Unit-II

SOURCES OF WATER

1. Surface Sources

Surface water sources are classified into:

- Rivers
- Streams
- Lakes
- Ponds
- Springs

1) Rivers:

A river is a flowing body of water originating from mountains or steep slopes. It's characterized by rapid water flow, waterfalls, eddy flows, and strong currents.

- Public water supply schemes rely heavily on rivers as a significant water source.
- Rivers can be classified as:
    - **Perennial rivers:** These rivers have a continuous flow throughout the year, although they may experience increased flow during summer due to melting ice.
    - **Seasonal rivers:** These rivers flow full during the rainy season but have significantly reduced flow afterward, potentially drying up during summer. Dams and reservoirs are constructed across seasonal rivers to store surplus water for use during dry periods.

Water Quality:

Water is considered pure when it is transparent, colorless, odorless, and has an agreeable taste due to minimal mineral content.

Pollution:

Pollution refers to the presence of foreign elements or natural constituents in excess concentration, negatively impacting the basic nature of water. This can be of physical, chemical, or biological origin.

- Water with a salt concentration greater than 1000 mg/l is considered brackish. For reference, seawater has a TDS (Total Dissolved Solids) content of 35000 mg/l.
- Dissolved oxygen is crucial for aquatic life. Pure water at 0°C has a dissolved oxygen content of 14.6 mg/l, which decreases to 7.6 mg/l at 30°C.
- The presence of impurities reduces dissolved oxygen levels.
- The type of fish present in a water body is a good indicator of water quality, as fish survival depends on dissolved oxygen levels.
- The absence of certain natural ingredients also indicates pollution.

Water pollution arises from human activities like discharging wastewater into water bodies.

Self Purification:

Rivers have the potential for self-purification by oxidizing impurities through their currents and continuous flow.

- The flow length and broad catchment area of a river contribute to collecting various impurities. These include:
    - **1. Floating impurities:** These have a specific gravity less than water and are easily separated, e.g., wood, leaves, and paper.
    - **2. Suspended solids:** These are fine inorganic solids with a specific gravity greater than water but are carried along the flow due to water velocity. When the flow velocity decreases, these solids settle due to sedimentation.
    - **3. Colloidal solids:** These are microscopic particles with a large surface area and charge. Chemical coagulants are added to neutralize their charge, causing them to clump together (agglomerate) and form larger particles (flocs), which then settle. Alum [$Al_2(SO_4)_3.18H_2O$] is a common coagulant for water treatment.

4. Turbidity: Turbidity is the cloudiness of water caused by suspended and colloidal matter, making it aesthetically objectionable. It can be addressed through:

- **Screens/Grading:** Remove floating solids.
- **Plain sedimentation tanks:** Collect settled solids as sludge.
- **Classiflocculators:** Remove suspended and colloidal solids.
- **Sand filters:** Remove suspended solids and colloidal solids, along with color and odor.

Disinfection: This process kills disease-causing microbes (pathogens) in water.

5. E-coli:

E-coli is a bacterium found in the intestinal tracts of warm-blooded animals. Its presence in water indicates fecal contamination and the potential presence of disease-causing pathogens.

Self-Purification of Streams:

Rivers and streams have a natural ability to purify themselves by oxidizing impurities like organic matter due to their continuous flow. This process is called self-purification and involves several physical, chemical, and biological actions:

1. Dilution: Discharged pollutants are rapidly dispersed and diluted in the flowing water.

2. Sedimentation: Settleable organic solids in the water settle to the bottom as sludge.

3. Oxidation: As soon as organic matter comes into contact with water, it begins to oxidize due to the presence of oxidizing organisms in the water.

4. Reduction: This occurs through the chemical and biological breakdown (hydrolysis) of organic matter, often facilitated by bacteria.

5. Sunlight: Sunlight contributes to self-purification by stabilizing the water and reducing bacterial growth through its bleaching effect.

Factors Influencing Self-Purification:

1. **Velocity:** Higher flow velocity leads to faster self-purification.
2. **Waterfalls/Rapids/Eddy currents:** These create turbulence, slowing down the water flow and providing more time for self-purification.
3. **Vegetation along river course:** Trees and plants release oxygen during photosynthesis, accelerating the self-purification process.
4. **Initial D.O (Dissolved Oxygen):** Higher dissolved oxygen levels in the receiving water body allow for quicker breakdown of pollutants and faster recovery.
5. **Aquatic life:** A water body rich in aquatic flora, fauna, and microbes recovers more quickly.

Lakes and Ponds, Tanks & Reservoirs

These are stagnant water bodies, either naturally occurring or artificially created.

- **Natural Lakes:** Elevated lakes formed along mountain slopes generally contain extremely pure water due to their elevation and minimal chances of contamination or pollution.
- **Natural Depressions:** A large-sized depression filled with water is known as a "lake," while smaller ones are called "ponds."
- **Water Sources:** These water bodies can be filled by streams, underground water through springs, or a combination of sources.
- **Tanks:** These are artificial, stagnant water bodies created to supply water to villages.
- **Reservoirs:** These are large, static water bodies formed by constructing an annual (or) dam across a river, regulating its flow and creating a steady and uniform water source. Reservoirs are often called "artificial lakes."
- **Canals:** These are artificial surface water sources with a uniform cross-section, designed to transport water from reservoirs based on our requirements. The flow through canals is controlled and uniform.

Water Quality:

Lakes, ponds, tanks, and reservoirs are stagnant water bodies and are susceptible to pollution if their catchments are not adequately protected.

- They typically have water free from suspended solids due to the stagnant nature of the water.
- However, the water may contain more dissolved solids due to the limited area of their catchment and prolonged water contact time.
- Low-lying ponds and lakes without any natural boundaries are more vulnerable to pollution.

Types of Lakes:

- **Oligotrophic Lake:** A lake with a transparent water column, colorless, odorless, and with few nutrients. Freshwater fish and small amounts of green algae may be present.
- **Eutrophic Lake:** Over the years, lakes accumulate nutrients (nitrates and phosphates) and become increasingly turbid, taking on a deep yellow-green color due to algal mats and aquatic plant growth.
- **Senescent Lake:** As eutrophication continues, the depth of the lake decreases, the water content is reduced, and plant growth intensifies.
- **Cultural Eutrophication:** While natural eutrophication takes thousands of years, human activities like discharging septic tank effluent and industrial wastewater can accelerate the process, converting a freshwater lake into a eutrophic lake within a few days.

GROUND SOURCES

Groundwater sources originate from the water cycle and are stored in aquifers beneath the ground surface.

- **Aquifer:** A water-bearing porous rock or sediment layer that allows the passage of water through it. Wells can be drilled into aquifers to provide a clean water source.
- **Global Water Distribution:** Groundwater sources constitute 0.6% of global water, while surface water constitutes only 0.02%.
- **Advantages of Groundwater:** Surface water sources are unevenly distributed globally, while groundwater can be tapped almost anywhere.
  - Groundwater is often a more reliable water source in arid and semi-arid regions.
  - It is also generally more affordable and accessible, making it a vital resource for less affluent communities.
  - 85% of India's rural domestic water requirements and more than 50% of irrigation needs are met by groundwater.

Types of Rocks:

Rocks can be classified as:

- **Porous:** e.g., syenite, dolerite, gabbro.
- **Impervious:** e.g., granite, gneiss, quartzite.

Beds of gravel, sand, and sandstone are considered aquifers because they are porous and allow easy infiltration of water.

- **Aquiclude:** A porous rock or sediment layer that absorbs water but does not release it easily. Shale is an example of an aquiclude because it is highly porous (greater than 50% porosity) but its pores are not interconnected.
- **Aquifuse:** An impervious rock or sediment layer that does not allow water to pass through.

Groundwater Formation:

A groundwater source is formed only when an aquifer overlies an aquiclude.

- **GWT (Groundwater Table):** The upper surface of the groundwater in an unconfined aquifer.
- **Zone of Aeration:** This layer lies above the GWT and contains a mix of soil, moisture, and air-filled spaces called voids. The water content in this zone is typically very low but can fluctuate seasonally.
- **Capillary Water:** Thread-like columns of water that extend upward from the GWT into the zone of aeration. This water is held in place by capillary action and is the primary source of moisture for plants.

Perched Water Table: A localized zone of saturation above the main water table, formed when a layer of less permeable material (aquiclude) of limited extent overlies the main aquifer. The perched water table is typically shallower than the main water table and can create a spring or seep where it intersects the surface.

Types of Groundwater:

- **Free Water:** Water found in aquifers above the first confining layer. This water is easily accessible but can be susceptible to contamination from surface activities.
- **Confined Water:** Water found in an aquifer sandwiched between two impermeable layers (aquicludes). This water is typically under pressure and can rise above the top of the aquifer if a well is drilled into it. Confined aquifers are generally less vulnerable to contamination than unconfined aquifers because the confining layers act as barriers to the downward movement of pollutants.

Sub-surface water sources

- Infiltration galleries
- Infiltration wells
- Springs
- Wells, including tube wells

1. Infiltration galleries: These are underground tunnels used for tapping groundwater near rivers, lakes, or streams.

- Groundwater is allowed to enter these galleries from one or both sides as desired.
- The yield of these galleries can be as high as 1.5×10^4 liters/day/meter of length.
- They are also called horizontal wells.
- For maximum yield, they should be placed at the full depth of the aquifer.
- They are constructed with masonry or concrete, with weep-holes of 5cm×10cm, surrounded by gravel or pebbles on the sides and top to increase intake capacity.

2. Infiltration wells: These are shallow wells constructed in a series along the banks of a river to collect river water seeping through the bottom.

- They are typically constructed with brick masonry with open joints. They are generally covered at the top and kept open at the bottom.
- Manholes are provided in the top cover for inspection purposes.
- The various infiltration wells are connected by porous pipes to a sump well called a "jack well." The water collected in the jack well is then lifted, treated, and distributed to consumers.
- **Radial Wells:** These are wells with a vertical shaft 3 to 6 meters in diameter and horizontal radial collectors extending outwards.
    - The length of these radial collectors can be 60-80 meters.
    - About 10 radial collectors can be installed at one level, and another set of collectors at another level to increase the yield.
    - The water from radial wells is generally clean, fresh, and free from bacterial contamination and can be pumped directly into the mains.

3. Springs: A spring is a natural outflow of groundwater at the Earth's surface.

- Springs are generally capable of supplying small amounts of water and may be used as small-town water supply sources, especially in hilly areas.
- Hot springs, which are rich in sulfur, are not suitable for drinking water but have other uses.

<u>Types of Springs:</u>

- **a. Gravity springs:** When the groundwater table is high and water overflows through the sides of a natural valley or depression, the spring formed is known as a gravity spring.
- **b. Surface springs:** Sometimes an impervious layer can obstruct the underground water flow, causing the water table to rise and the water to be exposed at the ground surface. This type of spring is known as a "surface spring."
- **c. Artesian springs:** When a water-bearing stratum is under pressure, sandwiched between impermeable layers above and below, water can flow to the surface through weaker spots in the upper impervious layer. This is an artesian spring. The yield of an artesian spring is more uniform and consistent throughout the year compared to other types of springs.

4. Wells: A well is a hole, usually vertical, excavated in the earth to bring groundwater to the surface.

Types of Wells:

- **a) Open wells:** These wells are open to the atmosphere and rely on gravity to draw water from the surrounding aquifer.
- **b) Tube wells:** These wells are typically drilled into confined aquifers and use a pump to draw water to the surface.

Classification of Open Wells:

- **Gravity well:** A gravity well is a well in which the surface of the water inside the well is at atmospheric pressure. The water flows under gravity from the surrounding aquifer into the well and rises to the height of the saturated material surrounding it.

- **Pressure well:** In a pressure well, also called an artesian well, the aquifer is confined between two impervious layers, one above and one below, so that the water is under pressure. When the well is drilled into the confined aquifer, the pressure forces the water to rise above the top of the aquifer, sometimes even flowing freely at the surface.

Classification of Wells based on Aquifer Tapped:

- **Shallow well:** A shallow well is one that is constructed by tapping the uppermost water-bearing stratum. However, if a deeper well is needed to access larger and more reliable supplies of water, then it is called a deep well.

<u>Types of Wells based on Construction:</u>

- **i) Dug well:** This is a shallow well with a masonry wall excavated from the ground surface. A well curb is constructed at the site where the well is to be dug. As the excavation proceeds, the soil is removed from inside, and the masonry is built from the top. The well curb's weight causes the well to sink, and masonry is added as the excavation deepens.
- **ii) Sunk well:** This type of well is constructed by sinking a prefabricated well casing into the ground. These wells are not commonly used anymore. They were primarily built at locations where water-bearing strata of large extent and porosity could be easily found below ground level.
- **iii) Driven well:** This is a shallow well constructed by driving a casing pipe into the ground. The casing pipe is typically 25mm-100mm in diameter. The lower end of the pipe is closed and pointed to form a well point. The pipe is driven into the ground by a hammer.
- **iv) Tube wells:** Tube wells are constructed by boring into the ground and driving in a casing with a well screen at the bottom. These wells are suitable for both deep and shallow aquifers and can be constructed in soft soil or rock formations. They are also known as bored wells (or) drilled wells and have diameters ranging from 25mm to 900mm.

<u>DESALINATION</u>

Desalination is the process of extracting fresh water from brackish water, seawater, or brine.

Types of Water Based on TDS:

- Freshwater: < 500 mg/l of TDS
- Brackish water: 1000 mg/l of TDS
- Seawater: > 35,000 mg/l of TDS
- Brine: > 70,000 mg/l of TDS

Desalination can be used for municipal, industrial, or commercial applications. The process separates saline water into two parts:

1. **Treated water:** Water with a lower salt concentration.
2. **Concentrate:** Water with a higher salt concentration than the original feed water.

Desalination Technologies:

- **Thermal Technologies:**

- **1. Multi-Stage Flash Distillation (MSF):** This process involves distilling seawater through a series of chambers (20-50 boilers) operating at progressively lower pressures. This method is energy-intensive but produces a large volume of freshwater.
- **2. Multi-Effect Distillation (MED):** This process uses a series of evaporators (effects) operating at progressively lower temperatures and pressures. This method is more energy-efficient than MSF but produces a smaller volume of freshwater.
- **3. Vapor Compression Distillation (VCD):** This process uses mechanical compression to increase the pressure of the vapor, which raises its boiling point. This allows the vapor to be condensed at a higher temperature, reducing the energy required for desalination.

Membrane Technologies:

- **1. Electrodialysis (ED):** This process uses an electric current to separate the salt ions from the water. It is most effective for treating brackish water.
- **2. Electrodialysis Reversal (EDR):** A variation of ED that periodically reverses the polarity of the electric current to prevent scaling on the membranes. This extends the membrane life and reduces the need for chemical cleaning.
- **3. Reverse Osmosis (RO):** This process forces water through a semi-permeable membrane that allows water molecules to pass through but rejects salt ions, organics, bacteria, and other impurities. RO is a widely used desalination technology that can be used for a variety of water sources, including seawater, brackish water, and wastewater.

Reverse Osmosis (RO):

RO is a process that removes minerals and deionizes water by forcing it under pressure through a semi-permeable membrane.

How Osmosis Works:

Osmosis is a natural process where a weaker saline solution will naturally move towards a stronger saline solution through a semi-permeable membrane. This occurs without needing additional energy.

Reverse Osmosis:

RO reverses the natural process of osmosis. It requires energy to force water from a high salt concentration solution to a low salt concentration solution through a semi-permeable membrane. This removes impurities and produces clean water.

RO Pretreatment:

Proper pre-treatment is essential for RO systems to function efficiently and prevent membrane damage. This includes:

- **Mechanical Treatment:** Removing particulate matter like dirt, silt, and clay through filtration.
- **Chemical Treatment:** Adjusting pH, removing chlorine, and adding scale inhibitors to prevent membrane scaling and fouling.

RECYCLING OF WASTE WATER

Wastewater recycling involves reusing treated wastewater for beneficial purposes, such as:

- **Irrigation:** For agriculture and landscaping.
- **Industrial processes:** Cooling water for power plants and other industries.
- **Toilet flushing:** Using treated wastewater for non-potable purposes.
- **Groundwater recharge:** Replenishing depleted aquifers.

Benefits of Water Recycling:

- **Resource Conservation:** Reduces the demand for freshwater sources, which are under increasing pressure due to population growth, industrialization, and pollution.
- **Environmental Protection:** Reduces pollution of surface and groundwater by treating and reusing wastewater.
- **Economic Benefits:** Provides a cost-effective alternative to developing new water sources.

Characteristics of Suitable Reclaimed Water:

- **Colorless and Odorless:** Treated wastewater should be free from unpleasant colors and odors.
- **Free from Pathogens:** Wastewater must be thoroughly disinfected to eliminate harmful pathogens.
- **Safe for Intended Use:** The quality of treated wastewater should meet the specific requirements of its intended use.

Examples of Wastewater Reuse:

- **Greywater Reuse:** Wastewater from bathrooms (excluding toilets) and kitchens can be used for irrigating gardens and landscaping.
- **Washing Machine Water:** Water from washing machines can be used for flushing toilets.
- **Kitchen Wastewater:** Kitchen wastewater, a valuable source of nutrients, can be used for irrigating crops after proper treatment.

Standards for Recycled Water:

- **Turbidity:**
    - Wastewater with turbidity less than 25 NTU can be used for any purpose after proper treatment.
    - Wastewater with turbidity less than 10 NTU can be used for creating lawns, playgrounds, cooling machines, and raising all types of crops after disinfection.
    - Wastewater with turbidity less than 10 NTU can be used for flushing toilets, fire fighting, construction, and washing animals without disinfection.
- **Coliform Bacteria:**

- Disinfected wastewater with coliform levels below 200/100ml can be used for non-edible crops like cotton, tobacco, fodder, boiler feed, concrete mixing, dust control, and street cleaning.
- Wastewater with coliform levels below 1000/100ml and BOD below 60 mg/l can be used for irrigating the sanitary sewer.

BOD (Biochemical Oxygen Demand):

BOD is a measure of the amount of oxygen required to decompose organic matter in water into stable and harmless products at a particular temperature.

Water Recycling Process:

Wastewater recycling utilizes physical, chemical, and biological principles to remove contaminants from water.

RECHARGING OF AQUIFERS

Aquifers, porous underground layers that hold water, are recharged naturally by rainfall. However, due to increasing water demands and unpredictable rainfall patterns, artificial recharge methods have become crucial to replenish depleted aquifers.

Artificial Recharge: This is the process of artificially augmenting groundwater resources by intentionally increasing the amount of water that enters an aquifer.

Suitable Water for Artificial Recharge:

The water used for artificial recharge should be:

- **Clean and Free from Clogging Agents:** To prevent clogging the pores of the aquifer, the water must be free of suspended solids and other contaminants.
- **Disinfected:** To prevent contamination of the aquifer, the water should be disinfected to eliminate harmful pathogens.

Methods of Artificial Recharge:

- **1. Rapid Infiltration:**
  - **Selecting a Site:** A barren land not used for cultivation is selected for this method.
  - **Creating Basins:** Basins are created on the selected land to hold water up to a depth of 1-2 meters.
  - **Filling the Basins:** The basins are filled with clean, disinfected wastewater meeting specific quality standards:
    - Suspended solids: < 10 mg/l
    - Nitrates: < 12 mg/l
  - **Infiltration Period:** The basins are allowed to hold water for 1 to 7 days, depending on the soil type, temperature, and other atmospheric conditions, allowing water to seep into the ground and recharge the aquifer.

- **Infiltration Rate:** The rate of infiltration should be around 75 mm/day, not exceeding 225 mm/day, to avoid waterlogging and ensure proper aeration of the soil.
- **Drying and Aeration:** After the basin empties, it's left open to the sky for 5-14 days to dry and allow air to enter the soil pores. This helps in restoring aerobic conditions in the soil and promoting the activity of beneficial microorganisms.

- **2. Deep well Injection:** This liquid waste disposal technology involves injecting treated wastewater into deep aquifers that have no potential for contaminating potable water resources.

Wastewater Treatment for Deep Well Injection:

- **Biological Treatment:** The wastewater is treated biologically to remove organic matter and kill pathogens.
- **Disinfection:** It's then disinfected to further eliminate any remaining pathogens.
- **TDS Removal:** The TDS (Total Dissolved Solids) levels are reduced to below 3000 mg/l.
- **Nitrogen Removal:** Total nitrogen levels are reduced to less than 10 mg/l.

Well Placement: Any well used for deep well injection should be at least 1.5 km away from other wells used for drinking water supply to prevent contamination.

Limitations of Deep Well Injection:

- **Seismic Activity:** Deep well injection should be avoided in areas prone to earthquakes as it could trigger seismic activity.
- **Clogging:** Wastewater with high suspended solids (greater than 2 ppm) can clog the injection well, reducing its efficiency.
- **Corrosion:** Wastewater with high iron concentrations can corrode the well components, leading to premature failure.
- **Pretreatment:** Wastewater streams containing organic contaminants above their solubility limits may require pretreatment before injection to prevent clogging the injection well.