Air Pollution

Causes of pollution

Pollution is the effect of undesirable changes in our surroundings that have harmful effects on plants, animals and human beings. Two basic problems result from the consumption of resources for our energy requirement.

i. **Resource Crunch**

   It refers to a particularly critical situation in which a particular resource becomes extremely scarce and overused, leading to its complete depletion or great shortage. In simple words, it is a shortage of an important resource.

ii. **Environmental degradation**

   It is the deterioration of the environment through depletion of resources such as, air, water and soil; the destruction of ecosystems; habitat destruction; the extinction of wild life and pollution.

Environmental degradation causes various pollution problems.

- Degradation in air environment causes air pollution problem.
- Degradation in noise environment causes noise pollution problem.
- Degradation in water environment causes water pollution problem.
- Dumping of solid waste on land causes land pollution problem.
- Pollution affects the flora and fauna in various ways causing ecological Pollution problem.

Nature of pollutants

In general, the pollutants can be classified depending on the degradation of them in the environment.

i. Easily degradable pollutants: Easily degradable, easily decomposed to simpler compounds by means of biodegradation and physico-chemical degradation. Most of the wastes released by living beings are biodegradable. Most of the wastes in our daily use are easily degradable.

ii. Difficultly degradable: These wastes are not easily degradable. They take a long time to degrade. Examples are plastic waste, chlorofluorocarbon, some pesticides etc.

iii. **Non-degradable:** These wastes are not degradable to simpler compounds. Examples are metallic waste. Toxic heavy metals like lead, mercury, cadmium, chromium, nickel etc. will always remain the same metal and hence toxic.

History of air pollution

The origin of air pollution on the earth can be traced from the times when man started using firewood as a means of cooking and heating. Hippocrates has mentioned air pollution in 400 BC. With the discovery and increasing use of coal, air pollution became more pronounced especially in urban areas. It was recognized as a problem 700 years ago in London in the form of smoke pollution, which prompted King Edward I to make the first antipollution law to restrict people from using coal for domestic heating in the year 1273. In the year 1300 another Act banning the use of coal was passed. Defying the law led to imposition of capital punishment. In spite of this air pollution became a serious problem in London during the industrial revolution due to the use of coal in industries. The earliest recorded major disaster was the 'London Smog' that occurred in 1952 that resulted in more than 4000deaths due to the accumulation of air pollutants over the city for five days. Pollutants are also found indoors from infiltration of polluted outside air and from various chemicals used or produced inside buildings. Both indoor and outdoor air pollution are equally harmful.

Atmospheric useful gases and air pollutants

Oxygen is required for human respiration (metabolic requirements). Oxygen is required for wild fauna in natural ecosystems and domestic animals used by man as food. Oxygen is a part of carbon dioxide; oxygen used for the photosynthetic activities of plants and prepares the first food of ecosystem. The atmosphere forms a protective shell over the earth. It is a complex dynamic system. If its nature is disrupted it affects all mankind. Most air pollutants have both global and regional effects. Living creatures cannot survive without air even for a span of a few minutes. To continue to support life, air must be kept clean. Major pollutants of air are created by industrial units that release various gases such as carbon dioxide, carbon monoxide and toxic fumes into the air. Air is also polluted by burning fossil fuels. The buildup of carbon dioxide which is known as greenhouse effect' in the atmosphere is leading to current global warming. The growing number of scooters, motorcycles, cars, buses and trucks which run on fossil fuel (petrol and diesel) is a major cause of air pollution in cities and along highways. Air pollution leads to acute and chronic respiratory diseases such as various lung infections, asthma and even cancer.

Types of air pollutants

Depending upon the occurrence, chemical nature and physical state etc. the air pollutants are classified into following category: **Natural air pollutants and Anthropogenic air pollutants**

Natural air pollutants

The various air pollutants are occurring naturally. But their occurrence is few and far between so as to cause significant air pollution problem.

- **Lightening:** Atmospheric nitrogen and oxygen can react at high temperature of lightening and cause nitrogen oxide and nitrogen dioxide pollution
- **Forest fire:** Fire remnants of forest have the air pollution in the form of particulates, unburnt hydrocarbon, carbon monoxide and some toxic pollutants
- **Volcanic eruptions:** Molten lava has the sulfur converted to sulfur dioxide that causes SO_2 pollution

Anthropogenic air pollutants

- **Use of fossil fuel** like coal, crude oil, petroleum products cause air pollution in the form of particulate pollution, SO_2 , NO_X , CO, CO_2 and other toxic pollutants
- **Vehicular pollution:** particulate, CO and NO_X
- **Mineral excavation and beneficiation:** particulate pollution
- **Transportation:** SO_2 , NO_X , CO, CO_2 and other hazardous pollutants
- **Loading and unloading:** Particulate pollution

Primary air pollutants

• Pollutants that are emitted directly from identifiable sources are produced both by natural and anthropogenic events.

Examples are SO_2, NO, NO_2, CO, CO_2, Particulates classified as PM 10 (Particle size.<= 10 micron) PM 2.5 (Particle size .<= 2.5 micron)

Secondary air pollutants

• Pollutants that are formed by atmospheric chemical combination among the primary pollutants and others

Examples are acid rain, photochemical smog [Peroxy Acyl Nitrate (PAN)] etc.

Hydrocarbons + NO_X + Sunlight = PAN

Gaseous air pollutants

These include gases mostly released from burning of fossil fuels. These are oxides of carbon (CO, CO_2), oxides of sulfur (SO_2, SO_3), oxides of nitrogen (NO, NO_2).

Besides other common gaseous pollutants include are hydrogen sulfide (H_2S), ozone (O_3) and ammonia (NH_3) etc.

Particulate air pollutants

These include dust particles from various activities. When the particle remains in suspension in air is generally referred to as suspended particulate matter (SPM) and is a common particulate pollution. The SPM is usually known as particulate matter (PM) or aerosol. The finer particulates are important from health point of view. Particulate size less than 10 microns is known as PM10 and size less than 2.5 micron is known as PM2.5. These small size PM values are enlisted in National ambient air quality standards (NAAQS).

Besides technical names PM10 and PM2.5, the popular names of particulate

• Aerosol: General term for particles suspended in air.

• Mist: Aerosol consisting of liquid droplets Sulfuric acid mist

• Dust: Aerosol consisting of solid particles that are blown into Dust storm the air or are produced from larger particles by grinding them down

• Smoke: Aerosol consisting of solid particles or a mixture of solid Cigarette smoke, smoke and liquid particles produced by chemical reaction such from burning garbage as fires

• Fume: Generally means the same as smoke but often applies Zinc/lead fumes specifically to aerosols produced by condensation of hot vapors of metals.

• Plume: Geometrical shape or form of the smoke coming out of a chimney

• Fog: Aerosol consisting of water droplets

• Smog: Term used to describe a mixture of smoke and fog

Dispersion of pollutants into atmosphere

One of the most effective and commonly adopted processes of air pollution control is to disperse air pollutants into atmosphere which acts as a great sink. The pollutants are effectively diluted and the ground level concentration comes to an acceptable level. The various factors affecting this dispersion process are mentioned here under.

Meteorological factors affecting dispersion process are

- Wind speed
- Wind direction
- Topography
- Humidity of air
- Atmospheric pressure
- Atmospheric lapse rate
- Cloud cover
- Solar insolation
- Atmospheric temperature

Anthropogenic factors affecting dispersion process are

- Position of the emitting source
- Height of the stack
- Concentration of the pollutant in flue gas
- Flue gas temperature
- Flue gas flow

- Flue gas velocity

Effects of air pollution

i. Effects on living organisms

Our respiratory system has a number of mechanisms that helps in protecting us from air pollution. The hair in our nose filters out larger particles. The sticky mucus in the lining of the upper respiratory tract captures smaller particles and dissolves some gaseous pollutants. When the upper respiratory system is irritated by pollutants sneezing and coughing expel contaminated air and mucus. Prolonged smoking or exposure to air pollutants can overload or break down these natural defenses causing or contributing to diseases such as lung cancer, asthma, chronic bronchitis and emphysema. Elderly people, infants, pregnant women and people with heart disease, asthma or other respiratory diseases are especially vulnerable to air pollution. Cigarette smoking is responsible for the greatest exposure to carbon monoxide. Exposure to air containing even 0.001 percent of carbon monoxide for several hours can cause collapse, coma and even death. As carbon monoxide remains attached to hemoglobin in blood for a long time, it accumulates and reduces the oxygen carrying capacity of blood. This impairs perception and thinking, slows reflexes and causes headaches, drowsiness, dizziness and nausea. Carbon monoxide in heavy traffic causes headaches, drowsiness and blurred vision. Sulfur dioxide irritates respiratory tissues. Chronic exposure causes a condition similar to bronchitis. It also reacts with water, oxygen and other material in the air to form sulfur-containing acids. The acids can become attached to particles which when inhaled are very corrosive to the lungs.

Nitrogen oxides especially NO_2 can irritate the lungs, aggravate asthma or chronic bronchitis and also increase susceptibility to respiratory infections such as influenza or common colds. Suspended particles aggravate bronchitis and asthma. Exposure to these particles over a long period of time damages lung tissue and contributes to the development of chronic respiratory disease and cancer. Many volatile organic compounds such as (benzene and formaldehyde) and toxic particulates (such as lead, cadmium) can cause mutations, reproductive problems or cancer. Inhaling ozone, a component of photochemical smog, causes coughing, chest pain, breathlessness and irritation of the eye, nose and the throat.

ii. Effects on plants

When some gaseous pollutants enter leaf pores they damage the leaves of crop plants. Chronic exposure of the leaves to air pollutants can breakdown the waxy coating that helps prevent excessive water loss and leads to damage from diseases, pests, drought and frost. Such exposure interferes with photosynthesis and plant growth, reduces nutrient uptake and causes leaves to turn yellow, brown or drop off altogether. At a higher concentration of Sulphur dioxide majority of the flower buds becomes stiff and hard. They eventually fall from the plants, as they are unable to flower. Prolonged exposure to high levels of several air pollutants from smelters, coal burning power plants and industrial units as well as from cars and trucks can damage trees and other plants.

iii. Effects on materials

Every year air pollutants cause damage worth billions of rupees. Air pollutants break down exterior paint on cars and houses. All around the world air pollutants have discolored irreplaceable monuments, historic buildings, marble statues, etc.

iii. Effects of air pollution on the stratosphere

The upper stratosphere consists of considerable amounts of ozone, which works as an effective screen for ultraviolet light. This region called the ozone layer extends up to 60 km above the surface of the earth. Though the ozone is present up to 60 km its greatest density remains in the region between 20 to 25 km. The ozone layer does not consist of solely ozone but a mixture of other common atmospheric gases. In the densest ozone layer there will be only one ozone molecule in 100,000 gas molecules. Therefore, even small changes in the ozone concentration can produce dramatic effects on life on earth. The total amount of ozone in a 'column' of air from the earth's surface up to an altitude of 50 km is the total column ozone. This is recorded in Dobson Units (DU), a measure of the thickness of the ozone layer by an equivalent layer of pure ozone gas at normal temperature and pressure at sea level. This means that 100DU=1mm of pure ozone gas at normal temperature and pressure at sea level. Ozone is a form of oxygen with three atoms instead of two. It is produced naturally from the photo dissociation of oxygen gas molecules in the atmosphere. The ozone thus formed is constantly broken down by naturally occurring processes that maintain its balance in the ozone layer. In the absence of pollutants, the creation and breakdown of ozone are purely governed by natural forces, but the presence of certain pollutants can accelerate the breakdown of ozone. Though it was known earlier that ozone shows fluctuations in its concentrations which may be accompanied sometimes with a little ozone depletion, it was only in 1985 that the large scale destruction of the ozone also called the Ozone Hole came into limelight when some British researchers published measurements about the ozone layer. Soon after these findings a greater impetus was given to research on the ozone layer, which convincingly established that CFC's were leading to its depletion. These CFCs (chlorofluorocarbons) are extremely stable, non-flammable, non-toxic and harmless to handle. This makes them ideal for many industrial applications like aerosols, air conditioners, refrigerators and fire extinguishers. Many cans, which give out foams and sprays, use CFCs. (eg: perfumes, room fresheners etc.) CFCs are also used in making foams for mattresses and cushions, disposable Styrofoam cups, glasses, packaging material for insulation, cold storage etc. India has signed the Montreal Protocol in 1992, which aims to control the production and consumption of Ozone Depleting Substances. Changes in the ozone layer have serious implications for mankind.

i. **Effects on human health:**

Sunburn, cataract, aging of the skin and skin cancer are caused by increased ultra-violet radiation. It weakens the immune system by suppressing the resistance of the whole body to certain infections like measles, chicken pox and other viral diseases that elicit rash and parasitic diseases such as malaria introduced through the skin.

ii. **Food production:**

Ultra violet radiation affects the ability of plants to capture light energy during the process of photosynthesis. This reduces the nutrient content and the growth of plants. This is seen especially in legumes and cabbage. Plant and animal planktons are damaged by ultra- violet radiation. In zooplanktons (microscopic animals) the breeding period is shortened by changes in radiation. As planktons form the basis of the marine food chain a change in their number and species composition influences fish and shell fish production.

iii. **Effect on materials:**

Increased UV radiation damages paints and fabrics, causing them to fade faster.

iv. **Effect on climate:**

Atmospheric changes induced by pollution contribute to global warming, a phenomenon which is caused due to the increase in concentration of certain gases like carbon dioxide, nitrogen oxides, methane and CFCs. Observations of the earth have shown beyond doubt that atmospheric constituents such as water vapour, carbon dioxide, methane, nitrogen oxides and Chloro Fluro Carbons trap heat in the form of infra-red radiation near the earth's surface. This is known as the '**Greenhouse Effect'**. The phenomenon is similar to what happens in a greenhouse. The glass in a greenhouse allows solar radiation to enter which is absorbed by the objects inside. These objects radiate heat in the form of terrestrial radiation, which does not pass out through the glass. The heat is therefore trapped in the greenhouse increasing the temperature inside and ensuring the luxuriant growth of plants. There could be several adverse effects of global warming.

- With a warmer earth the polar ice caps will melt causing a rise in ocean levels and flooding of coastal areas.

- In countries like Bangladesh or the Maldives this would be catastrophic. If the sea level rises by 3m., Maldives will disappear completely beneath the waves.

- The rise in temperature will bring about a fall in agricultural produce.

- Changes in the distribution of solar energy can bring about changes in habitats. A previously productive agricultural area will suffer severe droughts while rains will fall in locations that were once deserts. This could bring about changes in the species of natural plants, agricultural crops, insects, livestock and micro-organisms.

- In the Polar Regions temperature rises caused by global warming would have disastrous effects. Vast quantities of methane are trapped beneath the frozen soil of Alaska. When the permafrost melts the methane that will be released can accelerate the process of global warming.

National Ambient Air Quality Standard (NAAQS)-2009

It was notified on 16-11-2009 by government of India. Some of the important air quality parameters are mentioned in the table

Pollutant parameter	unit	Averaging	Concentration in ambient air	
			Industrial/residential area	Ecologically sensitive area
Sulfur dioxide	$\mu g/m^3$	24 hourly	80	80
Nitrogen dioxide	$\mu g/m^3$	24 hourly	80	80
Particulate PM10	$\mu g/m^3$	24 hourly	100	100
Particulate PM2.5	$\mu g/m^3$	24 hourly	60	60
Carbon monoxide	$\mu g/m^3$	8 hourly	2000	2000
ozone	$\mu g/m^3$	8 hourly	100	100

Air quality monitoring

India does not presently have a well-established system of monitoring air pollution. When air quality monitoring began in India in the late 1960s planners focused only on a few pollutants namely sulfure dioxide, nitrogen oxides and suspended particulate matter. Pollutants such as carbon monoxide and lead were monitored only on a limited scale. The threat from other air toxins such as benzene, ozone, and other small particulates is not known as these are not monitored at all. A database on ambient air quality in Indian cities has been prepared by the monitoring networks of the National Environmental Engineering Research Institute (NEERI), Nagpur. The Central Pollution Control Board (CPCB) initiated its own national Ambient Air Quality Monitoring (NAAQM) program in 1985. Data to the NAAQM is supplied by the respective state pollution control boards, which is then transmitted to the CPCB. Experts feel that the present air quality-monitoring network cannot capture the true profile of urban air pollution due to the lack of adequate monitoring stations. Moreover, critical toxins have still not been included in the list of pollutants to be monitored.

Air pollution Control

Air pollution can be controlled by two fundamental approaches: preventive techniques and effluent control. One of the effective means of controlling air pollution is to have proper equipment in place. This includes devices for removal of pollutants from the flue gases though scrubbers, closed collection recovery systems through which it is possible to collect the pollutants before they escape, use of dry and wet collectors, filters, electrostatic precipitators, etc. Providing a greater height to the stacks can help in facilitating the discharge of pollutants as far away from the ground as possible. Industries should be located in places so as to minimize the effects of pollution after considering the topography and the wind directions. Substitution of raw material that causes more pollution with those that cause less pollution can be done.

i. Gaseous pollutant control measure

Gaseous pollutants are mostly chemical in nature. Chemical methods are commonly used in this control measures.

Condensation: It involves removing heat from hot gas stream to reduce the temperature so that some of the pollutant like ammonia get condensed and so can be easily removed.

Absorption: It involves transfer of pollutant from gas stream to liquid stream. Examples are removal of ammonia by water, hydrogen sulphide by sodium hydroxide etc.

Adsorption: It involves transfer of pollutant from gas stream to solid surfaces having desirable surface properties.

Flue gas desulphurization: It involves removal of SO_2 from the flue gas NO_X emission control: It involves various techniques for the removal of NO and NO_2 (NO_X).

Incineration: It is a high temperature combustion process. It is suitable for destruction of hazardous substances.

ii. **Particulate pollution control measure**

Because of the particle dynamics, the control measures are entirely different from gaseous pollutant. The output results are viewed with the collection efficiency of particular equipment. The control measures are settling chambers, cyclone separators, bag filters, electrostatic precipitators and scrubbers.

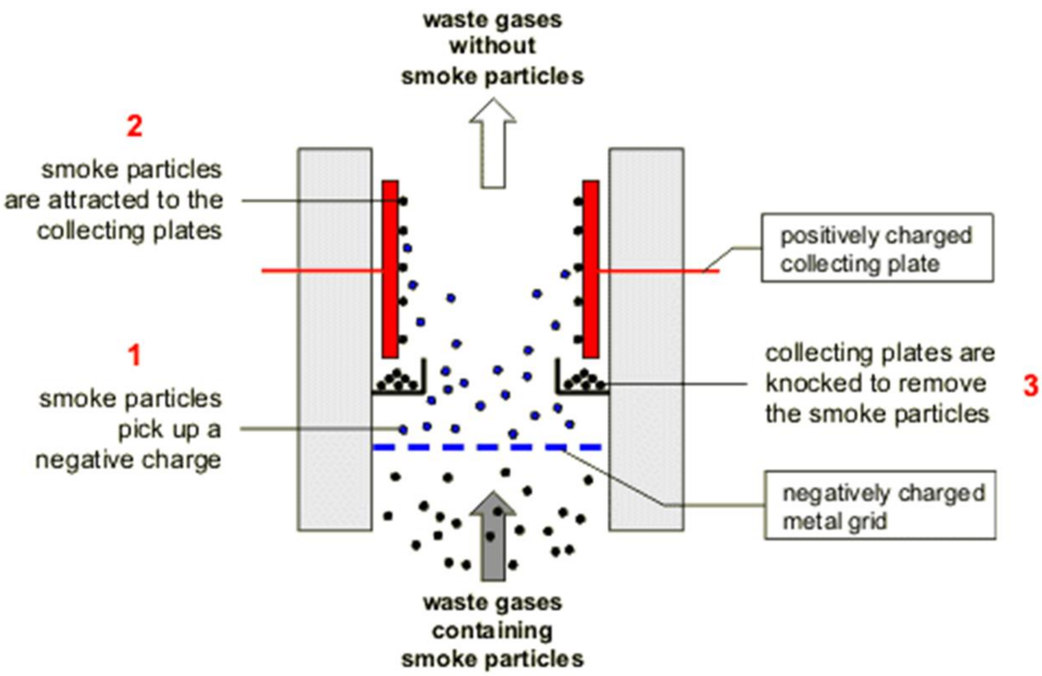
Particulate pollution control

Pollution control methods	Removal mechanism	Particle size removal	efficiency	Design parameters
Gravity settling chamber	Gravity	>50 µ	>50%	-
Cyclone separator	Centrifugal forces and gravity	>5 µ	>85%	-
Bag filter	Interception, impaction and diffusion	< 0.1 µ	>99%	Air to cloth or filtering ratio 0.5 to 5 m/minute
Electrostatic precipitator (ESP)	Electrostatic forces of attraction	< 0.1 µ	>99%	

A. Electrostatic precipitator (ESP)

An electrostatic precipitator is a filtration device that removes fine particles, like dust and smoke, from a flowing gas using the force of an induced electrostatic charge minimally impeding the flow of gases through the unit.

The operation of electrostatic precipitators is fairly simple. The dirty flue gas escaping through the smokestack is passed through two electrodes. The shape these electrodes depends on the type of electrostatic precipitator used, but they can be metal wires, bars, or plates inside a pipe or the smokestack itself. One of the electrodes is charged with a high negative voltage, and this plate causes particulates inside the smoke to obtain a negative charge as they pass by this electrode. Further along the pipe, the second electrode carries a similarly high positive voltage. Based solely on the fact that opposite charges attract, the negatively charged soot particles are pulled towards the positive electrode and stick to it. Occasionally these plates must be cleaned to remove the accumulated soot and dispose of it into a hopper. The soot and ash collected from coal burning power plants in this manner is referred to as fly ash.



Example 1: Compute the plate area of ESP handling a flow of 3600 m^3/min. The particulate velocity is taken as 0.15 m/s and efficiency of ESP as 99%.

Solution: $\eta = 1 - \exp(-Aw/Q)$

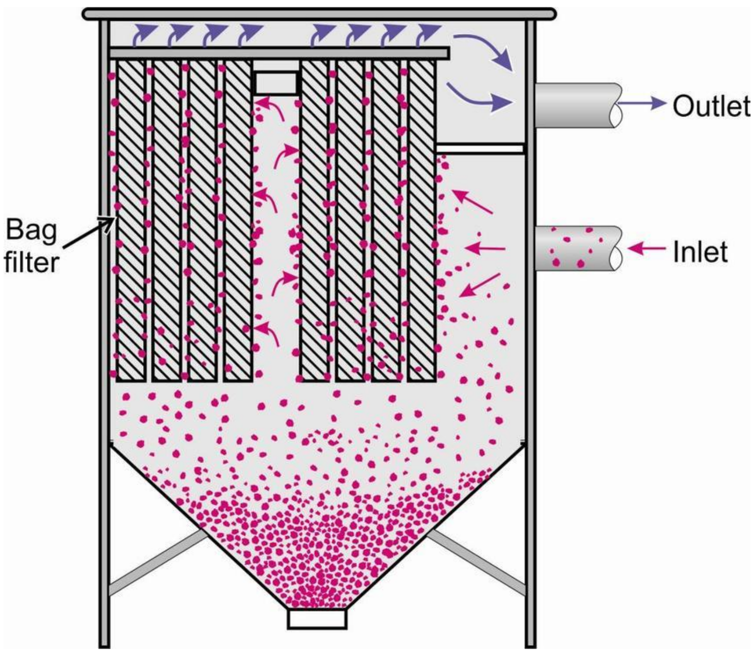
[A = Total area of the plates; w = Settling velocity; Q = Flow rate]

0.99 = 1- exp (-0.15 X A/3600/60)

A = Area of plate = 1842.1 m

B. Baghouse filters

One of the most efficient devices for removing suspended particulates is an assembly of fabric-filter bags, commonly called a baghouse. A typical baghouse comprises an array of long, narrow bags—each about 25 cm (10 inches) in diameter—that are suspended upside down in a large enclosure. Dust-laden air is blown upward through the bottom of the enclosure by fans. Particulates are trapped inside the filter bags, while the clean air passes through the fabric and exits at the top of the baghouse. A fabric-filter dust collector can remove very nearly 100 percent of particles as small as 1 μm and a significant fraction of particles as small as 0.01 μm.



Example 2: A bag house is to be constructed using bags of 0.25 m diameter and 6 m long. It is to receive 15 m^3 /s of air. Assuming the filtration rate of 2.2 m/min. Determine the no bags required in the bag house.

Solution: Total filtration area required= gas flow rate/filtration rate

$= 15 \times 60\ m^3/min / 2.2\ m/min = 409.1\ m^2$

Area of one bag = $\pi \times D \times H = 3.14 \times 0.25 \times 6 = 4.71\ m^2$

No. of bags required in bag house = 409.1/4.71 = 86.8 that is 87 bags