2. DETERMINATION OF BOD, COD, TDS AND TRACES METALS

The standard method for indirect measurement of the amount of pollution (that cannot be oxidized biologically) in a sample of water.

Determination of DO (Winkler's method):

PRINCIPLE

Dissolved Oxygen measurement is based on the fact that dissolved oxygen oxidizes KI and liberates I_2. The liberated iodine is titrated against thiosulfate solution using starch as an indicator. Since dissolved oxygen in water is in molecular state, it as such cannot oxidize the KI. Hence manganese hydroxide is used as an oxygen carrier. Manganese hydroxide in turn is obtained by the action of KOH on $MnSO_4$.

DO reacts with Mn^{2+} ions in alkaline medium forming basic manganic oxide which is a brown precipitate.

$$MnSO_4 + 2KOH + \tfrac{1}{2}O_2 \rightarrow MnO(OH)_2 \downarrow + K_2SO_4 \qquad (1)$$

basic manganic oxide

This brown precipitate dissolves on acidification liberates nascent oxygen.

$$MnO(OH)_2 + H_2SO_4 \rightarrow MnSO_4 + 2\,H_2O + [O]$$

when treated with iodide ions librates iodine in an amount equivalent to the initial DO

$$2KI + H_2SO_4 + [O] \rightarrow K_2SO_4 + I_2 + H_2O \qquad (2)$$

The liberated iodine is finally estimated by titration with sodium thiosulphate.

$$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^- \qquad (3)$$

The stoichiometric expression relating DO and sodium thiosulphate is given below.

$$1\text{ml of }0.025\text{ N } Na_2S_2O_3 = 0.2\text{ mg DO} \qquad (4)$$

Sodium thiosulphate is standardized using potassium dichromate by iodometric method. The sample of water is filled in a stopper bottle up to brim. This is done in order to exclude any air column present in the closed flask that may increase the actual DO leading to an error. 2 ml of manganous sulphate (36%) and 2 ml of alkaline KI are added to get a brown coloured basic manganic oxide floc and the precipitate allowed settling. The precipitate is dissolved using H_2SO_4 (1:1 few drops) and titration of clear solution is carried out using starch as an indicator against standard sodium thiosulfate solution. End point is taken by disappearance of blue colour.

DO = Normality of the sample waterX8X1000 mgs/lit

Biochemical Oxygen Demand (BOD):

Definition

BOD (Biochemical Oxygen Demand), also often referred to as biological oxygen demand, is defined as, "the amount of free oxygen required by bacteria for the biological oxidation of the organic matter under aerobic conditions at 20°C for a period of 5 days".

Determination of BOD

A known volume of sewage sample is diluted with a known volume of dilution water. The diluted sample of known volume is taken in two stoppered bottles (bottle I & II). The dissolved oxygen content of bottle-I is determined (blank). The bottle –II is incubated at 20°C for 5 days, after which unused dissolved oxygen is determined.

The difference between the original content in the blank and unused of sewage after 5 days gives the BOD.

$BOD_5=[DO_1-DO_5]X$ Dilution factor. mg/lit

DO_1= Initial sample DO

DO_5= After 5 days sample DO

Significance of BOD

- ✓ It indicates the amount of decomposable organic matter present in the sewage.
- ✓ It enables us to determine the degree of pollution at any time in the sewage stream.
- ✓ Lesser the BOD, better is the quality of water. Ie. The water sample with BOD of less than 3 ppm is considered as pure water, whereas the water more than 4 ppm is considered as polluted water.

Chemical Oxygen Demand (COD):

Definition

COD is defined as, "the amount of oxygen required to chemically oxidise all the oxidisable impurities present in the sewage using agent like acidified $K_2Cr_2O_7$.

Determination of COD

A known volume of wastewater (sewage) sample is refluxed with a known excess of $K_2Cr_2O_7$ in a dil. H_2SO_4 in the presence of Ag_2SO_4 and $HgSO_4$. The organic matter of the sample is oxidized to H_2O, CO_2 and NH_3. The excess unreacted $K_2Cr_2O_7$ in the solution is titrated with a standard solution of ferrous ammonium sulphate.

Let the volume of FAS = V_1 ml

A blank titration is also carried out using the same volume of distilled water in place of sewage. Let the volume of FAS = V_2 ml.

$COD = [(V_2-V_1)xNx8x1000]/X$ mg/lit

V1 = Volume of FAS consumed by sewage sample in mL.

V2 = Volume of FAS consumed by blank sample in mL.

N = Normality of FAS

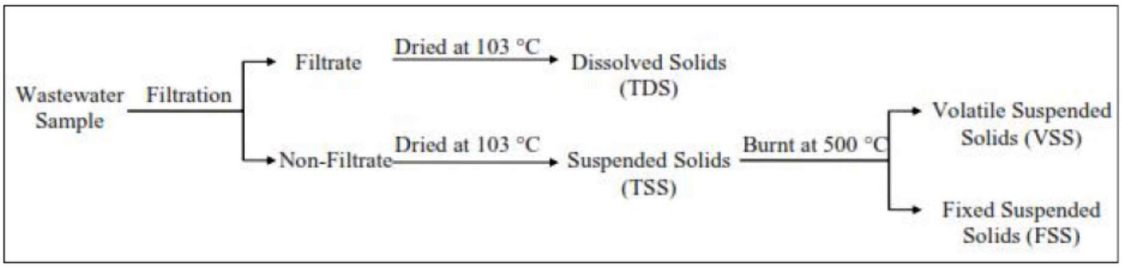
X = Volume of sewage sample

Significance of COD

- ✓ Determination of COD is carried out only in 3 hours, but determination of BOD is carried out after 5 days.
- ✓ It measures both biologically oxidisable and biologically inert organic matter. So, COD is always higher than BOD.

Determination of Total Solids, Dissolved Solids and Suspended Solids in Water
Definition

Environmental engineering is concerned with the solid material in a wide range of natural water and waste water. The usual definition of solids (referred to as "total solids") is the matter that remains as residue upon evaporation at 103~105℃. The various components of "total solids" can be simplified as follows.



Total Solids (TS) are the total of all solids in a water sample. They include the total suspended solids (TSS) and total dissolved solids (TDS).

Determination of TSS and TDS by gravimetric method

Total Suspended Solids (TSS) is the amount of filterable solids in a water sample. Samples are filtered through a glass fiber filter. The filters are dried and weighed to determine the amount of total suspended solids in mg/l of sample.

Total Dissolved Solids (TDS) are those solids that pass through a filter with a pore size of 2.0 micron or smaller. They are said to be non-filterable. After filtration the filtrate (liquid) is dried and the remaining residue is weighed and calculated as mg/l of Total Dissolved Solids.

Determination of TDS by electrical conductivity method

The TDS and the electrical conductivity are in a close connection. The more salts are dissolved in the water; the higher is the value of the electric conductivity. The majority of solids, which remain in the water after a sand filter, are dissolved ions. Sodium chloride for example is found in water as Na^+ and Cl^-. High purity of water contains no ions. H_2O without salts or minerals has a very low electrical conductivity. The water temperature affects the electric conductivity so that its value increases from 2 up to 3 % per 1 degree Celsius.

A conductivity sensor measures how much electricity is being conducted through a centimeter of water. Specific conductivity is expressed as mhos per centimeter (M/cm), sometimes called siemens per centimeter (S/cm). Because a mho (or siemen) is a very large unit, the micromho (microsiemen) or millimho (millisiemen) typically is used (mS/cm).

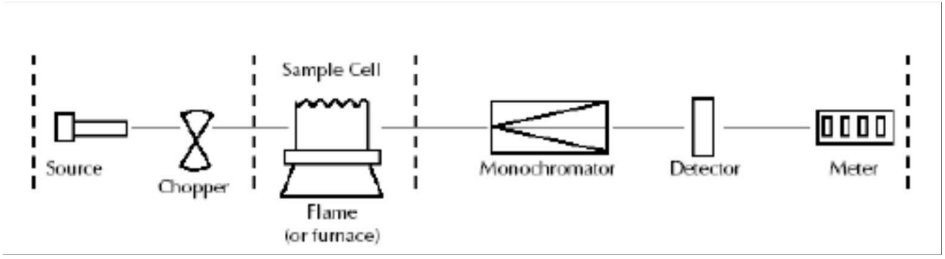
To convert the electric conductivity of a water sample (mS/cm) into the approximate concentration of total dissolved solids (ppm), the mS/cm is multiplied by a conversion factor. The conversion factor depends on the chemical composition of the TDS and can vary between 0.54 – 0.96. A value of 0.67 is commonly used as an approximation if the actual factor is not known,

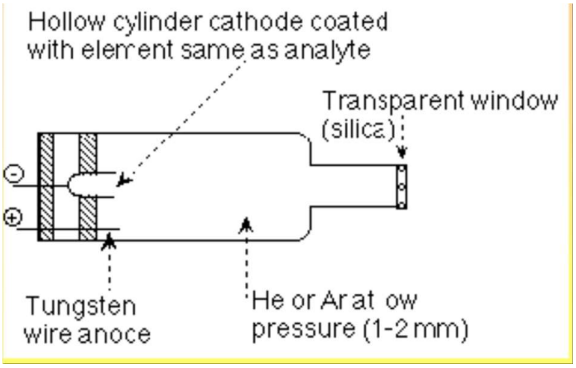
[(TDS)ppm = Conductivity µS/cm x 0.67].

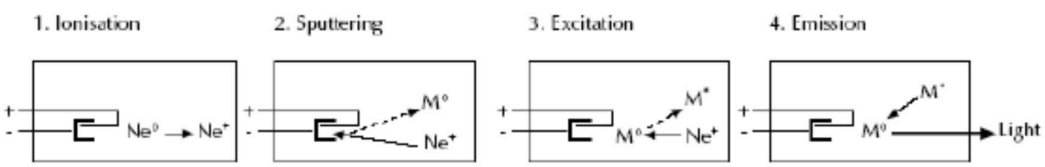
DETERMINATION OF TRACE METAL USING ATOMIC ABSORPTION SPECTROMETRY (AAS):

Atomic Absorption Spectrometry (AAS) is an analytical technique that measures the concentrations of elements. Atomic absorption spectroscopy can be used to analyze the concentration of over 62 different metals in a solution and is so sensitive that it can measure down to parts per billion of a gram (ug/dm^{-3}) in a sample. The technique makes use of the wavelengths of light specifically absorbed by an element. They correspond to the energies needed to promote electrons from one energy level to another, higher, energy level. Determination of metal ions such as Cd, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, Ag and Zn by direct aspiration into air oxyacetylene flame. Mercury (Hg) can be determined by flameless AAS.

Atoms of different elements absorb characteristic wavelengths of light. Analyzing, a sample to see if it contains a particular element means using light from that element. For example, with lead, a lamp containing lead emits light from excited lead atoms that produce the right mix of wavelengths to be absorbed by any lead atoms from the sample.







In AAS, the sample is atomised – ie., converted into ground state free atoms in the vapour state – and a beam of electromagnetic radiation emitted from excited lead atoms is passed through the vaporised sample. Some of the radiation is absorbed by the lead atoms in the sample.

An atomic absorption spectrophotometer consists of a light source, a sample compartment and a detector. In this method, light from a source is directed through the sample to a detector. The source of light is a lamp whose cathode is composed of the element being measured. Each element requires a different lamp.

Hollow Cathode Lamp

A Hollow Cathode Lamp usually consists of a glass tube containing a cathode made of the material of interest, an anode and a buffer gas (usually a noble gas). A large voltage across the anode and cathode will cause the buffer gas to ionize, creating plasma. These ions will then be accelerated into the cathode, sputtering off atoms from the cathode. These atoms will in turn be excited by collisions with other atoms/particles in the plasma. As these excited atoms decay to lower states, they will emit photons, which can then be detected, and a spectrum can be determined.

The shape of the cathode concentrates the radiation into a beam which passes through a quartz window, and the shape of the lamp is such that most of the sputtered atoms are redeposited on the cathode.

Atomization of the sample

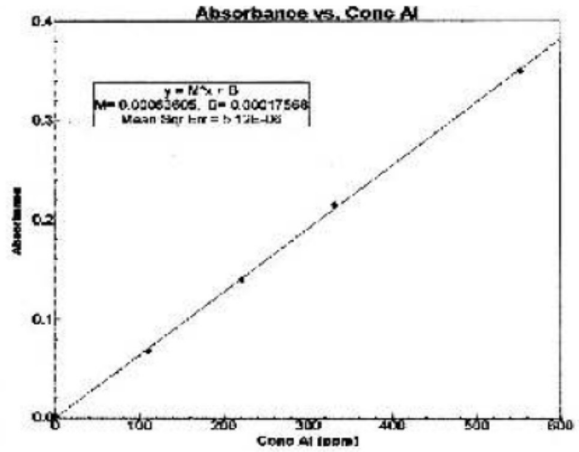
Ethyne/air (giving a flame with a temperature of 2200–2400 °C) or ethyne/dinitrogen oxide (2600–2800°C) are often used. A flexible capillary tube connects the solution to the nebuliser. At the tip of the capillary, the solution is 'nebulised' – ie broken into small drops. The larger drops fall out and drain off while smaller ones vapourise in the flame and atomise elements (including the element being analysed). Finally heating the tube to a still higher temperature – ca 2700 °C – cleans it ready for the next sample. During this heating cycle the graphite tube is flushed with argon gas to prevent the tube burning away. In electrothermal atomisation almost 100% of the sample is atomised. This makes the technique much more sensitive than flame AAS.

The **Beer-Lambert law** states that the quantity of light absorbed by a substance dissolved in a fully transmitting solvent is directly proportional to the concentration of the substance and the path length of the light through

$A = a(\lambda) * b * c.$

where A is the measured absorbance, a(λ) is a wavelength-dependent absorptivity coefficient, b is the path length, and c is the concentration of the sample.

Quantitative analysis can be achieved by measuring the absorbance of a series of solutions of known concentration. A calibration curve and the equation for the line can be used to determine an unknown concentration based on its absorbance.



DETERMINATION OF TRACE METAL USING INDUCTIVELY COUPLED PLASMA – ATOMIC EMISSION SPECTROMETRY (ICP-AES)

The radio frequency-generated and maintained Ar plasma, portions of which are as hot as 10,000 K, excites the electrons. The plasma is used to atomize and ionize the elements in a sample.

When the electrons return to ground state at a certain spatial position in the plasma, they emit energy at the specific wavelengths peculiar to the sample's elemental composition. Light emitted from the plasma is focused through a lens and passed through an entrance slit into the spectrometer.

There are two types of spectrometers used in ICP-AES analysis:

sequential (monochromator) and simultaneous (polychromator).

Steps of ICP-AES analysis

Step 1: sample preparation

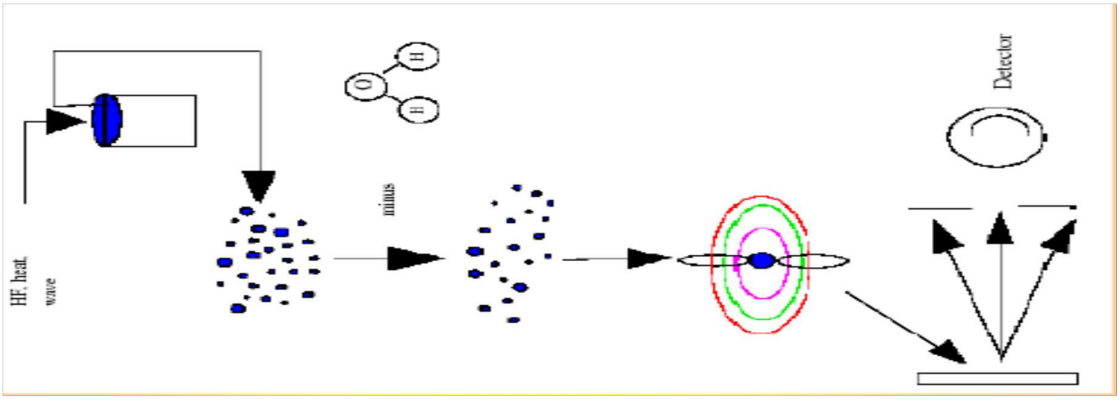
Step 2: nebulization (liquid becomes aerosol)

Step 3: desolvation/volatilization

Step 4: atomization

Step 5: excitation/emission (atoms gain energy by collisions and emit light with characteristic)

Step 6: separation/detection (light emitted is scattered and measured)



SOIL/LAND POLLUTION

Land pollution, in other words, means degradation or destruction of earth's surface and soil, directly or indirectly as a result of human activities. Anthropogenic activities are conducted citing development, and the same affects the land drastically. The degradation of land that could be used constructively in other words is land pollution.

Land Pollution has led to a series of issues that we have come to realize in recent times, after decades of neglect. The increasing numbers of barren land plots and the decreasing numbers of forest cover is at an alarming ratio. Moreover the extension of cities and towns due to increasing population is leading to further exploitation of the land. Landfills and reclamations are being planned and executed to meet the increased demand of lands. This leads to further deterioration of land, and pollution caused by the land fill contents. Also due to the lack of green cover, the land gets affected in several ways like soil erosion occurs washing away the fertile portions of the land.

CAUSES/SOURCES OF SOIL/LAND POLLUTION

1. Deforestation and soil erosion: Deforestation carried out to create dry lands is one of the major concerns. Land that is once converted into a dry or barren land, can never be made fertile again, whatever the magnitude of measures to redeem it are. Land conversion, meaning the alteration or modification of the original properties of the land to make it use-worthy for a specific purpose is another major cause. This hampers the land immensely. Also there is a constant waste of land. Unused available land over the years turns barren; this land then cannot be used. So in search of more land, potent land is hunted and its indigenous state is compromised with.

2. Agricultural activities: With growing human population, demand for food has increased considerably. Farmers often use highly toxic fertilizers and pesticides to get rid off insects, fungi and bacteria from their crops. However with the overuse of these chemicals, they result in contamination and poisoning of soil.

3. Mining activities: During extraction and mining activities, several land spaces are created beneath the surface. We constant hear about land caving in; this is nothing but nature's way of filling the spaces left out after mining or extraction activity.

4. Overcrowded landfills: Each household produces tons of garbage each year. Garbage like aluminum, plastic, paper, cloth, wood is collected and sent to the local recycling unit. Items that cannot be recycled become a part of the landfills that hampers the beauty of the city and cause land pollution.

5. Industrialization: Due to increase in demand for food, shelter and house, more goods are produced. This resulted in creation of more waste that needs to be disposed of. To meet the demand of the growing population, more industries were developed which led to deforestation. Research and development paved the way for modern fertilizers and chemicals that were highly toxic and led to soil contamination.

6. Construction activities: Due to urbanization, large amount of construction activities is taking place which has resulted in large waste articles like wood, metal, bricks, plastic that can be seen by naked eyes outside any building or office which is under construction.

7. Nuclear waste: Nuclear plants can produce huge amount of energy through nuclear fission and fusion. The left-over radioactive material contains harmful and toxic chemicals that can affect human health. They are dumped beneath the earth to avoid any casualty.

8. Sewage treatment: Large amount of solid waste is leftover once the sewage has been treated. The leftover material is sent to landfill site which end up in polluting the environment.

EFFECTS OF SOIL/LAND POLLUTION

1. Soil pollution: Soil pollution is another form of land pollution, where the upper layer of the soil is damaged. This is caused by the overuse of chemical fertilizers, soil erosion caused by running water and other pest control measures; this leads to loss of fertile land for agriculture, forest cover, fodder patches for grazing etc.

2. Change in climate patterns: The effects of land pollution are very hazardous and can lead to the loss of ecosystems. When land is polluted, it directly or indirectly affects the climate patterns.

3. Environmental Impact: When deforestation is committed, the tree cover is compromised on. This leads to a steep imbalance in the rain cycle. A disturbed rain cycle affects a lot of factors. To begin with, the green cover is reduced. Trees and plants help balance the atmosphere, without them we are subjected to various concerns like Global warming, the greenhouse effect, irregular rainfall and flash floods among other imbalances.

4. Effect on human health: The land when contaminated with toxic chemicals and pesticides lead to problem of skin cancer and human respiratory system. The toxic chemicals can reach our body through foods and vegetables that we eat as they are grown in polluted soil.

5. Cause Air pollution: Landfills across the city keep on growing due to increase in waste and are later burned which leads to air pollution. They become home for rodents, mice etc., which in turn transmit diseases.

6. Distraction for Tourist: The city loses its attraction as tourist destination as landfills do not look good when you move around the city. It leads to loss of revenue for the state government.

7. Effect on wildlife: The animal kingdom has suffered mostly in the past decades. They face a serious threat with regards to loss of habitat and natural environment. The constant human activity on land, is leaving it polluted; forcing these species to move further away and adapt to new regions or die trying to adjust. Several species are pushed to the verge of extinction, due to no homeland.

Other issues that we face include increased temperature, unseasonal weather activity, acid rains etc. The discharge of chemicals on land, makes it dangerous for the ecosystem too. These chemicals are consumed by the animals and plants and thereby make their way in the ecosystem. This process is called bio magnification and is a serious threat to the ecology.

Solutions for SOIL/Land Pollution

- Make people aware about the concept of Reduce, Recycle and Reuse.
- Reduce the use of pesticides and fertilizers in agricultural activities.
- Avoid buying packages items as they will lead to garbage and end up in landfill site.
- Ensure that you do not litter on the ground and do proper disposal of garbage.
- Buy biodegradable products.
- Do Organic gardening and eat organic food that will be grown without the use of pesticides.
- Create dumping ground away from residential areas.

Several creatures survive under the land too. Disrupting the harmony of the land, is disrupting their habitat. This has led to several creatures reaching the endangered status like the Gilbert's Potoroo in Australia.

THERMAL POLLUTION

When there is an increase in the temperature of water bodies by industrial processes or activity of thermal power stations it is referred to as thermal pollution.

The heated water causes a lowering of dissolved oxygen (DO) level in the body of water. As the DO content decreases the demand of oxygen increases in the water body, creating anaerobic conditions thereby disrupting the ecological balance.

CAUSES/SOURCES OF THERMAL POLLUTION:

- **Industrial Effluents**- Industries require cooling water for heat removal and cooling purposes. This heated water when discharged into the water system increases the temperature of water body.
- **Nuclear Power Plants**-Nuclear power plants emit large quantity of heat and traces of radioactive substances which increases the temperature of water bodies.
- **Coal- fired power plants**- It is one of the major sources of thermal pollution.
- **Domestic sewage**-When the domestic sewage is disposed off into water bodies like river, lakes etc., it increases the temperature of receiving water.
- **Radioactive waste**- Dumping of radioactive waste in marine system increases the temperature when these substances radiate energy.
- Stream temperature rises when trees and tall vegetation providing shade are cut.
- Soil erosion caused due to construction also leads to thermal pollution
- Removal of stream side vegetation.
- Poor farming Practices also lead to thermal pollution.

EFFECTS OF THERMAL POLLUTION:

- **Thermal shock**: Due to decrease in DO levels there is suffocation of plants and animal species which creates anaerobic conditions. The sudden change in the temperature causes harm to the aquatic organisms.
- **Thermal enrichment:** The heated water is used for irrigation purposes to extend plant growing seasons. The warmer water also increases the metabolic rate of aquatic organisms (which in turn decreases the life expectancy of these organisms). The speedy growth is beneficial for commercial purposes.
- **Increase in toxicity**: The rising temperature increases the toxicity of the poison present in water. A 10C increase in temperature of water doubles the toxicity effect of potassium cyanide, while 80ºC rise in temperature triples the toxic effects of o-xylene causing massive mortality to fish.
- **Interference in biological activity**: Temperature is of vital significance to physiology, metabolism and biochemical processes that control respiratory rates, digestion, excretion, and overall development of aquatic organisms. Temperature changes cause total disruption to the entire ecosystem.
- **Interference in reproduction:** In fishes, several activities like nest building, spawning, hatching, migration and reproduction depend on optimum temperature.
- **Direct mortality**: Thermal pollution is directly responsible for mortality of aquatic organisms. Increase in temperature of water leads to exhaustion of microorganisms thereby shortening the life span of fish. Above a certain temperature, fish die due to failure of respiratory system and nervous system failure.
- **Food storage for fish**: Abrupt changes in temperature alters the seasonal variation in the type and abundance of lower organisms leading to shortage of right food for fish at the right time.

Control measures for thermal pollution

The following methods can be adapted to control high temperature caused by thermal discharges:

1. **Cooling towers**: Use of water from water systems for cooling systems for cooling purposes, with subsequent return to the water way after passage through a condenser, is called cooling process. Cooling towers transfer heat from hot water to the atmosphere by evaporation. Cooling towers are of two types:

   (i) **Wet cooling tower:** Hot water coming out from the condenser (reactor) is allowed to spray over baffles. Cool air, with high velocity, is passed from sides, which takes away the heat and cools the water.

   (ii) **Dry cooling tower:** Here, hot water is allowed to flow in long spiral pipes. Cool air with the help of a fan is passed over these hot pipes, which cools down hot water. This cool water can be recycled.

2. **Cooling ponds:** Cooling ponds are the best way to cool thermal discharges. Heated effluents on the surface of the water in cooling ponds maximize dissipation of heat to the atmosphere and minimize the water area and volume. The warm water wedge acts like a cooling pond.

3. **Spray ponds**: The water coming out from condensers is allowed to pass into the ponds through sprayers. Here water is sprayed through nozzles as fine droplets. Heat from the fine droplets get dissipated to the atmosphere.

4. **Artificial lakes:** Artificial lakes are manmade water bodies that offer once-through cooling. The heated effluents can be discharged into the lake at one end and water for cooling purposes may be withdrawn from the other end. The heat is eventually dissipated through evaporation.

RADIOACTIVE POLLUTION

Radioactive pollution can be defined as the emission of high energy particles or radioactive substance into air, water or land due to human activities in the form of radioactive waste.

Radioactive waste is usually the product of a nuclear process such as nuclear fission, which is extensively used in nuclear reactors, nuclear weapons and other nuclear fuel-cycles

Radioactive pollution that is spread through the earth's atmosphere is called "**Fallout**". The atmospheric nuclear pollution becomes prominent during, the World War 2 period when United States, Britain and Soviet Union started conducting nuclear tests in the atmosphere.

The best example of fallout is the nuclear bomb attack on **Hiroshima and Nagasaki, Japan** in 1945 by United States of America during World War 2.

SOURCES OF RADIOACTIVE CONTAMINANTS:

Following are the major sources where most of the radioactive waste is generated and is responsible for causing radioactive pollution:

- Production of nuclear fuel
- Nuclear power reactors
- Use of Radionuclides in industries for various applications
- Nuclear tests carried out by Defense Personnel
- Disposal of nuclear waste
- Uranium Mining

Sources and Methods of Radioactive Pollution

Major sources	**Methods of pollution**
Nuclear power plants	• The waste resulted, in form of radioactivity, brings hazard when unsafely maintained • Nuclear power plant accidents, if radioactive core is exposed and meltdown is occurring and releasing high amount of radioactivity, will endanger the life and surrounding environment.
Nuclear weapon	• Nuclear weapon tests that are conducted above ground or under water • Nuclear bombing such as what have happened in Hiroshima and Nagasaki will create a vast and thorough devastation in a short time.
Transportation	• Transportation of nuclear wastes from one place to another, by any forms of transportation (air, land, water, sea) will possibly bring serious hazards to the environment if they are not maintained carefully and/or facing accidents.
Disposal of nuclear waste	• The decaying process of radioactive wastes takes a very long time in progress. Some radioactive substances have a half-life of more than 10,000 years, which means they are dangerous in that great amount of time. A half-life is the 'period of time required for the disintegration of half of the atoms in a sample of a radioactive substance' (Britannica). There are common ways to dispose nuclear waste (nuclear wastes are resulted from many kinds of use, for example medical use, mining, etc.): burying underground very deeply and burying under the sea, and even an idea that to send them to outer space. However, they are still dangerous and expensive. Science is still on its way finding a better way to solve this problem.
Uranium mining	• Uranium, substance that is used in nuclear power plants, is harvested from uranium mining. Uranium mining results in radioactive waste that pollutes the surrounding environment.

EFFECTS OF RADIOACTIVE POLLUTION

On the Environment

When soil is contaminated by radioactive substances, the harmful substances are transferred into the plants growing on it. It leads to genetic mutation and affects the plant's normal functioning. Some plants may die after such exposure, while others may develop weak seeds. Eating any part of the contaminated plant, primarily fruits, poses serious health risks. Since plants are the base of all food chains, their contamination can lead to radioactive deposition all along the food web. Similarly, when radioactive waste is washed up in a water source, it can affect the entire aquatic food web.

Both terrestrial and aquatic radioactive contamination can culminate in human consumption. Since humans are apex predators, the accumulation of radioactive materials on the last rung of the food chain would be maximum.

On Human Beings

The impact of radioactive pollution on human beings can vary from mild to fatal; the magnitude of the adverse effects largely depends on the level and duration of exposure to radioactivity. Low levels of localized exposure may only have a superficial effect and cause mild skin irritation. Effects of long, but low-intensity exposures include nausea, vomiting, diarrhea, loss of hair, bruises due to subcutaneous bleeding etc.

Long-term exposure or exposure to high amounts of radiation can have far more serious health effects. Radioactive rays can cause irreparable damage to DNA molecules and can lead to a life-threatening condition. Prolonged exposure leads to a large number of molecules in the body being ionized into free radicals. Free radicals promote the growth of cancerous cells, i.e. tumors, in the body. People with heavy radiation exposure are at a very high risk for cancers.

The rapidly growing/dividing cells, like those of the skin, bone marrow, intestines, and gonads are more sensitive towards radioactive emissions. On the other hand, cells that do not undergo rapid cell division, such as bone cells and nervous cells, aren't damaged so easily. Skin cancer, lung cancer and thyroid cancer are some of the common types of cancers caused by radiation.

The effects of genetic mutation are passed on to the future generations as well. In other words, if the parents are exposed to nuclear radiation, their child could have severe congenital birth defects, both physical and mental. This is tragically illustrated in the case of Hiroshima and Nagasaki, where the aftereffects of nuclear radiation were carried on for generations, and thousands of children were born with physical abnormalities and mental retardation. The radiation also brought about a spike in cancer; the region still (after more than 65 years) has a much higher rate of cancer and congenital abnormalities than the rest of Japan.