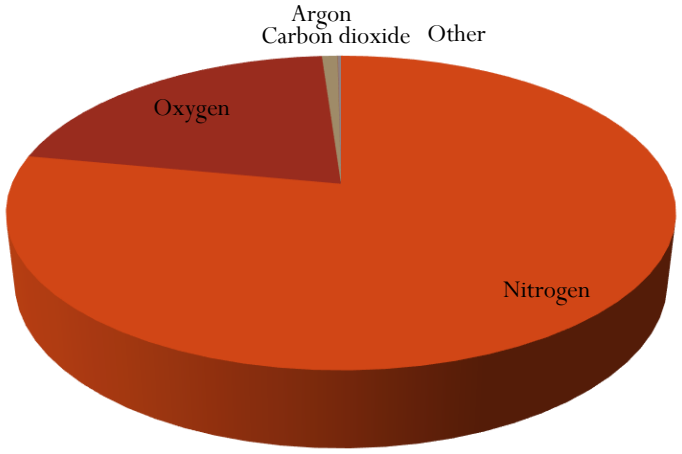
INTRODUCTION TO AIR POLLUTION

Composition of Air

- Major : Nitrogen (N_2), Oxygen (O_2)
- Minor : Argon (Ar), Carbon dioxide (CO_2)
- Trace: Neon(Ne),Helium, Methane etc.
- Density of air is 1.54 gm/cc;

Constituent	Mole Percent(%)
Nitrogen	78
Oxygen	20.9
Argon	0.9
Carbon dioxide	0.03
Other	0.17



Air Pollutant?

What is air pollution?

Air pollution may be defined as the presence of impurities in excess quantity (concentrations) and duration in the atmosphere to cause adverse effects on plants, animals, human beings and materials.

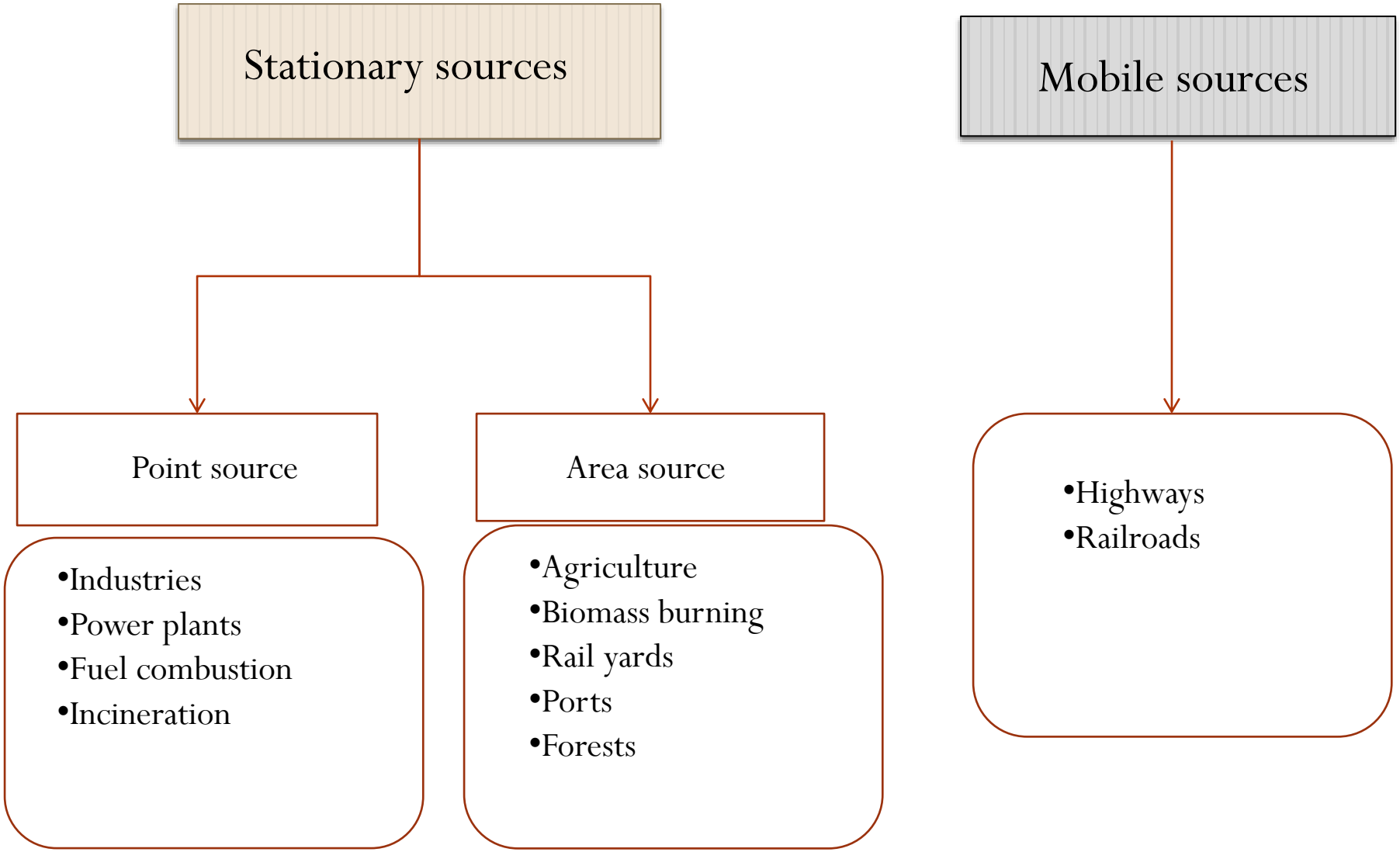
Sources of Air Pollutants

- **NATURAL SOURCES:**

  Volcanic eruptions, forest fires, sand storms, cosmic dust, pollen, fungal spores, bacteria and viruses from waste, etc.

- **ANTHROPOGENIC:**

  Burning of fossil fuels, agricultural activities, industries, automobile exhausts, domestic wastes, etc.


Stationary sources
Mobile sources
Point source
Area source
•Industries
•Power plants
•Fuel combustion
•Incineration
•Agriculture
•Biomass burning
•Rail yards
•Ports
•Forests
•Highways
•Railroads

Types of Air Pollutants

Air pollutants are generally grouped into the following two types:

1) Particulate pollutants
2) Gaseous pollutants

Gaseous Pollutants

- CO
- NOx ($NO+NO_2$)
- Ozone
- Volatile Organic Compounds (VOCs)

Particulate pollutants

- The term ***"particulate"*** refers to all atmospheric substances which are not gases.
- They can be suspended droplets or solid particles or mixture of the two-Aerosols
- Particulates can be composed of materials ranging in different sizes. Eg. *Dust*, *smoke*.

Dust

- Dust contains particles of size ranging from 1 to 200µm.
- These are formed by the disintegration of rock and soil or by the mechanical processes of grinding and spraying
- Examples

  Magnesium, Aluminium, Silica.

Smoke

- Smoke is formed from incomplete combustion of organic matter.
- Smoke may have different colors depending on the nature of material burnt.
- It contains fine particles of size ranging from 0.01 μm to 1 μm.

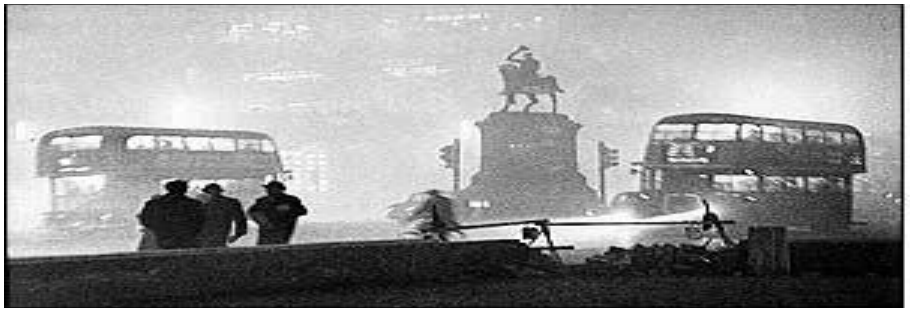
SMOKEFOG

- Sulfurous smog or London smog
- Photochemical smog or Los Angeles smog

The London Smog Disaster of 1952.

Days of toxic darkness.

•Early on 5th of December 1952 the London sky was clear, the weather was considerably colder than usual, as it had been for some weeks. As a result the people of London were burning large amounts of coal and smoke bellowed from the chimneys. The winds were light and the air near the ground was moist, conditions ideal for formation of ***smog***.



•During the day of 5th December the fog was not particularly dense, it possessed a dry smoky character, however when nightfall came the fog thickened and visibility dropped to a few meters.

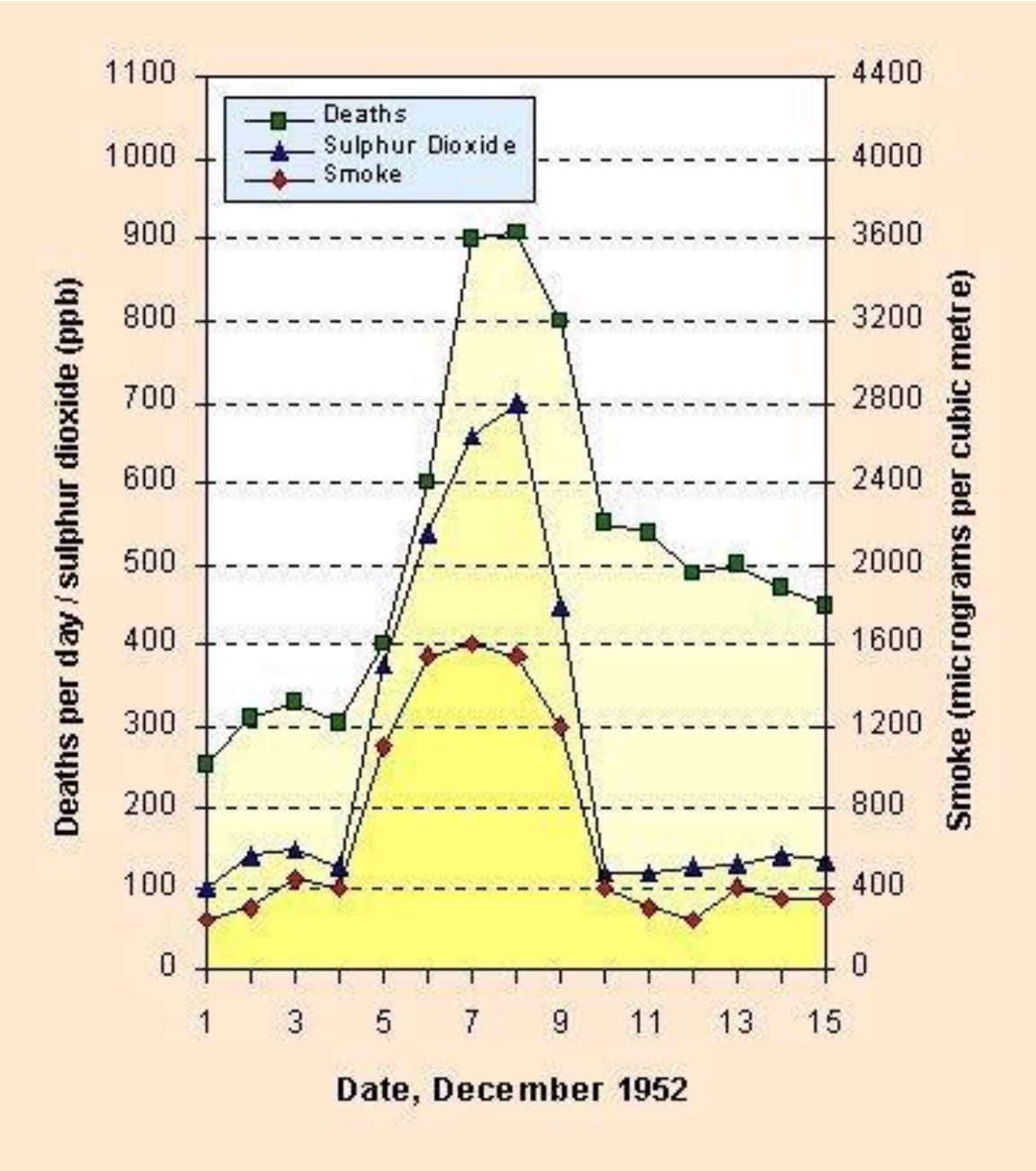
•In central London the visibility remained below 500 meters continuously for 114 hours and below 50 meters continuously for 48 hours.

•At Heathrow airport visibility remained below 10 for almost 48 hours from the morning of 6 December.

•Road, rail and air transport were brought to a standstill. Theatres had to be suspended when fog in the auditorium made conditions intolerable. But, most importantly the smoke laden fog that shrouded the capital brought the premature death of an estimated 12,000 people and illness to many others.

•This smog stayed stewing away for five days from the 5 to the 10 December as more and more pollution entered it before winds from the west blew it down the Thames Estuary and out into the North sea.

http://www.portfolio.mvm.ed.ac.uk/studentwebs/session4/27/greatsmog52.htm



http://www.portfolio.mvm.ed.ac.uk/studentwebs/session4/27/greatsmog52.htm

Indian Air Quality Standards

Species	Time average	Ecologically sensitive area	Others
SO_2 ($\mu g/m^3$)	Annual	20	50
	24 hours	80	80
NO_2($\mu g/m^3$)	Annual	30	40
	24 hours	80	80
PM_{10} ($\mu g/m^3$)	Annual	60	60
	24 hours	100	100
$PM_{2.5}$ ($\mu g/m^3$)	Annual	40	40
	24 hours	60	60
Ozone($\mu g/m^3$)	8 hours	100	100
	1 hours	180	180
CO($\mu g/m^3$)	8 hours	2000	2000
	1 hours	4000	4000
Lead($\mu g/m^3$)	Annual	0.5	0.5
	24 hours	1	1

Indian Air Quality Standards

Species	Time average	Ecologically sensitive area	Others
$NH_3(\mu g/m^3)$	Annual	100	100
	24 hours	400	400
$C_6H_6(\mu g/m^3)$	Annual	5	5
BaP (ng/m^3)	Annual	1	1
Ni (ng/m^3)	Annual	20	20
As (ng/m^3)	Annual	6	20

What does 10 and 2.5 in

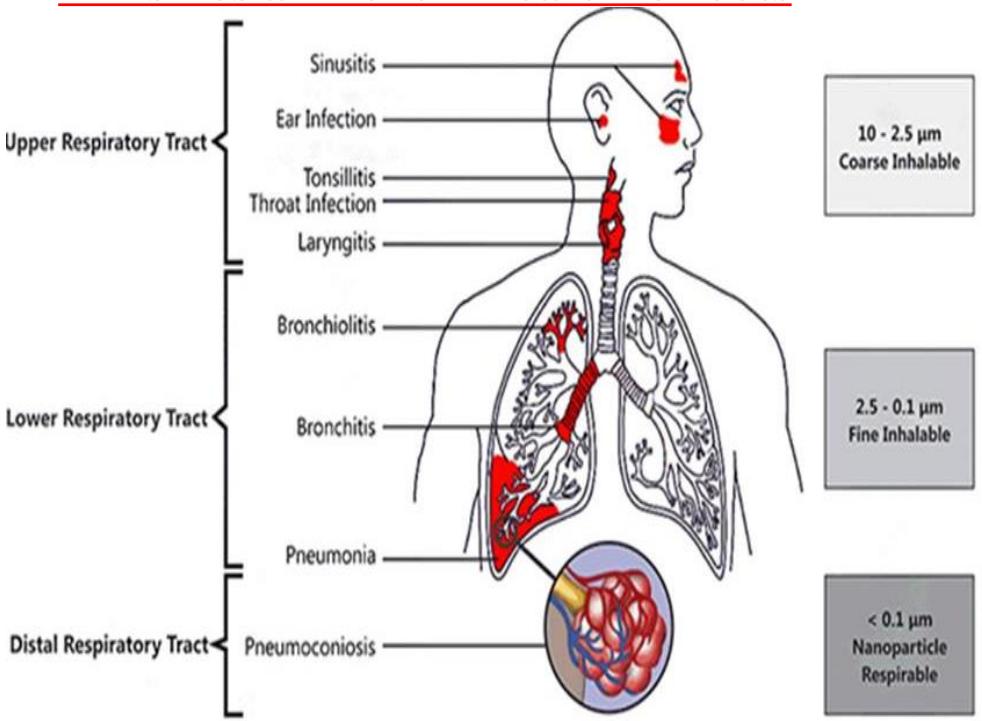
PM10 and PM2.5

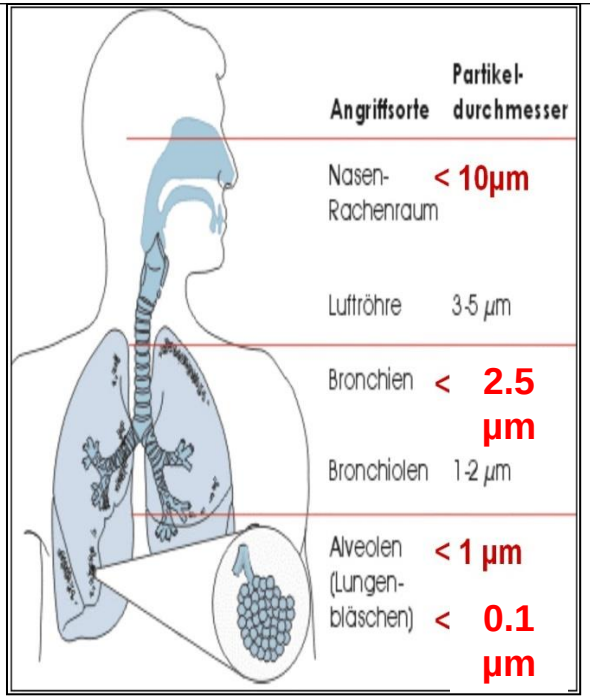
signify?

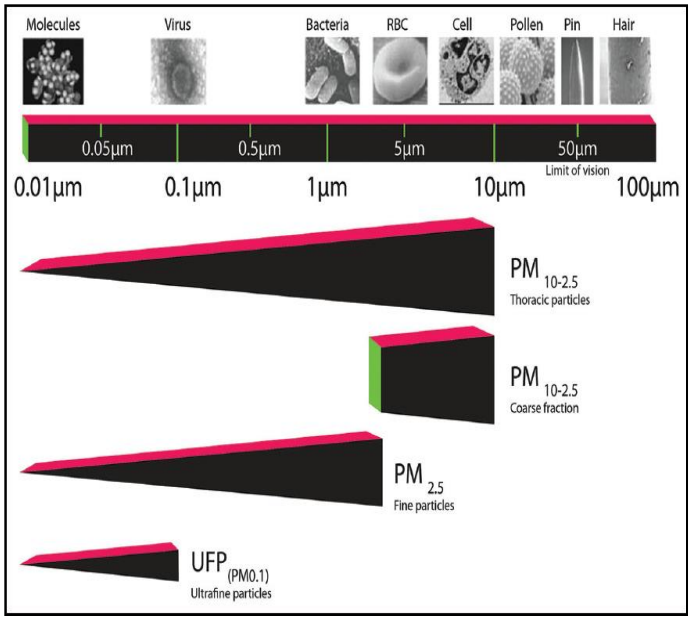
Why PM 10 and 2.5 are of prime importance?

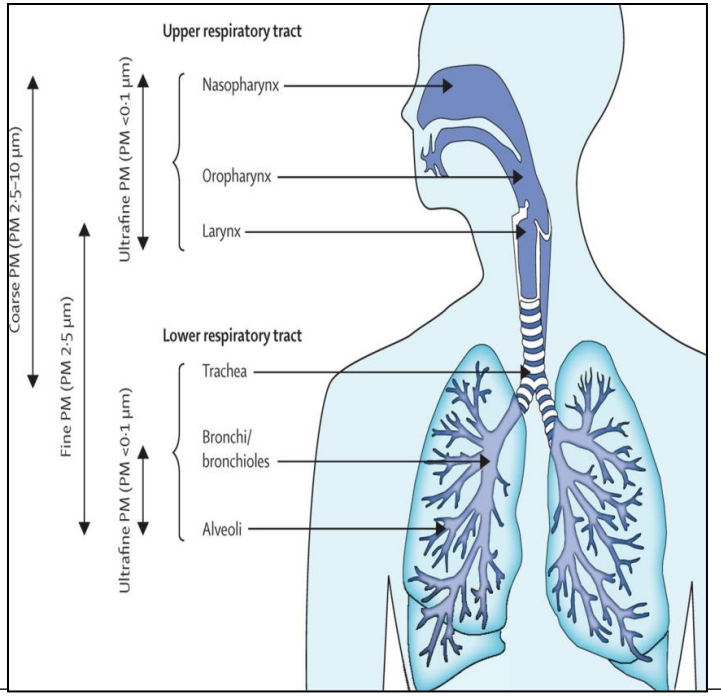
- PM toxicity tends to increase as particles' size decreases.
- During 1970's major scientific advances took place and identified that not all forms of total suspended particles (TSP). penetrates the lower areas of respiratory system unlike the 'inhalable fraction' of TSP i.e. PM10.
- Particles especially $PM_{2.5}$ penetrate deep into the lungs and in the alveoli, provoking inflammation, producing upper respiratory and mucous membrane irritation, and causing neuropsychological effects.

PM sizes and their health-effects









CLASSIFICATION OF AIR POLLUTANTS

- On the basis of origin, air pollutants can be divided into Primary air pollutants and Secondary air pollutants.

- **PRIMARY AIR POLLUTANTS**

  They are directly emitted to the atmosphere, and are found there in the form in which they are emitted.

SECONDARY AIR POLLUTANTS

- There are produced in air by interaction among two or more primary pollutants or by reaction with normal atmospheric constituents

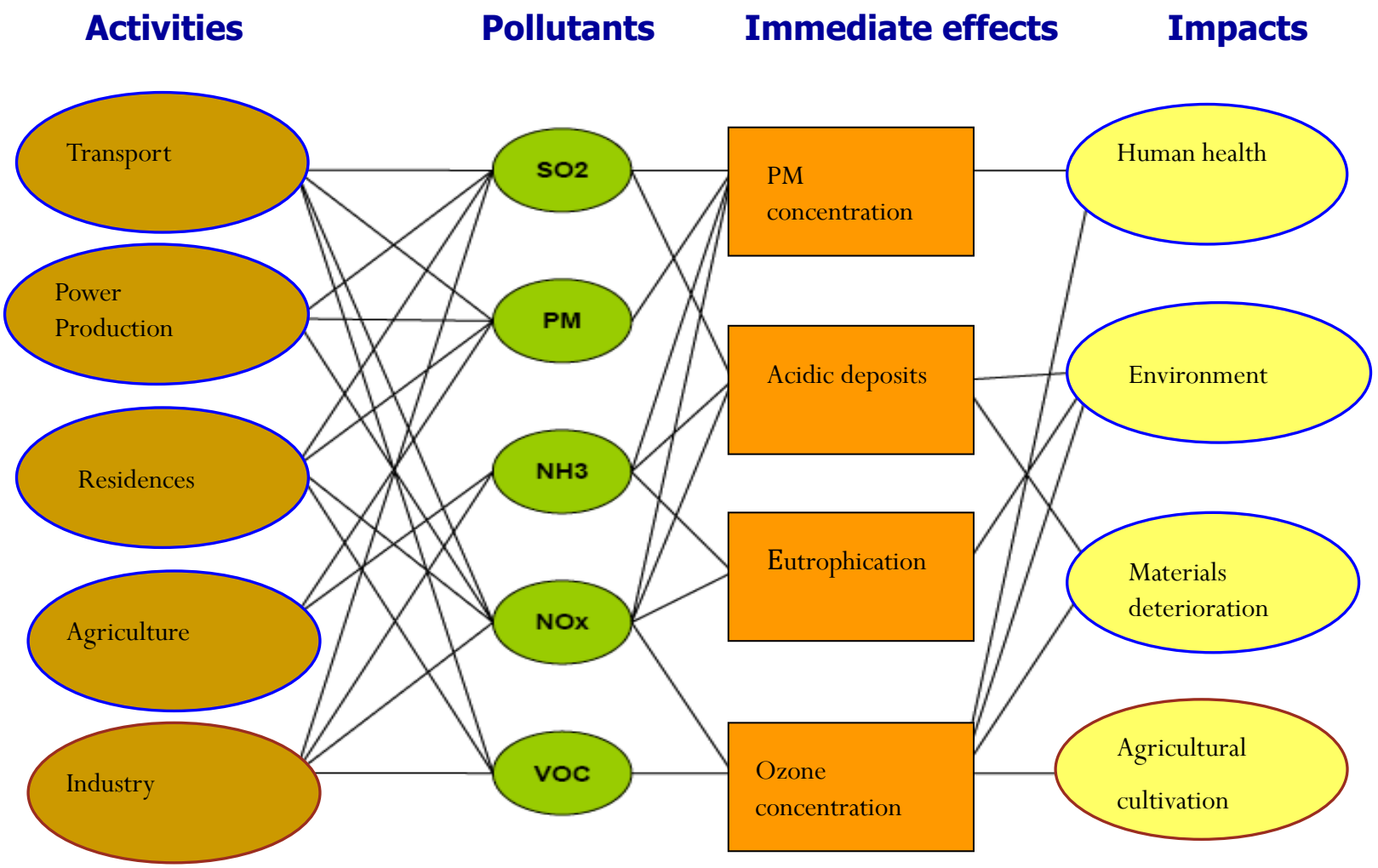
  (Chemical or Photochemical reactions)

- Ozone, formaldehyde (HCHO), PAN (Peroxy Acetyl Nitrate).

- Photochemical smog

- Formation of Acid mist (H_2SO_4)due to reaction of sulphur dioxide and dissolved oxygen, when water droplets are present in the atmosphere.

Sources and Impacts of Air Pollutants



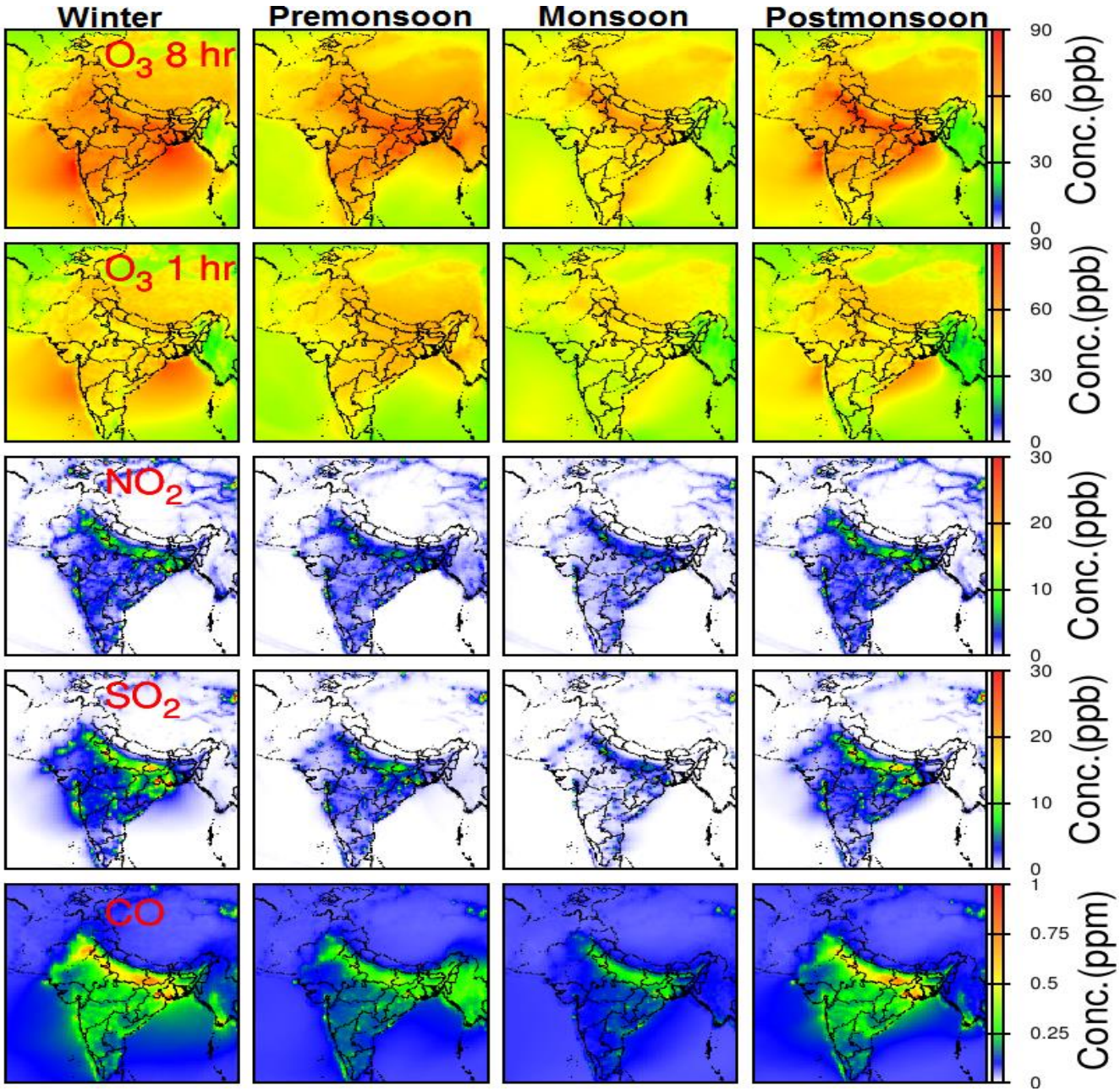
Sources	**Pollutants**
Power Plants	
• Thermal Power Plants	Smoke, CO, CO_2, SOx, dust.
• Nuclear Power Plants	Argon, Sr , CS, C etc
• Hydro Power Plants	Methane from water logged area
• Diesel generators	HC, CO, NOx Noise.
Industries	
• Non-Ferrous Metallurgical (Rotating , smelting)	SOx, smoke, COx ,fluorides, H_2S ,Organic Vapors.
• Non-Metallic Minerals (Ceramic Manufacture, glass)	Mineral and Organic Particulates.

- ***Transportation***

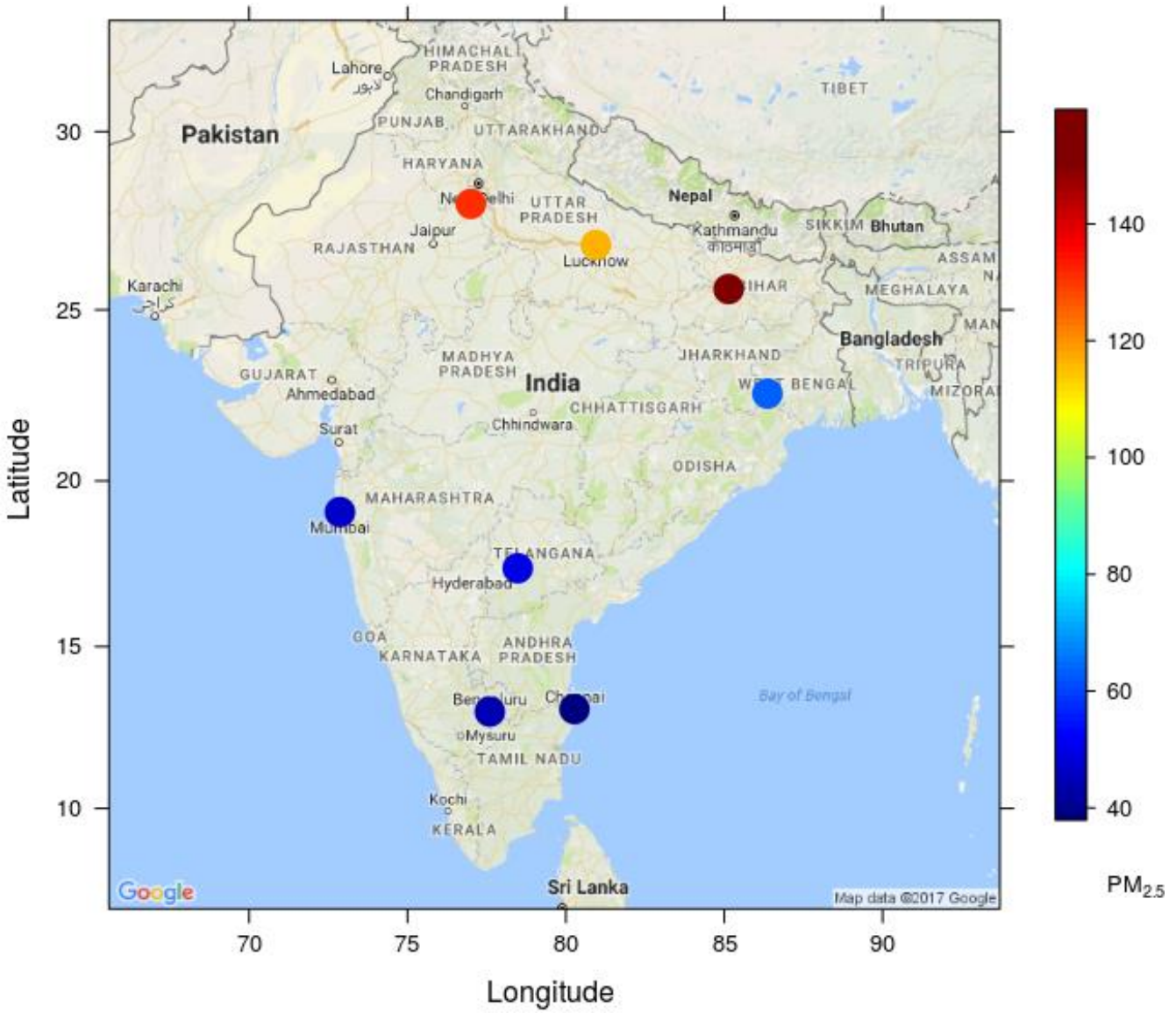
Automobiles (Bike, cars, trucks, trains, aircrafts)	HC, CO, CO_2, NOx, VOCs, Lead, Olefins, Paraffin, PM, H_2S, SO_2

- ***Agriculture***

Spraying Pesticides, fungicides	Organic phosphates, chlorinated hydrocarbons, lead


Winter
Premonsoon
Monsoon
Postmonsoon
O3 8 hr
O3 1 hr
NO2
SO2
CO
90
60
30
0
Conc.(ppb)
30
20
10
0
Conc.(ppb)
30
20
10
0
Conc.(ppb)
1
0.75
0.5
0.25
0
Conc.(ppm)

PM2.5 in Indian cities



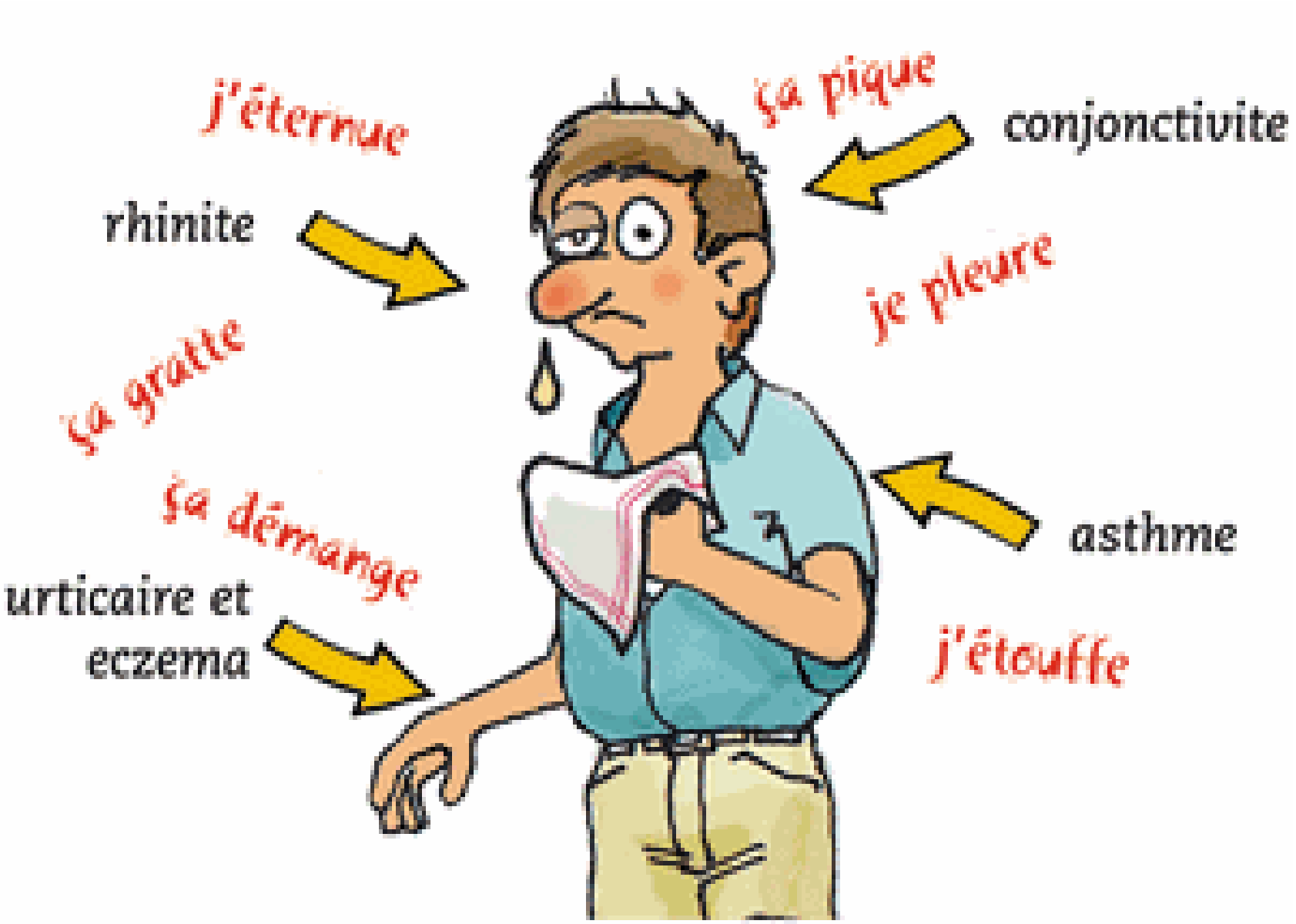
PM2.5 in Indian cities

Delhi	Winter	Pre-Monsoon	Monsoon	Post-Monsoon
	209.49	112	65.88	148.57
Lucknow	206.19	100	29.70	127.66
Patna	233.13	81.12	50.4	172.2
Kolkata	135.4	49.44	17.23	68.7
Mumbai	61.68	30.93	37.80	53
Hyderabad	58.44	45.78	31.93	59.94
Chennai	39.46	32.80	51.64	31.93
Bangalore	69.15	53.07	21.75	32

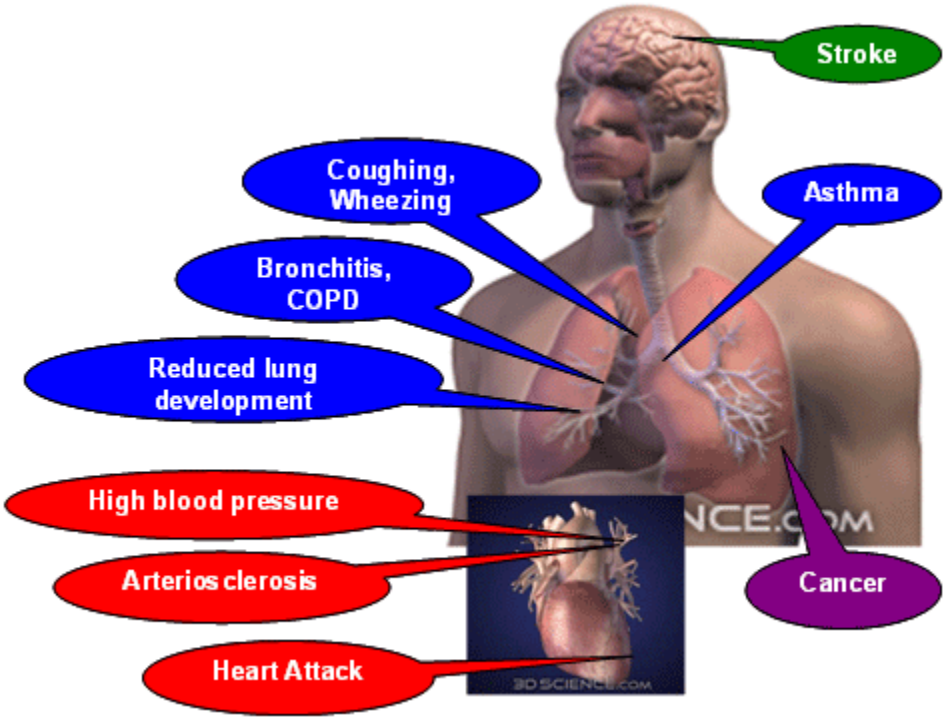
Effects of Air Pollutants

Effect on Humans

- On An average man breathes 22,000 times a day and takes in 16Kg of air each day.
- Eye, Nose, throat, respiratory tract irritation
- Co(g) is a poisonous gas (hemoglobin + CO→Carboxyhaemoglobin)
- Illness and death
- Hydrogen fluoride –causes florosis, and mottling of teeth.
- Dust - silicosis (associated with silica dust)
- Asbestosis (associated with asbestos dust)
- Lead – (from vehicles) Its high concentration can damage, liver, Kidney and
- Can cause abnormality in fertility and pregnancy.
- Radio active Isotopes – causes anemia (iron deficiency) leukemia (RBC deficiency), cancer, genetic defects


j'éternue
rhinite
ça pique
conjonctivite
je pleure
ça gratte
ça démange
urticaire et
eczema
asthme
j'étouffe

Health effects of PM



http://www.marlborough.govt.nz/Environment/Air-Quality/Smoke-and--Smog/Health-effects-of-PM10.aspx

Effect on Vegetation :

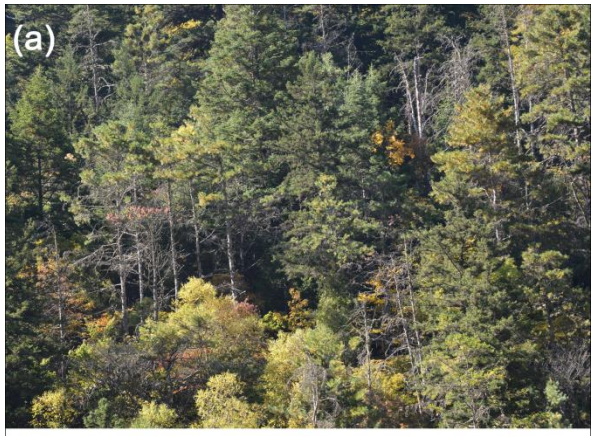
- **Necrosis** : Killing of tissues
- **Pigmented lesions**: dark brown, black, purple, red spots on leaves
- **Epinasty:** Rapid growth of upper side of the leaves
- **Chlorosis**: Loss of green plant pigment chlorophyll (Yellow leaves)
- **Abscission**: Dropping of leaves

Necrosis

Epinasty

Chlorosis

Abscission



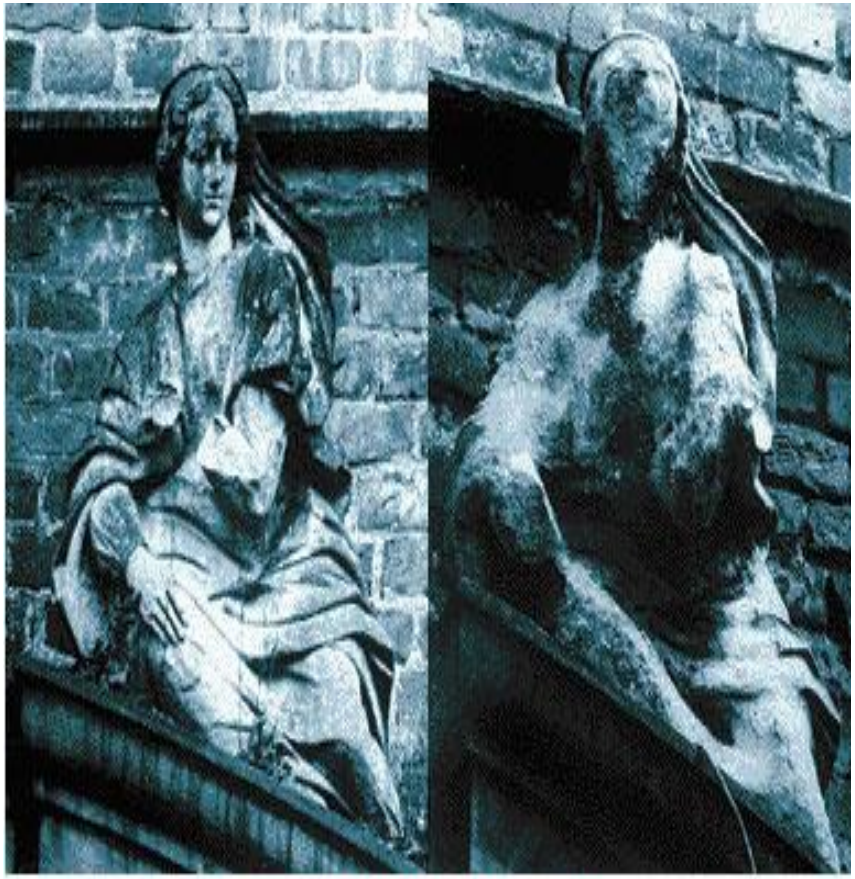
Dieback of trees

Increase in algal production in surface water

Tufa degradation

Effect on Materials

- Corrosion of metals
- Eroding of building surfaces
- Fading of dyed materials
- Rubber cracking

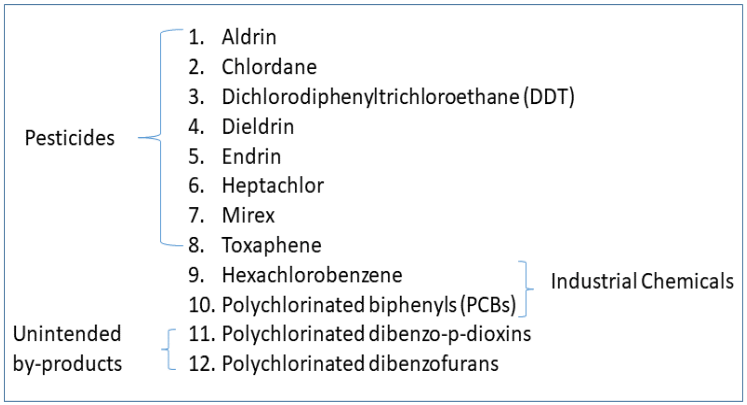


How acid rain affects stonework.
The picture on the left was taken in 1908.
The picture on the right was taken in 1968

Hazardous Air Pollutants (HAPs)

- US EPA identifies 187 HAPs
- Persistent Organic Pollutants
- Dirty Dozen

Stockholm convention



Practice

Using hourly concentrations, show hourly, monthly and seasonal trends of PM2.5 and PM10 measured at your corresponding stations. Clearly show all your calculations and interpretations.

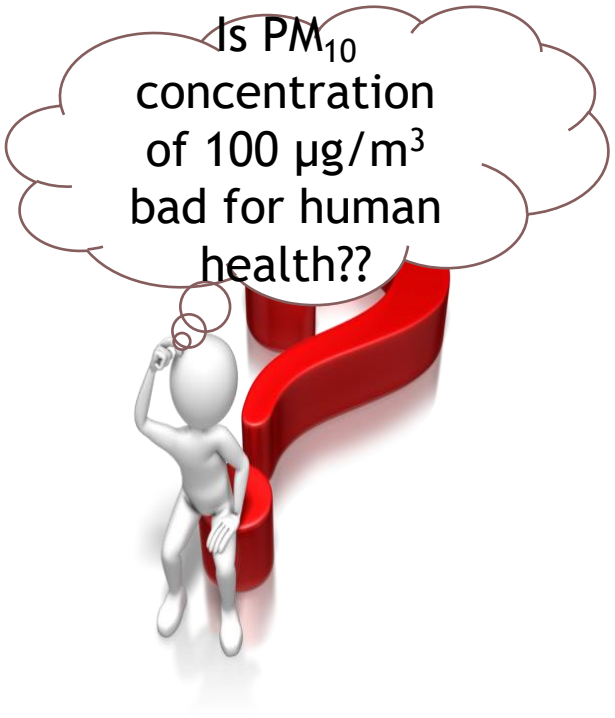
- Period: 1st January -31st December 2019
- Pollutants: PM2.5, PM10
- Stations :

  ITO

  CPCB data can be downloaded from https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing/data

- Seasons: Winter (December to February), Pre-monsoon (March to May), Monsoon (June to August) and Post-monsoon (September to November)

Air Quality Index (AQI)



AQI simplifies understanding of health effects of pollutants

Good (0-50)	Satisfactory (51-100)	Moderately polluted (101-200)	Poor (201-300)	Very poor (301-400)	Severe (> 401)

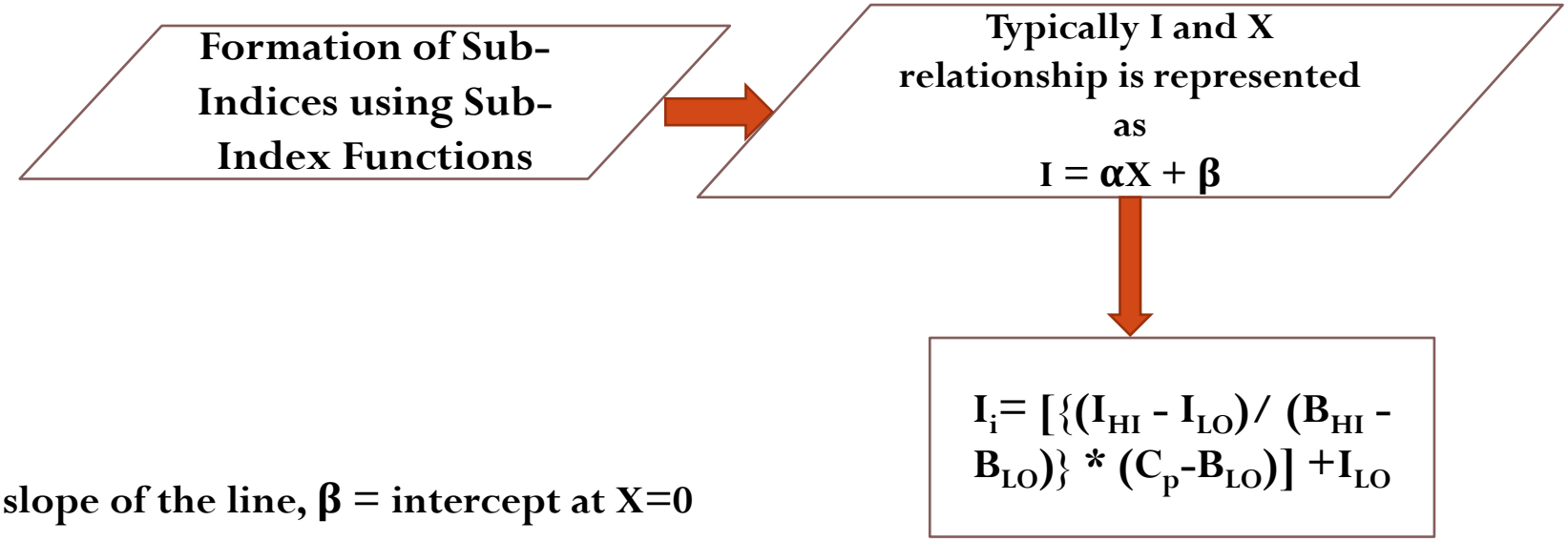
AQI and it's applications

AQI is defined as an overall scheme that transforms weighted values of individual air pollutants (SO_2, CO etc.) into a single number or set of numbers.

Applications:

1. **Resource allocation**
2. **Ranking of locations**
3. **Enforcement of standards**
4. **Trend analysis**
5. **Public information**
6. **Scientific research**

Structure of an Index



α =slope of the line, β = intercept at X=0

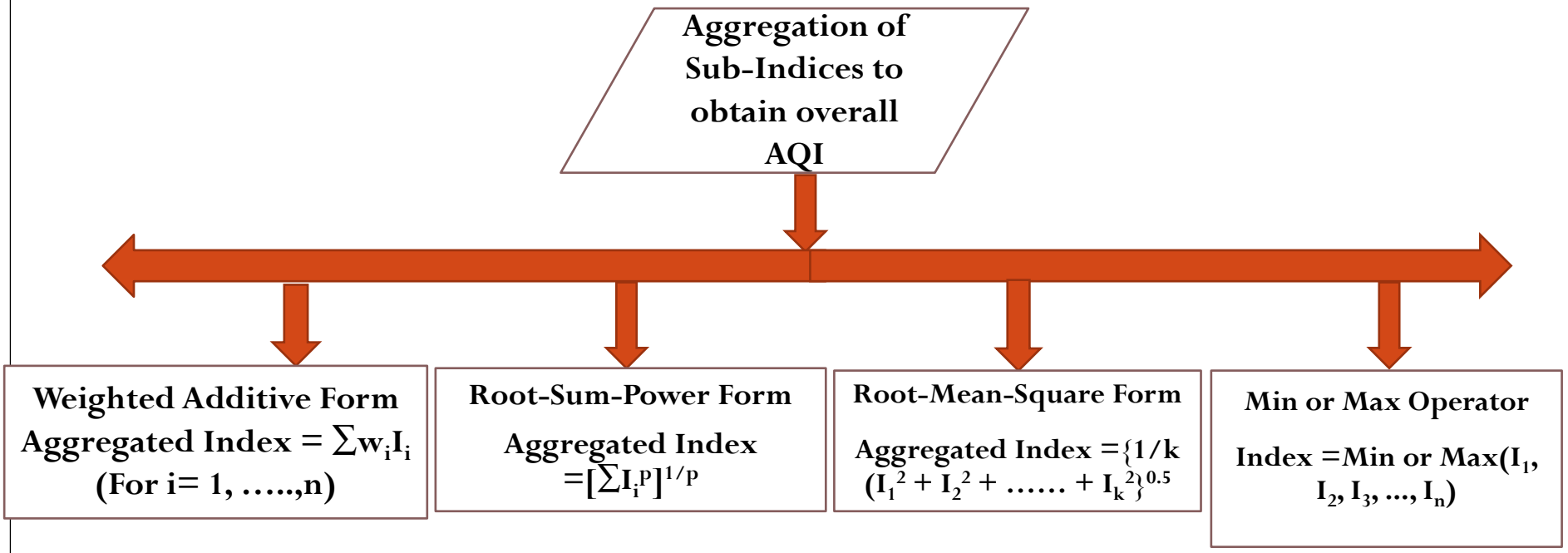
B_{HI}= Breakpoint concentration greater or equal to given concentration

B_{LO}= Breakpoint concentration smaller or equal to given concentration

I_{HI} = AQI value corresponding to B_{HI}

I_{LO} = AQI value corresponding to B_{LO}; subtract one from I_{LO}, if I_{LO} is greater than 50

C_p= Concentration of pollutant



$\sum w_i = 1$

I_i= sub-index for pollutant i

n = number of pollutant variables

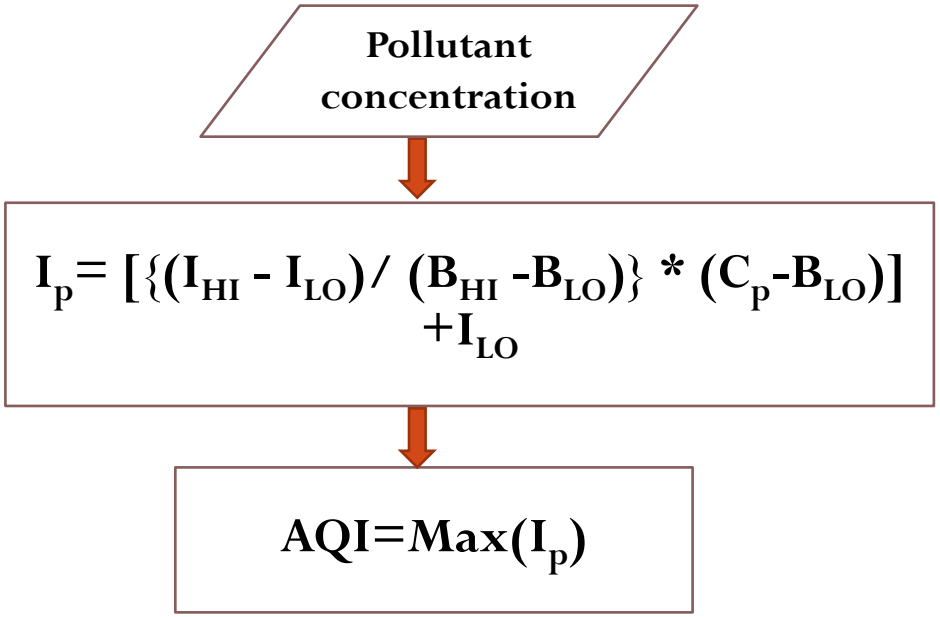
w_i= weightage of the pollutant

p is the positive real number >1

Countries

Countries	Index calculation Method
USA	Min or Max operator
China	Min or Max operator
India	Min or Max operator
Canada	***Root-Sum-Power Form***

Indian AQI Calculation



- **<u>Included pollutants</u>**: Carbon monoxide (CO), Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2) , PM2.5, PM10, Ozone (O_3), Lead (Pb) , Ammonia (NH_3), Benzo(a)Pyrene (BaP), Benzene(C6H6), Arsenic (As), Nickel (Ni)
- Calculation of AQI requires availability of data for minimum three pollutants of which one should necessarily be PM10 or PM2.5

Breakpoints for AQI Scale 0-500 (units: µg/m^3 unless mentioned otherwise)

AQI Category (Range)	PM10 24-hr	PM2.5 24-hr	NO2 24-hr	O3 8-hr	CO 8-hr (mg/m3)	SO2 24-hr	NH3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6-1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430+	250+	400+	748+*	34+	1600+	1800+	3.5+

*One hourly monitoring (for mathematical calculation only)

Health Statements for AQI Categories

AQI	Associated Health Impacts
Good (0–50)	Minimal Impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people
Moderate (101–200)	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease with short exposure
Very Poor (301–400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe (401-500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases.The health impacts may be experienced even during light physical activity

- PM2.5=135
- PM10= 294
- SO_2= 20
- NO_2=45

Units: $\mu g/m^3$

AQI Category (Range)	PM10 24-hr	PM2.5 24-hr	NO2 24-hr	O3 8-hr	CO 8-hr (mg/m3)	SO2 24-hr	NH3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
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Severe (401-500)	430+	250+	400+	748+*	34+	1600+	1800+	3.5+

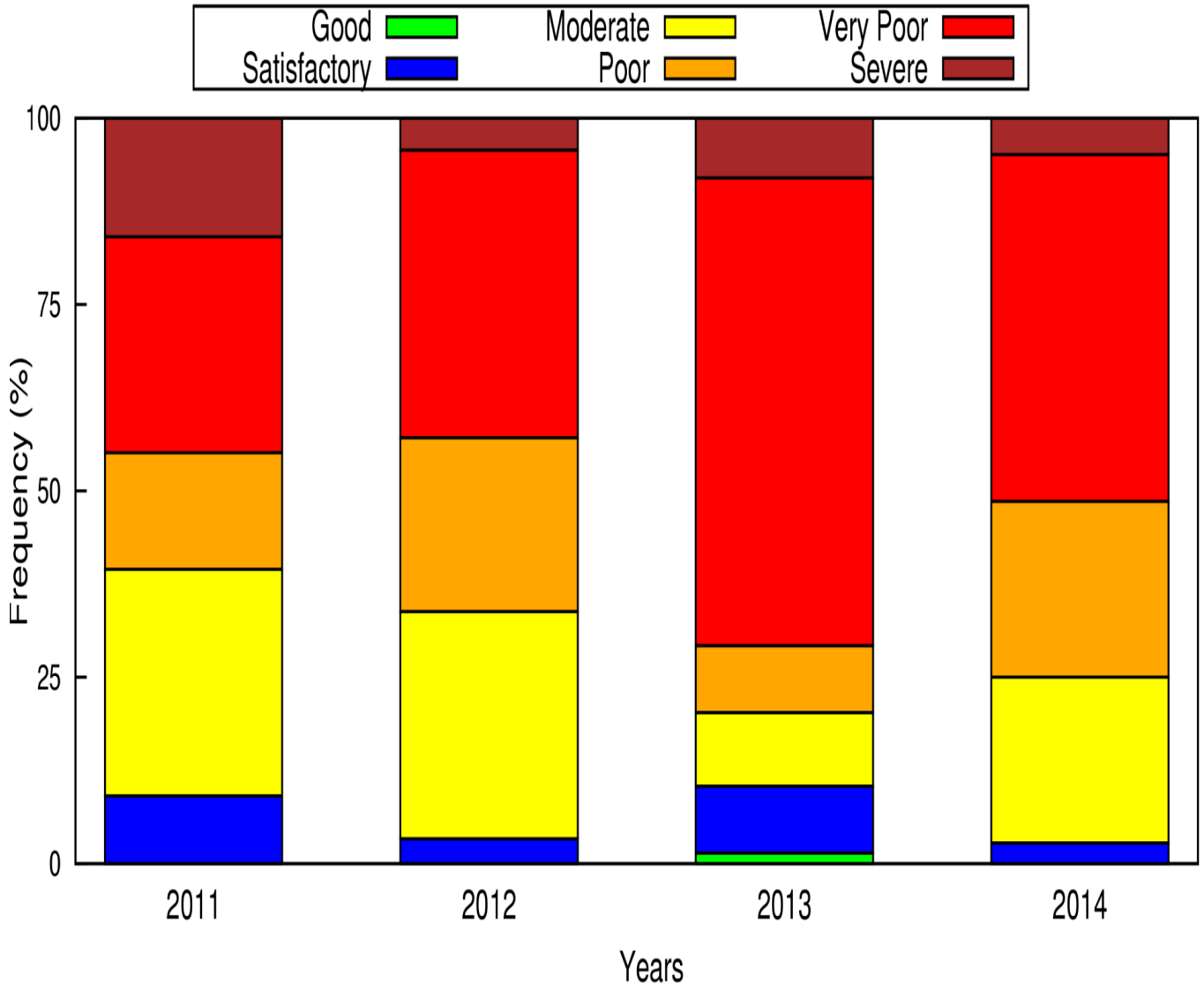
	PM2.5	PM10	SO_2	NO_2
C_P	135	294	20	45
I_{HI}	400	300	50	100
I_{LO}	300	201	0	51
B_{HI}	250	350	40	80
B_{LO}	121	251	0	41
I_P	*310.8*	*244*	*25*	*56*

$$I_p = [\{(I_{HI} - I_{LO})/ (B_{HI} - B_{LO})\} * (C_p - B_{LO})] + I_{LO}$$

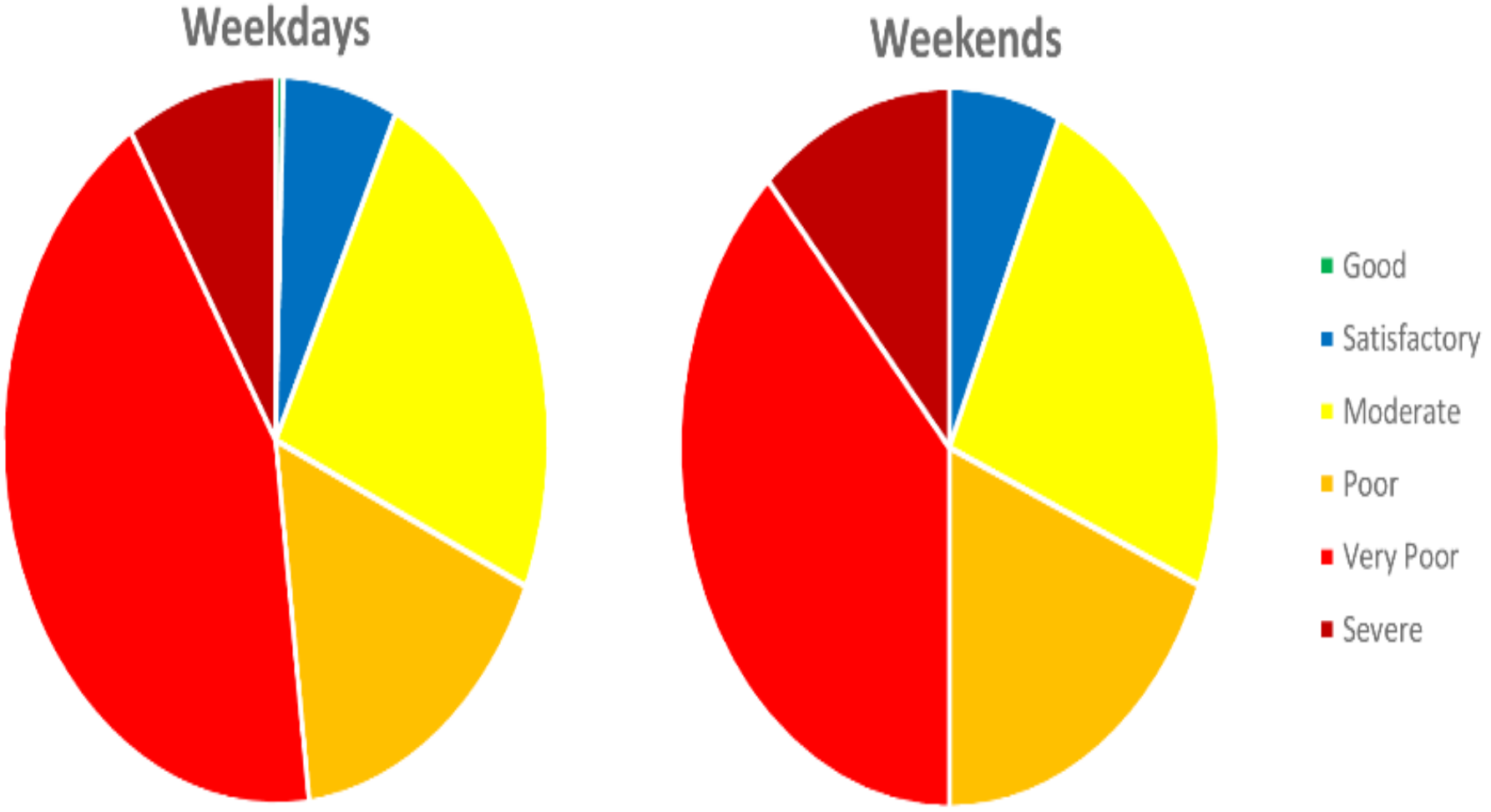
AQI=310.8

Dominant Species=PM2.5

Yearly variation of AQI in New Delhi



Delhi


Weekdays
Weekends
Good
Satisfactory
Moderate
Poor
Very Poor
Severe

Practice

Consider a day in Mumbai where the concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, O_3 be 100 µg/m³, 190 µg/m³, 35 µg/m³, 50 µg/m³, 3 mg/m³ and 18 µg/m³ respectively, calculate the AQI

AQI Category (Range)	PM10 24-hr	PM2.5 24-hr	NO2 24-hr	O3 8-hr	CO 8-hr (mg/m3)	SO2 24-hr	NH3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6-1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430+	250+	400+	748+*	34+	1600+	1800+	3.5+

Consider a day in Bangalore wherein the concentrations of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, O_3 be 80 µg/m^3, 135 µg/m^3, 48 µg/m^3, 35 µg/m^3, 6 mg/m^3 and 15 µg/m^3 respectively, calculate the AQI

AQI Category (Range)	PM10 24-hr	PM2.5 24-hr	NO2 24-hr	O3 8-hr	CO 8-hr (mg/m3)	SO2 24-hr	NH3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6-1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430+	250+	400+	748+*	34+	1600+	1800+	3.5+

Practice

Estimate AQI for each of the months using the data from your corresponding CPCB station. Clearly show all your calculations and interpretations.

- Period: 1st January -31st December 2019
- Pollutants: PM2.5, PM10, SO_2 and NO_2
- Stations :
  - ITO
  - CPCB data can be downloaded from https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing/data
- Seasons: Winter (December to February), Pre-monsoon (March to May), Monsoon (June to August) and Post-monsoon (September to November)