AIR POLLUTION

WHY AIR POLLUTION STUDIES ARE IMPORTANT?

AIR ? NOT ORDINARY!

Without ‘Food’ (but ‘Water’) human can live for ‘3 Days’.
Without ‘Water’ (and no ‘Food’) human can live for ‘1 Day’.
Without ‘Air’ (even with ‘Food’ and ‘Water’) human can live for ‘1 Minute’.

What is ‘Death’?
No Air for ‘1 Minute’ is called as ‘Death’.

Air is so important. Pollution is a serious issue

AIR ? NOT ORDINARY!

Air is what we Breathe every Second, even during Sleep!

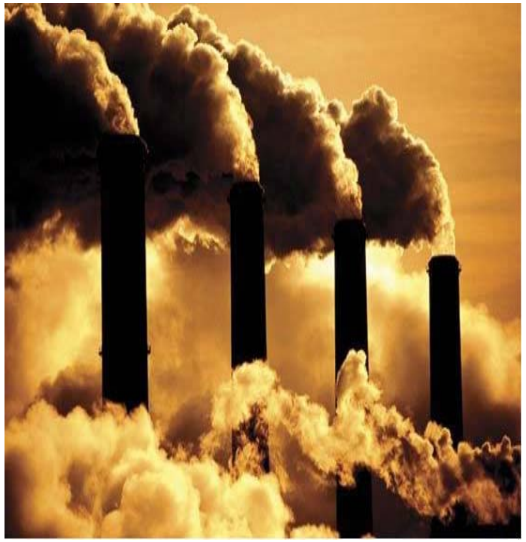
Air is taken into lungs every few seconds and the system of the lungs helps the oxygenation of blood in every drop.

Heart pumps Blood and Blood carries O2 (by Hemoglobin) to every part/cell of the body to sustain Life inside.

'More O2' into the body is called 'More Life'.
Similarly 'Better O2 ' into the body is called 'Better Life'.
But then 'Polluted O2 ' into the body is called 'Polluted Life'.

WHAT IS AIR POLLUTION ?

This occurs when the air contains gases, dust, fumes or odour in harmful amounts. That is, amounts which could be harmful to the health or comfort of humans and animals or which could cause damage to plants and materials.



FACTORS AFFECTING AIR POLLUTION

1. **Emissions (traffic, industrial, domestic)**
2. **Geography (terrain)**
3. **Weather conditions (rain, winds, humidity)**
4. **Season**
5. **Time of day**
6. **Population density**
7. **Indoor vs. outdoor**

NATURAL AIR POLLUTION

1. Forest fires
2. Volcanoes
3. Dust storms
4. Pollen
5. Radioactive decay

MAN-MADE AIR POLLUTION

1. Vehicle emissions
2. Waste disposal
3. Power plants
4. Factories
5. Cookers
6. Fuel

WHAT ARE THOSE IMPORTANT POLLUTANTS?

DELHI POLLUTION DEATHS UP BY 100% SINCE 1991

By **Neetu Chandra Sharma** in New Delhi

THE health of Delhiites has been hit hard by air pollution, with the number of deaths and cardiovascular and respiratory diseases linked to the menace shooting up in recent years.

A World Health Organisation (WHO) study ranked New Delhi as the world's worst city for air pollution, with an annual average of 153 micrograms of small particulates, known as PM 2.5 per cubic metre. Released on Wednesday, the study conducted in 1,600 cities found that air pollution has worsened since a smaller survey in 2011, putting Delhi residents at higher risk of cancer and heart disease.

A similar study done by Indian Institute of Technology (IIT)-Roorkee in association with the University of Minnesota and University of Colorado at Denver has revealed a marked rise in deaths due to cardiovascular and respiratory diseases and hospital admissions for "chronic obstructive pulmonary diseases" (COPD) linked to pollution.

It is not just Delhi. Twenty-five other Indian cities — including Dehradun, Pune and Jammu — have higher air pollution levels. The levels of particulate matter with diameter of 2.5 micrometres recorded in the three cities are higher than in Beijing.

"As many as 8,945 cases of total mortality, 3,413 cases of cardiovascular mortality, 1,302 cases of respiratory mortality and over 12,809 hospital admission of COPD were recorded in Delhi in 1991. With 100 per cent growth, these figures in 2010 became 18,229 cases of total mortality, 6,374 cases of cardiovascular mortality, 2,701 cases of respiratory mortality and 26,525 hospital admission," the study done by Professor Bhola Ram Gurjar of IIT-Roorkee said.

In 2000, about "11,394 cases of total mortality, 3,912 cases of cardiovascular mortality, 1,697 cases of respiratory mortality and 16,253 cases of hospital admission of COPD" were recorded for Delhi, reported the study titled '*Human health risks in national capital territory of Delhi due to air pollution*'.

The study, recently published in *Atmospheric Pollution Research* journal, adopted WHO guideline concentrations for assessing air pollutants like sulphur dioxide (SO2), nitrogen dioxide (NO2) and total suspended particles (TSP). The study also assessed the risk to people from these pollutants. It found that higher ambient concentrations of suspended particulate matter (SPM) and nitrogen oxides (NOx) are responsible for excess number of deaths and illnesses in Delhi.

Doctors see rise in respiratory diseases

The study covered the areas of North-West, South, West, North-East, South-West, East, North, Central and New Delhi districts during 1991-2010. They calculated the health risks using ambient air pollution concentration data of nine districts. Concentration data of monitoring stations in each district was used for calculating district-wise health risk estimates.

The results found dissimilar trends in terms of deaths, diseases and hospital admissions. From 2002, the North-West district was at the top for the highest excess number of cases of hospital admission of COPD until 2010, while from 2002 to 2010, the North West district topped the chart with the excess number of cases of deaths due to cardiovascular diseases.

Doctors have been witnessing an increased number of cases of respiratory disease which they attribute to air pollution. "There is an increase in cases of respiratory diseases, especially in children. Air pollution is contributing to respiratory diseases while there is also a possibility of malformation of organs in new born babies as mothers are exposed to pollution for prolonged periods," said Dr. Dinesh Kapil, consultant pediatrician at Red Cross Hospital.

Asian Age/New Delhi/February 14, 2013

'Air pollution 5th largest killer in India'

RASHME SEHGAL
NEW DELHI, FEB. 13

Air pollution has jumped to number five spot amongst the top killers in India.

Releasing India-specific data, the Global Burden of Disease (GBD) warned that outdoor air pollution caused 627,000 deaths and 17.7 million healthy years of life lost in 2010.

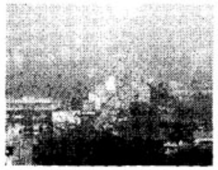
Worldwide, outdoor air pollution caused 3.2 million premature deaths and over 74 million years of healthy life lost in 2010.

A substantial rise in cardiovascular diseases, strokes and chronic obstructive pulmonary diseases in India in 2010 are directly attributed to rising levels of particulate matter pollution.

Two-thirds of the rising disease graph worldwide are found in South Asia.

Dr Vinod Raina, heading the oncology wing at AIIMS, confirmed that "we are getting 10 lakh new cancer cases every year, out of which approximately one lakh are lung cancer cases. We still have to quantify how many of these lung cancer cases are pollution-related".

Dr Aaron Cohen, principal scientist, Health Effects Institute, Boston,



and chair of the Air Pollution Group at Institute for Health Metrics and Evaluation for Global Burden of Disease, pointed out that a study of lung cancer amongst non-smokers had shown a 60 per cent increase caused by air pollution.

Prof. S.K. Chhabra, heading the department of cardio-respiratory physiology at the Vallabhbhai Patel Chest Institute, warned against the risk from new generation pollutants, especially ozone which is currently responsible for a four per cent increase in mortality rates.

"Ozone has become a key ingredient of urban smog," said Prof. Chhabra.

Prof. Randeep Guleria, head, pulmonary unit, AIIMS, highlighted how indoor air pollution had emerged as another major killer amongst women using biomass for their cooking requirements. "Women in the Gujjar community suffer high incidence of cancer caused by indoor air pollution," Prof. Guleria explained.

The India-related data was calculated from the largest global database ever assembled using India-specific levels of baseline mortality and incidence of five leading causes of death in India and was released at a workshop organised by ICMR and CSE.

The 2010 GBD was produced by a rigorous scientific process involving 150 global experts led by the Institute of Health Metrics and Evaluation along with WHO and Harvard University.

CRITERIA POLLUTANTS

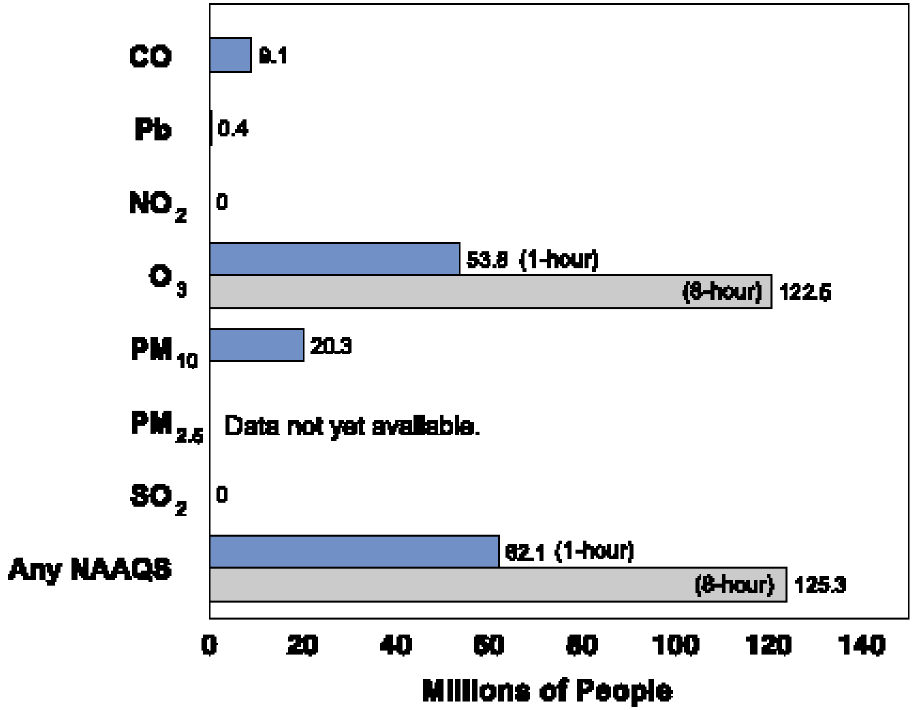
- Nitrogen Dioxide: NO_2
  - Brownish gas originates from combustion (N_2 in air is oxidized); NOx sum of NO, NO2, other oxides of N
- Ozone: Ground level O_3
  - Primary constituent of urban smog
  - Reaction of VOC + NOx in presence of heat +sun light
- Carbon Monoxide: CO
  - Product of incomplete combustion

CRITERIA POLLUTANTS

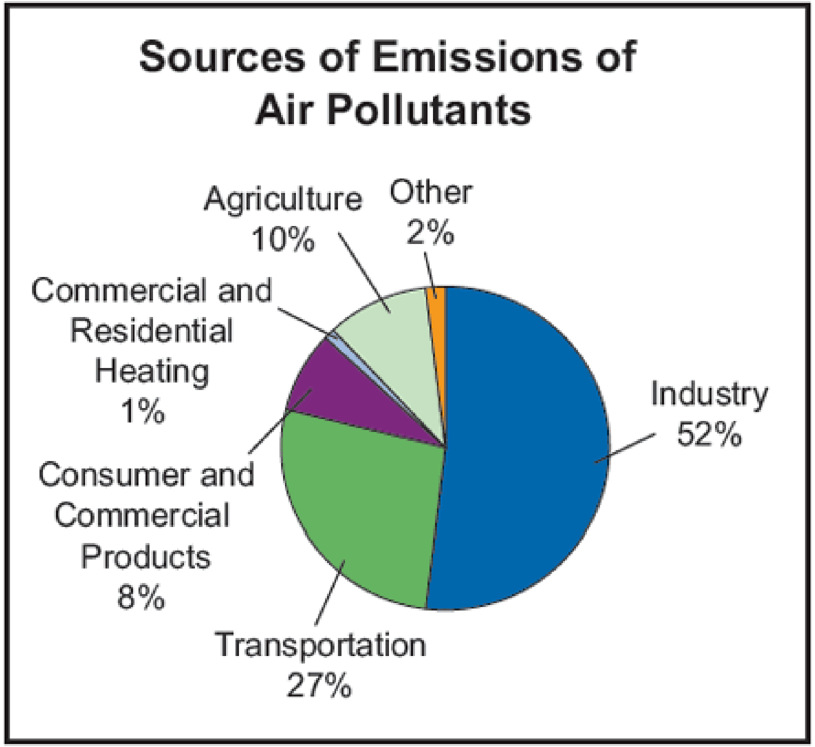
- Lead: Pb
  - tetraethyl lead – anti knock agent in gasoline
- Particulate Matter: PM10 (PM 2.5)
  - Small particles (size mentioned along with)
- Sulfur Dioxide: SO_2
  - formed when fuel (coal, oil) containing S is burned and metal smelting
  - precursor to acid rain along with NOx

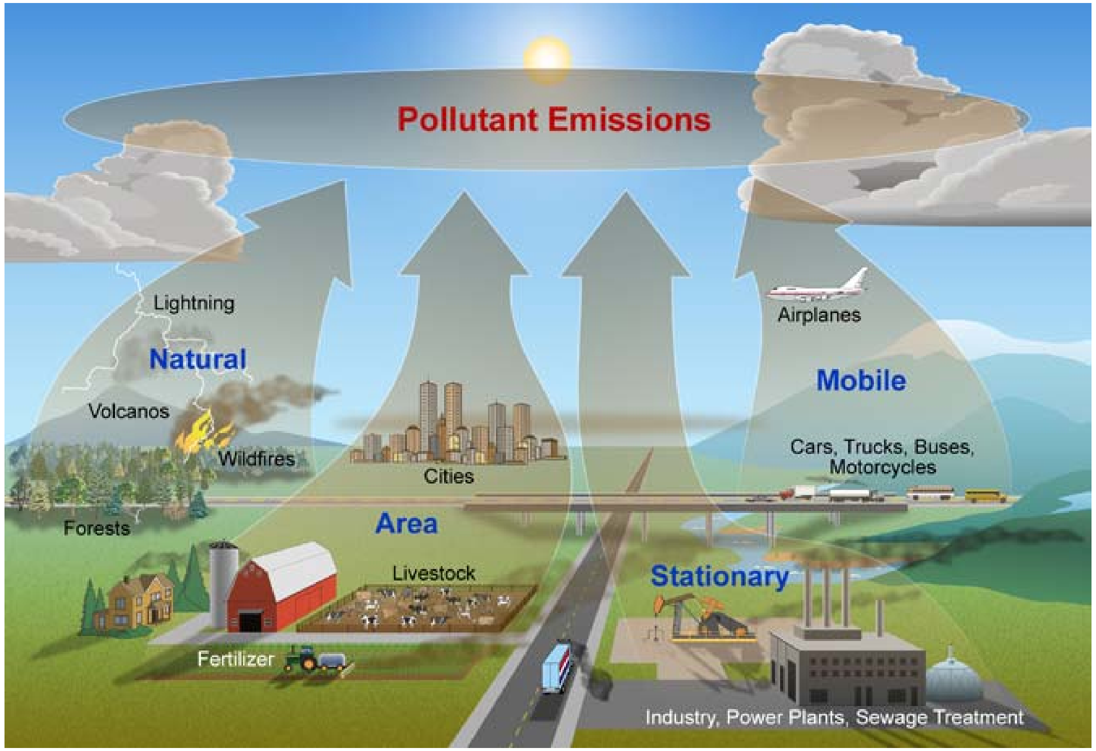
CRITERIA POLLUTANTS

Number of People Living in Counties with Air Quality Concentrations Above the Level of the NAAQS in 1999



POLLUTANTS: SOURCES





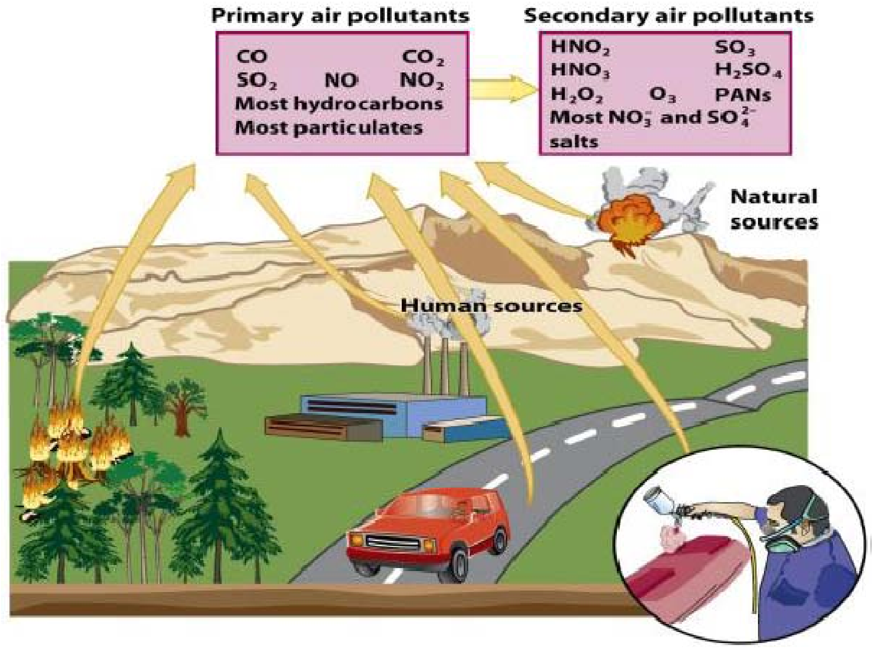
TYPES OF AIR POLLUTION

Primary Air Pollutant

Harmful substance; emitted directly into the atmosphere

Secondary Air Pollutant

Harmful substance formed when a primary air pollutant reacts with substances normally found in the atmosphere in the atmosphere or with other air pollutants



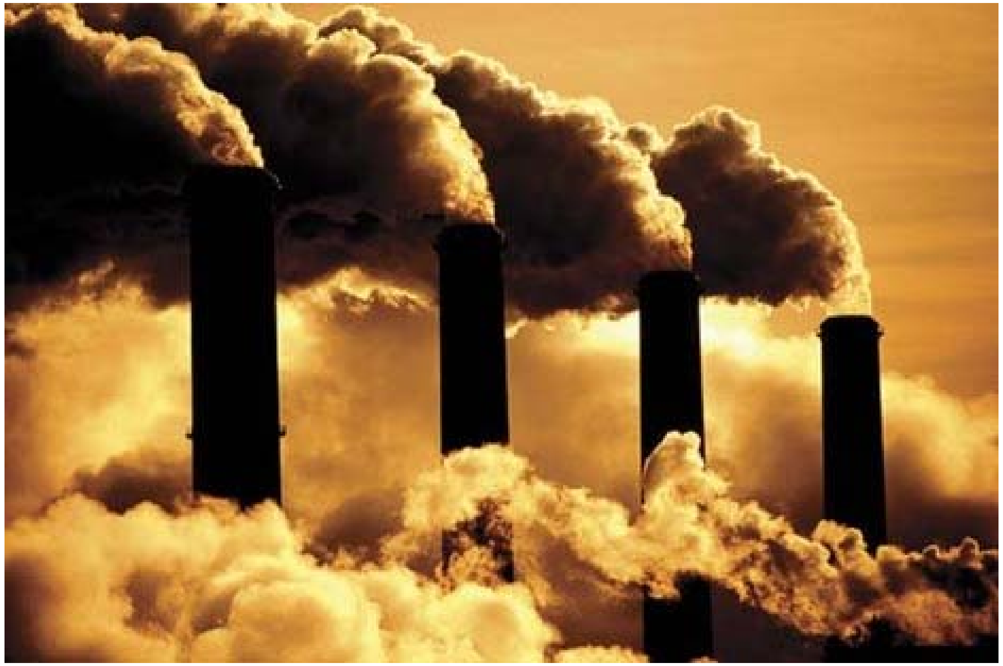
TYPES OF AIR POLLUTION

- **Aerosols**

- **Particulates solid phase**
  Dust, Ash, Fumes
- **Solid and liquid**
  Smoke (from combustion),
  Coastal aerosols
- **Liquid**
- **Aggregate gases** (sulfate, nitrate)
- **Gases**
  COx, SOx, NOx, etc

COMBUSTION POLLUTANTS

- VOCs, NOx,
- N-organics, Halo-organics
- Metals, CO

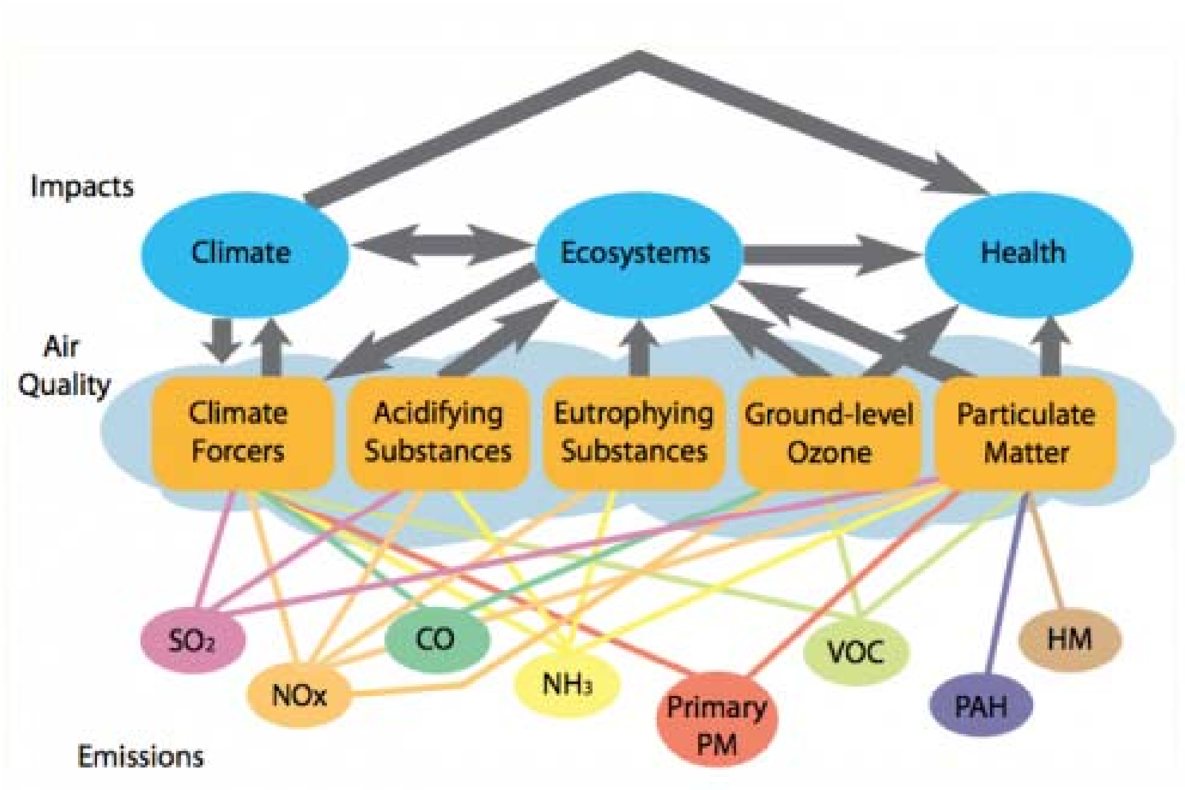


Sources

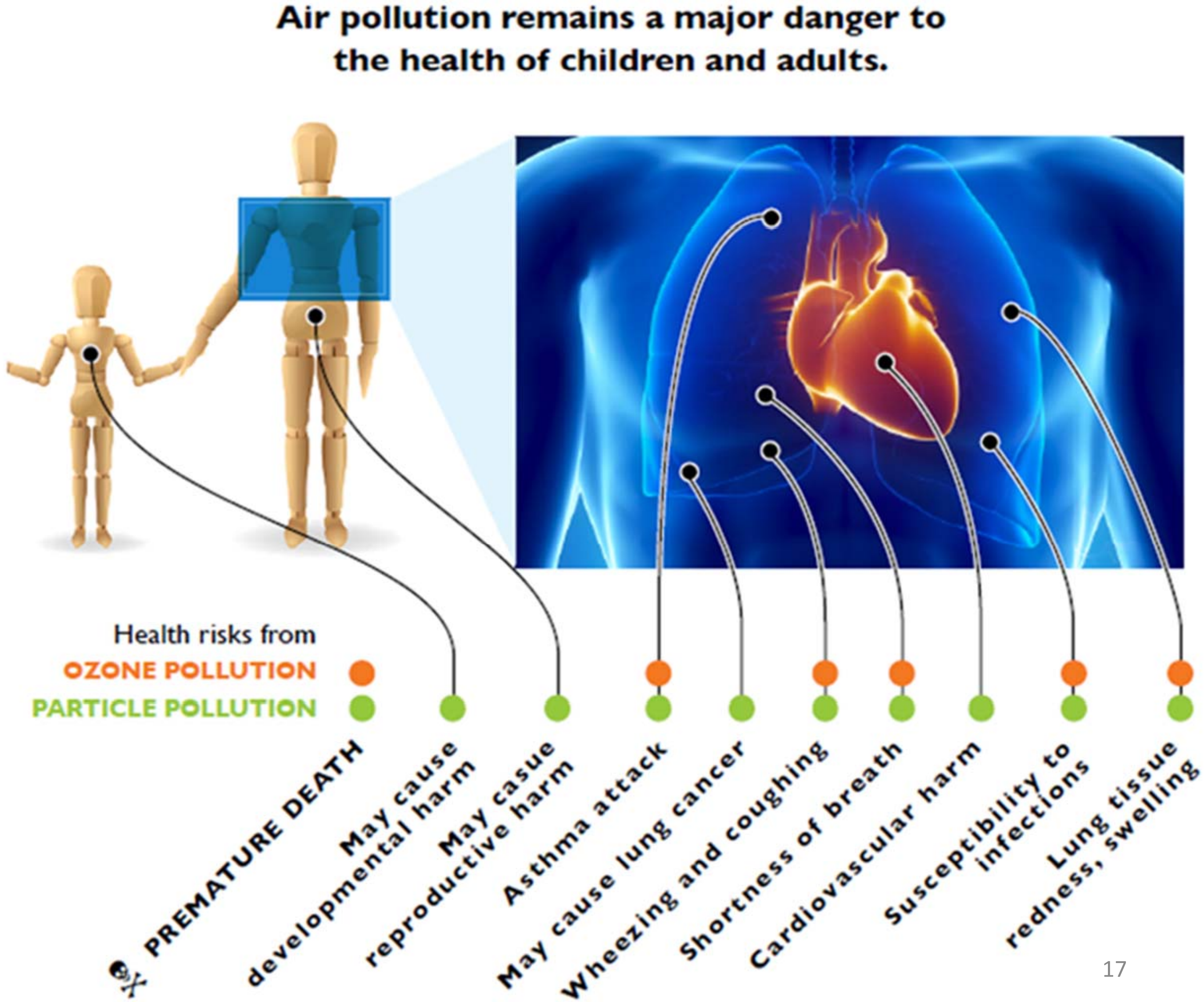
- Tobacco, Power plants
- Incinerators, Automobiles
- Industry

IMPACT

i. Greenhouse effect
ii. Ozone depletion
iii. Acidification
iv. Smog formation
v. Eutrophication
vi. HUMAN HEALTH
vii. Ecosystem health



HEALTH EFFECTS



- **Exposure to air pollution can cause both acute (short-term) and chronic (long-term) health effects.**
- **Acute effects are usually immediate and often reversible when exposure to the pollutant ends. Some acute health effects include eye irritation, headaches, and nausea.**
- **Chronic effects are usually not immediate and tend not to be reversible when exposure to the pollutant ends.**
    - **Some chronic health effects include decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants**

RESPIRATORY PROBLEMS

- Both gaseous and particulate air pollutants can have negative effects on the lungs.
- Solid particles can settle on the walls of the trachea, bronchi, and bronchioles.
- Continuous breathing of polluted air can slow the normal cleansing action of the lungs and result in more particles reaching the lower portions of the lung.
- Damage to the lungs can inhibit this process and contribute to bronchitis, emphysema, and cancer.

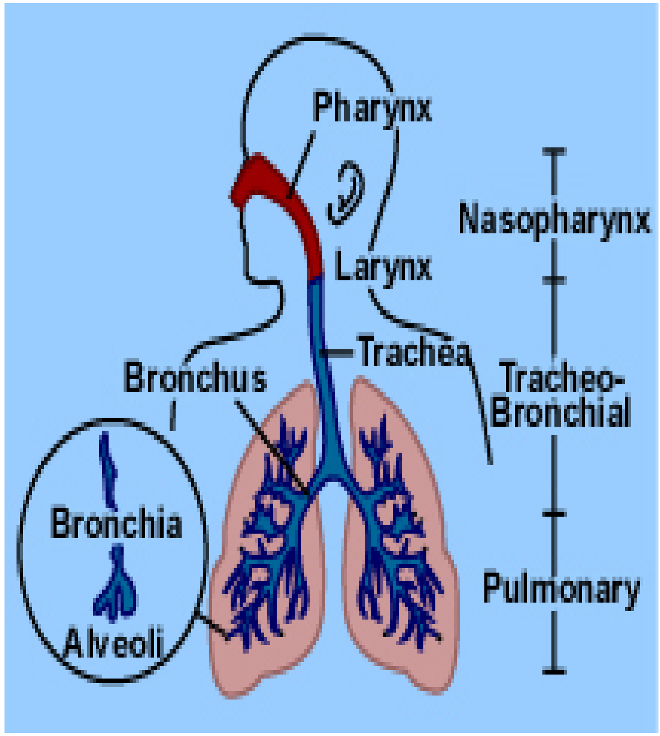
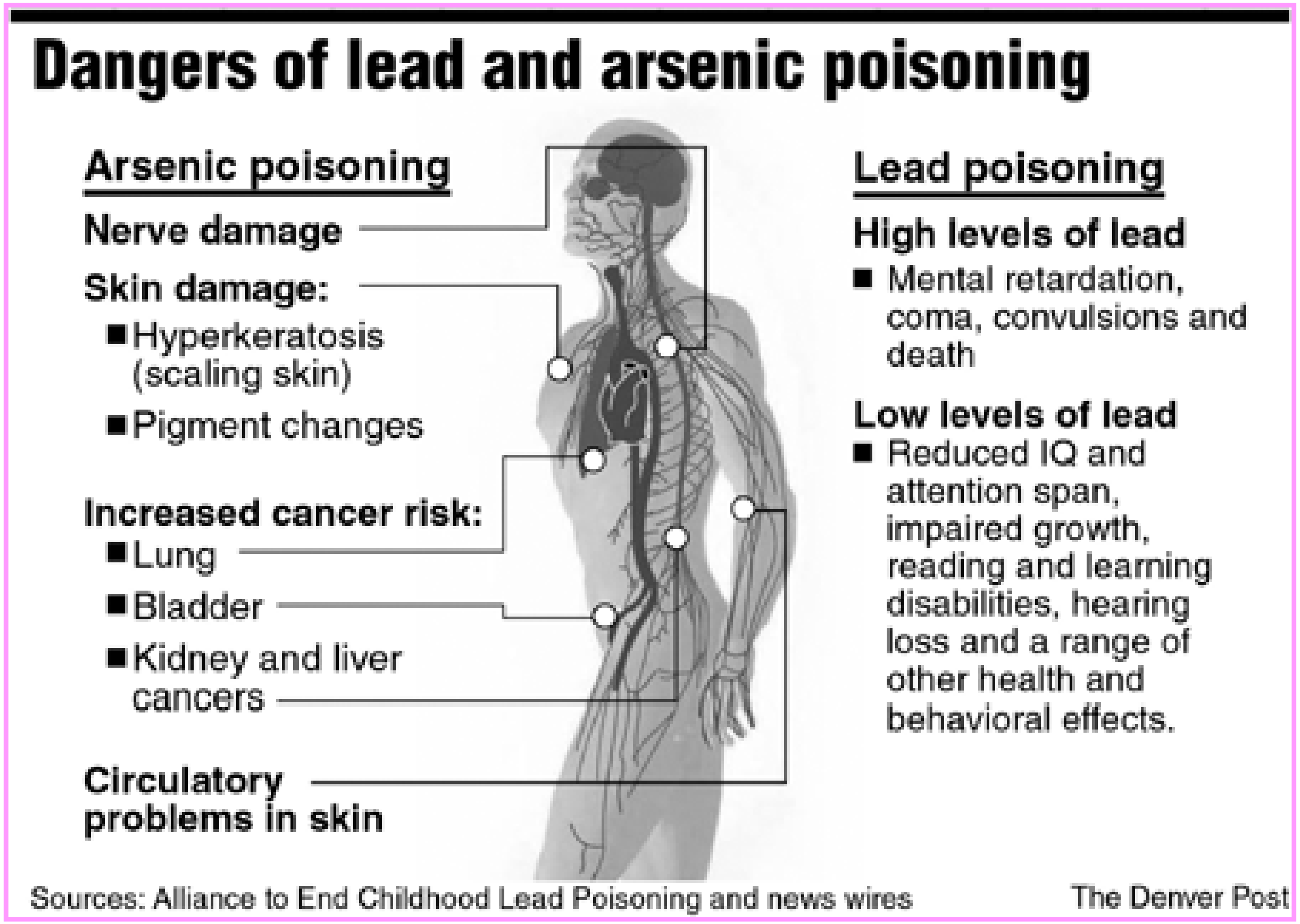
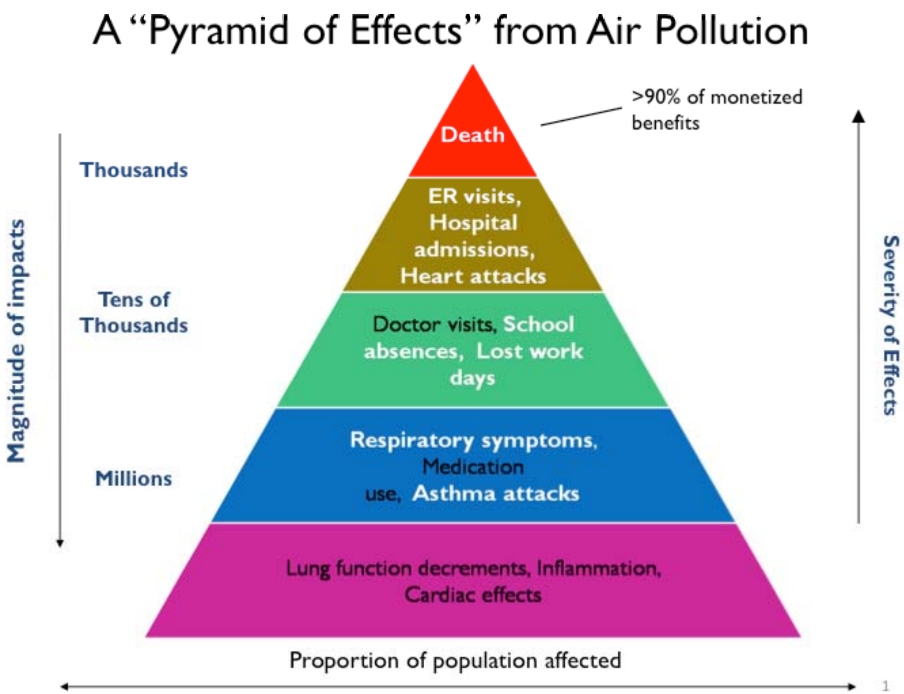


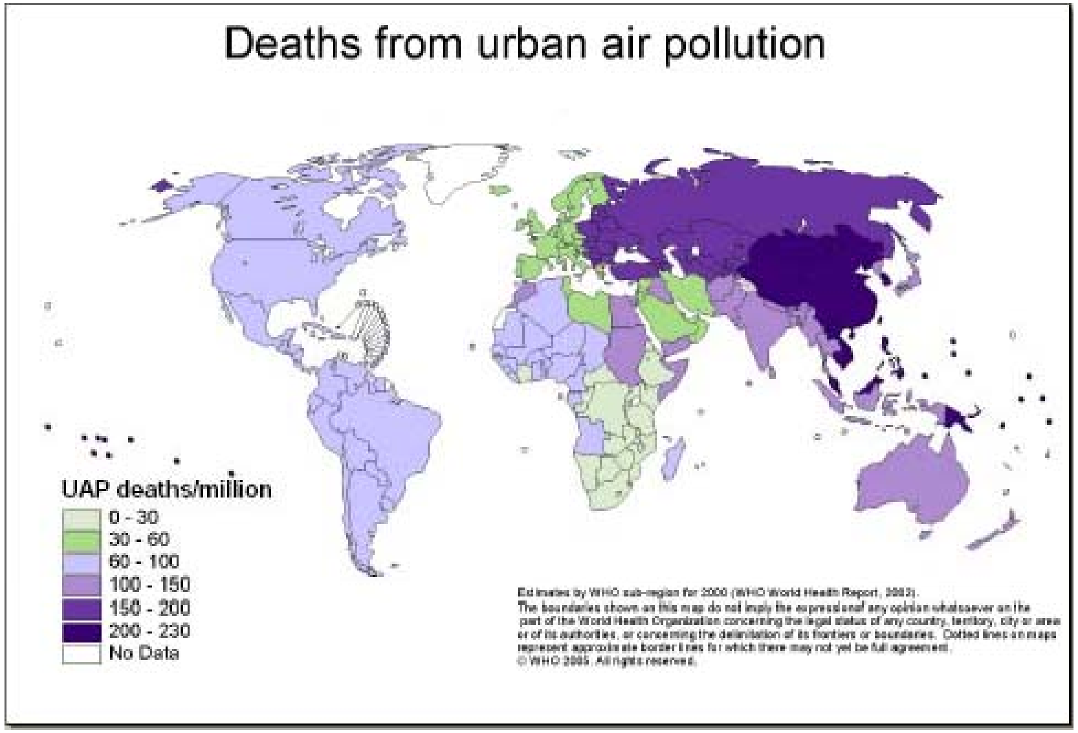
Table 1: Sources, Health and Welfare Effects for Criteria Pollutants				
Pollutant	**Description**	**Sources**	**Health Effects**	**Welfare Effects**
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death.	Contribute to the formation of smog.
Sulfur Dioxide (SO_2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO_2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O_3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

Table-2: Sources, Effects of Air Pollutants on Vegetables		
Pollutants	**Sources**	**Effects on Vegetables**
Aldehydes	Photochemical reactions	The upper portions of Alfalfa etc. will be affected to Narcosis if 250 ppm of aldehydes is present for 2 hrs duration.
Ozone (O_3)	Photochemical reaction of hydrocarbon and nitrogen oxides from fuel combustion, refuse burning, and evaporation from petroleum products.	All ages of tobacco leaves, beans, grapes, pine, pumpkins and potato are affected. Fleck, stipple, bleaching, bleached spotting, pigmentation, growth suppression, and early abscission are the effects.
Peroxy Acetyl Nitrate (PAN)	The sources of PAN are the same as ozone	Young spongy cells of plants are affected if 0.01 ppm of PAN is present in the ambient air for more than 6 hrs.
Nitrogen dioxide (NO2)	High temperature combustion of coal, oil, gas, and gasoline in power plants and internal combustion engines.	Irregular, white or brown collapsed lesion on intercostals tissue and near leaf margin. Suppressed growth is observed in many plants.
Ammonia & Sulfur dioxide	Thermal power plants, oil and petroleum refineries.	Bleached spots, bleached areas between veins, bleached margins, chlorosis, growth suppression, early abscission, and reduction in yield and tissue collapse occur.
Chlorine (Cl2)	Leaks in chlorine storage tanks, hydrochloric acid mists.	If 0.10 ppm is present for at least 2 hrs, the epidermis and mesophyll of plants will be affected.
Hydrogen fluoride, Silicon tetrafluoride	Phosphate rock processing, aluminum industry, and ceramic works and fiberglass manufacturing.	Epidermis and mesophyll of grapes, large seed fruits, pines and fluorosis in animals occur if 0.001 ppm of HF is present for 5 weeks.
Pesticides & Herbicides	Agricultural operations	Defoliation, dwarfing, curling, twisting, growth reduction and killing of plants may occur.
Particulates	Cement industries, thermal power plants, blasting, crushing and processing industries.	Affects quality of plants, reduces vigor & hardness and interferences with photosynthesis due to plugging leaf stomata and blocking of light.
Mercury (Hg)	Processing of mercury containing ores, burning of coal and oil.	Greenhouse crops, and floral parts of all vegetations are affected; abscission and growth reduction occur in most of the plants.


Dangers of lead and arsenic poisoning
Arsenic poisoning
Nerve damage
Skin damage:
■ Hyperkeratosis (scaling skin)
■ Pigment changes
Increased cancer risk:
■ Lung
■ Bladder
■ Kidney and liver cancers
Circulatory problems in skin
Lead poisoning
High levels of lead
■ Mental retardation, coma, convulsions and death
Low levels of lead
■ Reduced IQ and attention span, impaired growth, reading and learning disabilities, hearing loss and a range of other health and behavioral effects.
Sources: Alliance to End Childhood Lead Poisoning and news wires
The Denver Post

AIR POLLUTION





UNIT CONVERSION

There are two systems of unit in common:

Mass per unit volume: usually μg^{-3}. The mass of pollutant is expressed as a ratio to the volume of air.

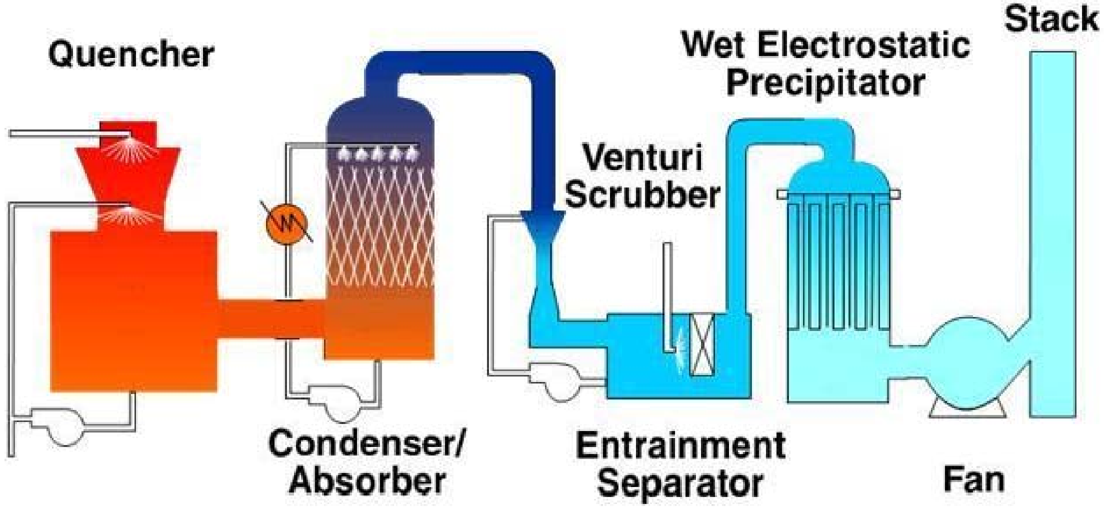
Since the volume of a given parcel of air is dependent upon the temperature and pressure at the time of sampling, the pollutant concentration expressed in these units should, strictly speaking, specify the conditions at the time of sampling.

UNIT CONVERSION

Volume mixing ratio: **usually ppm - parts per million (10^{-6}); or ppb - parts per billion (10^{-9}); or ppt - parts per trillion (10^{-12}). This is expressed as the ratio of its (pollutant) volume if segregated pure, to the volume of the air in which it is contained.**

Ideal gas behavior is assumed and thus the concentration is not dependent upon temperature and pressure as these affect both the pollutant and the air to the same extent. As a consequence of the gas laws, a gas present at a volume mixing ratio of 1 ppm is not only 1 cm^3 per 10^{-6} cm^3 of polluted air, it is also 1 molecule per 10^{-6} molecules and has a partial pressure of one millionth of the atmospheric pressure.

AIR POLLUTION CONTROL EQUIPMENT



Pollution Prevention and Abatement Handbook
WORLD BANK GROUP
Effective July 1998

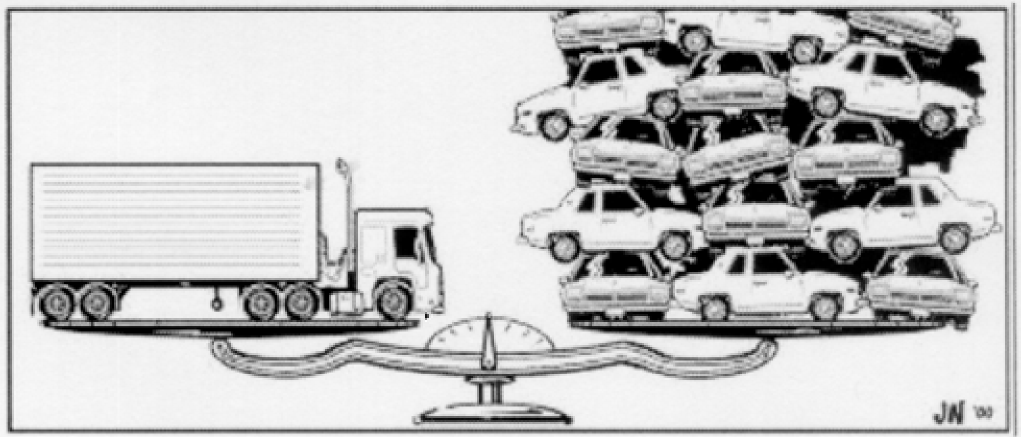
Airborne Particulate Matter: Pollution Prevention and Control

Airborne particulate matter (PM) emissions can be minimized by pollution prevention and emission control measures. Prevention, which is frequently more cost-effective than control, should be emphasized. Special attention should be given to pollution abatement measures in areas where toxics associated with particulate emissions may pose a significant environmental risk.

Approaches to Pollution Prevention

Fuel Cleaning

Reduction of ash by fuel cleaning reduces the generation of PM emissions. Physical cleaning of coal through washing and beneficiation can reduce its ash and sulfur content, provided that care is taken in handling the large quantities of solid and liquid wastes that are generated by the cleaning process. An alternative to coal cleaning is the co-firing of coal with higher and lower ash con-



One Diesel Truck Can Pollute As Much As 100 Cars.

AIR POLLUTION: CONTROL

- Air quality management sets the tools to control air pollutant emissions.
- Control measurements describe the equipment, processes or actions used to reduce air pollution.
- The extent of pollution reduction varies among technologies and measures.
- The selection of control technologies depends on environmental, engineering, economic factors and pollutant type.

Settling Chambers

- Cyclones (L)

Scrubbers (S)

- Venturi Scrubbers
- Wet Scrubbers
- Orifice Scrubbers
- Impigment Scrubbers

Fabric Filters (F)

ESPs

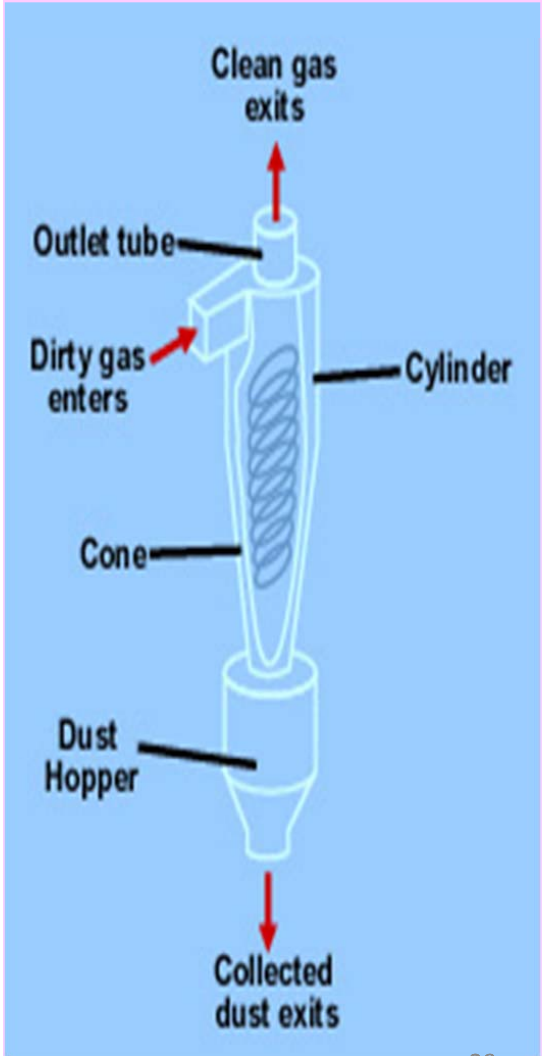
Stationary Source Control

- Absorption
- Adsorption
- Condensation
- Incineration

CYCLONES: CONSTRUCTION AND OPERATION

PRINCIPLE: The particles are removed by the application of a centrifugal force. The polluted stream is forced into a vortex. The motion of the gas exerts a centrifugal force on the particles, and they get deposited on the inner surface of the cyclones

- **The gas enters the inlet, and is forced into a spiral.**
- **At the bottom, the gas reverses direction and flows upwards.**
- **To prevent particles in the incoming stream from contaminating the clean gas, a vortex finder is provided to separate them. The cleaned gas flows out through the vortex finder**



CYCLONES

ADVANTAGES

- Cyclones have a low capital cost
- Reasonable high efficiency for specially designed cyclones.
- They can be used under almost any operating condition.
- Cyclones can be constructed of a wide variety of materials.
- There are no moving parts, so there are no maintenance requirements.

DISADVANTAGES

- They can not be used for small particles
- High pressure drops contribute to increased costs of operation.

CYCLONES

EFFECT OF CHANGE IN OPERATING CONDITIONS.

- The penetration is defined as

$$P_t = 1 - \eta_o$$

where η_o is the efficiency.

- The effect of changes in operating conditions can be determined from the table given below.

Variable	Change	Efficiency	Relationship
Gas Flow Rate	Increase	Increase	$Pt_2/Pt_1 = (Q_1/Q_2)^{0.5}$
Gas Viscosity	Increase	Decrease	$Pt_2/Pt_1 = (\mu_2/\mu_1)^{0.5}$
Density Difference	Increase	Increase	$Pt_2/Pt_1 = \left[\frac{(\rho_p - \rho_g)_1}{(\rho_p - \rho_g)_2}\right]^{0.5}$
Dust Loading	Increase	Increase	$Pt_2/Pt_1 = (L_1/L_2)^{0.18}$

Problem

- A cyclone with a flow rate of 150 m^3/min has an efficiency of 80%. Estimate the efficiency if the flow rate is doubled.

$Q1 = 150\ m^3/min$

$Q2 = 300\ m^3/min$

$Pt_1 = 100\% - 80\% = 20\%$

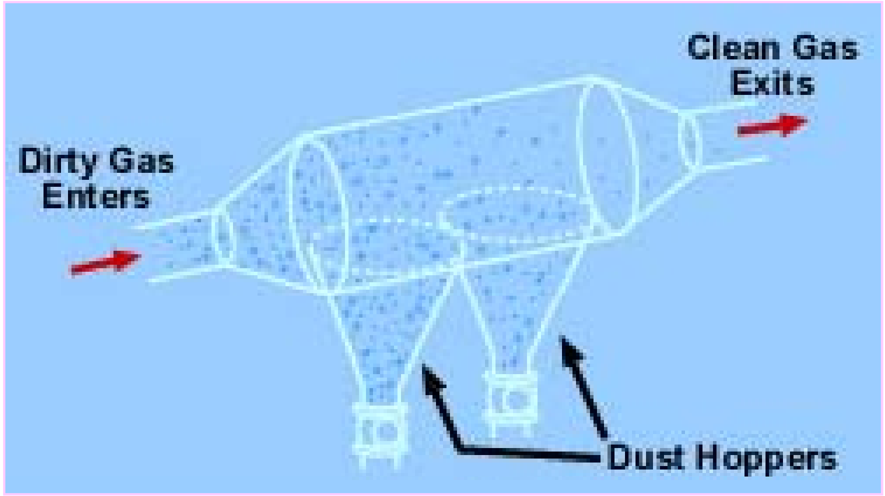
$$Pt_2/Pt_1 = (Q_1/Q_2)^{0.5}$$

Final Efficiency $= 1 - Pt_2$

$= 86\%$

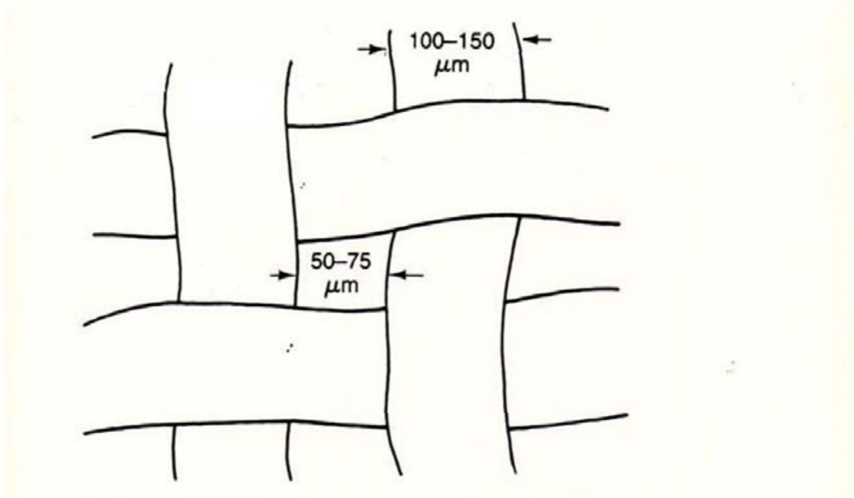
SETTLING CHAMBERS

- Settling chambers use the force of gravity to remove solid particles.
- The gas enters a chamber where the velocity of the gas is reduced. Large particles drop out of the gas and are collected in hoppers.
- Because settling chambers are effective in removing only larger particles, they are used in conjunction with a more efficient control device



FABRIC FILTERS

- **Principle**
  - **The filters retain particles larger than the mesh size**
  - **Air and most of the smaller particles flow through. Some of the smaller particles are retained due to interception and diffusion.**
  - **The retained particles cause a reduction in the mesh size.**
  - **The primary collection is on the layer of previously deposited particles.**



FABRIC FILTERS

ADVANTAGES

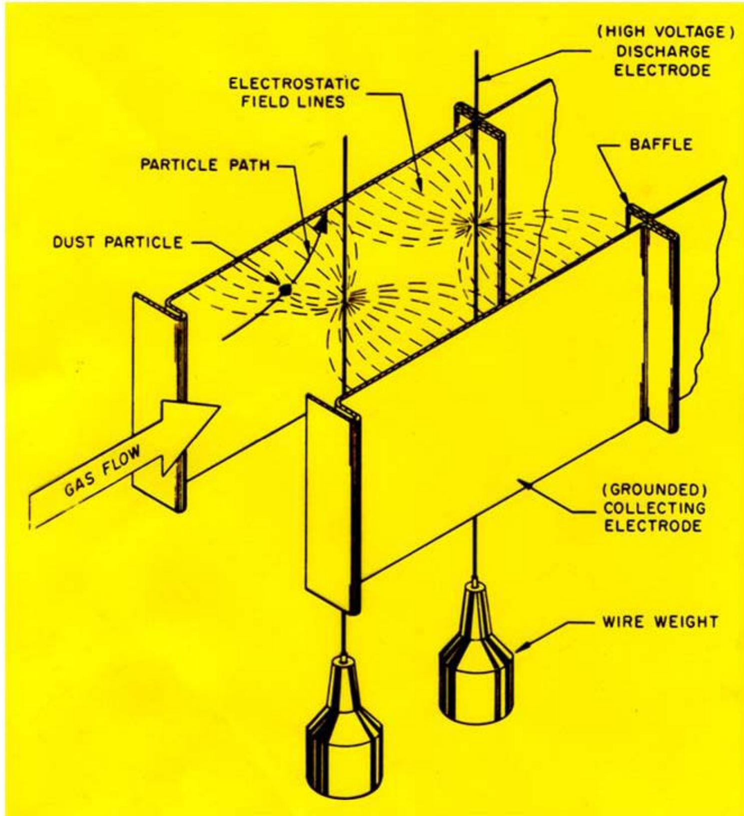
- Very high collection efficiency
- They can operate over a wide range of volumetric flow rates
- The pressure drops are reasonably low
- Fabric Filter houses are modular, and can be pre-assembled at the factory

DISADVANTAGES

- Fabric Filters require a large floor area.
- The fabric is damaged at high temperature.
- Ordinary fabrics cannot handle corrosive gases.
- Fabric Filters cannot handle moist gas streams
- A fabric filtration unit is a potential fire hazard

ESP PRINCIPLE

- **The particles in a polluted gas are charged by passing them through an electric field**
- **The charged particles are led through collector plates**
- **The collector plates have charges opposite to that on the particles**
- **The particles are attracted to these plates and are thus removed from the gas steam**



CONSTRUCTION/OPERATION

- **Charging Electrodes in the form of thin wires are placed in the path of the influent gas.**
- **The charging electrodes generate a strong electric field, which charges the particles as they flow through it.**
- **The collector plates get deposited with the particles. the particles are occasionally removed either by rapping or by washing the collector plates.**

ELECTROSTATIC PRECEPTOR/ESP

ADVANTAGES

- **Very high efficiency, generally of the order of 99.5-99.9%.**
- **Since the ESPs act on the particles and not on the air, they can handle higher loads with lower pressure drops.**
- **They can operate at higher temperatures.**
- **Operating costs are generally low.**

DISADVANTAGES

- **The initial capital costs are high.**
- **Although they can be designed for a variety of operating conditions, they are not very flexible to changes in the operating conditions, once installed.**
- **Particulate with high resistivity may go uncollected.**

ESP PRINCIPLE

- **The efficiency of removal of particles by an Electrostatic Precipitator is given by**

$$\eta = 1 - e^{\left(-\frac{wA}{Q}\right)}$$

η = fractional collection efficiency

w = drift velocity, m/min.

A = available collection area, m^2

Q = volumetric flow rate m^3/min

MIGRATION VELOCITY

$$W = \frac{q * Ep * C}{6\prod r\mu}$$

Where,

q = charge (Columbus)

Ep = collection field intensity (volts/m)

r = particle radius (m)

μ = dynamic viscosity of gas (Pa-S)

c = Cunningham correction factor

CUNNINGHAM CORRECTION FACTOR

$$c = 1 + \frac{6.21 * 10^{-4}(T)}{d_p}$$

where,

T = absolute temperature (°k)

d_p = diameter of particle (µm)

Problem

- An ESP is designed to treat 50,000 m^3/min with 97 % efficiency. Assuming an effective drift velocity of 2.5 m/min, calculate the required plate area and the number of plates. The plate size is 10 m by 5 m (height by length).

Efficiency of an Electrostatic Precipitator is given by $$\eta = 1 - e^{(-\frac{wA}{Q})}$$

$$A = -[(Q/w)*\ln(1 - \eta)]$$

$$\mathbf{A = 70{,}000\ m^2}$$

Number of plates = total area/plate area

= 1400

AIR POLLUTION MODELS:
PROBLEMS

FIXED-BOX MODELS: GENERAL MATERIAL BALANCE EQUATION

0 = (all flow rates in) – (all flow rates out)

0 = u W H b + q W L – u W H c

$$c = b + \frac{qL}{uH}$$

Where c is the concentration in the entire city

- **The equation indicates that the upwind concentration is added to the concentrations produced by the city.**
- **To find the worst case, you will need to know the wind speed, wind direction, mixing height, and upwind (background) concentration that corresponds to this worst case.**

Problem

A city has the following description: W = 5 km, L = 15 km, u = 3 m/s, H = 1000 m. The upwind, or background, concentration of CO is b = 5 μg/m^3. The emission rate per unit are is $q = 4 \times 10^{-6}$ g/s.m^2. what is the concentration c of CO over the city?

$$c = b + \frac{qL}{uH}$$

$$c = \frac{5\ \mu\text{g}}{\text{m}^3} + \frac{\left(4 \times 10^{-6}\ \frac{\text{g}}{\text{s}\,.\,\text{m}^2}\right)(15000\ \text{m})}{(3\ \text{m/s})(1000\ \text{m})}$$

$= 25\ \mu\text{g/m}^3$

GUASSIAN PLUME MODELS

The general equation to calculate the steady state concentration of an air contaminant in the ambient air resulting from a point source is given by:

$$C(x, y, z) = \frac{Q}{2\pi\sigma_y\sigma_z\bar{u}} \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2} + \frac{(z-H)^2}{\sigma_z^2}\right)\right]$$

Where;

c(x,y,z) = mean concentration of diffusing substance at a point (x,y,z) [kg/m^3]

x = downwind distance [m],

y = crosswind distance [m],

z = vertical distance above ground [m],

Q = contaminant emission rate [mass/s],

σ_y = lateral dispersion coefficient function [m],

σ_z = vertical dispersion coefficient function [m],

ū = mean wind velocity in downwind direction [m/s],

H = effective stack height [m].

GUASSIAN DISPERSON EQUATION

$$\Delta h = \frac{V_s D}{u}\left(1.5 + 2.68 \times 10^{-3} PD \frac{(T_s - T_a)}{T_s}\right)$$

This equation is only correct for the dimensions shown.

- Δh = plum rise in m
- V_s = stack exit velocity in m/s
- D = stack diameter in m
- u = wind speed in m/s
- P = pressure in millibars
- T_s = stack gas temperature in K
- T_a = atmospheric temperate in K

Correction is needed for stability classes other than C:

→ For A and B classes: multiply the result by 1.1 or1.2

→ For D, E, and F classes: multiply the result by 0.8 or 0.9

QUESTIONS

- What is pollution?
- What is air pollution?
- What are criteria pollutants?
- What are the methods / techniques used to control air pollution?
- What are the health effects of ozone, lead, and arsenic pollution?
- Write the principle, advantage and disadvantage of any three (e.g. large, small and fine particle separators) pollution control techniques/devices.

- PROBLEMS