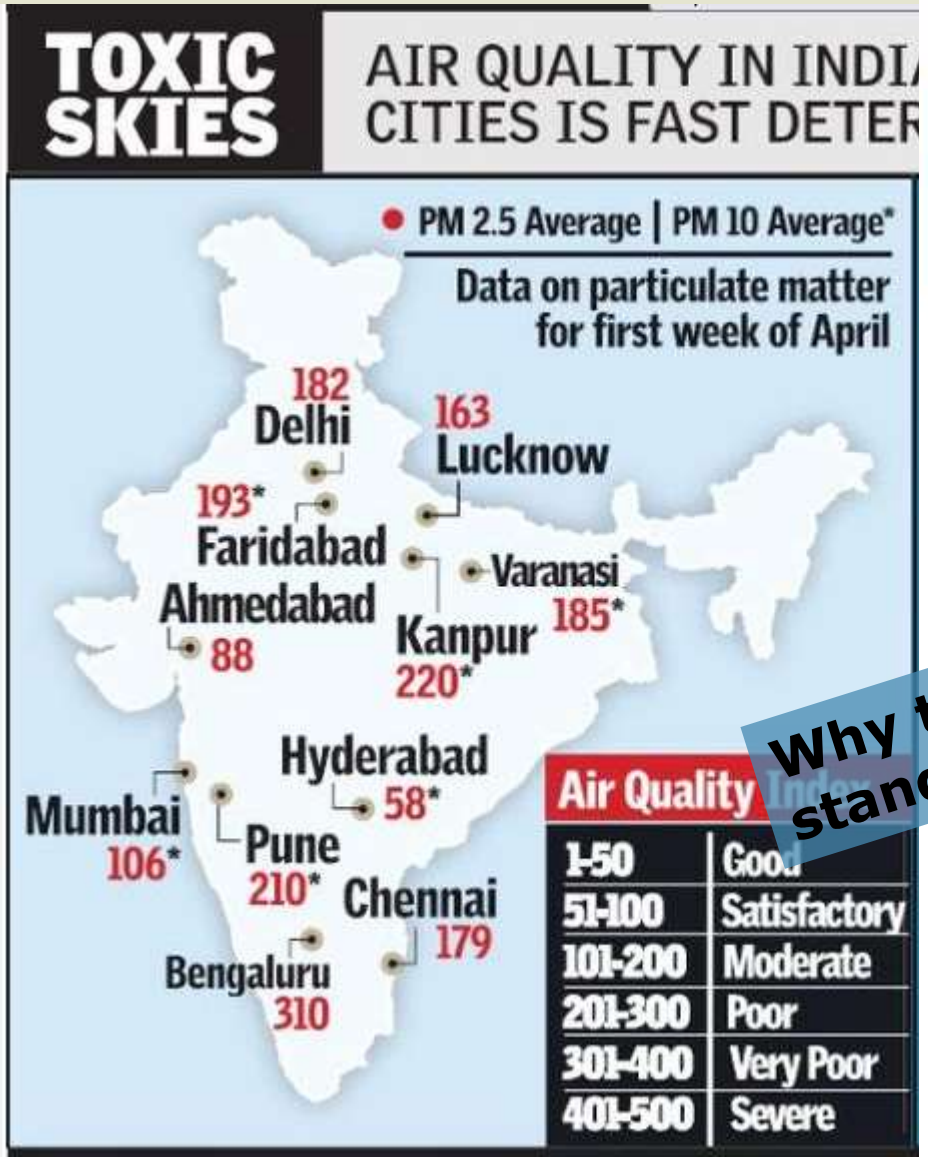


# Air quality monitoring network

How to manage air quality
… in a city, region or countrywide ???

- To monitor state of environment:
  - to enforce regulations, and
  - to evaluate success of control measures
- For use in scientific studies (e.g. in investigating environmental and/or health effects of air pollution)

# Air quality in Indian citie




**The Hindu @7.Apr.2015**

**Violations of Air Quality standards**
(on the basis of average levels at all stations)

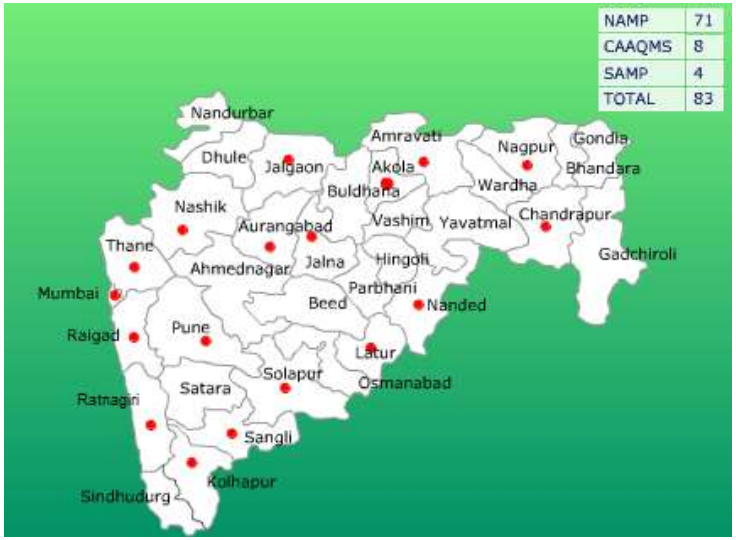
| City | Days with data | % of days exceeding standards | |
|---|---|---|---|
| | | Apr-Jun | Jul-Nov |
| Mumbai | 142 | NA | 33 |
| Hyderabad | 232 | 44 | 45 |
| Navi Mumbai | 217 | 57 | |
| Agra | 211 | | 51 |
| Chandrapur | | | 54 |
| Pune | | NA | 57 |
| Ahmedabad | 180 | 63 | 60 |
| Faridabad | 179 | 79 | 69 |
| Bangalore | 235 | 77 | 70 |
| Varanasi | 218 | 86 | 76 |
| Chennai | 233 | 99 | 71 |
| Kanpur | 220 | 89 | 81 |
| Lucknow | 232 | 99 | 83 |
| Delhi | 236 | 100 | 93 |

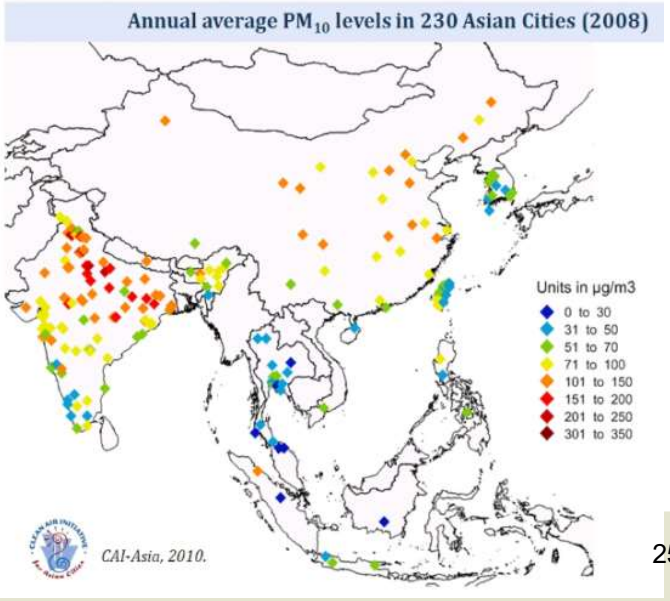
**Why there are higher number of AQ standards violations in Apr-Jun?**

**Times of India @16.Dec.2015**

# Monitoring networks & data sources

- **Central Pollution Control Board (CPCB)**
  http://www.cpcb.nic.in/air.php
- **Maharashtra Pollution Control Board (MPCB)**
  http://mpcb.gov.in/envtdata/envtair.php
- **US Environmental Protection Agency (USEPA)**
  http://www.epa.gov/gateway/science/air.html
- **California Air Resources Board (CARB)**
  http://www.arb.ca.gov/aqmis2/aqdselect.php
- **European Environmental Agency (EEA)**
  http://www.eea.europa.eu/themes/air/airbase/airbase
- **Clean Air Portal/ Clean Air Initiative for Asian Cities (CAI-Asia)**
  http://cleanairinitiative.org
- **Clean Air World/ National Association of Clean Ai**
  http://www.cleanairworld.org/
- **World Health Organization (WHO)**
  http://www.who.int/topics/air_pollution



# Home work !!!

- Do you have an air quality monitoring station in your city? If not, in the nearest city? What is the current status of air quality there?

- In the last 5 years or decade has the air quality improved or worsened? Why?

Please do this **by Mon, 6.11**; we will then discuss!

**http://www.cpcb.gov.in/CAAQM/frmUserAvgReportCriteria.aspx**

**www.cpcb.gov.in/CAAQM/**

**Use the resources mentioned in the lecture, OR simply Google !!**