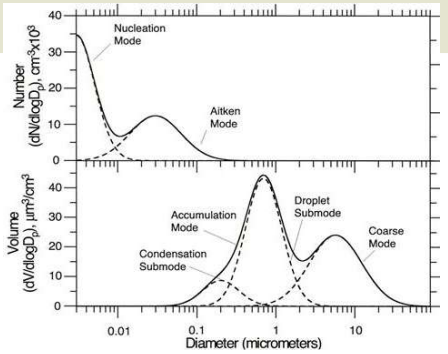
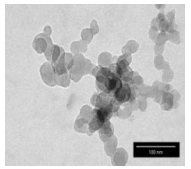


Complex Mixture



Lecture 3

Module B/Air Quality:

Particles Size & composition Measurement Methods

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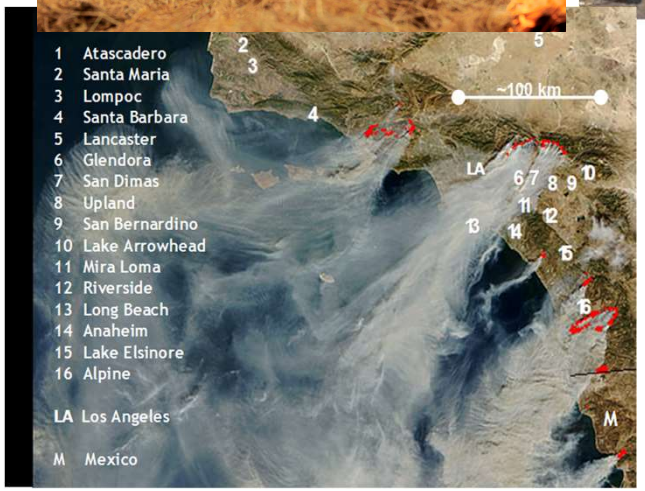
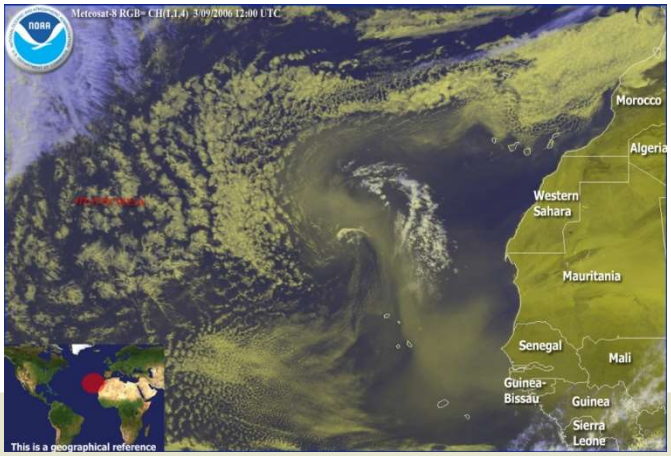
CESE, IIT Bombay

Email: phuleria@iitb.ac.in

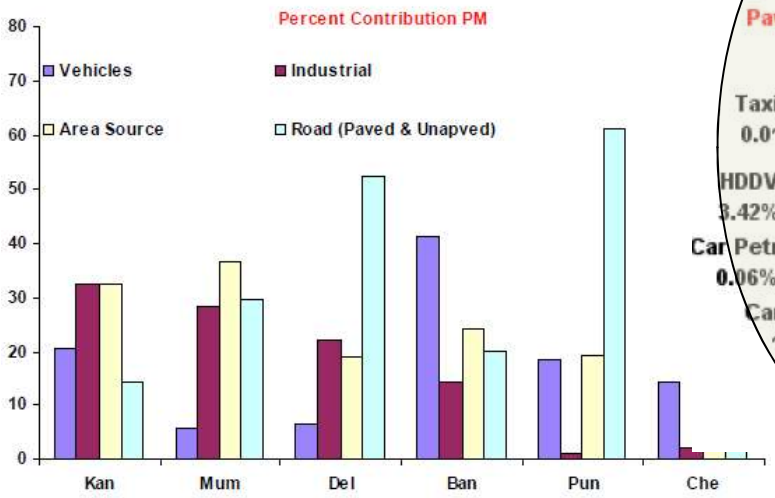
Recap 1

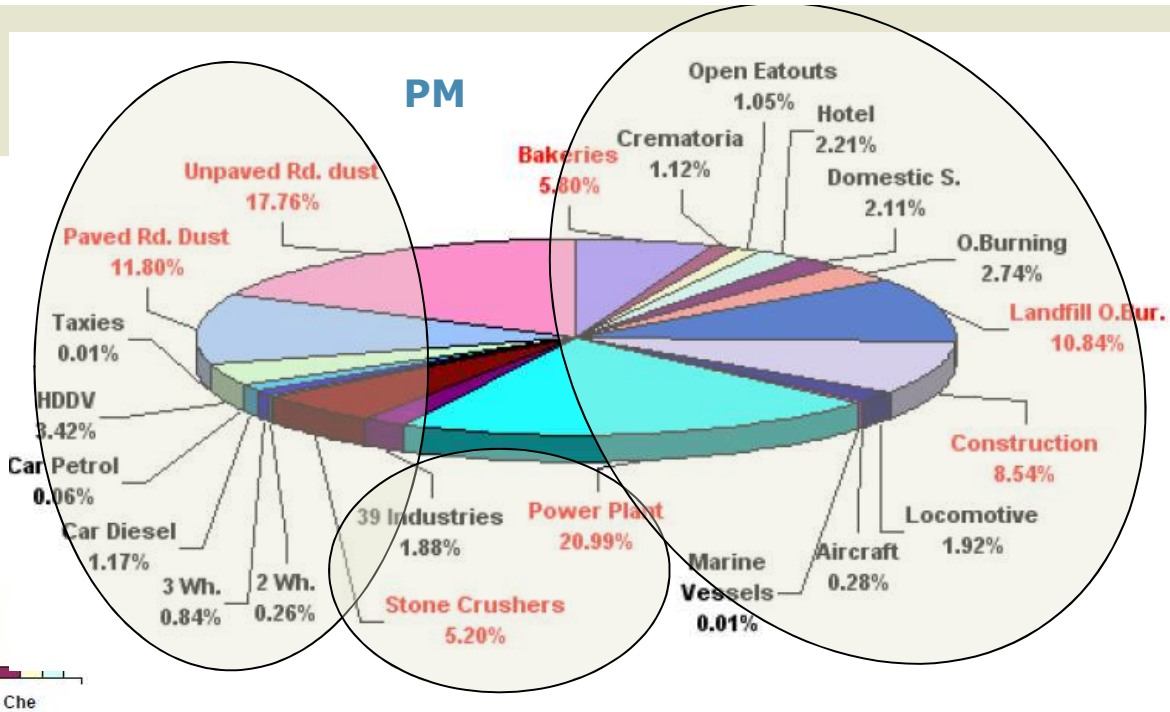


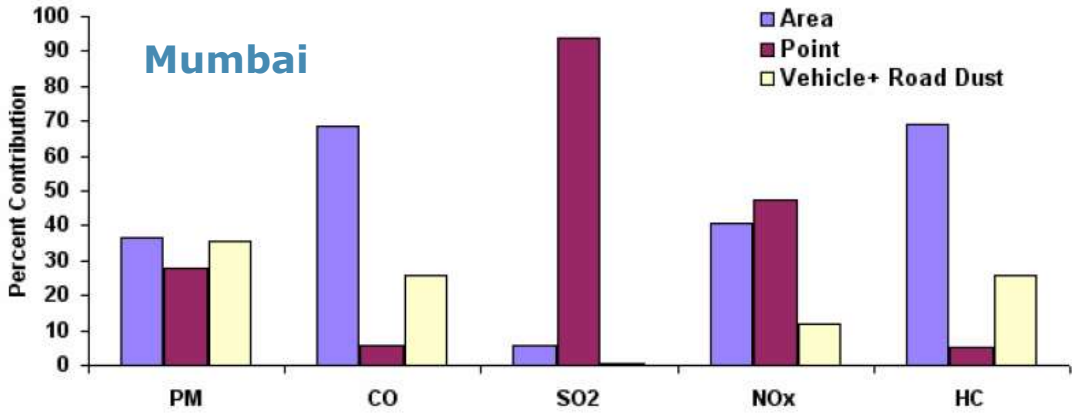


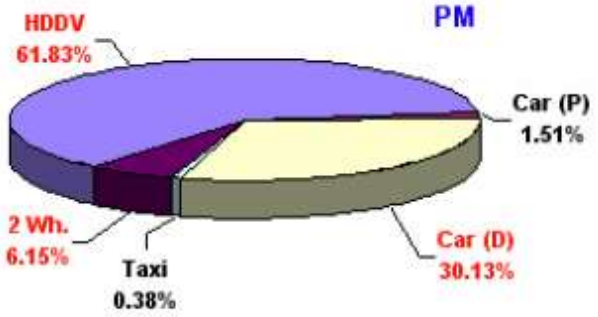
Prabir Mallik/The World Bank

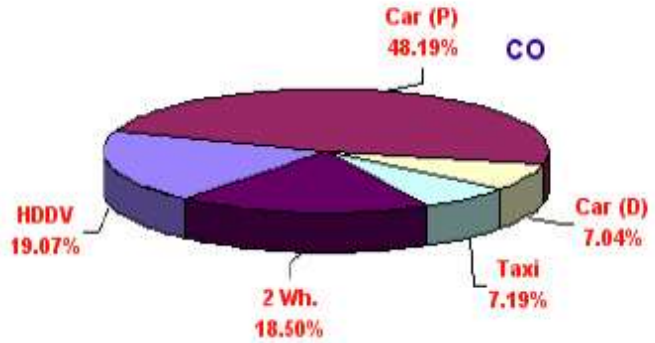
Recap 2


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%
Paved Rd. Dust
11.80%
O.Burning
2.74%
Taxies
0.01%
Landfill O.Bur.
10.84%
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%

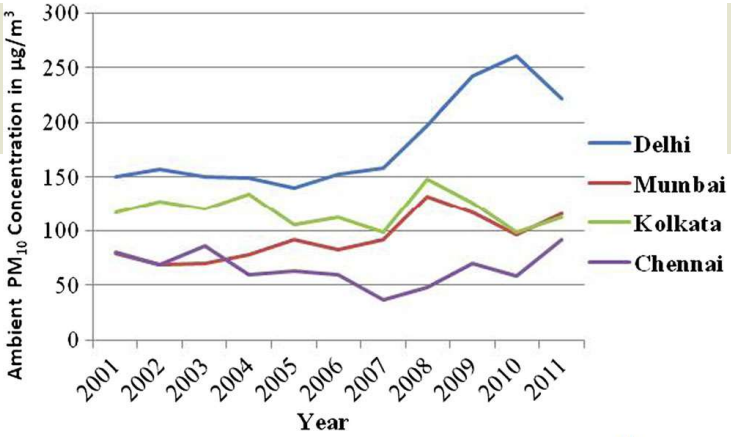

Mumbai
Area
Point
Vehicle+ Road Dust
Percent Contribution
100
90
80
70
60
50
40
30
20
10
0
PM
CO
SO2
NOx
HC

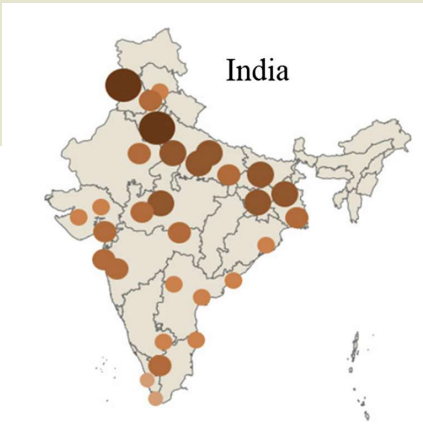

PM
HDDV
61.83%
Car (P)
1.51%
2 Wh.
6.15%
Car (D)
30.13%
Taxi
0.38%

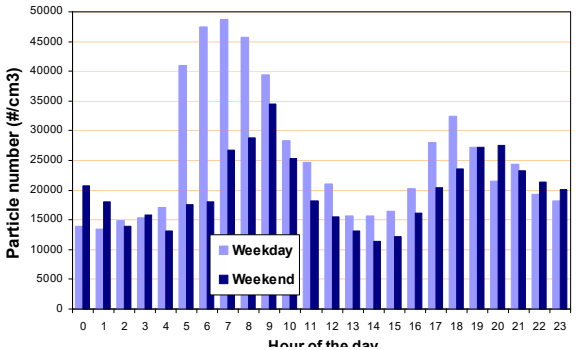

Car (P)
48.19%
CO
HDDV
19.07%
Car (D)
7.04%
Taxi
7.19%
2 Wh.
18.50%

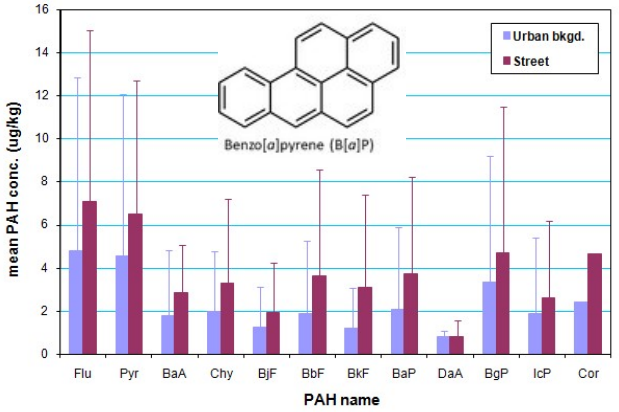
Recap 3

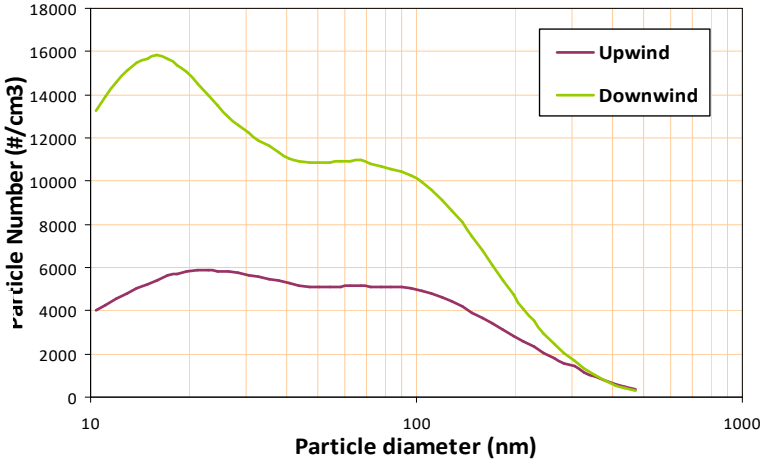
- **Spatial variation:**
  - Local/urban
  - state or national
  - regional or global
- **Temporal variation:**
  - hourly
  - daily
  - weekday
  - seasonal
  - annual
  - diurnal

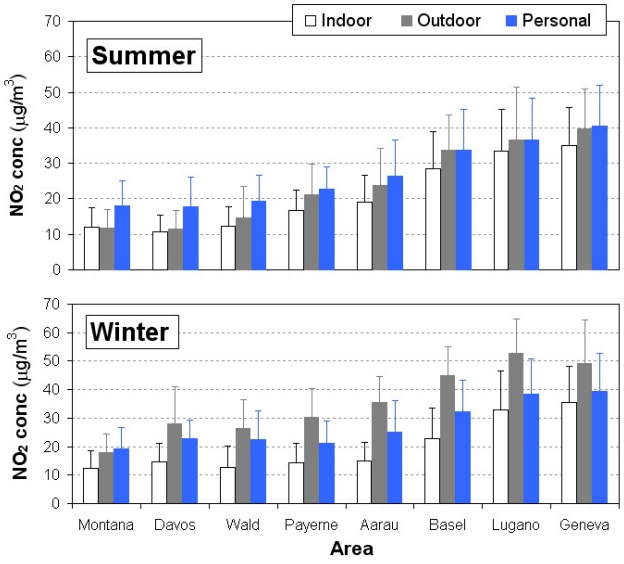


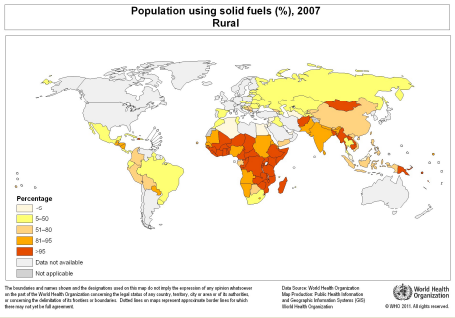












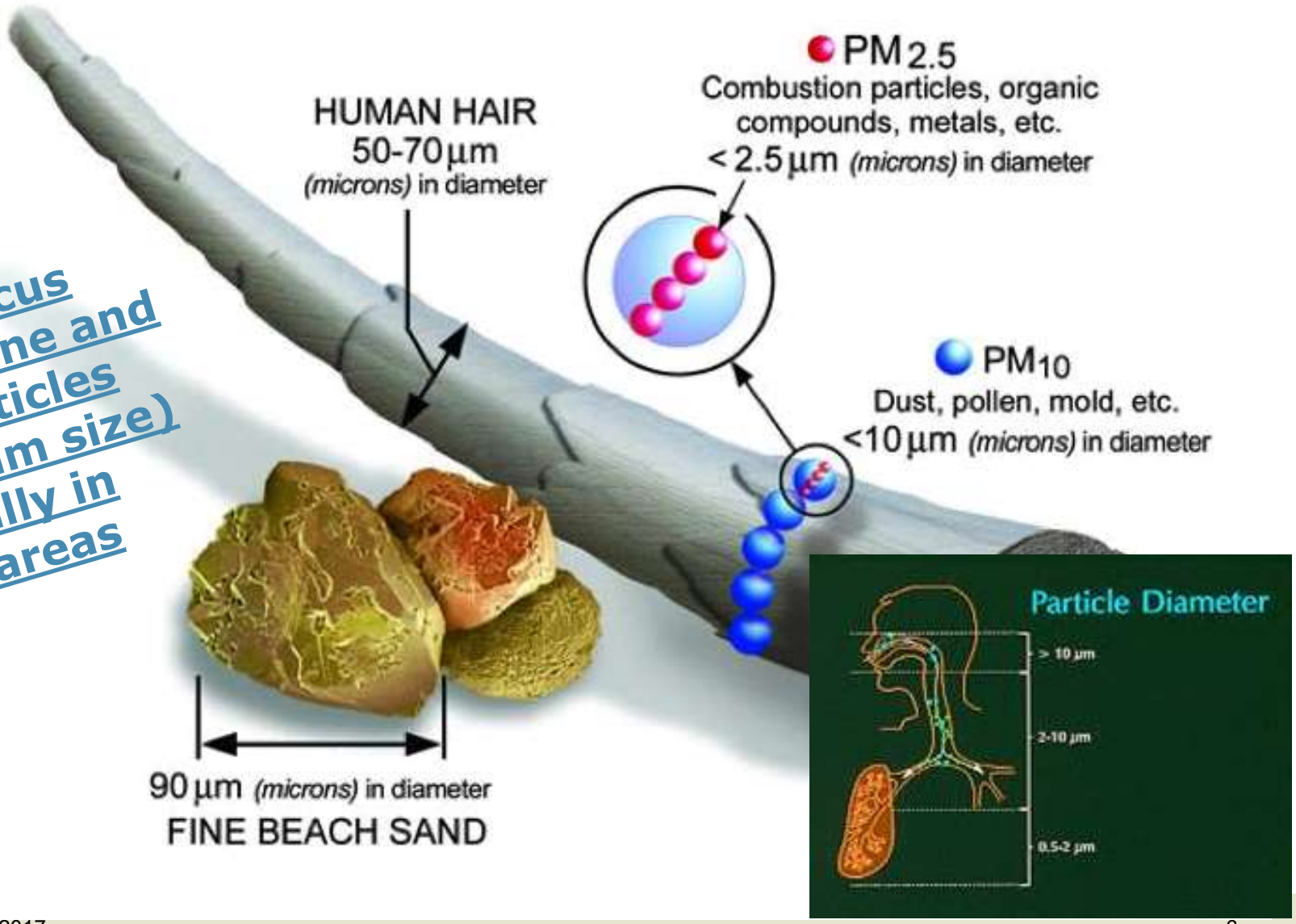
Today's Learning Objectives !

- To understand particle composition & size distribution

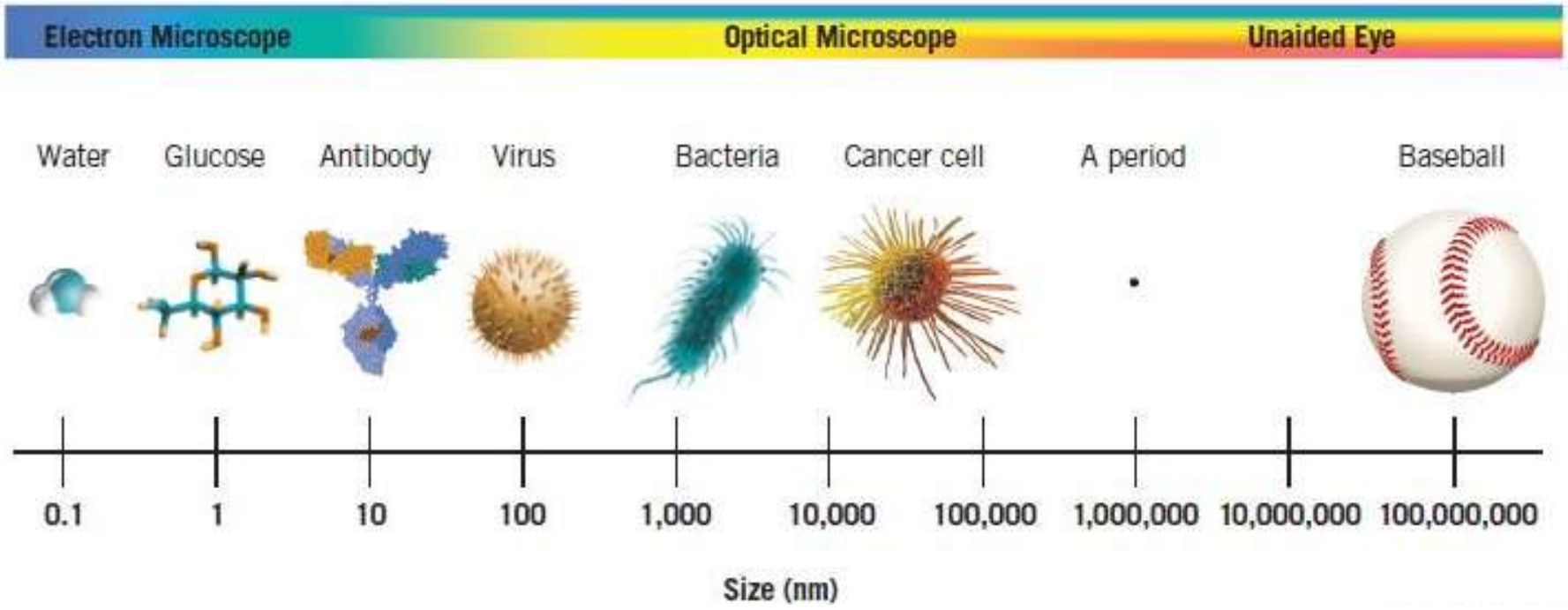
- To learn about monitoring methods and thus able to quantify pollutants' concentrations

Particles – size matters !

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

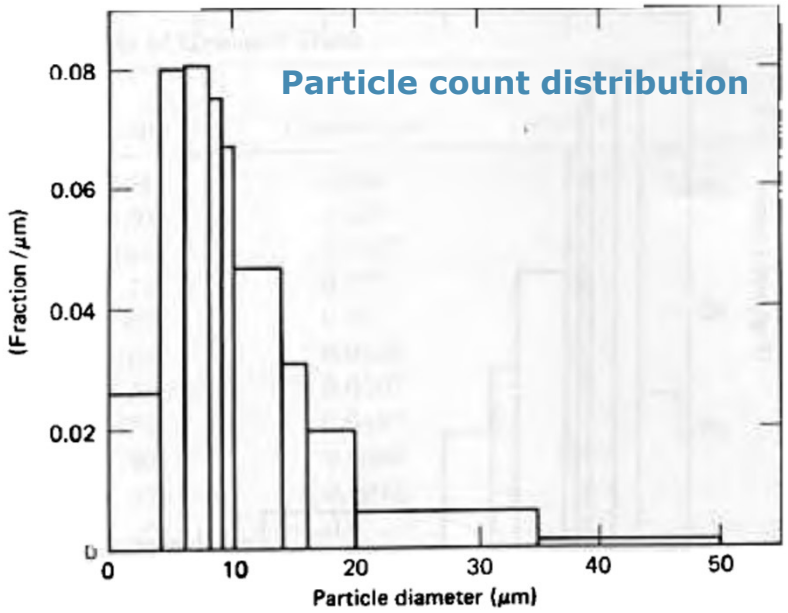


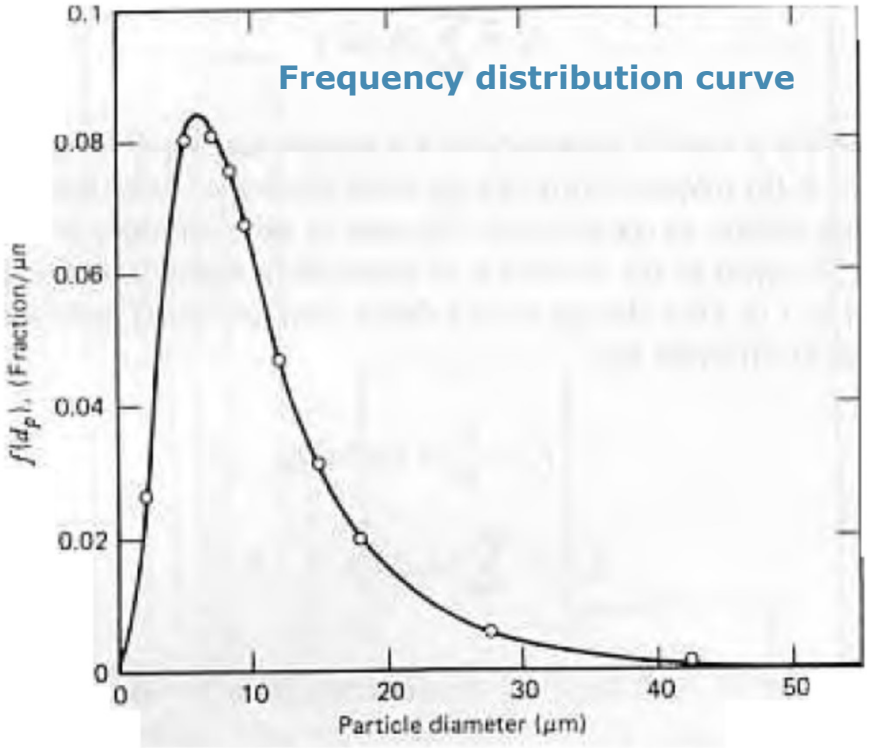
Particles – size matters !



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

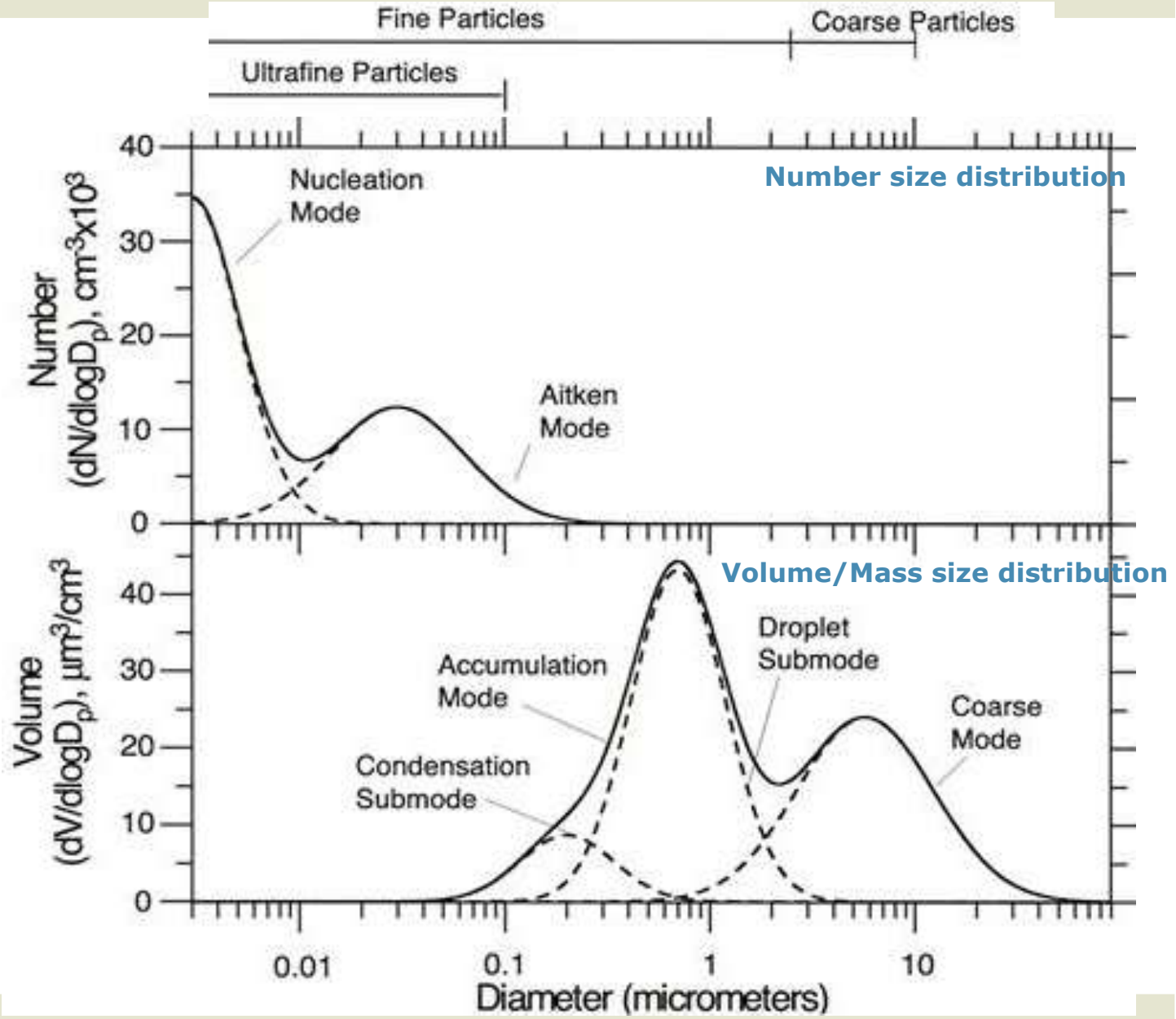
Particle size distribution: Ambient aerosols





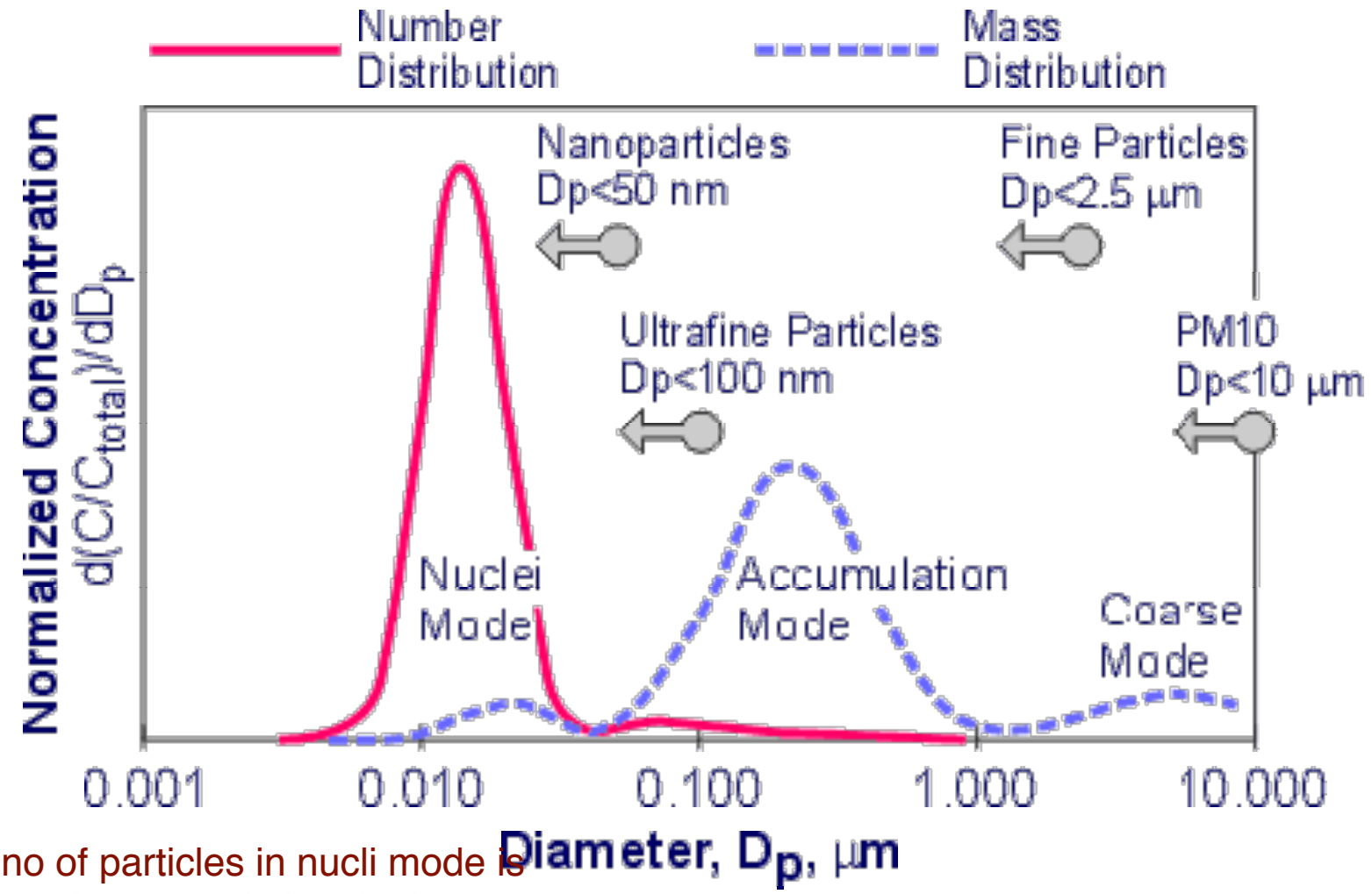
Hinds, 1999

Particle size distribution: Ambient aerosols



NARSTO, 2004

Particle size distribution: Diesel exhaust

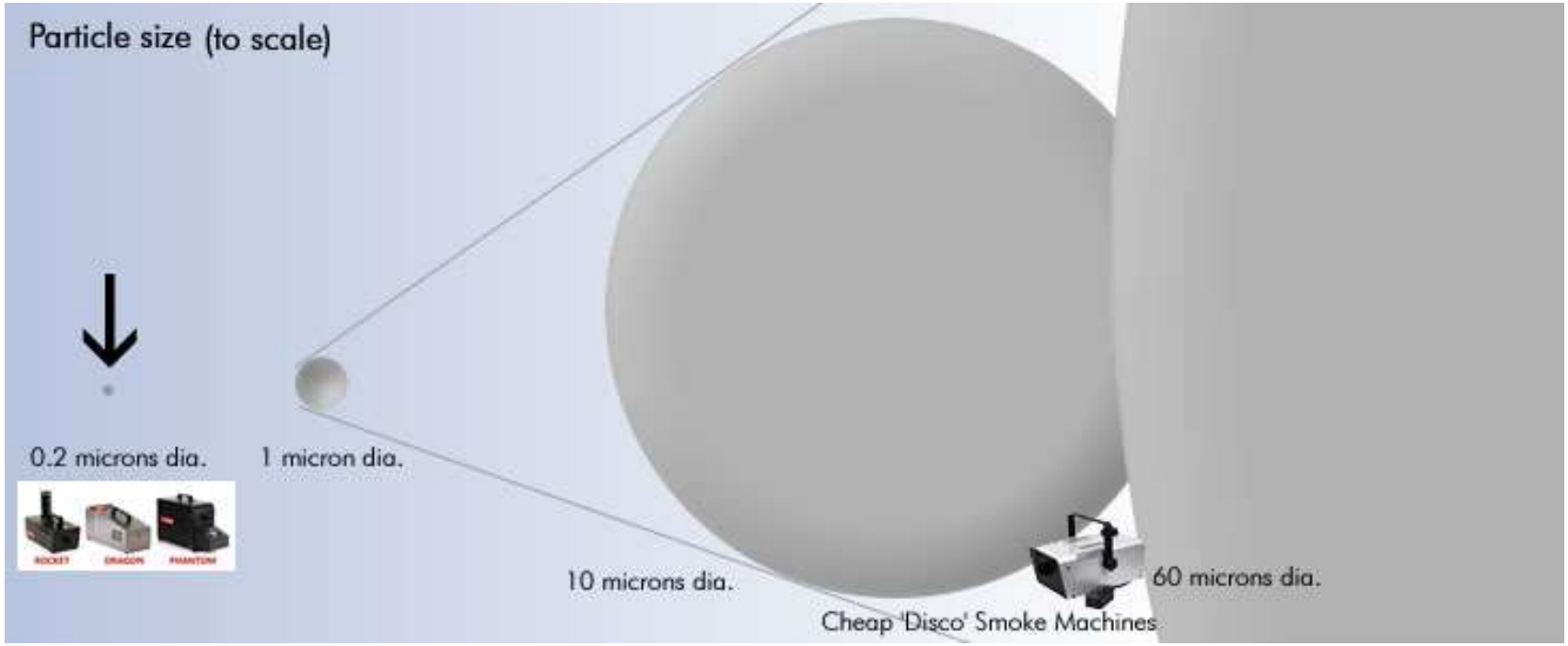


in diesel exhaust no of particles in nucli mode is most while accumulation mode has highest mass conc

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

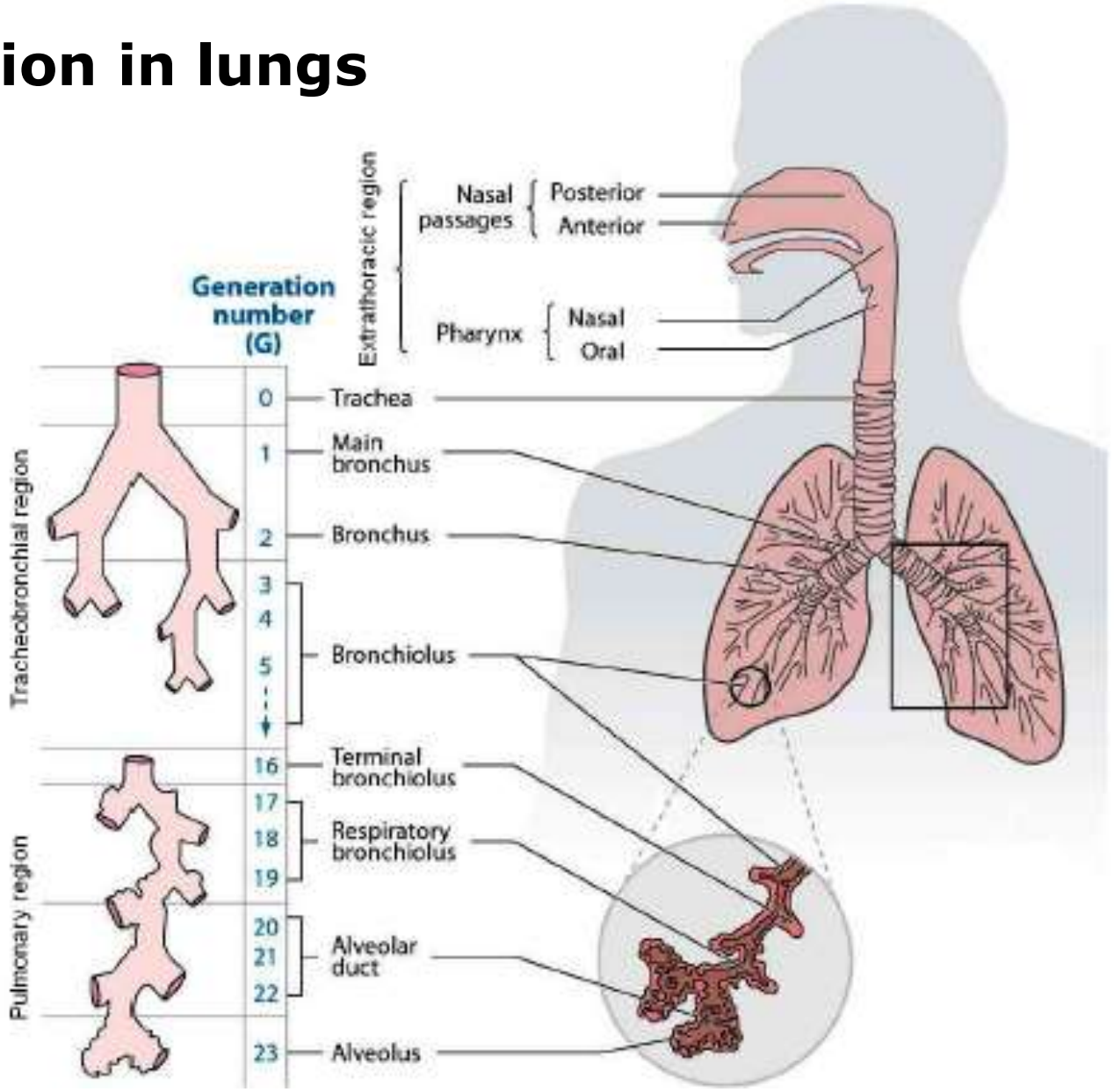


Figure 1: ICRP[1] anatomical regions and airway generation model; Tracheobronchial region (generations 0-16) and pulmonary region (generations 17-23). (modified 19)

Husain et al., Health, 2011

Particle deposition in lungs

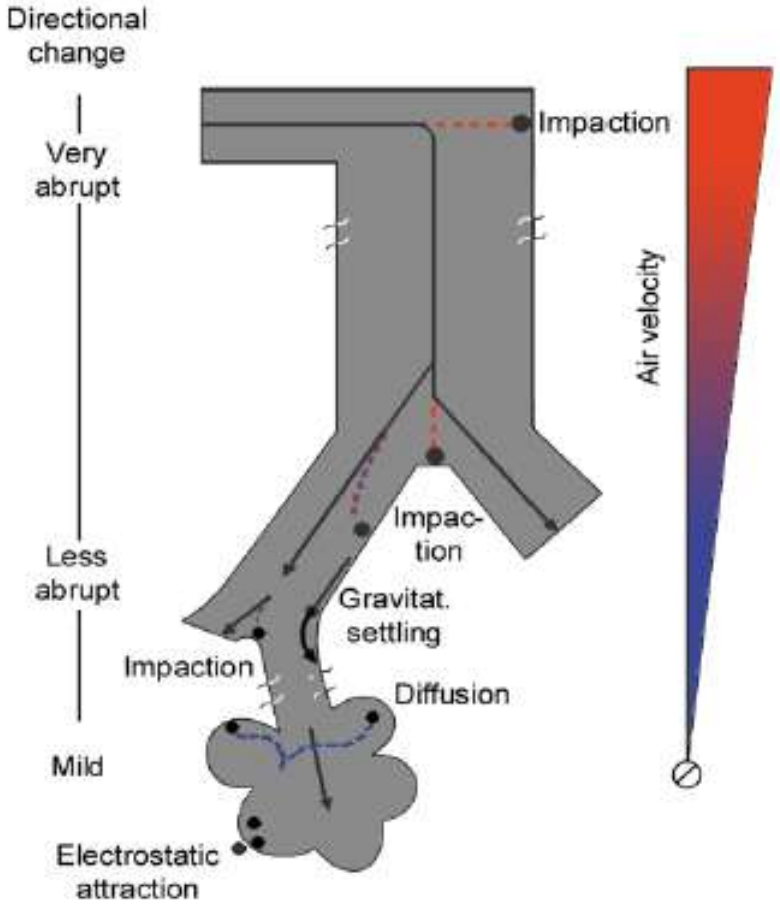


Figure 2: Major mechanisms of particle deposition in the respiratory tract. [20]

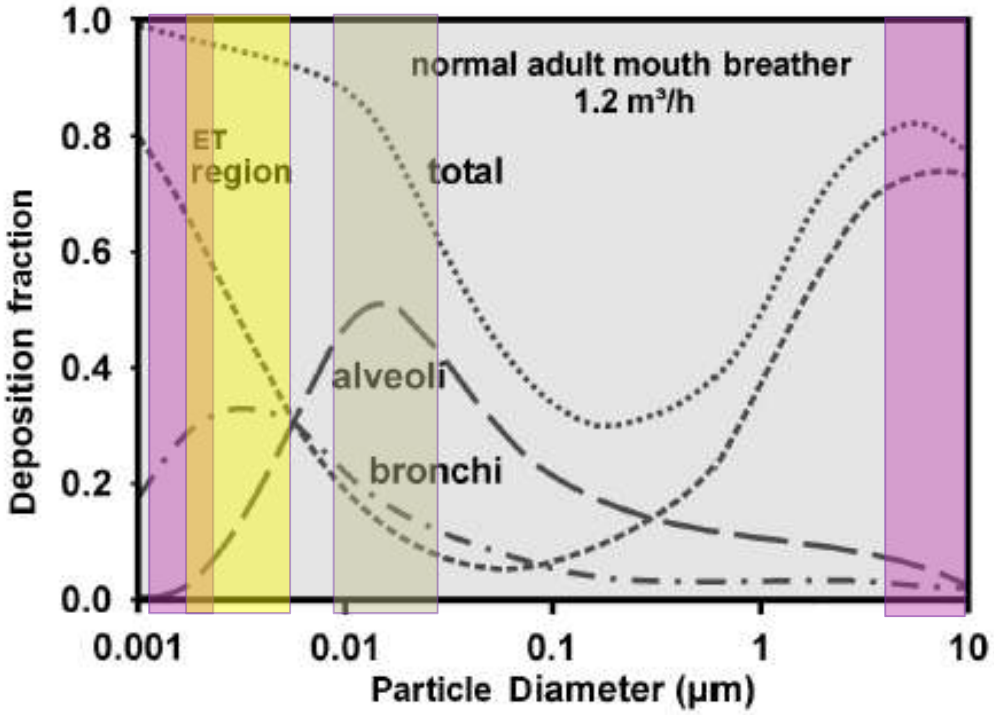
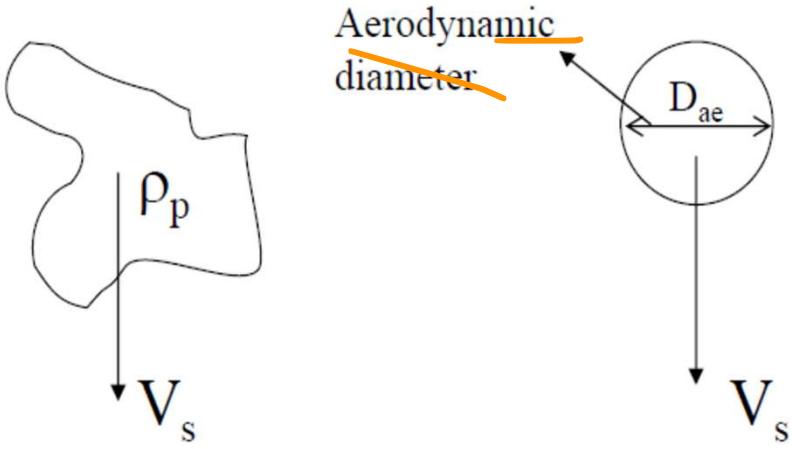


Figure 6: Average predicted total and regional lung deposition based on ICRP [1] deposition model for nose breathing for light exercise breathing condition. Highest deposition (ET region for 0.001 and 10 µm particles, bronchi region for 0.005 to 0.007 µm particles and alveolar region for 0.01 to 0.05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

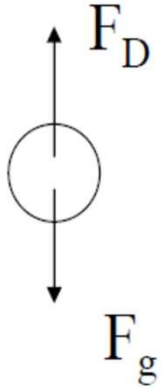
Husain et al., Health, 2011

Aerodynamic diameter

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



PM_{10}: Mass concentration of all particles having **aerodynamic diameter** $\leq$ 10μm



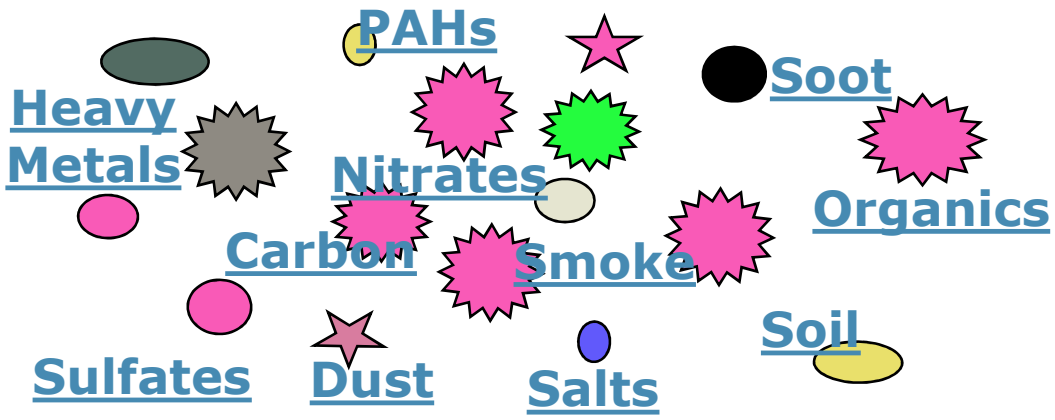
$$F_D = 3\pi\eta V d_p$$

- Settling velocity of a spherical particle

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

- Aerodynamic size characterizes particle deposition in human lungs and filtration.

Particles composition



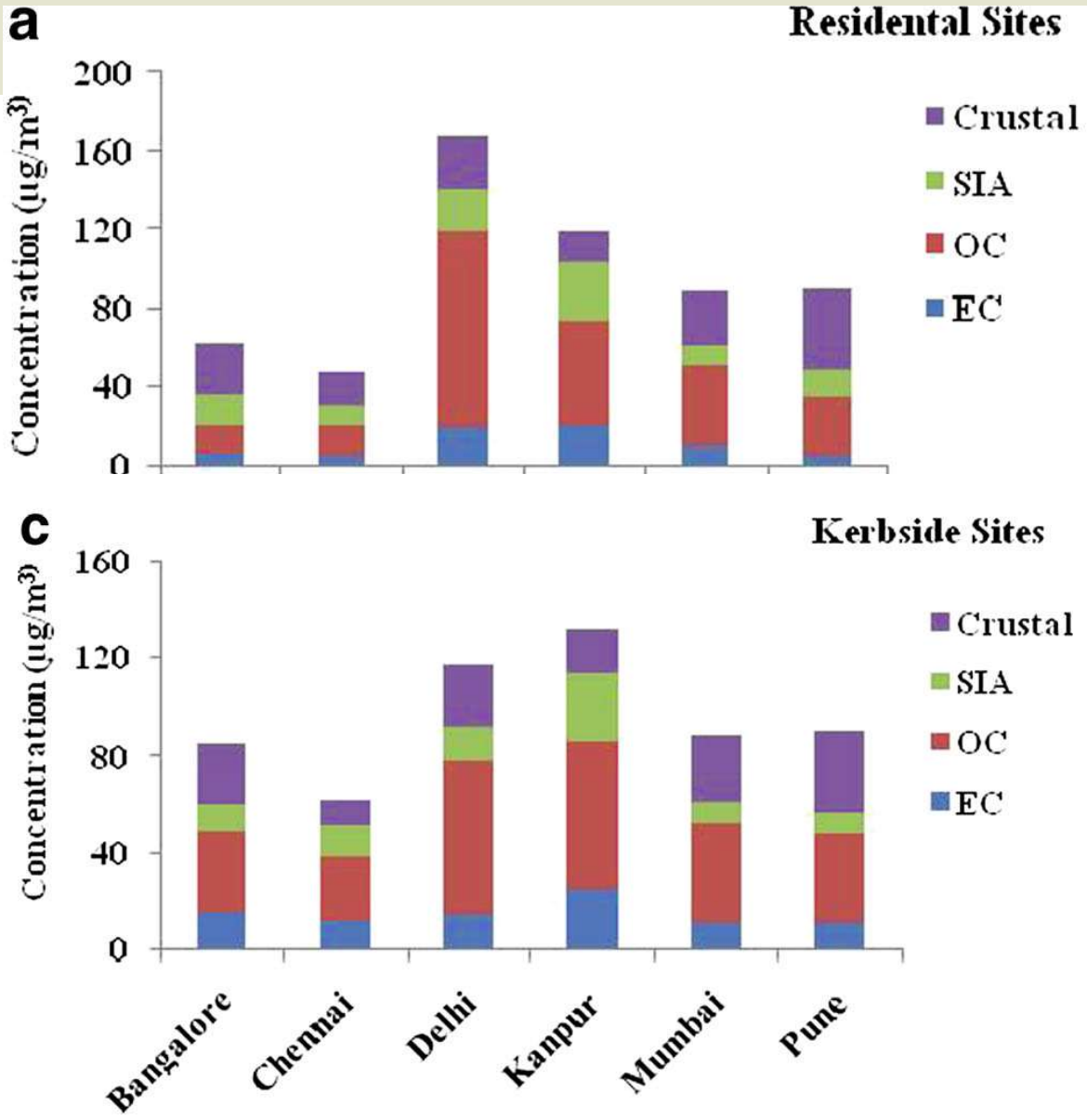
- PM a complex mixture of particles that can be solid/ liquid or both
- vary in size composition and origin

Complex Mixture

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

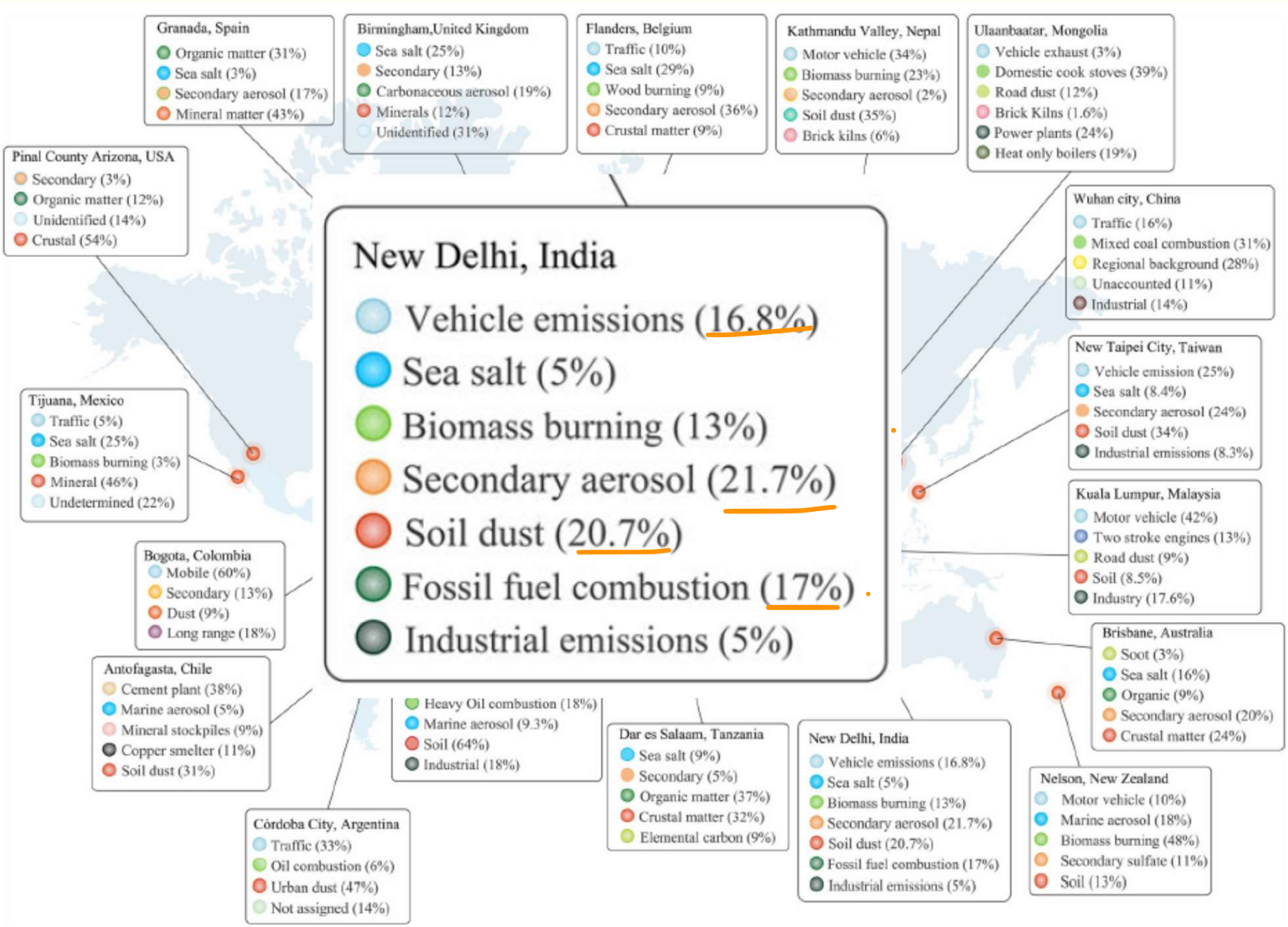
PM_{10} chemical composition across Indian cities

kerbside site are less polluted than the residential or industrial side



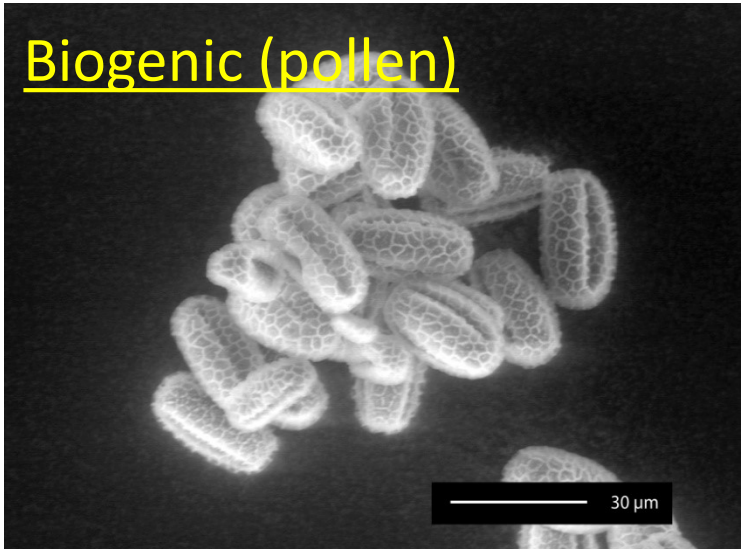
(Gargava & Rajagopalan, 2016)

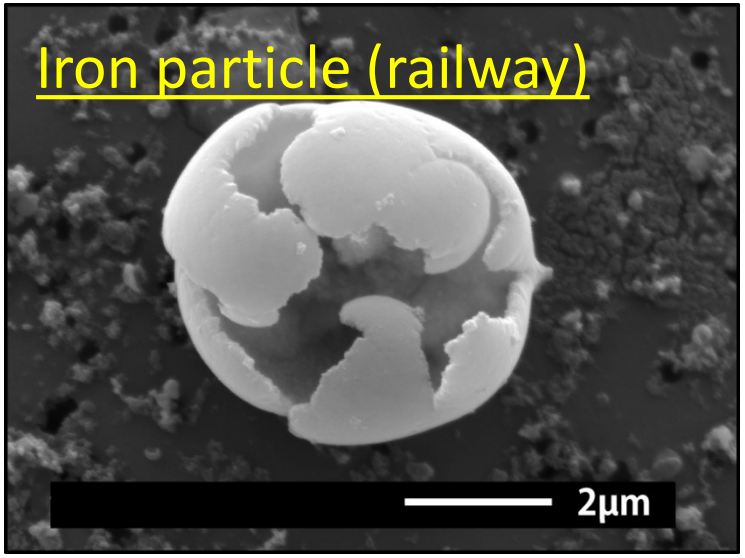
PM_{10} sources in cities across the globe

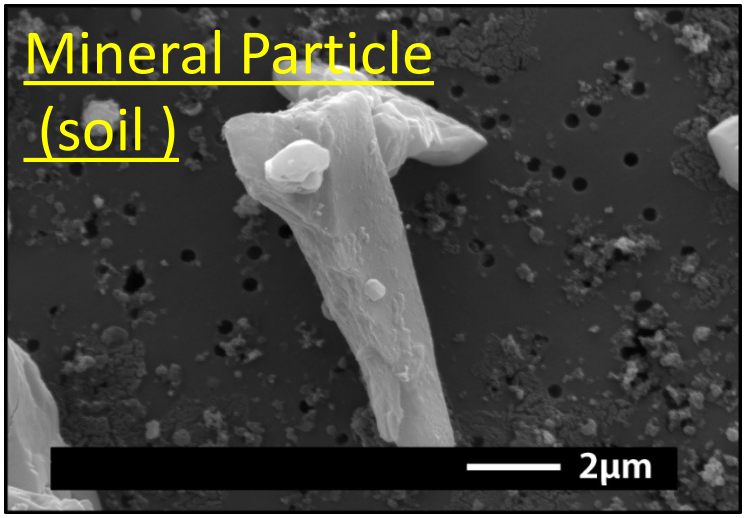


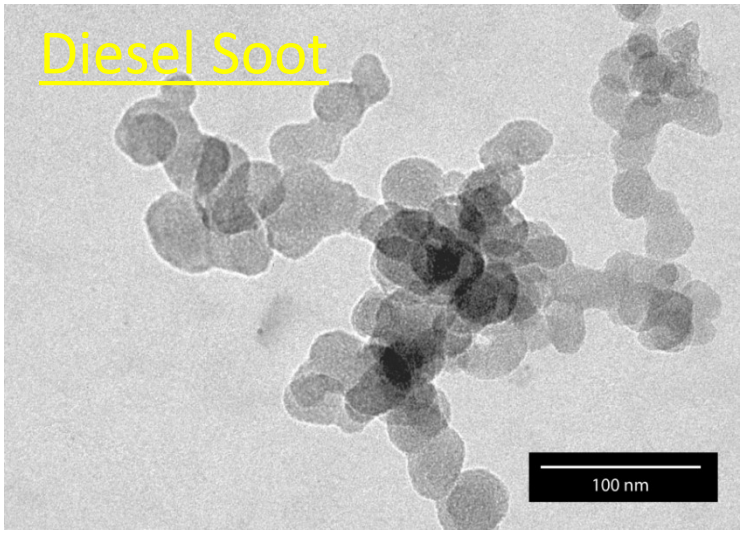
(Mukherjee et al., 2017)

Particle shape & size









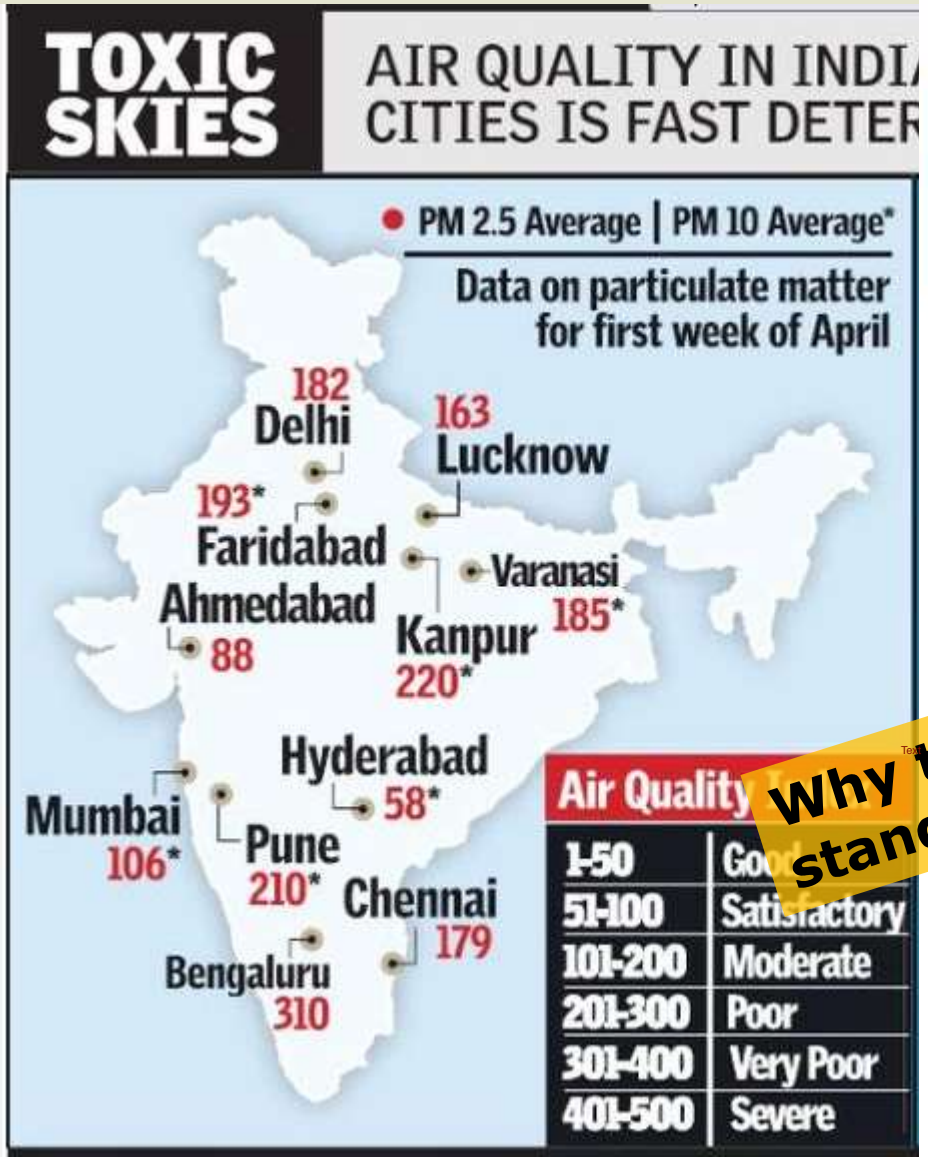
Air quality monitoring network

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

- 1981: Air Prevention & Control of Pollution Act
- NAMP (National Air Monitoring Program): 342 stations in 127 cities/areas (http://www.cpcb.nic.in/air.php)
- Typically SO_2, NO_2, O_3, (SPM), RSPM measured
- Since Nov 2009 revisions, $PM_{2.5}$ also added

- 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)

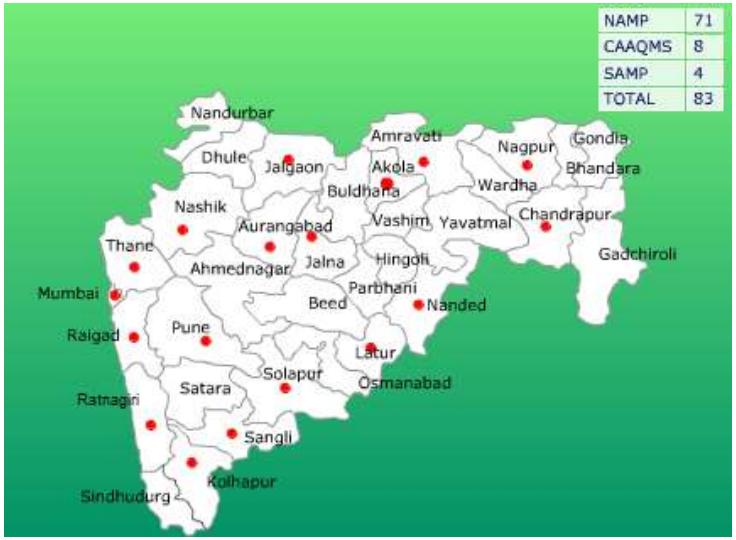
City	Days with data	% of days exceeding standards	
		Apr-Jun	Jul-Nov
Mumbai	142	NA	33
Hyderabad	232	44	45
Navi Mumbai	217	57	46
Agra	211	50	51
Chandrapur	123	NA	54
Pune	141	NA	57
Ahmedabad	179	63	60
Faridabad	179	79	69
Bangalore	235	77	70
Varanasi	218	86	76
Chennai	233	99	71
Kanpur	220	89	81
Lucknow	232	99	83
Delhi	236	100	93

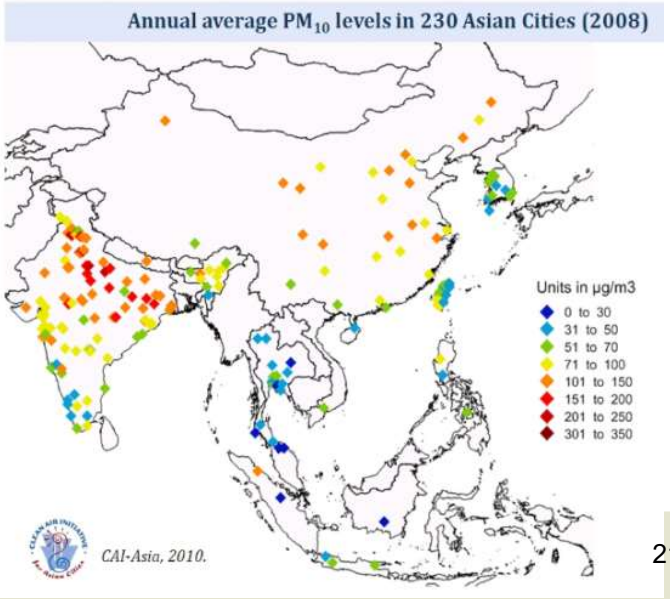
Why there are higher number of AQ standards violations in Apr-Jun? rainfall

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 Thu, 17.08**; we will discuss in the class!

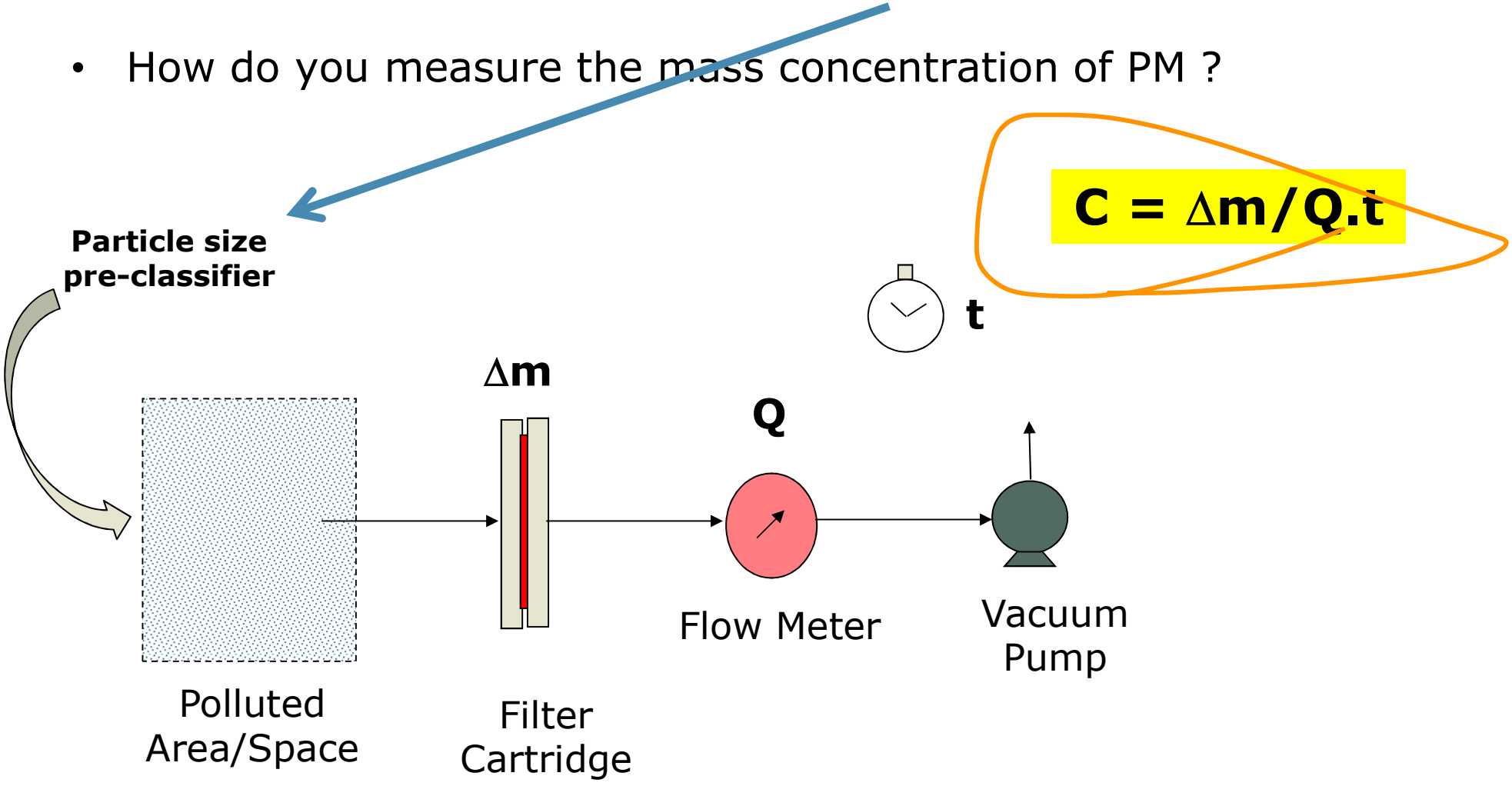
http://www.cpcb.gov.in/CAAQM/frmUserAvgReportCriteria.aspx

www.cpcb.gov.in/CAAQM/

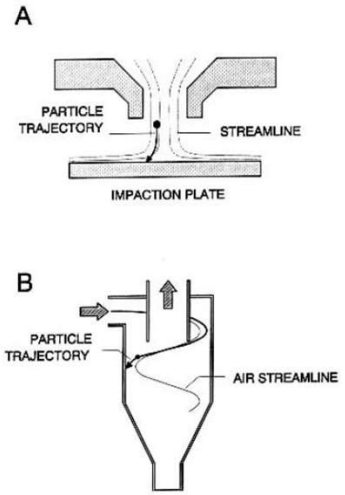
Use the resources mentioned in the lecture, OR simply Google !!

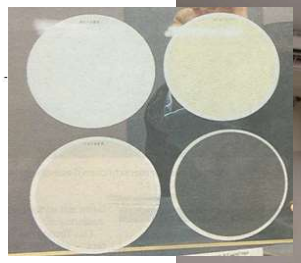
Quantifying pollutants: Particle mass concentration ($PM_{10}/PM_{2.5}$)

- How do you measure the mass concentration of PM ?



Particle mass measurements





Inertial Collectic
(b) Cyclone.

- **Filter substrates are collected using impactors/cyclones (for desired size) and designed flow rate (with a suction pump)**
- **Collected filters are conditioned in laboratory & weighed with precision microbalance**