CE2354 – ENVIRONMENTAL ENGINEERING-II

(FOR VI – SEMESTER)

UNIT – V

DISPOSAL OF SEWAGE AND SLUDGE

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Treated Effluent Disposal

The proper disposal of treatment plant effluent or reuse requirements is an essential part of planning and designing wastewater treatment facilities. Different methods of ultimate disposal of secondary effluents are discussed as follows.

Natural Evaporation

The process involves large impoundments with no discharge. Depending on the climatic conditions large impoundments may be necessary if precipitation exceeds evaporation. Therefore, considerations must be given to net evaporation, storage requirements, and possible percolation and groundwater pollution. This method is particularly beneficial where recovery of residues is desirable such as for disposal of brines.

Groundwater Recharge

Methods for groundwater recharge include rapid infiltration by effluent application or impoundment, intermittent percolation, and direct injection. In all cases risks for groundwater pollution exists. Furthermore, direct injection implies high costs of treating effluent and injection facilities.

Irrigation

Irrigation has been practiced primarily as a substitute for scarce natural waters or sparse rainfall in arid areas. In most cases food chain crops (i.e. crops consumed by humans and those animals whose products are consumed by humans) may not be irrigated by effluent. However, field crops such as cotton, sugar beets, and crops for seed production are grown with wastewater effluent.

Wastewater effluent has been used for watering parks, golf courses and highway medians.

Recreational Lakes

The effluent from the secondary treatment facility is stored in a lagoon for approximately 30 days. The effluent from the lagoon is chlorinated and then percolated through an area of sand and gravel, through which it travels for approximately 0.5 km and is collected in an interceptor trench. It is discharged into a series of lakes used for swimming, boating and fishing.

Aquaculture

Aquaculture, or the production of aquatic organisms (both flora and fauna), has been practiced for centuries primarily for production of food, fiber and fertilizer. Lagoons are used for aquaculture, although artificial and natural wetlands are also being considered. However, the uncontrolled spread of water hyacinths is itself a great concern because the flora can clog waterways and ruin water bodies.

Municipal Uses

Technology is now available to treat wastewater to the extent that it will meet drinking water quality standards. However, direct reuse of treated wastewater is practicable only on an emergency basis. Many natural bodies of water that are used for municipal water supply are also used for effluent disposal which is done to supplement the natural water resources by reusing the effluent many times before it finally flows to the sea.

Industrial Uses

Effluent has been successfully used as a cooling water or boiler feed water. Deciding factors for effluent reuse by the industry include (1) availability of natural water, (2) quality and quantity of effluent, and cost of processing, (3) pumping and transport cost of effluent, and (4) industrial process water that does not involve public health considerations.

Discharge into Natural Waters

Discharge into natural waters is the most common disposal practice. The self-purification or assimilative capacity of natural waters is thus utilized to provide the remaining treatment.

Self Purification Of Natural Streams

The self purification of natural water systems is a complex process that often involves physical, chemical, and biological processes working simultaneously. The amount of Dissolved Oxygen (DO) in water is one of the most commonly used indicators of a river health. As DO drops below 4 or 5 mg/L the forms of life that can survive begin to be reduced. A minimum of about 2.0 mg/L of dissolved oxygen is required to maintain higher life forms. A number of factors affect the amount of DO available in a river. Oxygen demanding wastes remove DO; plants add DO during day but remove it at night; respiration of organisms removes oxygen. In summer, rising temperature reduces solubility of oxygen, while lower flows reduce the rate at which oxygen enters the water from atmosphere.

Factors Affecting Self Purification

1. Dilution: When sufficient dilution water is available in the receiving water body, where the wastewater is discharged, the DO level in the receiving stream may not reach to zero or critical DO due to availability of sufficient DO initially in the river water before receiving discharge of wastewater.

2. Current: When strong water current is available, the discharged wastewater will be thoroughly mixed with stream water preventing deposition of solids. In small current, the solid matter from the wastewater will get deposited at the bed following decomposition and reduction in DO.

3. Temperature: The quantity of DO available in stream water is more in cold temperature than in hot temperature. Also, as the activity of microorganisms is more at the higher temperature, hence, the self-purification will take less time at hot temperature than in winter.

4. Sunlight: Algae produces oxygen in presence of sunlight due to photosynthesis.

Therefore, sunlight helps in purification of stream by adding oxygen through photosynthesis.

5. Rate of Oxidation: Due to oxidation of organic matter discharged in the river DO depletion occurs. This rate is faster at higher temperature and low at lower temperature. The rate of oxidation of organic matter depends on the chemical composition of organic matter.

Oxygen Sag Analysis

The oxygen sag or oxygen deficit in the stream at any point of time during self purification process is the difference between the saturation DO content and actual DO content at that time.

Oxygen deficit, D = Saturation DO – Actual DO

The saturation DO value for fresh water depends upon the temperature and total dissolved salts present in it; and its value varies from 14.62 mg/L at $0^{o}C$ to 7.63 mg/L at $30^{o}C$, and lower DO at higher temperatures.

The DO in the stream may not be at saturation level and there may be initial oxygen deficit

'D_o'. At this stage, when the effluent with initial BOD load L_o, is discharged in to stream, the DO content of the stream starts depleting and the oxygen deficit (D) increases. The variation of oxygen deficit (D) with the distance along the stream, and hence with the time of flow from the point of pollution is depicted by the 'Oxygen Sag Curve' (Figure 12.1). The major point in sag analysis is point of minimum DO, i.e., maximum deficit. The maximum or critical deficit (D_c) occurs at the inflexion points of the oxygen sag curve.

Deoxygenation and Reoxygenation Curves

When wastewater is discharged into the stream, the DO level in the stream goes on depleting. This depletion of DO content is known as deoxygenation. The rate of deoxygenation depends upon the amount of organic matter remaining (L_t) to be oxidized at any time t, as well as temperature (T) at which reaction occurs. The variation of depletion of DO content of the stream with time is depicted by the deoxygenation curve in the absence of aeration. The ordinates below the deoxygenation curve (Figure 12.1) indicate the oxygen remaining in the natural stream after satisfying the bio-chemical oxygen demand of oxidizable matter.

When the DO content of the stream is gradually consumed due to BOD load, atmosphere supplies oxygen continuously to the water, through the process of re-aeration or reoxygenation, i.e., along with deoxygenation, re-aeration is continuous process.

The rate of reoxygenation depends upon:

i) Depth of water in the stream: more for shallow depth.

ii) Velocity of flow in the stream: less for stagnant water.

iii) Oxygen deficit below saturation DO: since solubility rate depends on difference between saturation concentration and existing concentration of DO.

iv) Temperature of water: solubility of oxygen is lower at higher temperature and also saturation concentration is less at higher temperature.

Mathematical analysis of Oxygen Sag Curve: Streeter – Phelps equation

The analysis of oxygen sag curve can be easily done by superimposing the rates of deoxygenation and reoxygenation as suggested by the Streeter – Phelps analysis. The rate of change in the DO deficit is the sum of the two reactions as explained below:

dDt/ dt = f (deoxygenation and reoxygenation)

$dDt/dt = K'Lt - R'Dt$ ….(1)

Where,

Dt = DO deficit at any time t,

Lt = amount of first stage BOD remaining at any time t

K' = BOD reaction rate constant or deoxygenation constant (to the base e)

R' = Reoxygenation constant (to the base e)

t = time (in days)

dDt/ dt = rate of change of DO deficit

Now,

$$Lt = Lo.e^{\tilde{}K't}$$

Where, Lo = BOD remaining at time t = 0 i.e. ultimate first stage

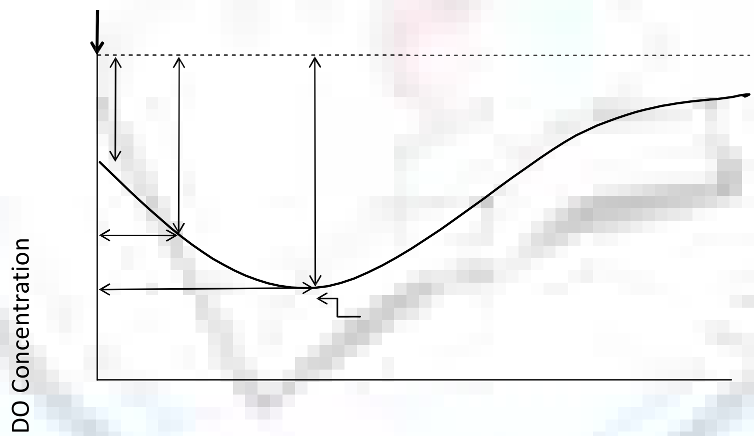
Do = Initial oxygen deficit at the point of waste discharge at time t = o t = time of travel in the stream from the point of discharge = x/u

x = distance along the stream u = stream velocity

This is Streeter-Phelps oxygen sag equation. The graphical representation of this equation is shown in Figure 12.2.

Point of waste discharge

Saturation DO



Do

Dt

Dc

X

Xc Critical point

Distance downstream, X

Figure 12.2 Oxygen sag curve of Streeter-Phelps equation

Note: Deoxygenation and reoxygenation occurs simultaneously. After critical point, the rate of re-aeration is greater than the deoxygenation and after some distance the DO will reach to original level and stream will not have any effect due to addition of wastewater. At time t=0 at x = 0.

SLUDGE

- The polluted solid-liquid matter that is skimmed off or removed from wastewater during primary, secondary and tertiary treatment.
- It contains 0.25 to 12% organic to inorganic solid content
- Constituents
  - Organic material, nutrients, pathogens, metals, toxic substances

Goals of Sludge Management

- Stabilize sludge
- Kill pathogens
- Decrease water content from 0.5-2% solids to 6 to 12% solids

SLUDGE PROCESSING

(a) Thickening

(b) Conditioning, Stabilization, Disinfection

(c) Dewatering

(d) Drying

(e) Composting

(f) Incineration

(g) Final Disposal

[A] SLUDGE THICKENING

- Thickening: Capacity of sludge to increase concentration of solid in sludge
- Purpose: To decrease volume
- Benefits:
  - Reduces required capacity of downstream equipment
  - Reduce chemicals for conditioning
  - Reduce heat required by digesters
  - Reduce volume for transportation
- **Equipment types**
  - Gravity
  - Gravity Belt Thickener (GBT)
  - Flotation
  - Rotary drum
  - Centrifuge

[B] SLUDGE CONDITIONING

- Sludge particles are negative (anionic) in surface charge
- The negative surface charge leads to electrostatic repulsive forces which hamper the settling process of the sludge particles.
- Cationic conditioning agents minimizes the electrostatic repulsive force and starts floc formation
- Chemical conditioning is similar to flocculation/coagulation process

[C] SLUDGE DEWATERING

- Mostly done in filtration type of units where solid particles from a fluid are retained on a filtering medium which allows the water to pass through it.
- Five types of equipment
  - Belt Filter Press (18-25%)
  - Centrifuge (30-35%)
  - Recessed Chamber Press
  - Vacuum Filtration
  - Drying Beds

[D] SLUDGE DRYING

- **Direct**: Sludge in contact with heat surface, e.g. fluidized bed dryer, revolving drum dryers
- **Indirect**: There is no direct contact between heat source and sludge, e.g. Disc dryer
- More expensive than mechanical methods such as pressing or centrifugation
- Yields greater volume reduction and a storable free flowing and hygienic product.
- End product can be used as
  - fertilizer/soil conditioner in agriculture and forestry
  - fuel in cement kilns, power plants and incinerators
  - top soil, landscaping, and landfilling use.

[E] SLUDGE COMPOSTING

- Can be applied to either digested or non-digested sludge
- Need to have sufficient mixture of organic matter content and water
- Carbon to nitrogen ratio: 25-30
- May be used as pretreatment to incineration
- Advantages
  - reduction in volume of materials to be transported for distribution in agricultural fields

  - allows the facilitation of storage
  - easier to spread
  - control in the nutrients in the compost
  - compost is more hygienic than raw sludge application
- Disadvantage
  - costly
  - requires aeration
  - requires a market

[F] SLUDGE INCINERATION

- A method used for drying and reducing sludge volume and weight. Since incineration requires auxiliary fuel to obtain and maintain high temperature and to evaporate the water contained in the incoming sludge, concentration techniques should be applied before incineration.
- Sludge incineration is a two-step process involving drying and combustion after a preceding dewatering process, such as filters, drying beds, or centrifuges.
- Multiple Hearths
  - Top – Drying
  - Middle – Incineration
  - Lower – Cooling
- Flue gas – need to be treated

[G] SLUDGE DISPOSAL

- Agriculture: For raw and treated sludge
  - Things to consider:
    - Heavy Metal content
    - Dry solid content
  - **Advantage**:
    - Utilization of nutrients in soil (organics, nitrogen, phosphorus)
    - Cheaper (raw sludge)
  - **Disadvantage**: need for storage facility (investment)
- Landfilling

DEWATERING
FILTERS

- Filtration is the removal of solid particles from a fluid by passing the fluid through a filtering medium, or septum, on which the solids are deposited. However, the mechanical separation (filtration or clarification) of primary sludge is only partially effective as a treatment because 30 to 40 % of BOD and COD are water soluble and cannot be so removed.

- Filtration is generally complete in 1 to 2 days and results in solids concentration as high as 15 to 20%. The rate of filtration depends drainability of the sludge, which in turn is related to the specific resistance [1]

TYPES OF DEWATERING FILTERS

[2] [A] Rotary drum vacuum filters

(RDVF)

- The filtration, washing, partial drying and discharge of the sludge all take place simultaneously.
  - Process involves sucking of liquid through a moving septum to deposit a cake of solids.
- The cake is moved out of the filtering zone, washed, sucked dry, and dislodged from the septum, which then reenters the slurry to pick up another load of solids.

Advantages and disadvantages of rotary drum filters

Advantages	**Disadvantages**
Filter is entirely automatic.	Maximum available pressure difference is limited as it being a vacuum filter.
Large capacity, hence large quantities can be filtered.	Difficulty in filtration of hot liquids because of their tendency to boil.
Cakes of varying thickness can be built by varying speed which results in removal of fine or coarser solids easily.	Initial cost of filter and vacuum equipment is high.
Low maintenance cost.	These are inflexible and do not perform well if their feed stream conditions are changing.

[B] Filter press

- It contains a set of plates designed to provide a series of chambers or compartments in which solids may collect.
- The plates are covered with a filter medium such as canvas.

- Slurry is admitted to each compartment under pressure; liquor passes through the canvas and out a discharge pipe, leaving a wet cake of solids behind.
- During operation, when the frames are full of solids and no more slurry can enter. The press is then said to be jammed.
- Wash liquid may then admitted to remove soluble impurities from the solids.

[C] Horizontal belt filter

- It is suitable for coarser particles as compared to rotary-drum filters.
- Feed slurry flows onto the belt from a distributor at one end of the unit; filtered and washed cake is discharged from the other.
- It is suitable for waste treatment as it is available in various sizes. They are available in sizes ranging from 0.6 to 5.5 m wide and 4.9 to 33.5 m long, with filtration areas up to 110 m^2.

[D] Rotating-leaf filter

- During filtration, the slurry enters, the filtrate exits, and solids are retained on leaves and covered with a filter cloth.
- Upon completion of filtration, the washing and drying bottom closure opens.
- The drive motor starts and rotates the stack of filter leaves.
- Centrifugal force causes the solids to move off the filter leaves, strike the inside wall of the tank and flow down to solid exit.
- Sizes are available up to 540 ft^2 per unit.

[E] Deep bed filter

- Filters with deep beds of sand, diatomaceous earth, coke, charcoal, and other inexpensive packing materials are normally used.
- Without preseparation the bed becomes loaded quickly.
- When the particle and bacteria in sizes smaller than the interstices of the bed, plus suspended BOD, are remove from the liquid, exceptional clarity is obtained.
- The dissolved substances, including dissolved BOD are not removed.

THERMAL DRYERS

Heat treatment followed by filtration is economical for dewatering sludge without using chemicals. Thermal drying of the sludge is economical only if a market for the product is available. Several types of thermal dryers used by the chemical process industry can be applied to sludge drying. The sludge is always dewatered prior to drying, regardless of the type of dryer selected.

TYPES OF DRYERS [2]

[A] Flash dryer

- It operates by promoting contact between the wet sludge and a hot gas stream.
- Drying takes place in less than 10 sec of violent action, either in a vertical tube or in a cage mill.
- A cyclone, with a bag filter or wet scrubber, if necessary, separates the solid from the gas phase.
- The vapors are returned through preheaters to the furnace, minimizing odor problems.
- A portion of the solid product is often returned to precondition the wet sludge.
- Being of only moderate thermal efficiency, this type of furnace is appropriate only for low sludge flows and where heat is available cheaply [3]

[B] Screw conveyor dryers

- It uses a hollow shaft and blades through which hot gas or water is pumped.
- The heat is transferred to the sludge as it is conveyed through the dryer.