UNIT V- Pollution & its mitigation methods

Pollution & its mitigation methods: Causes, effects and controlling methods of air and water pollution.

Air Pollution

Air pollution is a main environmental issue nowadays. The air pollution is a mixing of many harmful substances like dust, mist, smoke and color in the fresh air and pollutes the environment. It causes many damages, human health disorders, reducing the quality of life, etc. The composition of Air is given below:

Nitrogen	*78%*
Oxygen	*21%*
Argon	*less than 1%*
Carbon dioxide	*0.037%*
Water vapour	*Remaining*
Ozone, Helium and ammonia	*Trace amount*

But, recently this composition is getting disturbed because of

1. Rapid industrialization
2. Rapid growth in population
3. Fast urbanization
4. Growth of vehicles on the roads and
5. Activities of human beings have disturbed the natural balance of the atmosphere.

Sources of Air Pollution

1. **Natural sources** of pollution are those that are caused due to natural phenomena.
   Ex: Volcanic eruptions, Forest fires, Biological decay, Pollen grains, Marshes, Radioactive materials.
2. **Artificial sources** are those which are created by man.
   Ex: Thermal power plants, Vehicular emissions, Fossil fuel burning, agricultural activities etc.

Causes of Air Pollution

The major causes of Air Pollution are discussed below:

1. **Fossil fuel based power plants** – Power plants that are mainly dependent on fossil fuels is one of the major causes of air pollution. Using fossil fuels for thermal generation and other purposes lead to harmful effects in air and atmosphere. Combustion of these fuels result in production of excessive carbon dioxide. This further adds up to problems like global warming and greenhouse effect.
2. **Ever-increasing transportation vehicles** – Vehicles are growing more and more every day on the roads. All vehicle engines burn fuel and produce dangerous air pollutants including nitrogen oxides, carbon monoxide, PM (particulate matter), etc., that are responsible for various risky diseases in children as well as adults.
3. **Urbanization** – The ever-increasing urbanization is making way for more cities, more power plants, industries and traffic. All these sources are constantly contributing in air pollution turning it into a major problem today.

4. **Emission of greenhouse gases from various sources** –Many dangerous gases like methane, nitrous oxide, carbon dioxide, etc., are emitted on combustion of coal, natural gas and oil in various factories & industries.
5. **Forest fires & big volcanic eruptions** – Forest fires and huge volcanic eruptions are major natural causes for air pollution. Many poisonous gases enter into air due to forest fires and volcanic eruptions, thus, causing air pollution.
6. **Mining Procedures** – During the mining procedures, big machines are used for extracting minerals that are buried deep down inside the Earth. These extractions' processes of mining give out a lot of dust and dangerous particles that cause air pollution on a large scale.
7. **Household products causing air pollution** – There are many household products that contribute to air pollution inside our homes. Products like wall paints, detergents, floor cleaners, etc., contribute to air pollution by emitting chemicals that are harmful for our health.
8. **Dust constantly adding up to air** – Dust is continuously adding up to atmosphere causing air pollution. There is not one single reason for this 'dust addition' to air ' Processes like construction, driving on rough semi-constructed roads, etc., are some of the many reasons that add dust to air, making it polluted and unsafe.
9. **Dependence on wood-fuel for cooking –** Many people use wood fuel for cooking. This is also an important cause of air pollution. Wood fuel emissions contain PM **(**particulate matter), carbon monoxide, formaldehyde, nitrogen dioxide and other dangerous gases

Major Air Pollutants:

1. **Primary pollutants** are those that are directly emitted in the atmosphere in the harmful form.
   Ex: CO, NO, CO_2, SO_2 etc.

2. **Secondary pollutants** are those that are formed by reacting with other components or some basic component of the atmosphere to form new pollutants.Ex: Oxides of Nitrogen NOx (NO_2 or NO_3) react with moisture in the atmosphere to give Nitric acid

Effects of Air Pollutants

Sr No	Name of pollutant	Property	Source	Effects
1	**Carbon monoxide**	It is a colourless, odourless gas that is poisonous to human and animals	It is formed by incomplete combustion of carbon containing fuels.	It combines with haemoglobin of blood to form carboxy-haemoglobin. It reduces the ability of red blood cells to carry oxygen to body cellsand tissues. This leads to headache and anemia. At high Levels it causes coma, irreversible brain damage and death.
2	**Nitrogen Dioxide**	It is a reddish-brown irritating gas that causes photochemical smog. In the atmosphere, it gets converted into nitric acid (HNO_3)	It is caused by burning fossil fuels in industries and power plants. .	Lung irritation and damage. Environmental effects involve acid deposition leading to damage of trees, lakes, soil and ancient monuments. NO_2 can damage fabrics.
3	**Sulphur Dioxide**	It is a colourless and irritating gas	It is formed by combustion of sulphur containing fossil fuels such as coal	Breathing problems for healthy people, reduced visibility and acid deposition on trees, lakes, soils and monuments leading to their deterioration and adverse effect on aquatic life.
4	**Suspended Particulate Matter (SPM)**:	Includes a variety of particles and droplets (aerosols)	Human sources for SPM include burning coal in power and industrial units, burning diesel and other fuels in vehicles, agriculture, unpaved roads, construction, etc.	Nose and throat irritation, lung damage, bronchitis, asthma, reproductive problems and cancer
5	**Photochemical smog**	It is a browinsh smoke that frequently forms on clear, sunny days over large cities with significant amounts of automobile traffic	due to chemical reactions among nitrogen oxides and hydrocarbons in the presence of sunlight	Breathing problems, cough, eye, nose and throat irritation, heart diseases, reduced resistance to colds and pneumonia. Damage to plants and trees. Additionally, Smog reduces visibility.
6	**Ozone**	It is a highly reactive gas with an unpleasant odor occurring in the stratosphere where it protects mankind from the harmful ultra-violet rays from the Sun. However on earth, it is a pollutant.	It occurs on earth due to reaction between Volatile Organic Compounds (VOCs) and Nitrogen Oxides. It moderates the climate	Skin cancer

***Carbon dioxide**:*

Carbon dioxide (CO_2) is released into the atmosphere by respiration, burning of fossil fuels for energy, and by decomposition of limestone during the manufacture of cement. It is also emitted during volcanic eruptions. Carbon dioxide gas is confined to troposphere only. Normally it forms about 0.03 per cent by volume of the atmosphere. With the increased use of fossil
fuels, a large amount of carbon dioxide gets released into the atmosphere. Excess of CO_2 in the air is removed by green plants and this maintains an appropriate level of CO_2 in the atmosphere. Green plants require CO_2 for photosynthesis and they, in turn, emit oxygen,thus maintaining the delicate balance. Deforestation and burning of fossil fuel increases the CO_2 level and disturb the balance in the atmosphere. The increased amount of CO_2 in the air is mainly responsible for global warming.

Global Warming and Greenhouse Effect

About 75 % of the solar energy reaching the earth is absorbed by the earth's surface, which increases its temperature. The rest of the heat radiates back to the atmosphere. Some of the heat is trapped by gases such as carbon dioxide, methane, ozone, chlorofluorocarbon compounds (CFCs) and water vapour in the atmosphere. Thus, they add to the heating of
the atmosphere. This causes global warming.

Just as the glass in a greenhouse holds the sun's warmth inside, atmosphere traps the sun's heat near the earth's surface and keeps it warm. This is called *natural greenhouse effect* because it maintains the temperature and makes the earth perfect for life. In a greenhouse, solar radiations pass through the transparent glass and heat up the soil and the plants. The warm soil and plants emit infrared radiations. Since glass is opaque to infrared radiations (thermal region), it partly reflects and partly absorbs these radiations. This mechanism keeps the energy of the Sun trapped in the greenhouse. Similarly, carbon dioxide molecules also trap heat as they are transparent to sunlight but not to the heat radiation. If the amount of carbon dioxide crosses the delicate proportion of 0.03 per cent, the natural greenhouse balance may get disturbed.

Carbon dioxide is the major contributor to global warming. Besides carbon dioxide, other greenhouse gases are methane, water vapour, nitrous oxide, CFCs and ozone.

Methane is produced naturally when vegetation is burnt, digested or rotted in the absence of oxygen. Large amounts of methane are released in paddy fields, coal mines, from rotting garbage dumps and by fossil fuels.

Chlorofluorocarbons (CFCs) are man-made industrial chemicals used in air conditioning etc. CFCs are also damaging the ozone layer.

Nitrous oxide occurs naturally in the environment. In recent years, their quantities have increased significantly due to the use of chemical fertilizers and the burning of fossil fuels. If these trends continue, the average global temperature will increase to a level which may lead to melting of polar ice caps and flooding of low lying areas all over the earth. Increase in the global temperature increases the incidence of infectious diseases like dengue, malaria, yellow fever, sleeping sickness etc

Oxides of Sulphur

$SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$

The reaction is promoted by Ozone and Hydrogen Peroxide

$SO_2\ (g) + O_3(g) \rightarrow 2SO_{3(g)} + O_{2(g)}$

$SO_{2(g)} + H_3O_2\ (l) \rightarrow H_2SO_4(aq)$

Oxides of Nitrogen

N_2 and O_2 are main constituents of air

At high altitudes when lightning strikes they (N2 and O2) combine to form oxides of Nitrogen

$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$

$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2\,(g)}$

Rate of production of NO_2 is faster when nitric oxide reacts with ozone in the stratosphere

$2NO_{(g)} + O_{3(g)} \rightarrow 2NO_{2\,(g)} + O_{2(g)}$

The irritant red haze in the traffic and congested places is due to oxides of nitrogen. Higher concentrations of NO_2 damage the leaves of plant and retard the rate of photosynthesis.NO_2 is a lung irritant that can lead to an acute respiratory disease in children. It is toxic to living tissues also.NO_2 is also harmful to various textile fibers and metals.

Acid Rain

Normally rain water has a pH of 5.6 due to presence of H+ ions formed due to reaction of rain water with carbon dioxide present in the atmosphere.

$H_2O_{(l)} + CO_{2(g)} \rightarrow H_2CO_{3\,(aq)}$

$H_2CO_3\,(aq) \rightleftharpoons H^+\,(aq) + HCO_3^-{}_{(aq)}$

$2SO_{2(g)} + O_{2(g)} + 2H_2O_{(l)} \rightarrow 2H_2SO_{4(aq)}$

$4NO_{2(g)} + O_{3(g)} + 2H_2O_{(l)} \rightarrow 4HNO_{3\,(aq)}$

Smog-A mixture of smoke, gases, and chemicals, especially in cities, that makes the atmosphere difficult to breathe and harmful for health

Photochemical Smog

$NO_2\,(g) \xrightarrow{h\gamma} NO(g) + O\,(g)$

$O + O_2 \rightarrow O_3$

$NO(g) + O_{3\,(g)} \rightarrow NO_{2\,(g)} + O_{2(g)}$

NO_2 and O_3 react with un-burnt hydrocarbons in the polluted air to produce chemicals such as

Formaldehyde

$3CH_4 + 2O_3 \rightarrow 3CH_2{=}O + 3H_2O$

Acrolein

$CH_2{=}CHCH{=}O$

Peroxyacetyl Nitrate(PAN)

CH_3COONO_2

O

Effects of photochemical smog

The common components of photochemical smog are ozone, nitric oxide, acrolein, formaldehyde and peroxyacetyl nitrate (PAN).

Photochemical smog causes serious health problems. Both ozone and PAN act as powerful eye irritants. Ozone and nitric oxide irritate the nose and throat and their high concentration causes headache, chest pain, dryness of the throat, cough and difficulty in breathing. Photochemical smog leads to cracking of rubber and extensive damage to plant life. It also causes corrosion of metals, stones, building materials, rubber and painted surfaces.

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Photochemical smog control

Many techniques are used to control or reduce the formation of photochemical smog. If we control the primary precursors of photochemical smog, such as NO_2 and hydrocarbons, the secondary precursors such as ozone and PAN, the photochemical smog will automatically be reduced. Usually **catalytic converters** are used in the automobiles, which prevent the release of nitrogen oxide and hydrocarbons to the atmosphere. **Certain plants e.g., Pinus, Juniparus, Quercus, Pyrus and Vitis can metabolise nitrogen oxide** and therefore, their plantation could help in this matter.

Stratospheric Pollution

Formation and Breakdown of Ozone

Ozone in the stratosphere is a product of UV radiations acting on dioxygen (O_2) molecules. The UV radiations split apart molecular oxygen into free oxygen (O) atoms.

These oxygen atoms combine with the molecular oxygen to form ozone.

$O_2(g) \xrightarrow{UV} O(g) + O(g)$

$O(g) + O_2(g) \xrightarrow{UV} O_3(g)$

Ozone is thermodynamically unstable and decomposes to molecular oxygen. Thus, a dynamic equilibrium exists between the production and decomposition of ozone molecules.

In recent years, there have been reports of the depletion of this protective ozone layer because of the presence of certain chemicals in the stratosphere. The main reason of ozone layer depletion is believed to be the release of chlorofluorocarbon compounds (CFCs), also known as freons.These compounds are nonreactive, non flammable, non toxic organic molecules and therefore used in refrigerators, air conditioners, in the production of plastic foam and by the electronic industry for cleaning computer parts etc. Once CFCs are released in the atmosphere, they mix with the normal atmospheric gases and eventually reach the stratosphere. In stratosphere, they get broken down by powerful UV radiations, releasing chlorine free radical.

$CF_2Cl_2(g) \longrightarrow Cl(g) + CF_2Cl(g)$ (i)

The chlorine radical then react with stratospheric ozone to form chlorine monoxide radicals and molecular oxygen.

$Cl(g) + O_3(g) \rightarrow ClO(g) + O_2(g)$ (ii)

Reaction of chlorine monoxide radical with atomic oxygen produces more chlorine radicals.

$ClO(g) + O(g) \rightarrow Cl(g) + O_2(g)$ (iii)

The chlorine radicals are continuously regenerated and cause the breakdown of ozone. Thus, CFCs are transporting agents for continuously generating chlorine radicals into the stratosphere and damaging the ozone layer.

The Ozone Hole

In 1980s atmospheric scientists working in Antarctica reported about depletion of ozone layer commonly known as ozone hole over the South Pole. It was found that a unique set of conditions was responsible for the ozone hole.In summer season, nitrogen dioxide and methane react with chlorine monoxide (reaction iv) and chlorine atoms (reaction v) forming chlorine sinks, preventing much ozone depletion, whereas in winter, special type of clouds called polar stratospheric clouds are formed over Antarctica. These polar stratospheric clouds provide surface on which chlorine nitrate formed (reaction iv) gets hydrolysed to form hypochlorous acid (reaction (vi)). It also reacts with hydrogen chloride produced as per reaction (v) to give molecular chlorine.

$ClO(g) + NO_2(g) \rightarrow ClONO_2(g)$ (iv)

$Cl(g) + CH_4(g) \rightarrow CH_3(g) + HCl(g)$ (v)

$ClONO_2(g) + H_2O(g) \rightarrow HOCl(g) + HNO_3(g)$ (vi)

$ClONO_2(g) + HCl(g) \rightarrow Cl_2(g) + HNO_3(g)$ (vii)

When sunlight returns to the Antarctica in the spring, the sun's warmth breaks up the clouds and HOCl and Cl_2 are photolysed by sunlight, as given in reactions (viii) and (ix).

$HOCl(g) \xrightarrow{h\nu} OH(g) + Cl(g)$ (viii)

$Cl_2(g) \xrightarrow{h\nu} 2Cl(g)$ (ix)

The chlorine radicals thus formed, initiate the chain reaction for ozone depletion as described earlier.

Effects of Depletion of the Ozone Layer

With the depletion of ozone layer, more UV radiation filters into troposphere. UV radiations lead to ageing of skin, cataract, sunburn, skin cancer, killing of many phytoplanktons, damage to fish productivity etc. It has also been reported that plant proteins get easily affected by UV radiations which leads to the harmful mutation of cells.

It also increases evaporation of surface water through the stomata of the leaves and decreases the moisture content of the soil. Increase in UV radiations damage paints and fibres , causing them to fade faster.

Air quality standards as per WHO (World Health Organization)

	Annual Mean	**24 hour mean**	**8 hour mean**	**1 hour mean**	**10 minute mean**
Particulate Matter					
PM 2.5	10 $\mu g/m^3$ annual mean	25 $\mu g/m^3$ 24-hour mean			
PM10	20 $\mu g/m^3$ annual mean	50 $\mu g/m^3$ 24-hour mean			
Ozone O3			100 $\mu g/m^3$ 8 hour mean		
Nitrogen Dioxide	**40** $\mu g/m^3$ annual mean			200 $\mu g/m^3$ 1 hour mean	
Sulfur Dioxide SO_2		20 $\mu g/m^3$ 24 hour mean			500 $\mu g/m^3$ 10 minute mean

PM2.5 and PM10 denotes particulate matter size in less than 2.5 and 10 µm respectively.

WHO air quality guidelines and interim targets for particulate matter: annual mean concentration

	PM10 (μg/m3)	PM2.5 (μg/m3)	Basis for the selected level
Interim target-1 (IT-1)	70	35	These levels are associated with about a 15% higher long-term mortality risk relative to the AQG level.
Interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% [2–11%] relative to theIT-1 level
Interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce the mortality risk by approximately 6% [2-11%] relative to the -IT-2 level.
Air quality guideline (AQG)	**20**	**10**	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to PM2.5

Preventive measures to control Air Pollution

The solutions/preventive measures to control Air Pollution are discussed below:

1. **Using renewable energy/non-conventional sources of energy-** renewable energy sources like sunlight, wind, water, air, etc., produce energy without causing air pollution. Therefore, the use of renewable energy should be enhanced and encouraged.
2. **Protecting forests and planting more tress** –reforestation will help in setting up a forest on land that had treeson it sometime back; the process of afforestation will help establish a forest on land that has no forest or trees on it for a long period of time. In addition to this, planting trees near the industrial areas will also help in the prevention of air pollution.
3. **Using Solar energy based equipments** –Using solar panels, solar cooker, solar lamps, lights, solar cars, batteries, inverter, energy collectors and similar other useful solar equipment can help prevent air pollution at a significant level because solar devices do not pollute the air.
4. **By proper vehicular maintenance** –Vehicles that are in proper condition produce lesser harmful emissions than those which are in bad condition. Vehicular pollution can be checked by regular tune up of engines: replacement of more polluting old vehicles; installing catalytic converters: by engine modification to have fuel efficient (lean)mixtures to reduce CO and hydrocarbon emissions: and slow and cooler burning of fuels to reduce NOx emission(Honda Technology)
5. **Arranging clean and efficient garbage disposable system** – Efficient garbage disposal systems should be arranged at various public places so that the garbage can be disposed in the right way.
6. **Adopting measures to control dust** – Efficient and appropriate measures should be taken to control dust emission during various activities like mining, building constructions, road constructions, etc. Dust particles add up to atmosphere and degrade the quality of air, causing air pollution.
7. **Encouraging environmental audits at regular intervals** –The environmental audits are done in an organized document form so that a track record can be established for necessary measures.
8. **Supporting & encouraging the use of human-made products & handicraft items** – Human-made products and handicraft items are environmental friendly and help control air pollution. These items are made manually and do not require a processing through factories or industries. Thus, obviously, there are no chances of harmful emissions.
9. **Using unadulterated vehicular fuels** –.unadulterated fuels are comparatively safer than the adulterated fuels as the former produce lesser harmful emissions.
10. **Creating awareness among people** – Creating awareness for air pollution is very necessary. If people stay aware about air pollution, its causes and dangerous effects, they will definitely make individual efforts to combat and prevent air pollution.
11. **Using mass transport system, bicycles etc**
12. **Shifting to less polluting (clean) fuels(hydrogen gas)**
13. Removing NOx during the combustion process and controlling the flow of air and fuel in industrial boilers.
14. Using biological filters and bio-scrubbers

15. Using low sulfur coal in industries
16. Removing sulfur from coal (by washing or with the help of bacteria)
17. Modification of process and /or equipment's.
18. Reduction of pollution at source.

Reduction of Air Pollution at Source (Pollution Control in Factories)

Gaseous Pollutants:

Gaseous pollutants can be reduced by physical adsorption on porous solid materials like activated charcoal, silica gel, fuller's earth etc. Effluent gases can be absorbed in liquid absorbent, e.g SO_2 absorbed in ammonia solution. They can be removed by condensation which is carried out by cooling medium in tubes where the gases in contact condense and can be collected thereafter. Combustion can be used to reduce pollution by burning the pollutants in combustion equipment's at optimal conditions of oxygen and temperature.

Particulate Matter

Many devices are available now a days, choice of which depends on characteristics of particulate, flow rate, collection, efficiency, costs, etc.

Cyclones:

Cyclone separators or simply cyclones are separation devices (dry scrubbers) that use the principle of inertia to remove particulate matter from flue gases.

Cyclone separator is one of many air pollution control devices known as pre-cleaners since they generally remove larger pieces of particulate matter.

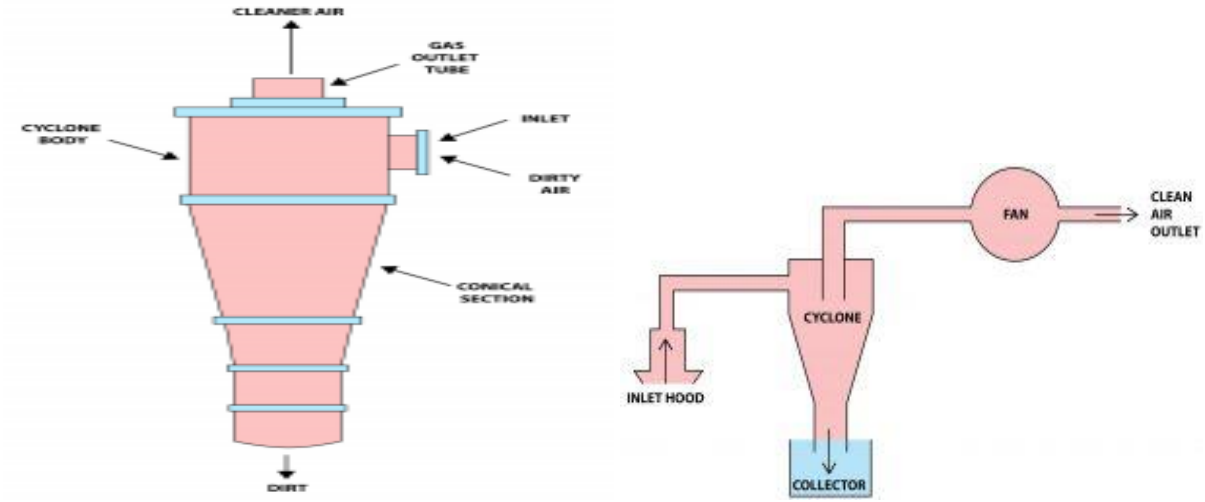

Fig : Cyclone Separator

It consists of a cylinder with an inverted cone attached at the bottom. The gas with particles in it enters tangentially at the top of the cylinder and spins forming a votex. Due to centrifugal force, the particles

strike the wall of the cylinder. The particles then fall in the hopper due to gravity from where they are removed. The spinning gas forms an inner vortex and leaves from the top. The cyclone is very efficient for large particles. However, smaller particles which pose human health problems are not removed efficiently. Therefore, cyclones are employed before the use of other costly devices.

Bag House Filters

A bag house filter contains a large number of filter bags made of fabric. They are hung upside down in several compartments of bag house filter. Dirty gas is passed through the filter bags which leaves the bags through their pores. the dust particles get deposited on the inner surface of the bag filters and may form a cake which can be removed by shaking. The device is efficient for removal of very small particles and is preferred in various types of industries. The bag house filters are expensive and cannot be operated for moist gases. Corrosive gases may damage the material of the bags. Various types of materials depending on the nature of the flue gases to be cleaned are used for making the filter bags.

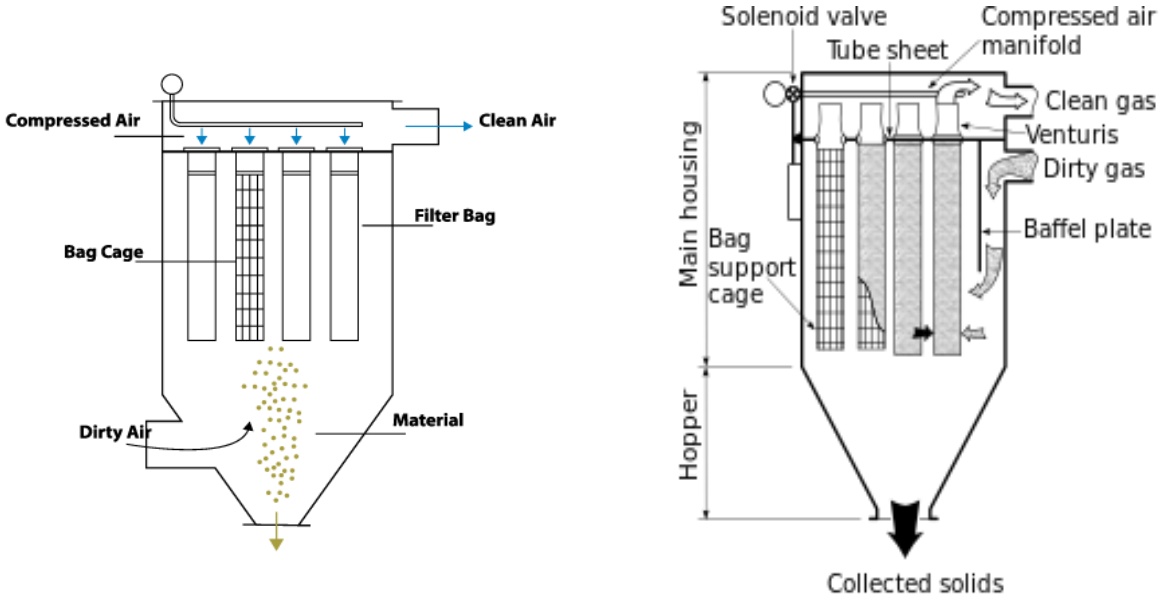

Fig:Bag House Filter

- **Scrubbers (**=a brush or other object used to clean something.)
- Some of the most commonly used air pollution control devices in manufacturing and processing facilities, industrial air scrubbers employ a physical process—i.e., scrubbing—which removes particulates and gases from industrial emissions, such as smokestack exhaust (in the case of exhaust air scrubbers), before they are released into the atmosphere. There are two main categories of scrubbers—dry scrubbers and wet scrubbers.

Dry Scrubbers

Dry scrubbers, also referred to as dry adsorption scrubbers, inject dry, neutralizing chemical agents, such as sodium bicarbonate, into the emission stream, causing the gaseous pollutants contained within to undergo a chemical reaction which either neutralizes the pollutants or converts them into innocuous substances. Once the chemical reaction concludes, filters within the scrubber chamber collect and remove the spent agents from the cleaned emission gas. In some cases, the collected agents can be washed and reused for future dry scrubbing processes, but, if not possible, the scrubbing waste must be disposed of by specialists. Typically, dry scrubbers are used to remove or counteract acid gas within industrial emissions. The chemical reactions resulting from the addition of neutralizing agents during the dry scrubbing process helps to both reduce the acidity of the emissions and remove air pollutants

Wet Scrubbers

Dirty gases are passed through water in the chamber or water is sprayed on the gas. Particles are made wet and are removed from the gas stream which leaves from the top of the scrubber. Wet scrubbers are very efficient for removing the particulates. The scrubbers are very useful for removal of toxic and acidic gases also.

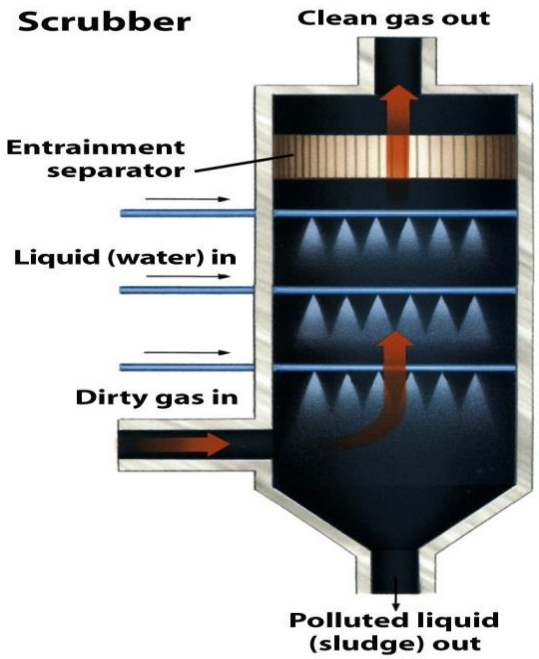

Fig: Wet Scrubber

Electrostatic Precipitators

The electrostatic precipitators may be plate type or cylinder type. Vertical wires are placed between the parallel plates or wire is hung along the axis of the cylinder. High negative voltage is applied to the wire. Dust particles while passing from the lower end get negatively charged(ionized) and are collected on the positively charged surface (plates/cylinder body) while the clean gas leaves from the top.

The deposited dust particles fall down in the dust collector or are removed by scrapping or by liquids. Electrostatic precipitators utilize electric energy and can efficiently remove even submicroscopic particles.

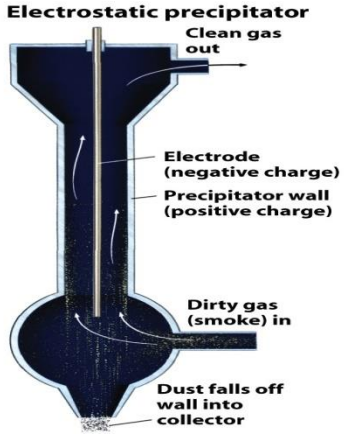

Fig: Electrostatic Precipitator

Control of air pollution caused by automobiles

1.By proper vehicular maintenance –Vehicles that are in proper condition produce lesser harmful emissions than those which are in bad condition. Vehicular pollution can be checked by regular tune up of engines: replacement of more polluting old vehicles; installing catalytic converters: by engine modification to have fuel efficient (lean)mixtures to reduce CO and hydrocarbon emissions: and slow and cooler burning of fuels to reduce NOx emission(Honda Technology)

2.Using unadulterated vehicular fuels –.unadulterated fuels are comparatively safer than the adulterated fuels as the former produce lesser harmful emissions

3.Modification of engine Design

Designing of more efficient internal combustion engines to minimize the emission of pollutants formed during combustion of gasoline**.**

The automobile emission consist of CO, NOx , Hydrocarbons and particulates. If some control measures are applied to reduce one of these pollutants, the amount of other pollutants are also affected simultaneously

Using **leaner air-fuel ratios** which result in improved fuel distribution and related ignition timing and the use of **lower compression ratios** are some of the modifications in engine design that have proved successful in checking pollution but with some sacrifice in fuel and power economy.

4.Fuel Modification and development of substitute fuels

Tetraethyl lead which is widely used as anti- knocking additive to gasoline, is the major source of lead pollution in the environment. Lead free gasoline is being marketed in an attempt to curb lead pollution.

5.Treatment of Exhaust Gases

In two stage catalytic convertors, **NOx are reduced to N_2 and NH_3 in the first converter** at elevated temperatures in presence of catalysts Pt..Pd and Ruthenium or some base metal alloys in the presence of reducing gas e.g Co and hydrocarbons.

For oxidizing CO and Hydrocarbons **in the second converter**, oxidizing catalysts of noble metals (Pt,IR and Ru) or oxides of CO,Cr,Cu,Ni and Mn supported on ceramic materials ae used in conjunction with suction of additional air to **ensure complete oxidation**.

However in case of noble metal catalysts, lead free gasoline will have to be used to prevent poisoning of the catalysts. Further, catalysts suitable for use in automobiles should be cheap, harmless, long-lasting and widely available.

Water pollution

Water pollution, in simple terms, can be defined as the contamination of the water bodies when pollutants are released into the water without thorough treatment and removal of harmful components. It not only affects the environment and human well-being, but also disrupts the balance of the ecosystem. Here are some of the major effects of water defilement on man and the environment.

Sources of Water Pollution

Pollution of water can be caused by point sources or non- point sources.
Point sources are specific sites near water which directly discharge effluents into them. Major point sources of water pollution are industries, power plants, underground coal mines, offshore oil wells etc.
The discharge from non- point sources is not at any particular site ,rather,these sources are scattered, which individually or collectively pollute water. Surface runoff from agricultural fields, overflowing small drains, rain water sweeping roads and fields, atmospheric deposition etc are the non- point sources of water pollution.

This section gives information about the most significant sources of water pollution.

Sewage (Waste Water)

Sewage is another name for waste water from domestic and industrial processes. Despite strict regulatory control, the Environment Agency data shows that the water and sewage industry accounted for almost a quarter of the serious water incidents in England and Wales in 2006.

Agricultural Pollution

Agricultural processes such as uncontrolled spreading of slurries and manure, disposal of sheep dip, tillage, ploughing of the land, use of pesticides and fertilisers cancause water pollution. Accidental spills from milk dairies can also affect the quality of water.

Oil Pollution

Oil spillages affect water quality in a number of ways. Oil can make drinking water unsafe to drink. A substantial amount of oil released intooceans and seas will destroy wildlife and the ecosystems that sustain them. Oil spills also reduce oxygen supplies within the water environment. The main causes of oil related water pollution are:
Loss from storage facilities
Spillage during delivery and;

- deliberate disposal of waste oil to drainage systems

Radioactive Substances

Radioactive waste is another source of water pollution. Radioactive substances are used in nuclear power plants, industrial, medical and other scientific processes. They can be found in watches, luminous clocks, television sets and x-ray machinery. There are also naturally occurring radioisotopes from organisms and within the environment. If not properly disposed of, radioactive waste can result in serious water pollution incidents.

River dumping

Lots of people dump supermarket trolleys, bicycles, garden cuttings and electronic waste into rivers or river banks. This is illegal and offenders may be charged for fly-tipping if caught. River dumping not only causes water pollution; it also harms wildlife and increases the risk of flooding. Fly-tipping (this includes river dumping) is a criminal offence.

Marine Dumping

The Worldwide Fund for Nature (WWF) estimates that a staggering amount of waste enters into the sea every year. Partof this is due to deliberate dumping of waste into coastal waters. Other sources of waste at sea include plastics and other materials blown or washed from land. Marine dumping is illegal under international and UK legislation.

Causes of Water Pollution

1. **Sewage** from domestic households, factories and commercial buildings Sewage that is treated in water treatment plants is often disposed into the sea. Sewage can be more problematic when people flush chemicals and pharmaceutical substances down the toilet.
2. **Dumping solid wastes** and littering by humans in rivers, lakes and oceans. Littering items include cardboard, Styrofoam, aluminum, plastic and glass.
3. **Oil Pollution** caused by oil spills from tankers and oil from ship travel. Oil does not dissolve in water and forms a thick sludge.
4. **Burning fossil fuels** into the air causes the formation of acidic particles in the atmosphere. When these particles mix with water vapor, the result is acid rain.
5. **Industrial waste** from factories, which use freshwater to carry waste from the plant into rivers, contaminates waters with pollutants such as asbestos, lead, mercury ,acids, alkalies, metallic salts, phenols, cyanides, ammonia, radioactive substances, and petrochemicals.
6. **Waste Heat**: Waste heat from industrial discharges increases the temperature of water bodies and affects distribution and survival of sensitive species. An increase in water temperature is caused by global warming and thermal plants that use lakes and rivers to cool down mechanical equipment.
7. **Agrochemicals**: Agrochemicals like fertilizers (containing nitrates and phosphates) and pesticides (insecticides , fungicides, herbicides etc)washed by rain water and surface run off pollute water.
8. **Synthetic Detergents**: Synthetic Detergents used in washing and cleaning produce foam and pollute water.

Types of Water Pollutants/Classification of Water Pollutants

Depending upon the types of water pollutants they are classified as

1) Organic
2) Inorganic
3) Sediments
4) Radioactive
5) Thermal Pollutants
6) Gases
7) Biological Pollutants

1) Organic Pollutants are further classified into a) Oxygen Demanding Waste b) Synthetic Organics c) Oils

a) **Oxygen Demanding Wastes**: Organic matter which reaches water bodies is decomposed by mico-oranisms present in water. For this degradation oxygen dissolved in water is consumed. Dissolved oxygen (DO)is the amount of oxygen dissolved in a given quantity of water at a particular temperature and atmospheric pressure. Amount of dissolved oxygen depends on aeration, photosynthetic activity in water, respiration of animals and plants and ambient

temperature. The saturation value of DO varies from 4-7mg/l. Lower DO may be harmful to animals especially fish population. Oxygen deletion (deoxygenation) helps in release of phosphates from bottom sediments and causes eutrophication. The low oxygen levels are not able to support most indigenous organisms in the area and therefore upset the natural ecological balance in rivers and lakes

b) Synthetic Organics

The organic pollutants like pesticides, detergents, food additives, synthetic fibres, plastics, rubbers, industrial organic chemicals are not easily biodegradable. Aromatic chlorinated hydrocarbons are resistant to microbial degradation and even if in traces, they spoil taste, colour, odour of water. Many of these pollutants are toxic. Detergents lead to persistant foams.

c) Oils

The hydrocarbon oils from oil spills from ships-tankers, oil leakages from pipeline, intentional oil release (gulfwar) pollute water. Being lighter than water, they float on water. The oil film on water does not allow O2 from air to dissolve in water and aquatic animals face DO shortage. The CO_2 required for photosynthesis by aquatic animals is also scared. The process of sea water evaporation and clouds formation is hampered due to oil films on sea surface. The hydrocarbons are very difficult to biodegrade.

2) Inorganic Pollutants

Inorganic pollutants include mineral acids, alkalies, inorganic salts, finely divided metals, metal compounds, cyanides, phosphates, nitrates, organometallic compounds. Various industries release these pollutants in waste water which meets to river or sea. These pollutants are harmful for plants and animals, microorganisms in water.

Some inorganic pollutants like Cr, Ni, Pb, Cd, Hg, Be, As, Sb, Se in the form of their compounds are highly toxic to the aquatic life and consumers.

3) Sediments(Particulates)

Sediments include soil, sand and mineral particles washed into the aquatic envirobment by storms and flood water, land run off. In addition, large deposits of sewage sludge, fly ash, some industrial solids are disposed off in sea or river water. These pollutants make water water unclear, do not allow light to reach up-to aquatic plants. This matter settled in the dam or lake, reduces water storage capacity. Soil erosion by floods, storms is the main factor contributing to the sediments deposition and it can be minimized by plantation and proper management of soil, forests.

Organic matter sediments are also present in the water.

4) Radioactive pollutants

Radioactive pollutants enter in water by following activities:

i) Mining and processing of radioactive ores
ii) Increased use of radio isotopes in research, agriculture, industrial and medical applications
iii) Radioactive material liberated from nuclear power plants, nuclear reactors
iv) Radioactive material from testing and used nuclear weapons.

The α, β,γ radiations from these radioactive materials are hazardous for all life forms. Their effect on man, is in the form of cancers, mental disorders, paralysis, irregular growth of body of children, tissue damage, etc. Even a very small quantity of these pollutants (few picocuries per liter) can cause the ill effects.

5) Thermal Pollutants

Human activity that causes temperature of water to increase, is the thermal pollution of water. A high temperature water is discharged from thermal power plants, nuclear power plans. A large quantity of water is used by many chemical industries as coolant(heat exchange) and such hot water meets to river or sea.

Higher temperature water has very low quantity of oxygen gas dissolved and therefore aquatic life comes in danger. Further if very hot water meets to river or sea,it can kill some of the aquatic life.

6) Gas Pollutants:

Gases like NO_2,SO_2, NH_3,H_2S are appreciably soluble in water.NH_3 gas makes water alkaline and other gases make water acidic. These gases may get dissolved from atmosphere or these gases are produced by aerobic bacteria during biodegradation of organic matter in water.

The gases in water cause bad taste, and such water corrodes bridges, metals, concrete in its contact. Presence of these gases in

water affects the growth of aquatic life.

7) Biological Pollutants

In a water if various disease causing bacteria (pathogenic),fungi, algae varieties are present, then it is said to be biologically polluted water. There can be some parasitic worms in the polluted water. These pollutants cause various water borne diseases to man. Presence of algae matter chokes up pipelines, fungi may be poisonous.

The pathogenic bacteria and fungi use organic waste in water as food and grow fast. Some viral infections are also water borne.

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Water Pollutants/Effects of Water Pollution

Important effects of various types of water pollutants

1. **Oxygen Demanding Wastes**: Organic matter which reaches water bodies is decomposed by mico-oranisms present in water. For this degradation oxygen dissolved in water is consumed. Dissolved oxygen (DO)is the amount of oxygen dissolved in a given quantity of water at a particular temperature and atmospheric pressure. Amount of dissolved oxygen depends on aeration, photosynthetic activity in water, respiration of animals and plants and ambient temperature. The saturation value of DO varies from 4-7mg/l. Lower DO may be harmful to animals especially fish population. Oxygen deletion (deoxygenation) helps in release of phosphates from bottom sediments and causes eutrophication. The low oxygen levels are not able to support most indigenous organisms in the area and therefore upset the natural ecological balance in rivers and lakes
2. **Nitrogen and Phosphorous compounds (nutrients):** Addition of compounds containing nitrogen and phosphorous helps in the growth of algae and other plants which when die and decay consume oxygen of water. Under anaerobic conditions foul smelling gases are produced. Excess growth or decomposition of plant material will change the concentration of CO_2 which will further change pH of water. Changes in pH , oxygen and temperature will change many physio-chemical characteristics of water.
3. **Pathogens:** Many wastewaters especially sewage contain many pathogenic (disease causing) and non-pathogenic micro-organisms and many viruses. Water borne diseases like cholera, dysentery, typhoid, jaundice etc are spread by water contaminated with sewage.
4. **Toxic Compounds**: Pollutants such as heavy metals, pesticides, cyanides and many other organic and inorganic compounds are harmful to aquatic organisms. Groundwater contamination from pesticides causes reproductive damage within wildlife in ecosystems.

The demand of DO increases with addition biodegradable organic matter which is expressed as biological oxygen demand(BOD).**BOD is defined as the amount of DO required to aerobically decompose biodegradable organic matter of a given volume of water over a period of 5 days at 20 ^{o} C.**

More BOD values of any water sample are associated with poor water quality. **The non –biodegradable toxic compounds bio-magnify in the food chain and cause toxic effects at various levels of food chain.**

Some of these substances like pesticides, methyl mercury etc move into the bodies of organisms from the medium in which these organisms live. Substances like DDT are not water soluble and have affinity for body lipids. These substances tend to accumulate in the organism's body. This process is called bioaccumulation. The concentration of these toxic substances builds up at successive levels of food chain. This process is called bio-magnification. Following is the example of bio-magnification of DDT in aquatic food chain.

Component	**DDT Concentration (ppm)**
Birds	10
↑	↑
Needle Fish	1.0
↑	↑
Minnows	0.1
↑	↑
Zooplankton	0.01
↑	↑
Water	0.000001

Toxic substances polluting the water ultimately affect human health. Some heavy metals like lead ,mercury and cadmium cause various types of diseases.

Mercury: Mercury dumped into water is transformed into water soluble methyl mercury by bacterial action.

Methyl mercury accumulates in fish. In 1953, people in Japan suffered from numbness of body parts, vision and hearing problems and abnormal mental behavior. This disease called Minamata disease occurred due to consumption of methyl mercury contaminated fish caught from Minamata bay in japan. The disease claimed 50 lives and permanently paralysed over 700 persons. Mercury is particularly poisonous to small children and women. Mercury has been found to interfere with the development of the nervous system in fetuses and young children

Cadmium: Pollution by Cadmium had caused the disease called Itai-itai in the people of japan. The disease was caused by Cadmium contaminated rice. The rice fields were irrigated with effluents of zinc smelters and drainage water from mines. In this disease bones, liver, kidney, lungs, pancreas and thyroid are affected.

Arsenic: Arsenic pollution of ground water in Bangladesh and West Bengal is causing various types of abnormalities.

Nitrate: Nitrate when present in excess in drinking water causes **blue-baby syndrome** or **methemoglobinemia**. The disease develops when a part of **haemoglobin** is converted into **non-functional oxidized** form.

Nitrate in stomach partly gets changed into nitrites which can produce cancer –causing products in the stomach**.**

Fluoride: Excess of fluoride in drinking water causes defects in teeth and bones called **fluorosis.**

Pesticides: Pesticides in drinking water ultimately reach humans and are known to cause various health problems.

5. Swimming in and drinking contaminated water causes skin rashes and health problems like cancer, reproductive problems, typhoid fever and stomach sickness in humans. Therefore, it's very important to make sure that your water is clean and safe to drink.
6. Ecosystems are destroyed by the rising temperature in the water, as coral reefs are affected by the bleaching effect due to warmer temperatures. Additionally, the warm water forces indigenous water species to seek cooler water in other areas, causing an ecological damaging shift of the affected area.
7. Human-produced litter of items such as plastic bags and 6-pack rings can get aquatic animals caught and killed from suffocation.
8. Water pollution causes flooding due to the accumulation of solid waste and soil erosion in streams and rivers.
9. Oil spills in the water causes animal to die when they ingest it or encounter it. Oil does not dissolve in water so it causes suffocation in fish and birds.

Eutrophication

Excess use of N and P fertilizers in the agricultural fields leads to another problem, which is not related to soil but water bodies like lakes.

A large proportion of nitrogen and Phosphorous . fertilizers in used in crop fields is washed off and along with runoff water reach the water bodies causing over nourishment of the lakes,a process known as Eutrophication .Due to eutrophication the lakes get invaded by algal blooms. These algal species grow very fast by rapidly using up the nutrients. They are often toxic and badly affect the food chain. The algal species quickly complete their life cycle and die thereby adding a lot of dead organic matter. The fishes are also killed and there is a lot of dead matter that starts getting decomposed. Oxygen is consumed in the process of decomposition and very soon the water gets depleted of dissolved oxygen. This further affects aqatic fauns and ultimately anaerobic conditions are created where only pathogenic anaerobic bacteria can survive. Thus due to excessive use of fertilizers in the agricultural fields the lake ecosystem gets degraded.

Effects of Water Pollution on man

	Impurities	Effects
A	**Suspended Matter**	
	Particulates	Water is unclear and not acceptable.The particles create living conditions for pathogenic bacteria
	Bacteria	May cause typhoid,Cholera,Dysentry
	Parasitic Worms	Cause roundworm and hookworm infections
	Insect Vectors	Cause maleria
	Algae	Cause turbidity ,bad taste and odour. They interfere in filtration process in water treatment
	Viruses	Cause enteroviral infections
	Polynuclear aromatic Hydrocarbons	They are present in synthetic detergents used for washing clothes,hence present in fishes and also in drinking water.They are carcinogenic health hazard.
	Organochlorine Compounds(e.g pesticides,chlorinated napthalemes,chloroform etc)	Get very easily absorbed on suspended matter. Present in fishes.All are carcinogenic in nature.
B	**Dissolved Salts and Metals**	
	Bicarbonates, chlorides and sulphates of calcium and Magnesium.	Cause Alkalinity and hardness in water. Causes corrosion in boilers. If consumed by humans, laxative effect observed.
	Sulphates of sodium, Potassium and Magnesium	Cause diarrhea in humans, scour in cattle. Sodium sulphate causes foaming in boilers.
	Sodium carbonate and bicarbonate	Cause alkalinity and softening effect in hard water.
	Flourides	Above 1 ppm level cause cumulative fluorosis-motting of teeth enamel, nervous and skeletal disorders.
	Sodium Chloride	Cause objectionable taste in water, also indicates pollution of water with human sewage
	Nitrates	Above 18 ppm level cause infant methaemoglobinaemia.
	Iron and Manganese	Causes stains in clothes, corrodes metals, interfere in dying, cause bad taste and odour. Manganese cause paralysis in lower limbs.
	Lead (From Lead water Pipes)	Lead is a cumulative poison, causing constipation , lose of apetite, abdominal pain, anemia, gradual paralysis of muscles, mental retardation, brain damage, nervous and skeletal disorders, a blue line at the junction of teeth and gums.
	Mercury Compounds(Converted into highly toxic methyl mercury when present at more than 10 ppm)	Concentration in fish and shellfish on ingesting cause nerve and brain damage, paralysis and even death.
	Zinc	Cause dizziness, vomiting and diarrhoea
	Arsenic	Very poisonous, even traces makes the water unfit for drinking: cause cramps, paralysis and even death.
	Cadmium	Gets absorbed on suspended matter in water which when ingested causes increased salivation, acute gastritis, liver and kidney damage.
	Phosphates(from detergents and fertilizers)	Cause eutrophication or over fertilization of plants in surface water. Promote algal growth which pollute water. Decrease DO level in water.
	Acids	Eye irritant and cause injury to teeth: corrosive to metals

WORLD HEALTH ORGANIZATION (WHO) STANDARDS OF DRINKING WATER

Parameter	WHO Guideline (Permissible value)		
	mg/l or ppm	ug/l	
Fluoride	1.5 mg/l		
Arsenic	0.01-0.05	10ug/l	
Benzene		10 ug/l	
Boron	2.4mg/l		
Cadmium		3ug/l	
Selenium		40ug/l	
Tetrachloroethene and trichloroethene		40ug/l	
Nitrate	50mg/l		
Chromium		50ug/l	
Mercury		6ug/l	
Barium		700ug/l	
BO			6
COD			10
Ammonia	0.5 mg/l		
Magnesium	150 mg/l		
Cyanide	0.05 mg/l		
Polyaromatic Hydrocarbons	0.2 mg/l		
Zinc	15 mg/l		
Alkalinity			
TDS (Total Dissolved Solids)	1000 mg/l		
Hardness	500 mg/l		
Chloride	250 mg/l		
Iron	0.3 mg/l		
Cadmium	0.005 mg/l		
Chromium	0.05 mg/l		
Lead	0.05 mg/l		
PH			6.5-8.5

Controlling Measures of Water Pollution

Water pollution in natural water bodies can be identified and quantified on the basis of various parameters, such as, dissolved oxygen (DO), biochemical oxygen demand (BOD), coliform organisms, pH etc. As per the water quality criteria, the DO levels in drinking water should be ≥ 6 mg/L and BOD levels should be < 2 mg/L. Moreover coliforms level should not exceed 50 MPN/100 mL in water which is safe for drinking purpose. If the water quality of any source is not complying with these criteria, the water cannot be used for drinking purpose without undergoing complete treatment. Water pollution can be controlled by diluting the water pollutants in a reservoir.

The various methods for the control of water pollution can be summarized as follows:

1. The sewage pollutants are required to be treated in sewage treatment plants before their discharge in natural water bodies.

2. Water pollution due to organic insecticides and pesticides can be reduced by the use of very specific and less stable chemicals in the manufacture of insecticides/pesticides. Moreover, use of bio-fertilizers needs to be promoted.

3. Oxidation ponds can be useful in removing low level of radioactive wastes.

4. Hot water should not be disposed directly into the river, as it adversely affects the life of aquatic organisms. Thermal pollution can be reduced by employing techniques such as cooling, cooling ponds, evaporative or wet cooling towers and dry cooling towers.

5. Domestic and industrial waste waters should be treated properly in waste water treatment plants, before discharge in the natural aquatic systems.

6. Strict implementation of legislations for water treatment should be done.

7. No solid waste should be dumped into water bodies.

8. Dead bodies of animals/human should not be floated in water sources.

9. Bathing, washing of clothes, and idol immersion should be strictly restricted in natural water bodies.

10. Judicious use of agrochemicals like pesticides and fertilizers which will reduce their surface run off and leaching. Avoid use of these on sloped lands.

11. Use of Nitrogen fixing plants to supplement the use of fertilizers.

12. Adopting integrated pest management to reduce reliance on pesticides

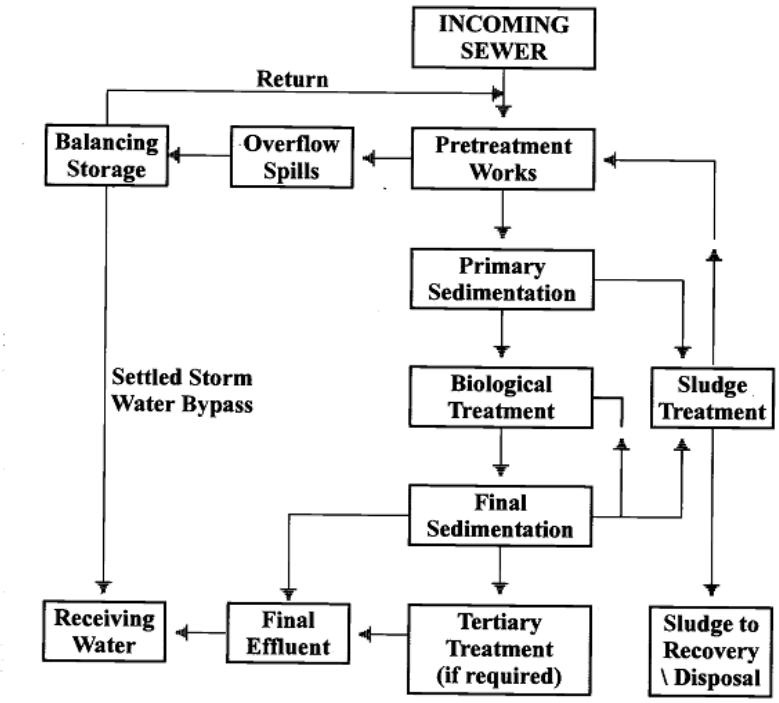
13. Prevent run off of manure. Divert such run off to basin for settlement. The nutrient rich water can be used as fertilizer in the fields.

14. Separate drainage of sewage and rain water should be provided to prevent overflow of sewage with rainwater.

15. Planting trees would reduce pollution by sediments and will also prevent soil erosion.

For controlling water pollution from point sources, treatment of wastewaters is essential before being discharged.
Parameters which are considered for reduction in such water are
Total solids, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrates and phosphates, oil and grease, toxic metals etc.
Wastewater should be properly treated by primary and secondary treatments to reduce the BOD, COD levels upto the permissible levels for discharge.

WATER TREATMENT TECHNOLOGIES



I. Drinking water treatment technology
II. Waste water treatment technology

I. Drinking water treatment technology

The various methods or the techniques which may be adopted for purifying the public water supplies are:

1. Screening
2. Plain sedimentation
3. Sedimentation aided with coagulation
4. Filtration
5. Disinfection
6. Softening

(Details from Unit I-Domestic water Treatment)

II. Waste water treatment technology

Sewage, before being discharged of either in river streams or on land, has to be treated so as to make it safe. The degree of treatment required, however, depends upon the characteristics of the source of disposal. Sewage can be treated in different ways.

Treatment processes are often classified as –

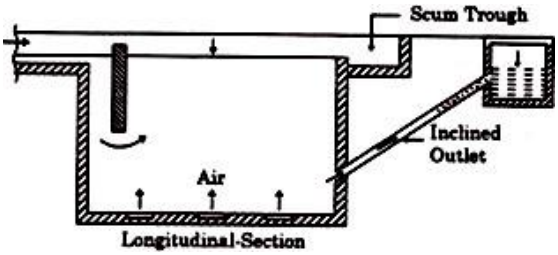
1. Preliminary treatment
2. Primary treatment
3. Secondary (or Biological) treatment

1. Preliminary treatment

Preliminary treatment consists solely in separating the floating materials (like dead animals, tree branches, papers, pieces of rags, wood etc.) and also heavy settle-able **inorganic solids**. It also helps in removing the oils and greases etc. from sewage.

The processes used in preliminary treatment are

a. **Screening** – for removing floating papers, rags, clothes etc.
b. **Grit chambers or Detritus tanks** – for removing grit and sand
c. **Skimming tanks** – for removing oils and greases.



Skimming Tank

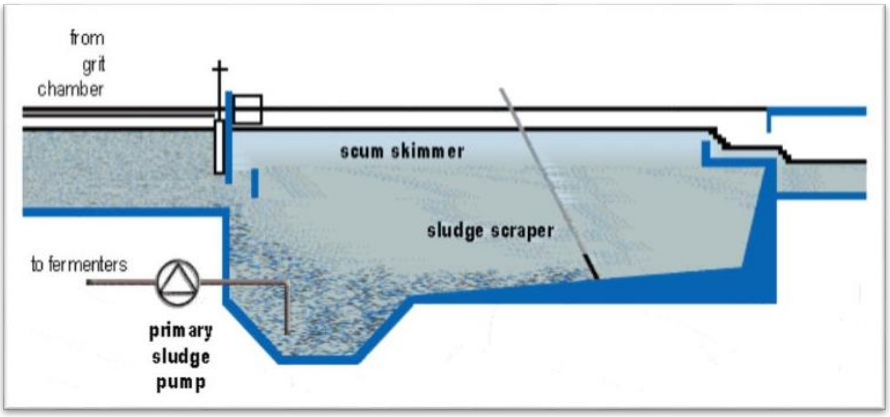
2. Primary treatment

For this continuous flow type settling tanks are used. The sewage from first step is allowed to stand in the big settling tank for few hours. A coagulant like ferrous sulphate or alum is also added in the waste during settlement. In this step, settle-able solids and colloidal matter settles down t large extent.

(Primary treatment consists in removing large suspended **organic solids**. This is usually accomplished by sedimentation in settling basins. The organic solids, which are separated out in the sedimentation tanks (in primary treatment), are often stabilized by anaerobic decomposition in a digestion tank or are incinerated. The residue is used for landfills or soil conditioners. The liquid effluent from primary treatment often contains a large amount of suspended organic material. It also has a high biochemical oxygen demand (BOD).)

The processes used in primary treatment are

a. **Sedimentation** – for removing part of the organic matter from the sewage effluent as in drinking water purification
b. **Sedimentation aided with coagulation** – similar to drinking water purification



Sedimentation Tank

3. Secondary (or Biological) treatment

Secondary treatment involves further treatment of the effluent coming from the primary sedimentation tanks. This is generally accomplished through biological decomposition of organic matter, which can be performed either under aerobic (in presence of oxygen) or anaerobic (in absence of oxygen) conditions. In these biological units, bacteria are used to decompose the fine organic matter to produce clearer effluent.

In treatment reactors, in which the organic matter is decomposed (oxidized) by aerobic bacteria are known as ***Aerobic Biological Units,*** *and may consists of*

a. **Filters (intermittent sand filters and trickling filters)** –.

Trikling filters are commonly used for the biological oxidation of sewage. It is rectangular or circular in shape and about 2 meters deep. They are filled with coarse, crushed rock or anthracite coal or broken bricks.Sewage is delivered to the filters by means of a rotating distributor. As the trickled sewage starts percolating downwards, through the filtering medium, the aerobic bacteria grow on the surface of aggregates by using organic matter in sewage as food. Highly aerobic condition is maintained constantly in this design. The bacteria bring about the biological oxidation of organic matter of sewage. The treated water comes out from bottom. A normal trikling filter removes about 90% BOD within few hours.

Sewage is kept in contact with filtering medium, sothat fine colloidal organic matter gets trapped in the voids (spaces) of filter medium.

b. **Aeration tanks** – Sewage received from primary sedimentation tanks is mixed with micro-organisms (e.g. bacteria) and large quantity of air, thus causing precipitation of organic and colloidal matter.

Activated Sludge Process-This is much faster oxidation of organic matter in sewage by aerobes, under highly aerobic conditions, in the presence of a part o sludge from previous oxidation process. This sludge from previous oxidation process is known activated sludge, since it contains organic matter inhabited by numerous aerobes.

This process consists of mixing the sedimented sewage from step 2 with proper quantity of activated sludge and the mixture is sent to the aeration tank in which agitation is carried out for 4-6 hours by blowing air in it.Here suspended and dissolved organic matter is oxidized efficiently by the aerobic bacteria. After aeration, the affluent is sent to sedimentation tank ,where sludge is deposited and clean water is drawn off. A part of the sludge deposited is used for next oxidation batch and the remainder is either spread on land as fertile matter or used for biogas or dumped in sea.

c. **Oxidation ponds and aerated lagoons** – Oxidation ponds are used for the oxidation of original organic matter and the production of algae which are discharged with the effluent in the natural water bodies. It results in the net reduction in BOD, approximately up to 90%, and coliform removal of up to 99% or so.

The treatment reactors in which the organic matter is destroyed and stabilized by anaerobic bacteria, are known as ***Anaerobic Biological Units,*** *and may consists of*

a. **Anaerobic lagoons** – These are deep stabilization ponds, usually operating under the action of anaerobic bacteria (bacteria which survive only in absence of oxygen). In these ponds, complex organic materials are broken down into short chain acids and alcohols, which are further degraded into gases such as methane andcarbon dioxide.

b. **Septic tanks** – A septic tank is a kind of sedimentation tank which directly receives raw sewage and removesabout 60 - 70% of the dissolved matter from it.

Septic tanks are generally provided in areas where sewers have not been laid and for serving to the sanitarydisposal of sewage produced from isolated communities, schools, hospitals, other public institutions etc.

c. **Imhoff tanks** – An Imhoff tank is an improvement over septic tank, in which the incoming sewage is not allowed to get mixed up with the sludge produced, and the outgoing effluent is not allowed to carry with it largeamount of organic load, as in the case of septic tank. These are very economical and do not require skilled supervision during operations. There is 60 – 65% removalof solids and 30 – 40% removal of BOD.

Tertiary Treatment

This is the final treatment meant for polishing the effluents from the secondary treatment processes, to improve its quality further.

Objectives

- Removal of fine suspended solids
- Removal of dissolved inorganic solids
- Removal of final traces of organics
- Removal of bacteria
- Decrease the load of nitrogen and phosphorus in the effluents
- Further purification of waste water to enable its reuse.

Processes employed

- **Chlorination**-Considerable part of pathogenic bacteria get destroyed during the second stage of treatment i.e aerobic oxidation. The total killing of the bacteria is done with process like chlorination
- **The removal of dissolved inorganic matter is done by any one of the following suitable processes**
- **Chemical Precipitation**- The heavy metal ions and toxic meta ions can precipitated with suitable reagents and then filtered off.e.g Cr3+,Cd2+,Hg2+,Pb2+,Be2+ etc.
- **Calcium compounds** removed by adding lime
- **Nitrogen Stripping**-Nitrogen present in the form of ammonia , nitrites and nitrates.Nitrogen compounds enhance eutrophication. Ammonia in the effluent is removed by trickling the effluent from the top of a baffle tower while it meets the air coming upwards.
- **Adsorption**-Activated charcoal possess very high affinity for dyes, pesticides, other organic materials and toxic inorganic matter. The effluent is filtered through the series of activated charcoal beds, to remove the above said impurities.
- **Coagulation**-By use of coagulants
- **Desalination**(Ion- Exchange , Electrodialysis or reverse Osmosis)
- a)-Ion ExchangeTreatment-This method can remove all the inorganic salts present in the waste but not economical. Hence it is employed for removal of only toxic inorganic salts in the waste.
- b) Electrodialysis- Electrodialysis is a process that removes ionic components under the driving force of an electric current from aqueous solutions through ion exchange membranes
- c)Reverse Osmosis-The dissolved solids waste water is passed through a semipermeable membrane at a pressure higher than osmotic pressure of the waste water. Only water (along-with limited quantity of

salts) passes through SPM leaving the concentrated solution of salts behind.

- **Evaporation**-The process is expensive and slow. It is undertaken for concentrating the radioactive liquid waste.
- **Several other methods** for tertiary treatment of waste to remove inorganic matter from water are available like use of plants(algae, water-hyacinth),extraction with solvents etc