SC209 Online Lecture 10 Notes

(Pollutants continued)

(Lighter text has been covered in lecture 9 as well)

Two types of Pollutants:

1. Primary: Emitted from a source directly into the atmosphere
   The Source may be either a natural process (sandstorms, eruptions, etc.) or human-influenced (industrial, vehicle emissions)
   Examples: Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Nitrogen Oxides (NO_x), particulate matter (PM)
2. Secondary: Does not directly affect the environment till it reacts with another primary pollutant or some atmospheric constituent.

There is another category outside this called the criteria pollutants

Primary pollutants which contribute over 90% of global air pollution:

- Carbon Monoxide CO
- Nitrogen oxides NO_x
- Hydrocarbons HC
- Sulphur Oxides SO_x
- Particulates
- Volatile Organic Compounds VOC

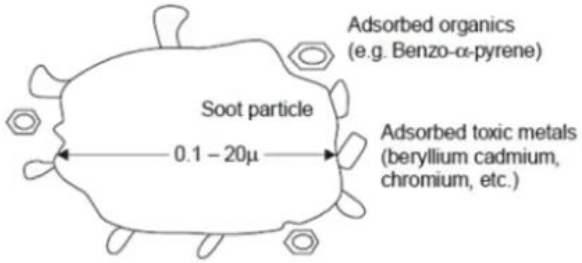
Secondary pollutants

- Ground level ozone
- Formaldehyde
- Smog
- Acid Mist

Sources

Sources	*Weight of pollutants produced**				*Particulates*		*Total weight of pollutant produced*
	CO	*NO_x*	*HC*	*SO_x*	*<20μ*	*>30μ*	
Transportation	70	10	10.8	0.8	1.2	1.0	94
Fuel combustion (stationary sources)	1.2	11.8	1.4	21.9	4.6	1.3	42.2
Industrial processes	7.8	0.7	9.4	4.1	6.3	2.7	31.0
Solid waste disposal	7.8	0.8	1.6	0.1	1.1	—	11.2
Miscellaneous	8.5	0.4	6.3	0.1	1.3	—	16.6
Total weight of pollutant produced	95.0	23.6	29.5	27.0	—	19.5	194.6

- **Particulate Matter**
  - Solids/liquids suspended in the air, collectively termed aerosols.
  - PM can be both primary or secondary pollutants
  - Range in size from 0.0002 to 500 μ.
  - Ex: dust and soil, sea salt spray, pollen, smoke, fumes, haze, etc.
  - **Soot particles** originate from fuel combustion and consist of highly condensed products of polycyclic aromatic hydrocarbons (PAH) - roughly 100 condensed aromatic rings.

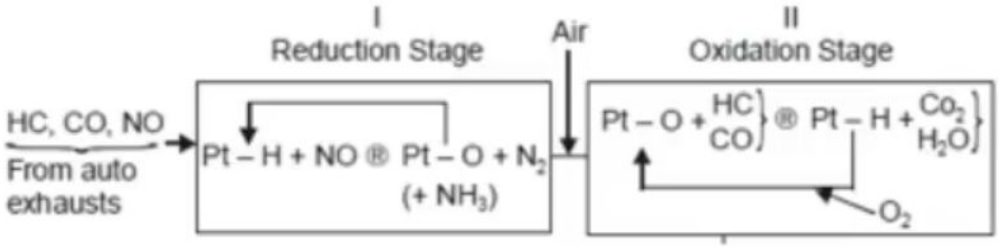


A soot particle

Hydrocarbon content of soot is 1-3% and oxygen content is 5-10% from partial surface oxidation. Due to large surface area, soot acts as a carrier of toxic organics: Be, Cd, Cr, Mn, etc.

  - Control of Particulate Emissions:
    - Removal of PM carried out by electrostatic precipitator
    - It is based on the principle that aerosol particles acquire charge when subjected to an electrostatic field and the charged particles are attracted to a grounded surface from which they are recovered.
- **Carbon Monoxide**
  - CO is a more significant pollutant than CO_2 which, on the other hand, is more prominent as a greenhouse gas and contributes to increasing temperatures.
  - CO is colourless, odourless and tasteless.
  - Diesel and petroleum engines primarily responsible for about 70% CO emissions.
  - Produced in 3 ways:
    - Incomplete combustion of fuels/carbon containing materials
      $2C + O_2 \rightarrow 2CO$
    - Reaction of CO_2 and carbon-containing materials at elevated temperatures in industries (e.g. in blast furnaces)
      $CO_2 + C \rightarrow 2CO$
    - Dissociation of CO_2 at high temperatures.
      $CO_2 \rightarrow CO + O$
  - Sinks
    - Part of CO is lost in upper atmosphere
    - Major sink is soil microorganisms (28kg of soil sample can completely remove 120 ppm CO form ambient air in 3 hrs)

- **Control of CO, HC, NO_x pollution**
  Use of catalytic converters in the internal combustion engines of automobiles



Pt–H = Platinum hydrogen compound;
Pt–O = Platinum oxygen compound

- **Nitrogen Oxides, NO_x**
  - Mix of nitric oxide and nitrogen dioxide (NO and NO_2)
  - Formation of NO and NO_2 inside automobile engines:

$$N_2 + O_2 \xrightarrow[\text{1210 – 1765 deg cent}]{} 2NO \quad \text{(nitric oxide)}$$

$$2NO + O_2 \rightleftharpoons 2NO_2$$

Exhaust consists of NO_x which is converted to HNO_3 (acid rain)

$$NO_2 + O_3 \longrightarrow NO_3 + O_2$$
(nitrogen trioxide)

$$NO_3 + NO_2 \longrightarrow N_2O_5$$
(nitrogen pentoxide)

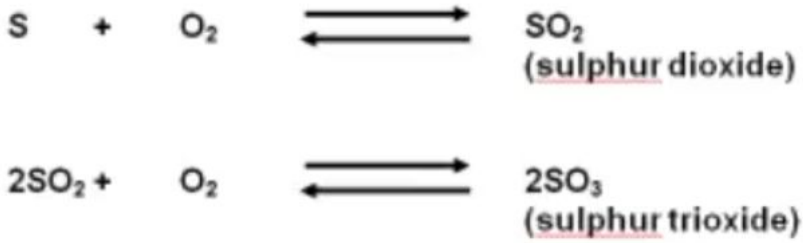
$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

- **Hydrocarbons and Photochemical Smog**
  - Primarily methane (CH_4), from anaerobic decomposition of organic matter by bacteria.

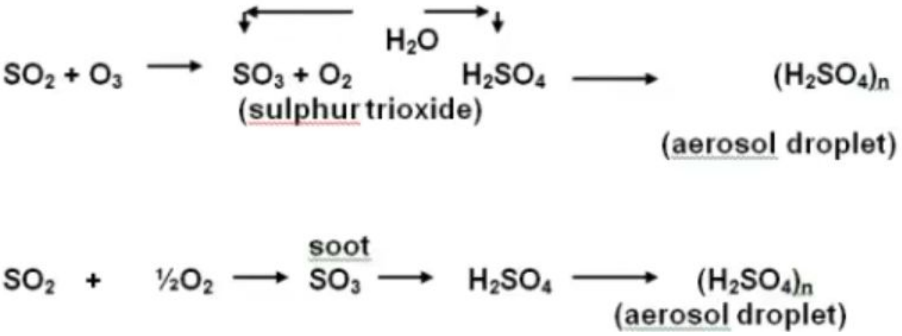
$$2\{CH_2O\} \xrightarrow{\text{bacteria}} CO_2\uparrow + CH_4\uparrow$$

  - Domestic animals are a major source of methane emission and automobiles are significant sources of hydrocarbons.
  - Chain reaction proceeds where hydrocarbons participate in photochemical reactions in presence of ozone, CO and nitrogen oxides releasing harmful products NO_2 and aldehydes (R-CHO).
  - A side reaction follows through the aldehyde which gives an injurious end product, Peroxy Acyl Nitrate (PAN) - a strong eye irritant.

    - These reactions lead to photochemical smog formation characterized by brown hazy fumes.
- **Sulphur Dioxide SO_2**
    - Volcanic eruptions are a major source of SO_x pollution.
    - Coal-fired power stations also contribute.



    - Soot particles containing metal oxides, catalyze the SO_2 to SO_3.

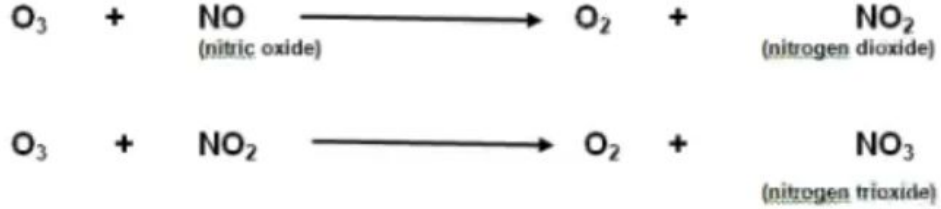


    - Control of SO_x pollution: Chemical Scrubbing

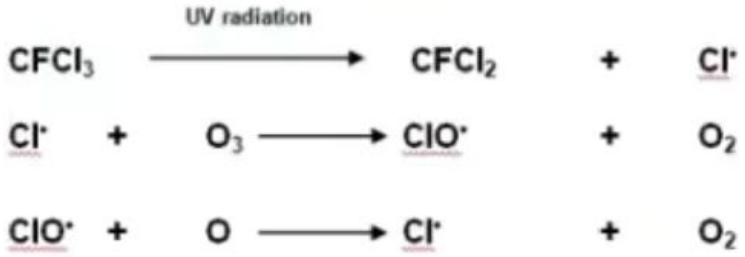
- **Volatile Organic Compounds VOC**
    - VOCs are chemicals containing carbon and.or hydrogen and evaporate easily.
    - VOCs are the main air emissions from oil and gas industry as well as indoor consumer products and construction materials, such as new fabrics, wood and paints.
    - VOCs are a major contributing factor to ground-level ozone.

STEPS	PHOTOCHEMICAL PRODUCTS
1. NO + VOC →	NO_2 (nitrogen dioxide)
2. NO_2 + UV sunlight →	NO + O (nitric oxide + atomic oxygen)
3. O + O_2 →	O_3 (ozone)
4. NO_2 + VOC →	PAN (peroxyacetyl nitrate)

- **Ozone Hole**
    - Exhaust gases from jet aircrafts: NO and NO_2 etc. immediately react with ozone.

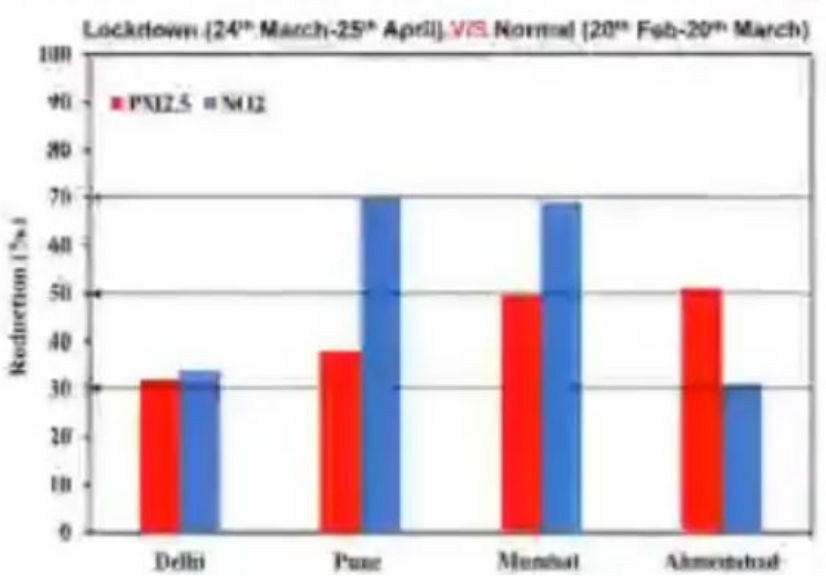


- In presence of UV (200nm) radiation from the sun, CFC break up into Chlorine-free radical (Cl) which readily consumes ozone.



- CFC slowly passes from the troposphere and stratosphere and stays there for 100 years.
- It is estimated that a single CFC molecule consumes 1 lakh molecules of Ozone.

- **SAFAR: S**ystem of **A**ir Quality and Weather **F**orecasting **A**nd **R**esearch
  http://safar.tropmet.res.in/
  Installed air quality monitoring systems in four cities: Ahmedabad, Pune, Delhi, Mumbai.
  - Significant reduction in PM2.5 and NO_2 in a month observed in the graphs.



  Reduction ranging from 30% to 70%.
- **Air pollution status in India**
  - Few pollution hotspots are:
    - Delhi (4th most polluted city in the world)
    - Ahmedabad
    - Kanpur
    - Solapur
    - Lucknow

      Sharp increase in NO_2 has been noticed in cities with heavy vehicular traffic and density.

  - The Supreme court helped protect the Taj Mahal which was suffering from ‘marble cancer’ (fungal growth which gave its surface a yellow tinge) due to exposure to SO_2 and suspended PM.
  - Reducing pollution:
    - Reduce electricity consumption
    - Develop better public transport

- Use of alternate energy sources
- Filtering air emissions
- Switching to low-sulphur coal (high-sulphur coal is cheaper and widely used)
- NO_x emissions can be reduced upto 50% by controlling flow of air and fuel
- Hydrocarbon emission can be controlled through complete combustion