GOVERNMENT POLYTECHNIC BHUBANESWAR

Lecture Notes

On

Environmental Science

1st Semester

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Water pollution:

Water pollution is the contamination of water bodies like lakes, rivers, and oceans with harmful substances, which degrades water quality and makes it toxic to humans and the environment.

Sources of water pollution:

The most significant sources of water pollution are:

1.Industrial Discharges:

Industries discharge untreated effluents containing toxic chemicals, heavy metals, and other pollutants into waterways which cause toxicity to aquatic life and contamination of drinking water sources.

2.Agricultural Activities:

The chemicals used in agriculture, such as pesticides and insecticides, are rich in nitrogen, potassium, hydrocarbon, metallic salts, and phosphorus. When these chemicals are mixed up with water, they produce harmful pollutants for plants and animals.

3.Domestic sewage:

Untreated wastewater from households contains organic matter, detergents, and harmful pathogens like bacteria and viruses that enter water systems.

4.Solid Waste:

Improper disposal of garbage, especially plastics, ends up in rivers and oceans, where it can take hundreds of years to decompose and harms wildlife.

5. Atmospheric Deposition:

Atmospheric deposition is the deposition of pollutants from the atmosphere onto water bodies.

Major pollutants include acid rain and other airborne pollutants.

6.Oil Spills:

Accidental oil leaks from ships, drilling operations, and land-based sources are a major cause of water pollution.

7.Mining Activities:

Mining activities can lead to water pollution through discharges of waste products and runoff from mining sites.

Major pollutants include heavy metals, acid mine drainage, and sedimentation.

8.Nuclear wastes:

Nuclear waste consists of several reactive chemicals such as uranium, which remain for decades without perishing. Nuclear power plants, hospitals, and science processes discharge massive radioactive wastes daily.

9.Thermal pollution:

Discharge of water used for cooling in industries can raise the temperature of water bodies, affecting aquatic life.

Types of water pollutants:

1.Organic Pollutants:

Organic pollutants can be further divided into following categories:

a) Oxygen Demanding wastes:

Wastewaters from domestic sewage and industries like food processing plants, slaughterhouses, paper mills, tanneries etc., contain biodegradable organic matter. Bacteria decompose this matter using the dissolved oxygen (DO) in water. As DO decreases, aquatic life is affected—especially when DO falls below 4.0 mg/L.

b) Synthetic Organic Compounds:

Man-made chemicals like pesticides, detergents, plastics, paints, and solvents enter the environment through human activities. They are often toxic and resistant to microbial degradation, leading to persistent pollution.

c)Oil:

Oil enters water through spills, leaks, and refinery waste. Oil pollution results in reduction of light transmission through surface water, thereby reducing photosynthesis. It also contains toxic, carcinogenic PAHs (polycyclic aromatic hydrocarbons) that cause long-term pollution.

2.Pathogens:
Microbes from sewage and industrial waste contaminate water, causing diseases like cholera, typhoid, dysentery, polio, and hepatitis.

3.Nutrients:

Runoff and sewage add nitrogen and phosphorus to water, causing algal blooms and oxygen depletion.

This leads to eutrophication, harming aquatic life and causing health problems like blue baby disease and skin irritation.

4. Suspended solids and sediments

Presence of suspended solids can block the sunlight penetration in the water, which is required for the photosynthesis by bottom vegetation. Finer suspended solids such as silt and coal dust may injure the gills of fishes and cause asphyxiation.

5. Inorganic Pollutants:

Inorganic pollutants are non-biodegradable and can persist in the water system for a long period of time, posing greater environmental and public health risks. These pollutants include mineral acids, inorganic salts, trace elements, metals, metals compounds, complexes of metals with organic compounds, cyanides, sulphates, etc.

6. Radioactive pollutants:

Radioactive materials are extremely hazardous because their residues can last thousands of years. Major sources include uranium mining, nuclear power plants, and medical research. They cause long-term water pollution and serious health effects like cancer and genetic mutations.

7.Heat:

Discharge of hot water from power plants and industries raises water temperature, reducing dissolved oxygen (DO). This harms aquatic life and increases bacterial decomposition of organic matter.

Characteristics of water pollutants

1.Turbidity:

Turbidity is the measure of water's cloudiness or haziness, caused by suspended particles like sediment, silt and algae. It's a measure of water's ability to transmit light.

Turbidity is measured using a turbidity meter. A turbidimeter measures turbidity by determining the amount of light absorbed or scattered by the suspended particles. It is typically expressed in nephelometric turbidity units (NTU) or as the equivalent amount of suspended solids in milligrams per liter (mg/L).

A higher NTU reading indicates more suspended particles and greater cloudiness, while a lower NTU value signifies clearer water.

Calculation: The calculation involves using a turbidimeter to measure the light scattering effect of the particles in the sample. The standard unit is the turbidity produced by
1mg of finely divided silica in 1litre of distilled water.

2.pH:

pH is a measure of the **acidity or alkalinity** of water, indicating the concentration of hydrogen ions (H^+) in the solution. It is a critical parameter in assessing **water quality**, as it influences **human health**, **aquatic ecosystems**, and **industrial processes**. The pH scale typically ranges from 0 (highly acidic) to 14 (highly basic), with 7 being neutral.The ideal pH for drinking water is 6.5–8.5, as water outside this range can cause health issues, corrode pipes, and have an unpleasant taste.

Calculation: pH is primarily measured using a **pH meter**, an instrument with an electrode that measures the electrical activity of hydrogen ions and translates it to a pH value. The formula for pH is the negative base-10 logarithm of the hydrogen ion concentration [H+].

$pH=-\log10[H+]$

A pH below 7is acidic.
A pH above 7 is alkaline (or basic).
A pH of 7is neutral.

3.Total suspended solids (TSS)

Total suspended solids in water are non-dissolved solid particles, larger than 2 microns, that are suspended in the water and can be trapped by a filter. They can be organic or inorganic, including silt, sediment, algae, and decaying matter, and contribute to water's turbidity and lack of clarity. High TSS levels can harm aquatic life by reducing light penetration, clogging gills, and carrying pollutants.

1. TSS is typically measured in milligrams per liter (mg/L).
2. The measurement involves filtering a known volume of water through a pre-weighed filter paper and then drying the filter and its contents in an oven.
3. The weight difference of the filter before and after drying is used to calculate the TSS concentration.

Calculation:

4. Find the weight of the solids:

$$Weight_{solids}(g) = Finalweight(g) - Initialweight(g).$$

5. Convert to milligrams:

$$Weight_{solids}(mg) = Weight_{solids}(g) \times 1000$$

6. Calculate concentration:

$$TSS\left(\frac{mg}{L}\right) = \frac{Weight_{solids}(mg)}{Samplevolume(mL)} \times 1000$$

4. **Total solids (TS):**

1. Total solids (TS) in water are the sum of total suspended solids (TSS) and total dissolved solids (TDS). TSS are particles that can be trapped by a filter, while TDS are substances that are dissolved in the water. TS is determined by evaporating a water sample and weighing the remaining residue.
2. Total solid(TS)=Total dissolved solid(TDS)+Total suspended solid(TSS)
3. Calculation: TS is determined by evaporating a water sample completely without filtering it first, and then weighing the remaining residue.

$$TS(mg/L) = \frac{Weight_{totalsolids}(mg)}{Samplevolume(mL)} \times 1000$$

5.**Biological oxygen demand (BOD)**:

1. BOD measures the amount of oxygen consumed by bacteria and other microorganisms as they break down organic waste in the water.

2. It serves as an indirect measure of the amount of organic matter present in a water sample

3. While a dissolved oxygen test indicates how much oxygen is available, a BOD test indicates how much oxygen is consumed.

4. Calculation: BOD is determined by comparing the dissolved oxygen level in a freshly collected sample to the dissolved oxygen level in a sample that was collected at the same time, but incubated under specific conditions for a certain number of days.

5. The difference in the two oxygen levels is recorded in units of mg/L.

6. **Calculation:**

$$BOD(mg/L) = \frac{(InitialDO - FinalDO)}{P}$$

$InitialDO$= Dissolved oxygen in the sample immediately after collection (mg/L)
$FinalDO$=Dissolved oxygen in the sample after some days of incubation at 20°C (mg/L)
P= Decimal dilution factor (1 if the sample is not diluted)

1. A high BOD value signifies more organic pollution, while a low value indicates cleaner water.

6. **Chemical Oxygen Demand (COD):**

1. Chemical Oxygen Demand, a measure of the amount of oxygen needed to chemically oxidize organic and inorganic pollutants in water.

2. A high COD level indicates a higher concentration of pollution, as it requires more oxygen to break down the contaminants.

3. The test involves exposing a water sample to a strong oxidizing agent, like potassium dichromate, under acidic conditions to measure the oxygen consumed.

4. The mixture is heated in a reflux condenser to allow the oxidation reaction to complete.

5. The amount of remaining oxidizing agent is determined, and this is used to calculate the amount of oxygen that was consumed by the organic and inorganic substances in the original sample.

6. The result is expressed in milligrams of oxygen per liter of water (mg/L), or parts per million (ppm)

Waste Water Treatment:

Wastewater treatment methods are divided into three groups.

- Primary treatment or Mechanical treatment
- Secondary treatment or Biological treatment
- Tertiary treatment or Advance Biological or Chemical treatment

Primary Treatment - In primary treatment suspended solid and floating material is removed.

1.Sedimentation:

Sedimentation is the process of **settling down suspended particles** at the bottom of water under the influence of **gravity**. It is also known as **clarification**.

Sedimentation is based on the principle of **allowing water to rest or flow at a very slow velocity** so that heavier particles can settle under gravity.

So, in this process, water is stored in a large basin or tank, where the flow is kept **very slow**, allowing suspended impurities to settle naturally.
Sedimentation can be **accelerated by adding coagulants** like **alum**. This process reduces heavy sediment load before the water moves to subsequent treatment stages.

The process of settling of particles depend mainly on velocity of flow, size, shape and specific gravity of particles and viscosity of liquid.

2.Froth flotation

Froth flotation is a physical process that removes suspended solids, oils, and grease from wastewater by using air bubbles.

The process works by **introducing air bubbles** into the wastewater.

These bubbles attach to particles, decreasing their **effective density**, and causing them to **rise to the surface**.

The floated material forms a **layer of scum or foam**, which is then **skimmed off** and removed.

This method is effective for removing lighter, suspended particles that may be difficult to remove by settling. Therefore, flotation is typically used for **removing low-density, floatable contaminants**.

Secondary treatment

Secondary treatment methods for wastewater primarily use **biological processes** where microorganisms break down dissolved and suspended organic matter remaining after primary treatment. The main methods include:

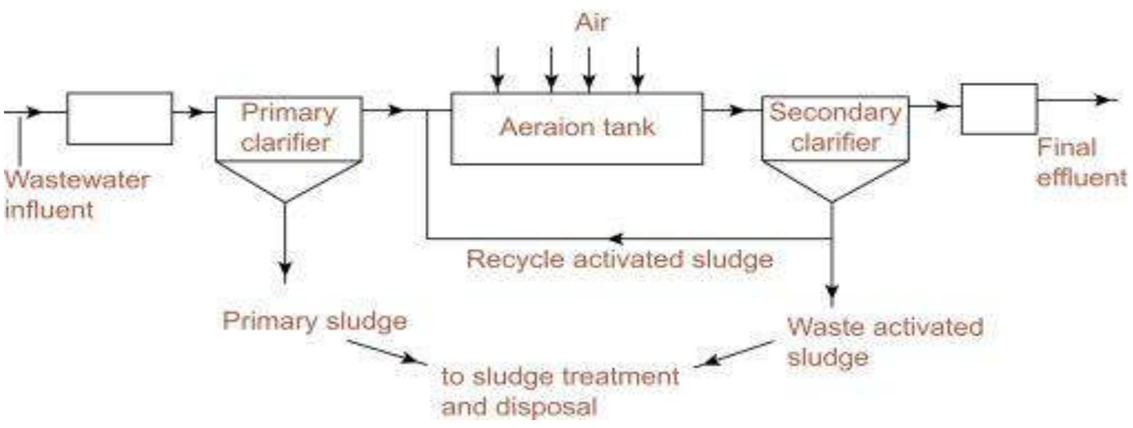
1.Activated Sludge Treatment:

1. This is a widely used suspended growth process where wastewater is mixed with a rich population of microorganisms (activated sludge) in an aerated tank.

2. Air is continuously supplied to provide oxygen for the microbes, which consume the organic pollutants as food. The treated water then flows to a secondary clarifier where the microbial mass settles out as "flocs."

3. A portion of this sludge is recycled back to the aeration tank to maintain the microorganism population, while the excess is removed for further sludge processing.

Advantages Activated sludge systems are highly effective at reducing biochemical oxygen demand (BOD) and removing suspended solids. They are commonly used in municipal and industrial wastewater treatment plants due to their efficiency**.**



2.Trickling Filter: This is a type of attached growth process (fixed-film reactor).

1. Trickling filter consists of filtering bed, spraying arm and water collecting chamber.

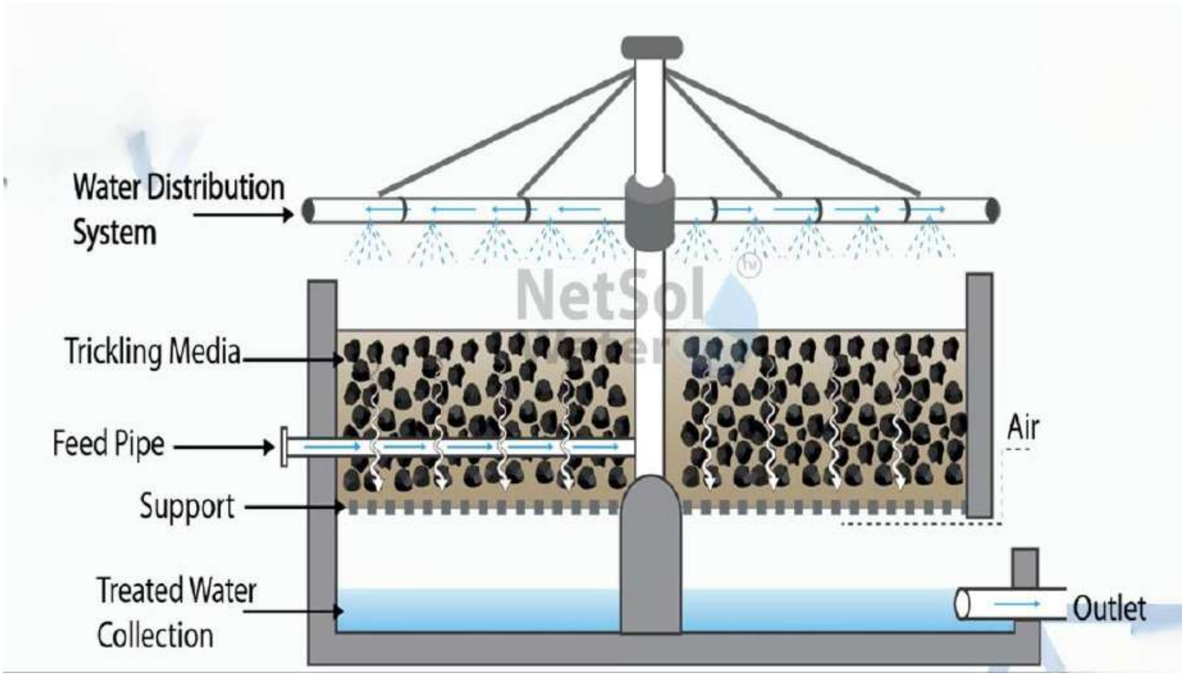
2. Filtering bed consists of well graded gravel, broken stone of size (40 150mm diameter).

3. Effluent or sewage from primary treatment tank is sprayed uniformly over the filter bed. During filtration a gelatinous layer of bacteria, algae, protozoa and some fungi is produced on the surface of filter bed. This layer is called Zoogleal layer.

4. As the water trickles through the filter bed, organic matter present in it is oxidized by microorganism of zoogleal layer.

5. Although trickling filter is classified as aeration process of sewage treatment, it is facultative system. It is because aerobic bacteria lie on the top of the filter bed whereas anaerobic bacteria lie in middle or bottom of filter bed.

6. Trickling filter can reduce BOD of sewage by about 65-85% depending on the rate of filtration.



Tertiary Method:
Membrane separation technology:

Membrane filtration is a method used to remove particles from a liquid by passing it through a semi-permeable membrane.This membrane acts as a barrier, allowing only certain molecules to pass through while blocking others based on their size, shape, and charge. Membrane filtration encompasses various processes such as microfiltration, ultrafiltration, nanofiltration, and **reverse osmosis**, each catering to specific filtration requirements.

Reverse osmosis

Reverse osmosis (RO) is a sophisticated water purification process that utilizes a semi-permeable membrane to remove ions, molecules, and larger particles from drinking water. In RO systems, water is pressurized and forced through the membrane, while contaminants are left behind, resulting in purified water on the other side. This process effectively eliminates a wide range of impurities, including salts, minerals, heavy metals, and organic compounds, producing high-quality drinking water.

The pore size of the reverse osmosis membrane is very small, generally 0.0001 microns, which can effectively remove pollutants such as soluble salts, organic matter, bacteria and viruses.

Application:

Reverse Osmosis: Reverse osmosis is commonly used for producing purified drinking water, desalination of seawater and brackish water, industrial process water treatment, and other applications where high-purity water is required.

Renewable Sources of Energy

Solar Energy

The sun is the largest source of renewable energy and this energy is abundantly available in all parts of the earth. It is, in fact one of the best alternatives to the non-renewable sources of energy.

Solar energy is the clean and endless energy we get from the Sun. The energy the Sun gives in one hour is more than what the whole world uses in a year.

Solar energy is a powerful source of energy, however, only a small portion of it can be mainly used to/for:

- Generate electricity
- Heating and cooling
- Cooking and
- Water desalination

Flat Plate Collector : A **flat plate collector** is a basic device used to collect solar energy, mostly for heating water at home.

Main parts of a flat plate collector:

Black absorber plate – absorbs sunlight

Glass cover – lets sunlight in and reduces heat loss

Tubes – carry water or air to transfer heat

Insulation – reduces heat loss from sides and bottom

Frame/support – holds all parts together

In a flat plate collector, the black plate absorbs sunlight and transfers the heat to the water or air in the tubes. The insulation on the sides and bottom, along with the glass cover on top, helps prevent heat loss.

Flat-plate systems usually work at **30°–80°C**, but advanced collectors with vacuum insulation and special coatings can reach **up to 200°C**.

Flat plate collectors transfer heat using a medium, which can be either a liquid (like water) or air.

Water based flat plate collector: In this type, water is used as a medium of heat transfer. Its main disadvantage is that it can freeze in winter, which may damage the collector or piping system **but this can be prevented by draining the collector occasionally.**

Air based flat plate collector: In this type of collector, air is used as the medium of heat transfer in stead of liquid/water. This type of plate collector is used for space heating or crop drying. A fan is usually required to facilitate air low in the pipe.

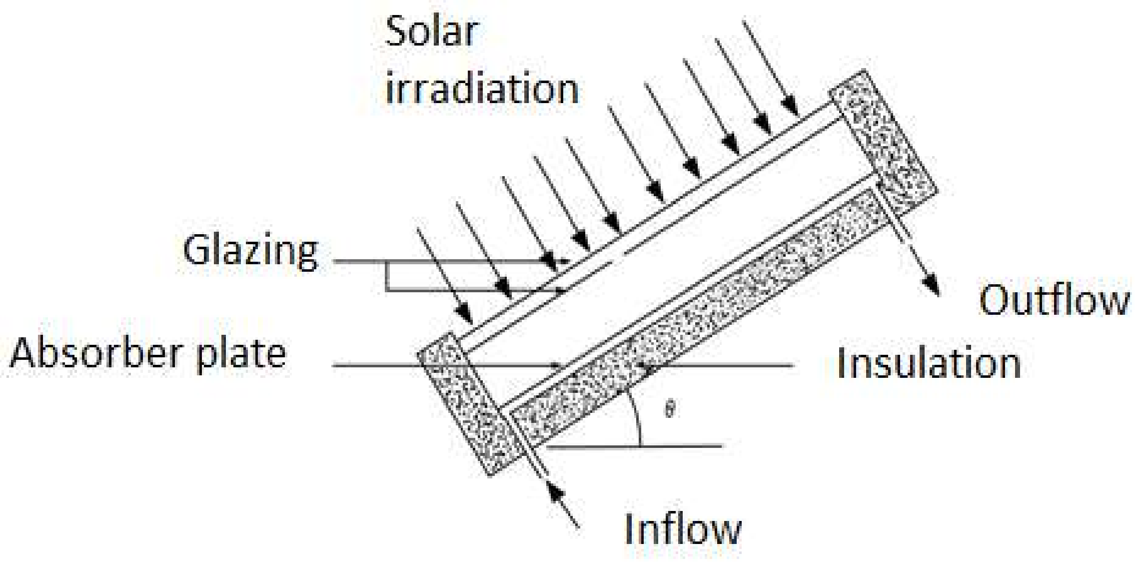
Theory of flat plate collector

When a metal sheet is exposed to sunlight, its temperature rises until the energy it gets from the sun equals the energy it loses.

If the plate is insulated at the back, painted black, and covered with glass, it will become much hotter.

This metal sheet can be converted into a heat collector by adding a water/air circulating system.

The absorbed heat from the heat collector gets transferred to the water/air in the tube and finally transferred to a storage tank.



Some of the advantages of flat plate collector includes;

6. easy to manufacture,
7. low manufacturing cost,
8. little maintenance etc.

Importance of coating

The solar absorber surface is the main part of a solar thermal collector as it absorbs sunlight and reduces heat loss. It is usually made of good heat-conducting metals like copper or aluminium and may have special coatings to absorb and retain heat better. These coatings improve features like high-temperature resistance, protection from UV and moisture, durability, and better optical performance.

Advanced collector :Normal plate collectors can heat water up to about 80°C, which limits them to uses like providing hot water and space heating. To reach higher temperatures for things like power generation, heat losses must be reduced. Instead of a flat plate, evacuated glass tubes with special black coatings are used. This design is called an advanced plate collector. It can heat fluids up to about 150°C, making it useful for power generation, solar air-conditioning, and other high-temperature applications."

Solar pond

A solar pond is a large pond built to collect and store solar energy. Normally, when water is heated by the sun, it rises and loses heat to the air. In a solar pond, salt is added so the water becomes heavier with depth. This prevents the warm water from rising, allowing the pond to trap and store heat.

A solar pond has three main layers. The top layer, called the Upper Convective Zone, is cool and has very little salt. The bottom layer, called the Lower Convective or storage zone, has the most salt and stores the heat. Between them is the Gradient Zone, where the salt content increases with depth. Because of this salt gradient, water in this middle zone cannot move up or down, so it acts like a clear insulator. Sunlight passes through it and heats the bottom layer, which can reach temperatures above 80°C. The hot water from the bottom is then sent through pipes to collect the stored heat.

Applications

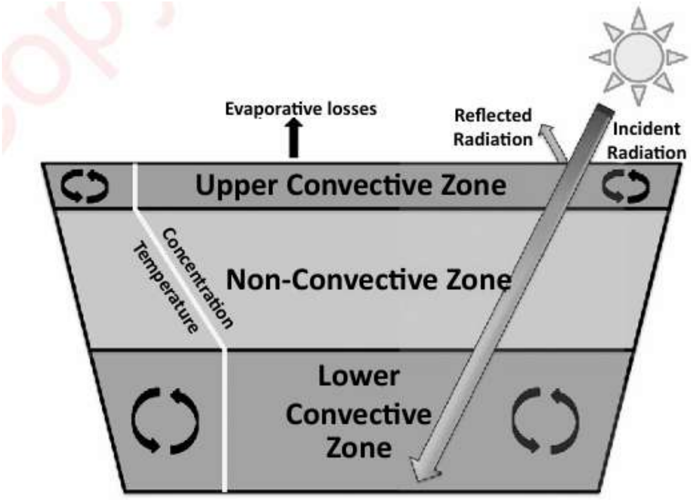
Heat from solar ponds can reduce the use of fossil fuels. It can be used in industries like chemicals, food, and textiles, or for heating greenhouses, swimming pools, and buildings. The heat can also generate electricity cheaply and is useful in remote areas. Solar ponds can even help purify water through desalination.

Advantages

Solar ponds have many advantages. They store heat, so energy is available day and night, all year. They are ideal for rural or less-developed areas, are cheaper than flat-plate solar systems, and provide clean energy without air pollution, helping conserve fossil fuels.

Disadvantages

Solar ponds have some drawbacks. They need a large area, lots of salt water, high sunlight, and regular maintenance.



Solar pond

Solar water heater

A solar water heater (SWH) uses sunlight to heat water, usually up to 60–80°C. Domestic systems of 100–300 litres are common, while larger systems serve hotels, hospitals, and restaurants. A 100-litre SWH can save about 1500 units of electricity and prevent 1.5 tons of CO_2 emissions each year.

The main components of solar water heater includes:

1. A collector to collect energy from solar radiation

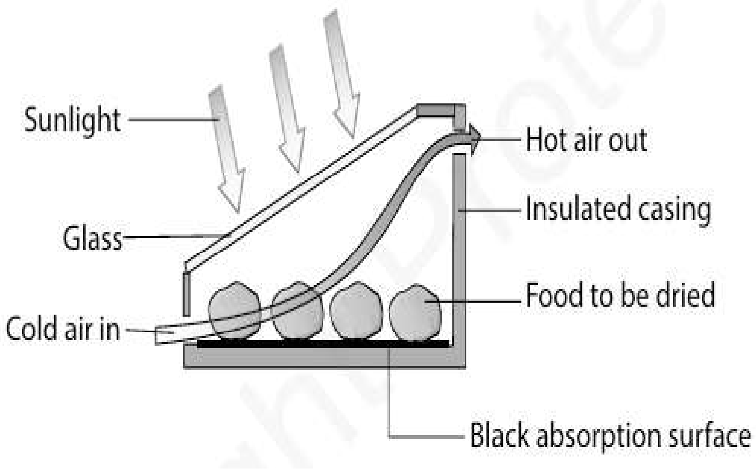
2. Insulated tank for storing heated water

3. Supporting arrangements

4. Connecting pipes and associated instrumentation.

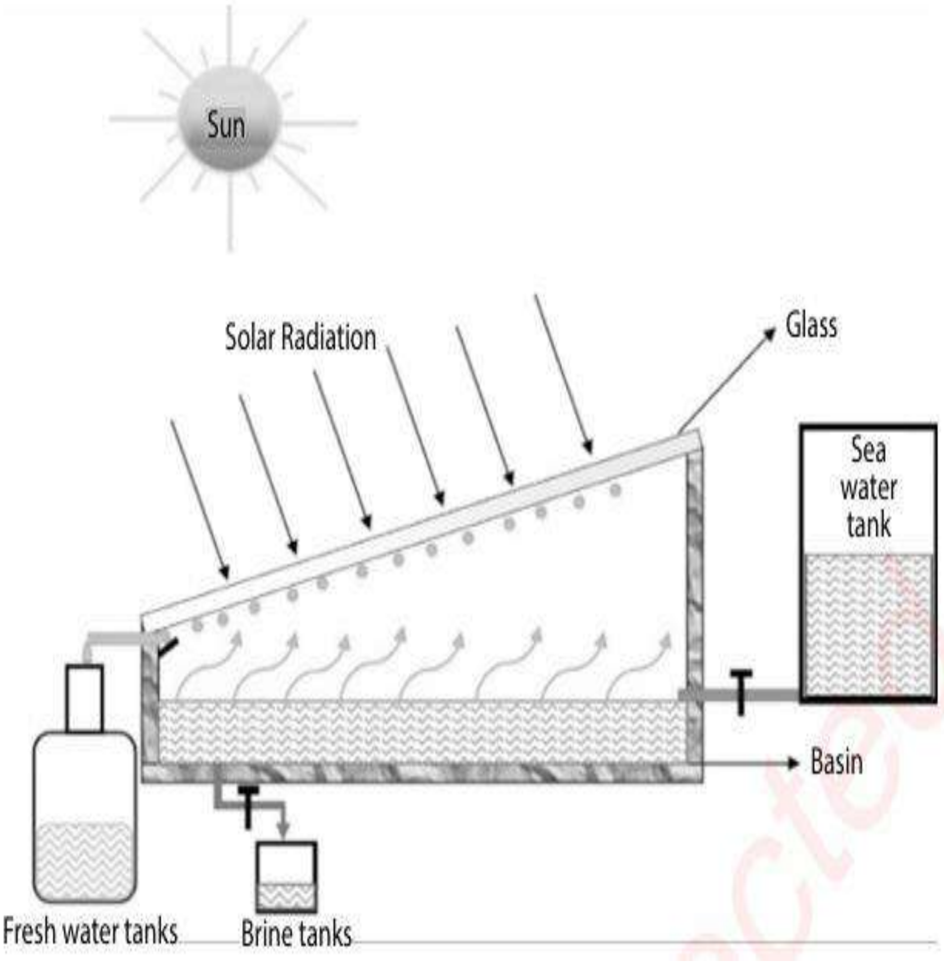
Sunlight hits the collector plate of a solar water heater and is absorbed by its black surface. The heat is transferred to the water, which is stored in an insulated tank to prevent heat loss. Solar water heaters are cost-effective and widely used in homes, hotels, industries, and community centers. A residence can save 70%-80% on electricity bill by replacing conventional water heater with solar water heater.

Solar dryer: A solar dryer uses sunlight to heat air, which is then circulated in a drying chamber to dry food like fruits and vegetables. Unlike traditional sun drying, the food is not exposed directly to the sun, preventing contamination from dust, rain, insects, or birds. Solar dryers are hygienic and suitable for drying large quantities, making them useful for small farmers and food producers.



Solar Stills

A solar still uses sunlight to purify water through evaporation and condensation. Impure water is placed in a basin covered with a transparent glass. Sunlight heats the water, which evaporates and leaves impurities behind. The steam condenses on the glass and flows into a clean basin as pure water, safe for drinking and cooking. Unlike boiling in commercial water purification, which lowers the water's pH and affects its taste, a solar still purifies water naturally, keeping the pH balanced and the taste intact.



Solar Still