Water Supply & Sanitary Engineering (DI05006021)

Unit 8: Sewage Treatment and Disposal

Lecture 35: Anaerobic Processes and Sludge Digestion

GTU Diploma Engineering

Agenda

- The Sludge Problem
- Principles of Anaerobic Digestion
- Stages of Digestion (Acid & Methane Formers)
- Design of a Sludge Digester
- Biogas Production and Use
- Sludge Dewatering: Sludge Drying Beds

The Sludge Problem

- Primary Sludge: Raw organic solids settled in the primary clarifier (highly putrescible, very odorous).
- Secondary Sludge (WAS): Waste bacterial biomass from the activated sludge process.
- Combined, this sludge is mostly water (95-99% water) and contains active pathogens and decomposing organics.
- If disposed of improperly, it poses severe health and environmental hazards.
- Goal: Stabilize the organics, destroy pathogens, and reduce volume by removing water.

Anaerobic Treatment Principles

- Anaerobic bacteria thrive in the strict absence of dissolved oxygen.
- They break down complex organic matter into simpler compounds and eventually into gases (primarily Methane and Carbon Dioxide).
- Process is slower than aerobic treatment but yields very little new bacterial biomass.
- It is highly suitable for treating high-strength wastes like sludge.
- Byproduct: Biogas, a valuable renewable energy source.

Stages of Anaerobic Digestion

- The process occurs in three main biological stages:
- 1. Hydrolysis: Complex solids (proteins, fats, carbs) are broken down into soluble amino acids, sugars, and fatty acids.
- 2. Acidogenesis (Acid Formers): Fermentative bacteria convert soluble compounds into volatile organic acids (e.g., acetic acid). pH drops.
- 3. Methanogenesis (Methane Formers): Methanogenic archaea consume the organic acids and produce Methane (CH4) and CO2. pH rises and stabilizes.

The Delicate Balance

- The success of digestion depends entirely on the Methane formers.
- Methane formers are highly sensitive to pH changes, temperature fluctuations, and toxins.
- Optimal pH: 6.8 to 7.2.
- If the system is overloaded with sludge, Acid formers produce acid too quickly. The pH drops, killing the Methane formers.
- This is called a 'sour' or 'stuck' digester, resulting in terrible odors and no methane production.

Sludge Digester: Physical Components

- Digesters are large, enclosed, airtight concrete or steel tanks.
- Components include:
- - Sludge inlet and outlet pipes.
- - Heating system (usually hot water pipes) to maintain mesophilic temperatures (35°C).
- - Mixing systems (mechanical impellers or gas recirculation) to keep the sludge uniform.
- - Gas dome/collector at the top to harvest biogas.
- - Supernatant draw-off pipes to remove separated liquid.

UASB (Upflow Anaerobic Sludge Blanket)

- UASB is an anaerobic technology used not just for sludge, but for direct treatment of wastewater.
- Wastewater flows upwards through a dense 'blanket' of anaerobic granular sludge.
- The bacteria in the blanket consume the organics and produce biogas.
- Gas bubbles rise, providing natural mixing.
- A Gas-Liquid-Solid (GLS) separator at the top ensures sludge remains in the reactor while gas and clear effluent escape.

Biogas Utilization

- Biogas composition: 60-65% Methane (CH4), 30-35% Carbon Dioxide (CO2), trace H2S.
- Methane is highly combustible and has significant calorific value.
- Uses at the treatment plant:
- - Burned in boilers to heat the digester itself.
- - Used in combined heat and power (CHP) engines to generate electricity for the plant.
- - Flared (burned off) safely if excess gas cannot be utilized.

Sludge Dewatering: The Need

- Digested sludge is now biologically stable (looks like black soil, smells earthy, not putrid).
- However, it is still mostly liquid (typically 95% water).
- Transporting liquid sludge to agricultural land or landfills is economically unfeasible.
- Dewatering is required to separate the solid fraction from the liquid fraction, reducing volume and transportation costs.

Sludge Drying Beds

- The simplest, oldest, and most common dewatering method in developing regions.
- Constructed as shallow rectangular beds with a porous bottom (layers of sand and gravel).
- Wet digested sludge is poured onto the bed to a depth of 20-30 cm.
- Dewatering occurs via two mechanisms:
- 1. Seepage: Water drains downwards through the sand/gravel into underdrain pipes.
- 2. Evaporation: Sun and wind dry the surface over several weeks.

Sludge Drying Beds: Operation and Output

- Drying time varies from 2 to 6 weeks depending on climate (fast in dry, hot weather; slow in monsoons).
- As it dries, the sludge cracks into blocks.
- Once dried to a solid 'cake' (usually 20-30% solid content), it is manually or mechanically removed.
- The dried sludge cake is rich in nutrients and is often used as a soil conditioner or fertilizer in agriculture.
- The liquid collected in the underdrains is highly polluted and is pumped back to the inlet of the treatment plant.

Summary

- Anaerobic digestion stabilizes volatile sludge without needing supplied oxygen.
- The process is a balance between acid-forming and methane-forming bacteria.
- Biogas (methane) is a valuable renewable energy byproduct.
- Digested sludge is biologically stable but must be dewatered.
- Sludge Drying beds offer a low-cost, natural method to dewater sludge before agricultural use.

Next Lecture: Disposal Methods

- With treatment complete, where does the clean effluent go?
- Next lecture covers Methods of Sewage Disposal.
- We will discuss disposal by dilution into water bodies.
- We will discuss disposal on land (sewage farming).
- We will look at standard effluent discharge criteria.