SPINTRONIC TECHNOLOGY AND ADVANCE RESEARCH, BHUBANESWAR

Department of Civil Engineering

LECTURE NOTES ON: WATER AND WASTE WATER ENGINEERING
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General requirement for water supply, sources, quality of water, intake, pumping and transportation of water..

Module-II

Physical, chemical and biological characteristics of water and their significance, water quality criteria, water borne diseases, natural purification of water sources.

Module-III

Engineered systems for water treatment : aeration, sedimentation, softening coagulation, filtration, adsorption, ion exchange, and disinfection. Design of water distribution system.

Module-IV

Generation and collection of waste water, sanitary, storm and combined sewerage systems, quantities of sanitary waste and storm water, design of sewerage system Primary, secondary and tertiary treatment of wastewater. Waste water disposal standards,

Module-V

Basic of microbiology. Biological wastewater treatment system : Aerobic processes activated sludge process and its modifications, trickling filter, RBC, Anaerobic Processes conventional anaerobic digester, High rate and hybrid anaerobic reactors, Sludge digestion and handling, Disposal of effluent and sludge, Design problems on water distribution, sewerage, water treatment units, wastewater treatment units and sludge digestion.

Reference Books:

1. Water Supply Engineering-Environmental Engineering v.1 by S.K.Garg, Khanna Publishers
2. Sewage Disposal and Air Pollution Engineering - Environmental Engineering v.2 by S.K.Garg, Khanna Publishers
3. Water Supply and Sanitary Engineering by B.S.BirdiDhanpat Rai Publishing Company
4. Water Supply Engineering by B. C. Punmia and A.K.Jain, Laxmi Publications
5. Water and Wastewater Technology by M.J.Hammer, PHI

MODULE-I

General Requirements for Water Supply:

1. **Demand Assessment**: Before planning, an assessment of water demand is crucial. This includes residential, commercial, industrial, and institutional needs.
2. **Infrastructure Planning**: Designing a water supply system involves determining the layout of pipelines, reservoirs, treatment facilities, and pumping stations.
3. **Legal and Regulatory Compliance**: Adherence to local laws and regulations governing water supply infrastructure, water quality standards, and environmental protection.
4. **Maintenance and Operations**: Establishing protocols for regular maintenance of infrastructure to ensure uninterrupted water supply and compliance with health and safety standards.

Sources of Water:

1. **Surface Water**: Rivers, lakes, and reservoirs are common sources. Intake structures are built to draw water from these sources.
2. **Groundwater**: Wells and boreholes are used to extract groundwater. Pumping systems bring water to the surface.
3. **Alternative Sources**: Desalination plants for seawater, rainwater harvesting, and wastewater treatment for reuse.

Quality of Water:

1. **Water Quality Parameters**: pH levels, turbidity, dissolved oxygen, and presence of contaminants like heavy metals, pathogens, and organic compounds.
2. **Treatment Processes**: Filtration, chlorination, UV disinfection, and chemical treatments to meet safety and health standards.
3. **Monitoring**: Continuous monitoring of water quality at intake points, treatment plants, and distribution networks.

Intake of Water:

1. **Intake Structures**: Screens to prevent debris, fish screens to protect aquatic life, and pumps or gravity flow systems to convey water to treatment facilities.
2. **Sedimentation**: Settling tanks to remove suspended solids before treatment.

Pumping:

1. **Pump Stations**: Installed along the distribution network to maintain pressure and flow rates.
2. **Types of Pumps**: Centrifugal pumps for high-flow, low-pressure applications; positive displacement pumps for high-pressure, low-flow situations.
3. **Energy Efficiency**: Use of variable speed drives and pump scheduling to optimize energy use.

Transportation of Water:

1. **Distribution Network**: Network of pipelines, valves, and storage tanks to deliver water to consumers.
2. **Pressure Management**: Control valves and pressure regulators to maintain optimal pressure levels and minimize leaks.
3. **Water Storage**: Reservoirs and elevated tanks to store and stabilize supply during peak demand periods or emergencies.

Conclusion:

Effective water supply systems require meticulous planning, adherence to quality standards, and robust infrastructure. Continuous monitoring, maintenance, and adherence to environmental regulations are essential to ensure sustainable water supply to communities and industries. Integrating advanced technologies and practices can enhance efficiency and resilience against challenges such as climate change and population growth.

MODULE-II

PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF WATER

1.Introduction

Water is essential to life. Without it, the biosphere that exists on the surface of the earth would not be possible. It is also the only known chemical compound that occurs in all the three physical states viz., solid (snow, hail, sleet and ice), liquid (rain, water droplets) and gas(water vapors)within the relatively small range of air temperatures and pressures found at the Earth's surface and it can change between these phases in a fairly short period of time. The gaseous state of water regulates the atmospheric moisture dynamics. On an average, a molecule of water vapour in the atmosphere will exist in its gaseous phase for only a few days before condensing to liquid droplets or ice crystals to form clouds or fog. Similarly, clouds and fog have limited lifespan and often evaporate away or precipitate much of their moisture within a few hours of their formation. Most of the earth's water sources get their water supplies from this precipitation. Thus, there is a continuous interchange of moisture between the earth and atmosphere, constituting the hydrological cycle. This cycle controls the temporal and spatial distribution of renewable fresh water in the form of evapo transpiration, precipitation and runoff. Climatic factors and changes in climate further complicate the predictability of this distribution. The total stock of ocean water and fresh water on this earth has been fairly constant throughout geological history but the ratio between ocean water and fresh water always changes according to climatic changes, mostly brought about by anthropogenic activities. Furthermore, the movement of water through hydrological cycle has a major influence on rainfall distribution and temperature modification. The cycle plays a vital role in creating habitable climate and moderating temperature. Water covers more than 70 % of the earth's surface, of which 97% is in the ocean, which is unfit for human consumption and other uses because of its high salt content. Of the remaining three percent, 2% is locked in the polar ice caps and glaciers and only one percent is available as fresh water in rivers, lakes, streams, reservoirs, and ground water which is suitable for human consumption. A continuous and supply of clean water is essential for the survival and health of all living organisms.

2. Properties of water

A water molecule (H_2O) is made up of three atoms, one oxygen and two hydrogen atoms. In each water molecule, the oxygen atom attracts more than its "fair share" of electrons.

3. Water Quality

Clean, safe and sufficient freshwater is vital for the survival of all living organisms and smooth functioning of ecosystems, communities and economies. Water quality refers to the basic physical, chemical and biological characteristics of water that determine its suitability for life or for human uses. The acceptable quality of water varies with its intended use. The characteristics of water can be classified into three broad categories:

1. Physical Characteristics: temperature, color, odor, turbidity and solids
2. Chemical Characteristics: pH, conductivity, salinity, hardness, BOD,
3. Biological Characteristics: counts of specific organisms and groups of organisms
4. Physical Characteristics:

Physical characteristics of water (temperature, colour, taste, odour and etc.) are determined by senses of touch, sight, smell and taste. For example temperature by touch, colour, floating debris, turbidity and suspended solids by sight, and taste and odor by smell.

Temperature: Temperature is a measure of the average energy (kinetic) of water molecules. It is measured on a linear scale of degrees Celsius or degrees Fahrenheit. Temperature is a basic water
quality variable. It determines the suitability of water for various forms of aquatic life. Depending on the geographic location the mean annual temperature varies in the range
of 10 to 21 ^{o}C with an average of 16 ^{o}C. Temperature affects a number of water quality parameters such as dissolved oxygen which is a chemical characteristic. Oxygen solubility is less in warm water than cold water. Temperature also affects the aquatic life, for example, trout and salmon require cool temperature for survival and reproduction whereas bass and sunfish do better at warmer temperatures. Temperature in water bodies generally follows mean daily air temperature. It influences: amount of oxygen that can be dissolved in water, rate of photosynthesis by algae and other aquatic plants, metabolic rates of organisms, sensitivity of organisms to toxic wastes, parasites and diseases, and timing of reproduction, migration, and aestivation of aquatic organisms.

Color: Color in water is primarily a concern of water quality for aesthetic reason. Colored water give the appearance of being unfit to drink, even though the water may be perfectly safe for public use. Color of the water body can indicate the presence of organic substances, such as algae or humic compounds. In recent times, color has been used as a quantitative assessment of the presence of potentially hazardous or toxic organic materials in water. Color is vital as most water users, be it domestic or industrial, usually prefer colorless water. Determination of color can help in estimating the costs related to discoloration of the water. Color is reduced or removed from water through the use of coagulation, settling and filtration techniques.

MODULE-3

Water treatment involves several engineered systems and processes aimed at ensuring water quality meets regulatory standards and is safe for consumption. Here are some key processes typically involved in water treatment:

1. **Aeration**: Aeration involves the introduction of air into water to remove dissolved gases (such as hydrogen sulfide and carbon dioxide) and volatile organic compounds. It also helps in oxidizing metals like iron and manganese for subsequent removal.
2. **Sedimentation**: Sedimentation is a physical water treatment process used to settle out suspended solids (such as sand, silt, and clay) from water under the influence of gravity. This is often done in settling tanks or clarifiers.
3. **Softening**: Water softening is the process of removing calcium, magnesium, and other metal cations that cause hardness in water. This is typically achieved through ion exchange or by precipitating these ions out of the water.
4. **Coagulation**: Coagulation is the process of destabilizing suspended particles in water by adding chemical coagulants such as alum (aluminum sulfate) or ferric chloride. This helps the particles clump together and settle out during sedimentation.
5. **Filtration**: Filtration involves passing water through a porous medium (such as sand, gravel, or activated carbon) to remove suspended particles, colloids, and microorganisms. This is an essential step in achieving high-quality water.
6. **Adsorption**: Adsorption is a process where contaminants are removed from water by adhering to the surface of an adsorbent material, such as activated carbon. This is effective for removing organic compounds, certain metals, and chlorine.
7. **Ion Exchange**: Ion exchange is a water treatment process where undesirable ions are exchanged for more desirable ions on an exchange medium such as zeolite or synthetic resins. It's commonly used for water softening and removing specific ions like nitrate or arsenic.
8. **Disinfection**: Disinfection is the final step in water treatment aimed at killing or inactivating disease-causing microorganisms (pathogens) such as bacteria, viruses, and protozoa. Common disinfection methods include chlorination, UV irradiation, and ozonation.

Design of Water Distribution System

Once water has been treated, it needs to be distributed to consumers efficiently and reliably. The design of a water distribution system involves several considerations:

- **Piping Network**: Designing the layout of pipes to ensure adequate water pressure, flow rates, and minimal losses due to friction.
- **Storage Facilities**: Determining the need for water storage tanks or reservoirs to meet peak demand and ensure continuous supply during maintenance or emergencies.
- **Pumping Stations**: Installing pumps at appropriate locations to maintain water pressure throughout the distribution network.
- **Water Quality Monitoring**: Implementing systems to monitor water quality at various points in the distribution network to ensure compliance with safety standards.
- **Hydraulic Analysis**: Conducting hydraulic analysis to optimize pipe sizes, flow velocities, and pressure zones within the network.
- **Emergency Planning**: Developing contingency plans for emergencies such as pipe bursts, power outages, or contamination events.

- **Regulatory Compliance**: Ensuring the design meets regulatory requirements and standards related to water quality, pressure levels, and safety.

Designing a water distribution system requires expertise in civil engineering, hydraulic modeling, water chemistry, and regulatory compliance. It aims to provide safe, reliable, and efficient delivery of treated water to consumers' taps.

Engineered systems for water treatment : aeration, sedimentation, softening coagulation, filtration, adsorption, ion exchange, and disinfection. Design of water distribution system. GIVE LECTURE NOTES ChatGPT

Certainly! Here are lecture notes on engineered systems for water treatment and the design of water distribution systems:

Lecture Notes: Engineered Systems for Water Treatment and Design of Water Distribution Systems

1. Introduction to Water Treatment

- **Objective**: Ensure safe and potable water supply through effective treatment processes.
- **Challenges**: Contaminants vary widely; effective treatment requires a combination of physical, chemical, and biological processes.

2. Engineered Systems for Water Treatment

A. Physical Processes

- **Aeration**: Introduction of air to remove dissolved gases (e.g., hydrogen sulfide) and aid in oxidation of metals (iron, manganese).
- **Sedimentation**: Settling out suspended solids by gravity in settling tanks or clarifiers.
- **Filtration**: Passage of water through porous media (sand, gravel, activated carbon) to remove suspended particles and microorganisms.

B. Chemical Processes

- **Coagulation**: Addition of coagulants (e.g., alum, ferric chloride) to destabilize particles for easier sedimentation.
- **Softening**: Removal of calcium, magnesium ions causing hardness through ion exchange or precipitation.
- **Disinfection**: Killing or inactivating pathogens (bacteria, viruses) through chlorination, UV irradiation, or ozonation.

C. Adsorption and Ion Exchange

- **Adsorption**: Contaminant removal by adhering to surface of adsorbent materials like activated carbon.

- **Ion Exchange**: Exchange of undesirable ions (e.g., calcium, nitrate) for more desirable ones on exchange resins.

3. Design of Water Distribution Systems

A. Components of Distribution System

- **Piping Network**: Layout ensuring adequate flow rates, pressure levels, and minimal friction losses.
- **Storage Facilities**: Tanks or reservoirs to meet peak demands and maintain supply during maintenance or emergencies.
- **Pumping Stations**: Installation for maintaining pressure throughout the network.

B. Design Considerations

- **Hydraulic Analysis**: Optimizing pipe sizes, flow velocities, and pressure zones using hydraulic modeling.
- **Water Quality Monitoring**: Implementing systems to monitor water quality at various points to ensure compliance with safety standards.
- **Emergency Planning**: Developing contingency plans for pipe bursts, power outages, or contamination events.

C. Regulatory Compliance

- **Standards and Guidelines**: Design must meet regulatory requirements for water quality, pressure levels, and safety.

4. Conclusion

- **Importance of Integrated Approach**: Effective water treatment and distribution system design crucial for public health and safety.
- **Future Directions**: Advancements in technology and sustainability (e.g., energy-efficient pumps, green infrastructure) shaping future designs.

MODULE-4

Introduction to Wastewater Management

- **Objective**: Proper management of wastewater to protect public health and the environment.
- **Sources of Wastewater**: Domestic (sanitary waste), industrial, and stormwater runoff.

2. Types of Sewerage Systems

A. Sanitary Sewer Systems

- **Purpose**: Collects wastewater from toilets, sinks, showers, and other household drains.
- **Design Considerations**: Sized to handle peak flows, prevent backups, and maintain flow velocities to avoid sedimentation.

B. Storm Sewer Systems

- **Purpose**: Collects rainwater, snowmelt, and surface runoff from streets, roofs, and parking lots.
- **Design Considerations**: Separate from sanitary sewers to prevent overload during heavy rainfall events.

C. Combined Sewer Systems

- **Purpose**: Collects both sanitary wastewater and stormwater runoff in a single system.
- **Challenges**: Potential for combined sewer overflows (CSOs) during heavy rains, impacting water quality in receiving bodies.

3. Generation and Quantities of Wastewater

- **Sanitary Waste**: Typically 60-80 gallons per capita per day (gpcd) in residential areas, influenced by water use habits and population density.
- **Stormwater**: Varies widely based on rainfall patterns and urbanization levels; peak flows crucial for sizing storm sewer systems.

4. Design of Sewerage Systems

A. Primary Treatment

- **Purpose**: Initial removal of large solids and debris through screening and sedimentation in primary clarifiers.
- **Process**: Screens to remove large objects → Grit chambers for sand and gravel removal → Primary clarifiers for settling out suspended solids.

B. Secondary Treatment

- **Purpose**: Biological treatment to remove dissolved and suspended organic matter, nutrients (nitrogen, phosphorus), and pathogens.

- **Processes**: Activated sludge process, trickling filters, or other biological reactors to promote microbial growth and organic degradation.

C. Tertiary Treatment

- **Purpose**: Further polishing to meet specific effluent quality standards (e.g., nutrient removal, disinfection).
- **Processes**: Filtration (sand, multimedia), chemical treatment (chlorination, ozonation), or advanced biological processes (membrane bioreactors).

5. Wastewater Disposal Standards

- **Regulatory Framework**: Compliance with local, national, and international standards (e.g., EPA regulations in the US, EU Water Framework Directive).
- **Parameters**: Limits on pollutants (BOD, COD, TSS), pathogens, nutrients, and toxic substances in effluent discharged into receiving waters.

6. Conclusion

- **Integrated Approach**: Effective management of wastewater requires a combination of engineering, environmental science, and regulatory compliance.
- **Future Directions**: Emphasis on sustainability (water reuse, energy recovery) and resilience (climate change adaptation) in wastewater management.

MODULE-V

Basics of Microbiology

- **Microorganisms**: Bacteria, fungi, protozoa, and viruses play crucial roles in environmental processes, including wastewater treatment.
- **Functions**: Decomposition of organic matter, nutrient cycling (nitrogen, phosphorus), and pathogen removal.

2. Biological Wastewater Treatment Systems

A. Aerobic Processes

- **Activated Sludge Process (ASP)**
  - **Purpose**: To treat organic matter and nutrients (BOD, nitrogen) in wastewater.
  - **Process**: Wastewater mixed with activated sludge (microbial biomass) in aeration tanks for biological oxidation → Clarification to separate treated water from sludge.
  - **Modifications**: Extended aeration, sequencing batch reactors (SBR), membrane bioreactors (MBR) for enhanced nutrient removal and effluent quality.
- **Trickling Filter**
  - **Purpose**: Treatment of organic matter and nutrients using attached growth biofilm.
  - **Process**: Wastewater trickles over a bed of media (rock, plastic) covered with microbial biofilm → Microorganisms degrade organic matter aerobically → Effluent collected for further treatment.
- **Rotating Biological Contactor (RBC)**
  - **Purpose**: Biological oxidation of organic matter and nutrients in a compact, rotating drum.
  - **Process**: Wastewater flows over rotating discs covered with microbial biofilm → Contact between wastewater and biofilm for aerobic degradation → Effluent collection and clarification.

B. Anaerobic Processes

- **Conventional Anaerobic Digester**
  - **Purpose**: Methane production (biogas) from organic matter degradation in the absence of oxygen.
  - **Process**: Organic-rich sludge undergoes digestion by anaerobic bacteria → Methane and carbon dioxide produced → Digested sludge dewatered for further handling.
- **High Rate Anaerobic Reactors**
  - **Purpose**: Increased efficiency and space-saving in anaerobic digestion.
  - **Types**: Upflow Anaerobic Sludge Blanket (UASB) reactor, Expanded Granular Sludge Bed (EGSB) reactor → Enhanced organic matter degradation and biogas production.
- **Hybrid Anaerobic Reactors**

- **Purpose**: Combining features of different anaerobic reactors for optimized performance.
- **Examples**: Anaerobic MBR (AnMBR), Anaerobic Fluidized Bed Reactor (AFBR) → Enhanced treatment efficiency and flexibility in handling varying wastewater characteristics.

3. Sludge Digestion and Handling

- **Purpose**: Stabilization of organic matter in sludge, reduction of pathogens, and volume reduction for disposal.
- **Processes**: Anaerobic digestion (methane production), aerobic digestion (oxidation), and composting (organic stabilization).
- **Handling**: Dewatering (centrifugation, drying beds), conditioning (chemical treatment), and disposal (land application, landfilling).

4. Disposal of Effluent and Sludge

- **Effluent**: Discharge into receiving waters meeting regulatory standards for BOD, nutrients, pathogens, and toxic substances.
- **Sludge**: Land application (agricultural use), incineration, landfilling, or beneficial reuse (e.g., energy generation).

5. Design Problems and Considerations

- **Water Distribution**: Hydraulic analysis, pipe sizing, pressure management, and system resilience.
- **Sewerage Systems**: Designing for peak flows, separation of stormwater and sanitary sewers, and mitigating overflow risks.
- **Water Treatment Units**: Sizing and selection of processes (coagulation, filtration, disinfection) based on raw water quality and treatment objectives.
- **Wastewater Treatment Units**: Designing biological reactors (ASP, trickling filters, anaerobic digesters) for optimal performance and effluent quality.
- **Sludge Digestion**: Sizing anaerobic digesters, optimizing retention times, and handling digested sludge for further treatment or disposal.