CAI 334 IRRIGATION WATER QUALITY AND WASTE WATER MANAGEMENT

UNIT IV NOTES

Low cost waste water treatment technologies

Low-cost wastewater treatment technologies are essential for addressing water pollution issues, especially in regions with limited resources. These technologies aim to treat wastewater effectively while minimizing the financial burden on communities. Here are some brief details about low-cost wastewater treatment technologies:

- **Slow sand filers**

Slow sand filters are a type of water filtration system used to purify water for drinking purposes. They are considered one of the oldest and simplest forms of water treatment,dating back to the early 1800s. These filters work by passing water through a bed of sand at a slow rate, allowing physical, biological, and chemical processes to remove impurities and pathogens from the water. Here's how slow sand filters typically work:

1. **Preparation**: The filter bed is typically constructed with layers of sand, gravel, and sometimes charcoal to improve filtration efficiency. The sand used is usuallyfine-grained and well-washed to remove any impurities.
2. **Inlet**: Contaminated water enters the filter from the top and percolates slowly through the sand bed. The rate of flow is typically very slow, often less than 0.4meters per hour.
3. **Filtration**: As the water moves through the sand bed, suspended particles, bacteria, and other contaminants are physically trapped in the sand matrix.

   Additionally, biological processes within the sand bed contribute to the removal ofpathogens through predation, adsorption, and other mechanisms.
4. **Cleaning**: Over time, the accumulation of trapped particles and biofilm on thesand surface can reduce the filter's effectiveness. Periodically, the top layer ofsand, known as the "schmutzdecke," which contains most of

the impurities, isscraped off and removed. This process, called "raking," is essential for maintaining the filter's efficiency.

5. **Disinfection (optional)**: While slow sand filters are effective at removing most pathogens, some systems incorporate additional disinfection steps, such as chlorination or UV treatment, to ensure the water is safe for consumption.

Slow sand filters have several advantages, including low cost, simplicity of operation, and the ability to effectively remove a wide range of contaminants. However, they also have limitations, such as the relatively slow filtration rate and the need for periodic maintenance. Despite these drawbacks, slow sand filters remain a popular choice for small-scale water treatment in rural and developing areas where access to clean wateris limited.

Constructed Wetlands:

Overview

A constructed wetland is an organic wastewater treatment system that mimics and improves the effectiveness of the processes that help to purify water similar to naturally occurring wetlands. The system uses water, aquatic plants (i.e.: reeds, duckweed), naturally occurring microorganisms and a filter bed (usually of sand, soils and/or gravel). Constructed wetlands can be used for either secondary or tertiary wastewater treatment. Many different designs exist including vertical wetlands, which require less land, but more energy for operations like pumping or siphoning than horizontal wetlands, which can instead rely on gravity and topography. The extensive options in design, materials and technology allow the constructed wetland to be adapted to local conditions and land availability. Costs are dependenton the price of land and materials, but where land is cheaper and widely available, constructed wetlands are a very cost-effective method of wastewater treatment.

The general concept is that the plants, microorganisms and substrates together act as a filter and purification system. First, water is slowed as it enters the wetland, allowing for the sedimentation of solids. Through the process of water flow through the constructed wetland, plant roots and the substrate remove the larger particles present in the wastewater. Pollutants and nutrients present in the wastewater are then naturally broken down andtaken up by the bacteria and plants, thereby removing them from the water. The retention time in the wetland, which varies depending on the design and desired quality level, along with UV radiation and plant secretion of antibiotics will also kill the pathogens present in wastewater. After treatment in a constructed wetland, water can be safely released into surface waters or used various purposes.

Salient features:

- Cost efficient in terms of construction, operations and maintenance
- Effectively treats wastewater from human waste, agricultural runoff, storm water and some metals or pollutants from mining and industry
- Uses technology that is simple to understand and manage
- Low energy consumption required for operations
- Prepares water for reuse
- Assists in maintaining groundwater and surface water levels
- Contributes to environmental protection by providing a habitat forplants and animals

- Acts as a means of water storage
- Pleasing natural aesthetics

- **Solar disinfection**, also known as SODIS, is a simple and inexpensive methodof water treatment that uses sunlight to destroy harmful pathogens and make water safe for drinking. It's particularly valuable in areas where access to cleanwater is limited and where conventional water treatment methods may not be feasible.

Here's how solar disinfection typically works:

1. **Fill**: Water from a contaminated source, such as a river, well, or rainwater tank, is collected in clear plastic or glass bottles. It's important that the bottles are transparent to allow sunlight to penetrate.
2. **Exposure**: The filled bottles are then placed in direct sunlight, preferably on a flatsurface, such as a roof or a sunny area outdoors. The bottles should be left exposed to sunlight for a certain period, typically around 6 hours or more, depending on the intensity of the sunlight and the degree of contamination.
3. **UV Radiation**: Sunlight contains ultraviolet (UV) radiation, particularly in the UV-A spectrum. When the water-filled bottles are exposed to sunlight, the UV radiation penetrates the water and disrupts the DNA of harmful microorganisms such as bacteria, viruses, and parasites, rendering them inactive and unable to cause illness.

4. **Temperature**: Solar disinfection also takes advantage of the heating effect of sunlight. As the water absorbs solar energy, its temperature increases, further enhancing the disinfection process. Higher temperatures can accelerate the
inactivation of pathogens.
5. **Storage**: After exposure to sunlight, the disinfected water can be stored in the same bottles for later use. It's essential to handle the bottles carefully to avoid recontamination. Additionally, storing the water in a clean, covered container canhelp prevent the reintroduction of pathogens.

Solar disinfection is a low-cost, easy-to-implement method of water treatment that has been shown to be effective in reducing the risk of waterborne diseases. It's particularly beneficial in rural and developing areas where access to clean water infrastructure is limited. However, it's important to note that solar disinfection may not remove chemical contaminants or particulate matter from water, so it's best suited for treating microbiologically contaminated water sources. Additionally, the effectiveness of SODIS can be influenced by factors such as cloud cover, water turbidity, and bottle material, so proper training and education are essential for its successful implementation.

- **Solar Oxidation and Removal of Arsenic (SORAS)** is a promising technology for mitigating arsenic contamination in groundwater, especially in regions where traditional treatment methods may be challenging to implement due to limited resources or infrastructure. SORAS combines solar energy with a chemical oxidation process to remove arsenic from water.

Here's how the SORAS process typically works:

1. **Oxidation**: Arsenic in groundwater typically exists in two forms: arsenite (As(III))and arsenate (As(V)). Arsenite is more difficult to remove than arsenate. In the SORAS process, sunlight is used to initiate the oxidation of arsenite to arsenate.
   This is achieved through the photochemical reaction between naturally occurringoxygen and UV radiation from sunlight. The oxidized arsenic species, arsenate,
   is easier to remove from water through subsequent treatment steps.
2. **Adsorption**: Once arsenic is oxidized to arsenate, it can be adsorbed onto solid adsorbents present in the water or added during treatment. Common adsorbentsused in SORAS include iron oxide-coated sand or granular ferric hydroxide. These adsorbents have a high affinity for arsenic and effectively remove it from the water.
3. **Filtration**: After oxidation and adsorption, the water is typically passed through a filtration system to remove the solid adsorbents loaded with arsenic. This step helps ensure that the treated water meets regulatory standards for arsenic concentration.
4. **Solar Energy**: Solar energy is the key driving force behind the SORAS process. It powers the oxidation of arsenite to arsenate and helps maintain the efficiency of the treatment system. The use of solar energy makes SORAS a sustainable and environmentally friendly water treatment technology.

SORAS has several advantages as a water treatment method for arsenic removal:

- Cost-effective: SORAS utilizes readily available solar energy, reducing the needfor external energy sources and operational costs.
- Environmentally friendly: The use of solar energy minimizes the carbon footprintassociated with water treatment.
- Suitable for decentralized applications: SORAS can be implemented at the community or household level, making it suitable for areas without centralizedwater treatment infrastructure.

However, SORAS also has limitations, such as the dependence on sunlight, which may affect treatment efficiency during periods of low solar radiation or cloudy weather.

Additionally, the effectiveness of SORAS may vary depending on the characteristics of the groundwater and the specific adsorbents used. Ongoing research and developmentare needed to optimize SORAS technology for different environmental conditions and water quality parameters.

- An **oxidation ditch** is a type of wastewater treatment system commonly used inmunicipal and industrial wastewater treatment plants. It's a variation of the activated sludge process and is designed to promote the biological oxidation of organic matter and the removal of nutrients from wastewater.

Here's how an oxidation ditch typically works:

1. **Influent**: Wastewater enters the oxidation ditch from the influent pipe or

channel. This wastewater contains organic pollutants, such as organic carbon, as well as nutrients like nitrogen and phosphorus.

2. **Aeration**: The oxidation ditch is a long, narrow channel or basin that contains aerated wastewater. Aeration is achieved by introducing air into the wastewater using mechanical aerators, such as surface aerators or submerged diffusers. Themixing and aeration promote the growth of aerobic microorganisms, primarily bacteria, which consume organic matter as food.
3. **Biological Oxidation**: As the wastewater flows through the oxidation ditch, aerobic microorganisms metabolize the organic pollutants, breaking them downinto simpler, less harmful substances. This process, known as biological oxidation or biodegradation, reduces the concentration of organic matter in the wastewater and helps to purify it.
4. **Settling**: After the biological oxidation stage, the wastewater enters a settlingtank or clarifier located at the end of the oxidation ditch. Here, the suspendedsolids and biomass (activated sludge) settle to the bottom of the tank under gravity, forming a sludge blanket or sludge layer.
5. **Recycle and Discharge**: A portion of the settled sludge, known as return activated sludge (RAS), is recycled back to the beginning of the oxidation ditch tomaintain the population of aerobic microorganisms. Excess sludge, called waste activated sludge (WAS), is periodically removed from the system and sent for further treatment or disposal. The treated effluent, which has undergone biological oxidation and settling, is discharged from the clarifier for further treatment or safe disposal.

Oxidation ditches offer several advantages for wastewater treatment, including efficient biological oxidation, good mixing and aeration, and relatively simple operation and maintenance. They are particularly well-suited for small to medium-sized treatment plants and can be easily expanded or modified to accommodate changes in wastewater flow or composition. However, oxidation ditches also have limitations, such as the potential for odor generation and the need for adequate space for construction. Proper design, operation, and maintenance are essential to ensure optimal performance and compliance with regulatory standards.

Dissolved Air Flotation (DAF) is a water treatment process used for the removal of suspended solids, oils, grease, and other contaminants from wastewater. It operates on the principle of introducing fine air bubbles into the water, which attach to the suspended particles, causing them to float to the surface where they can be removed.

Here's how the DAF process typically works:

1. **Saturation**: The process begins with the saturation of water with air under pressure. This is typically achieved using a specially designed DAF system that incorporates a pressure vessel or pump to dissolve air into the water. The high pressure allows for a significant amount of air to dissolve into the water, forming tiny bubbles.
2. **Release**: Once the water is saturated with air, it is released into a flotation tank or basin at atmospheric pressure. As the pressure drops, the dissolved air comes out of solution in the form of small bubbles.
3. **Attachment**: As the released air bubbles rise through the water, they attach to the suspended particles, oils, and grease present in the wastewater. The buoyant force of the air bubbles causes the attached particles to rise to the

surface of the flotation tank, forming a froth layer or "float."

4. **Skimming**: The float layer containing the suspended solids, oils, and grease is collected and removed from the surface of the flotation tank using mechanical skimmers or scrapers. The collected float material is then directed to a sludge handling system for further treatment or disposal.
5. **Clarification**: The clarified water, which is now free of most suspended solids and contaminants, exits the bottom of the flotation tank and is typically passed through a secondary clarification process to remove any remaining fine particlesbefore discharge or further treatment.

DAF systems offer several advantages for wastewater treatment, including high efficiency in the removal of suspended solids and fats, oils, and grease (FOG), flexibility in handling variable wastewater quality and flow rates, and the ability to achieve a high degree of clarification in a relatively compact footprint. DAF is commonly used in various industries, including food and beverage processing, pulp and paper manufacturing, and municipal wastewater treatment plants.

- **Waste stabilization ponds**, also known as wastewater stabilization ponds or lagoons, are shallow, man-made bodies of water designed to treat wastewater
  through natural biological and physical processes. These ponds are widely usedin both rural and urban settings as a cost-effective and environmentally friendly method of wastewater treatment.

Here's how waste stabilization ponds typically work:

1. **Primary Treatment**: Wastewater enters the first pond, known as the

primary or settling pond. In this pond, larger suspended solids settle to the bottom due to gravity, forming a sludge layer. This process helps to remove a significant portionof the solids and organic matter from the wastewater.

2. **Biological Treatment**: The partially clarified wastewater then flows into one or more secondary ponds, where biological treatment takes place. These secondary

   ponds are typically designed to encourage the growth of algae, bacteria, and other microorganisms, which help to further break down organic matter and nutrients in the water through processes such as photosynthesis, aerobic andanaerobic digestion, and sedimentation.

3. **Aeration and Mixing**: Some waste stabilization ponds incorporate mechanical ornatural aeration systems to promote the growth of aerobic microorganisms and

   improve oxygen transfer in the water. Aeration can help enhance the efficiency ofbiological treatment and reduce odors by preventing anaerobic conditions.

4. **Retention Time**: The wastewater remains in the stabilization ponds for a certain period, known as the retention time, which allows sufficient time for biological processes to occur and for contaminants to be removed or degraded. The retention time can vary depending on factors such as wastewater characteristics,pond design, and climate conditions.

5. **Discharge or Reuse**: After passing through the waste stabilization ponds, the treated effluent is discharged into receiving water bodies, such as rivers or streams, or reused for non-potable purposes such as irrigation, industrial processes, or groundwater recharge. The effluent from waste stabilization

pondsis typically of higher quality compared to the influent wastewater but may still require additional treatment depending on local regulations and water quality standards.

Waste stabilization ponds offer several advantages for wastewater treatment, including low construction and operating costs, simplicity of operation and maintenance, natural treatment processes that are relatively resilient to fluctuations in wastewater flow and quality, and the potential for habitat creation and aesthetic improvement. However, theyalso have limitations, such as land requirements, sensitivity to climate conditions, and potential for odor generation. Proper design, operation, and monitoring are essential to ensure the effectiveness and environmental sustainability of waste stabilization pond systems.

Economic And Social Dimensions

The economic and social dimensions refer to two key aspects of human society that are interconnected and influence each other. Here's a brief explanation of each:

1. **Economic Dimensions:**
   - **Definition:** The economic dimension involves the production, distribution, and consumption of goods and services within a society. It encompasses thefinancial systems, industries, and overall economic well-being of a community or nation.
   - **Components:**
     - **Gross Domestic Product (GDP):** A measure of the total economicoutput of a country.

- **Employment and Income:** The level of employment and thedistribution of income among the population.
- **Wealth Distribution:** The allocation of resources and assets amongindividuals and social classes.
- **Market Dynamics:** The functioning of markets, competition, and therole of supply and demand.

- **Impact on Society:** Economic dimensions significantly influence thestandard of living, access to resources, and the overall prosperity of individuals and communities.

2. **Social Dimensions:**

- **Definition:** The social dimension pertains to the relationships, interactions,and structures within a society. It encompasses aspects such as culture,
  education, health, social justice, and the well-being of individuals andcommunities.

- **Components:**
  - **Education and Knowledge:** Access to education and thedissemination of knowledge within a society.
  - **Health and Healthcare:** The overall health of the population and theavailability of healthcare services.
  - **Cultural Diversity:** The variety of cultural practices, beliefs, andexpressions within a community.
  - **Social Equity and Justice:** Fairness and equality in social, economic,and political opportunities.

- **Impact on Society:** The social dimension shapes the quality of life, societal cohesion, and the overall welfare of individuals. It reflects the values, norms,and inclusivity of a community.

Interconnectedness:

- **Mutual Influence:** Economic conditions can impact social dynamics, and social factors can influence economic outcomes. For example, a healthy and educated workforce may contribute to economic productivity.
- **Policies and Interventions:** Governments and institutions often implement policies that aim to balance economic growth with social well-being. Social policies may include measures to address poverty, inequality, and access to basic services.

Challenges and Opportunities:

- **Inequality:** Disparities in income, education, and access to Resources cancontribute to social and economic challenges.
- **Sustainable Development:** Balancing economic growth with social and environmental considerations is a key challenge for achieving sustainabledevelopment.
- **Social Innovation:** The development of solutions and interventions that address both economic and social issues, fostering positive change.

Understanding and addressing the economic and social dimensions of society are crucial for creating inclusive, sustainable, and resilient communities. Policymakers, businesses, and individuals play vital roles in shaping policies and practices that promote both economic prosperity and social well-being.