SLUDGE TREATMENT AND DISPOSAL

Sewage sludge treatment describes the processes used to manage and dispose of sewage sludge produced during sewage treatment. Sludge is mostly water with lesser amounts of solid material removed from liquid sewage. **Primary sludge** includes settleable solids removed during primary treatment in primary clarifiers. **Secondary sludge** separated in secondary clarifiers includes treated sewage sludge from secondary treatment bioreactors.

Sludge treatment is focused on reducing sludge weight and volume to reduce disposal costs, and on reducing potential health risks of disposal options. Water removal is the primary means of weight and volume reduction, while pathogen destruction is frequently accomplished through heating during thermophilic digestion, composting, or incineration. The choice of a sludge treatment method depends on the volume of sludge generated, and comparison of treatment costs required for available disposal options. Air-drying and composting may be attractive to rural communities, while limited land availability may make aerobic digestion and mechanical dewatering preferable for cities, and economies of scale may encourage energy recovery alternatives in metropolitan areas.

Energy may be recovered from sludge through methane gas production during anaerobic digestion or through incineration of dried sludge, but energy yield is often insufficient to evaporate sludge water content or to power blowers, pumps, or centrifuges required for dewatering. Coarse primary solids and secondary sewage sludge may include toxic chemicals removed from liquid sewage by sorption onto solid particles in clarifier sludge. Reducing sludge volume may increase the concentration of some of these toxic chemicals in the sludge.

1. Thickening

Thickening is usually the first step in sludge treatment because it is impractical to handle thin sludge, a slurry of solids suspended in water. Sludge from primary or secondary clarifiers may be stirred (often after addition of clarifying agents) to form larger, more rapidly settling aggregates. Primary sludge may be thickened to about 8 or 10 percent solids, while secondary sludge may be thickened to about 4 percent solids. Thickeners often resemble a clarifier with the addition of a stirring mechanism. Thickening is usually accomplished in a tank called a gravity thickener. A thickener can reduce the total volume of sludge to less than half the original volume. An alternative to gravity thickening is dissolved-air flotation. In this method, air bubbles carry the solids to the surface, where a layer of thickened sludge forms.

Methods of thickening

a) Gravity Thickening: This process involves the concentration of thin sludges to more dense sludge in special circular tanks designed for this purpose. Its use is largely restricted to the watery excess sludge from the activated sludge process. It may also be used to concentrate sludge to primary tanks or a mixture of primary and excess activated sludge prior to high rate digestion.

b) Dissolved Air Floatation: The objective of flotation-thickening is to attach a minute air bubble to suspended solids and cause the solids to separate from the water in an upward direction. This is due to the fact that the solid particles have a specific gravity lower than water when the bubble is attached.

Dissolved air flotation depends on the formation of small diameter bubbles resulting from air released from solution after being pressurized to 40 to 60 psi. Since the solubility of air increases with pressure, substantial quantities of air can be dissolved. Sludge solids are floated by the air bubbles that attach themselves to and are enmeshed in the floc particles. The degree of adhesion depends on surface properties of the solids. When released into the separation area of the thickening tank, the buoyed solids rise under hindered conditions analogous to those in gravity settling and can be called hindered separation or flotation. The upward moving particles form a sludge blanket on the surface of the flotation thickener.

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c) Centrifugation: Centrifuges are a compact, simple, flexible, self-contained unit. They have the disadvantages of high capitals, maintenance and power costs and often a poor, solids-capture efficiency if chemicals are not used for bio sludges. Centrifugal thickening is acceleration of sedimentation through the use of centrifugal force. Centrifuges are commonly used for thickening WAS (Waste Activated Sludge). Primary sludge is normally not fed to centrifuge as it may contain abrasive material. In addition of being effective in thickening, they have additional advantage of less space requirement, less odour potential & housekeeping requirement.

2. Digestion

Many sludges are treated using a variety of digestion techniques, the purpose of which is to reduce the amount of organic matter and the number of disease-causing microorganisms present in the solids. The most common treatment options include anaerobic digestion, aerobic digestion, and composting. Sludge digestion offers significant cost advantages by reducing sludge quantity by nearly 50% and providing biogas as a valuable energy source.

a) Anaerobic digestion

Anaerobic digestion is a bacterial process that is carried out in the absence of oxygen. The process can either be thermophilic digestion, in which sludge is fermented in tanks at a temperature of 55 °C, or mesophilic, at a temperature of around 36 °C. Though allowing shorter retention time (and thus smaller tanks), thermophilic digestion is more expensive in terms of energy consumption for heating the sludge.

Mesophilic anaerobic digestion (MAD) is also a common method for treating sludge produced at sewage treatment plants. The sludge is fed into large tanks and held for a minimum of 12 days to allow the digestion process to perform the four stages necessary to digest the sludge. These are hydrolysis, acidogenesis, acetogenesis, and methanogenesis. In this process the complex proteins and sugars are broken down to form more simple compounds such as water, carbon dioxide, and methane.

Anaerobic digestion generates biogas with a high proportion of methane that may be used to both heat the tank and run engines or microturbines for other on-site processes. Methane generation is a key advantage of the anaerobic process. Its key disadvantage is the long time required for the process (up to 30 days) and the high capital cost.

b) Aerobic digestion

Aerobic digestion is a bacterial process occurring in the presence of oxygen resembling a continuation of the activated sludge process. Under aerobic conditions, bacteria rapidly consume organic matter and convert it into carbon dioxide. Once there is a lack of organic matter, bacteria die and are used as food by other bacteria. This stage of the process is known as endogenous respiration. Solids reduction occurs in this phase. Because the aerobic digestion occurs much faster than anaerobic digestion, the capital costs of aerobic digestion are lower. However, the operating costs are characteristically much greater for aerobic digestion because of energy used by the blowers, pumps and motors needed to add oxygen to the process.

Aerobic digestion can also be achieved by using diffuser systems or jet aerators to oxidize the sludge. Fine bubble diffusers are typically the more cost-efficient diffusion method, however, plugging is typically a problem due to sediment settling into the smaller air holes. Coarse bubble diffusers are more commonly used in activated sludge tanks or in the flocculation stages. A key component for selecting diffuser type is to ensure it will produce the required oxygen transfer rate.

3. Dewatering

Water content of sludge may be reduced by centrifugation, filtration, and/or evaporation to reduce transportation costs of disposal, or to improve suitability for composting. Centrifugation may be a preliminary step to reduce sludge volume for subsequent filtration or evaporation. Filtration may occur through underdrains in a sand drying bed or as a separate mechanical process in a belt filter press. Filtrate and centrate are typically returned to the sewage treatment process. After dewatering sludge may be handled as a solid containing 50 to 75 percent water. Dewatered sludges with higher moisture content are usually handled as liquids.

Sludge Drying Beds

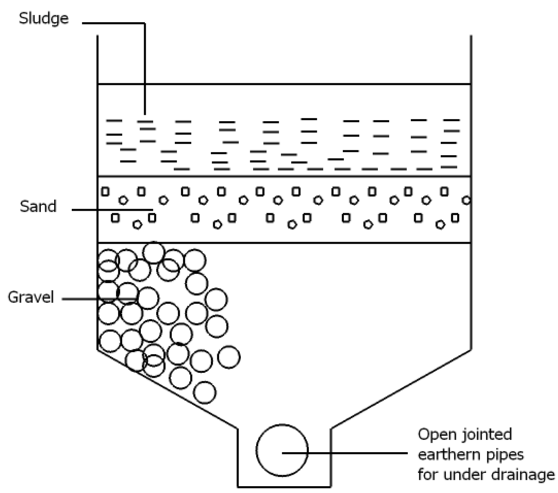
Sludge drying bed (SDB) is the most widely used method for sludge dewatering. Sludge drying involves natural ways of drying to mechanical ways of removing water content. SDB is generally used for small and medium sized communities. Drying beds are typically composed of four layers consisting of gravel and sand. The first layer is coarse gravel that is 15 to 20 centimeters thick. Followed by fine gravel that is 10 centimeters thick. The third layer is sand that can be between 10 and 15 centimeters and serves as the filter between the sludge and gravel. Sludge dries up and water percolates to the first layer that is collected at the drainage pipe that is beneath all layers.

Advantages

- Easy to operate.
- No electrical energy required.
- Organic content can be used as fertiliser.

Disadvantages

- Requires stabilised sludge to prevent nuisance and odours.
- Technology is land intensive.
- Climatic fluctuation may cause disturbance.
- Clogging of sand bed.
- Only applicable during dry seasons.



4. Sludge Disposal

Incineration

Incineration of sludge is less common because of air emissions concerns and the supplemental fuel (typically natural gas or fuel oil) required to burn the low calorific value sludge and vaporize residual water. Stepped multiple hearth incinerators with high residence time and fluidized bed incinerators are the most common systems used to combust wastewater sludge.

SLUDGE DIGESTION TANK

Design Considerations

- Diameter : 3 – 12 m
- Depth : 6 m
- Slope of bottom hoppered floor : 1:1 to 1:3
- Capacity of digestion tank

$$V = \left(\frac{V_1 + V_2}{2}\right) t$$

where $V_1 \Rightarrow$ volume of raw sludge (m^3/day)

* $V_2 \Rightarrow$ volume of digested sludge (m^3/day) $\approx 1/3 V_1$.

$t \Rightarrow$ Digestion period (days)

- Monsoon storage = $V_2 T$

$T \Rightarrow$ No. of days for which digested sludge is stored.

★ When the change during digestion is assumed to be parabolic than linear then

Avg. volume of digesting sludge $= V_1 - 2/3 (V_1 - V_2)$

∴ Required capacity, V

1) Without monsoon storage $V = \left[V_1 - 2/3 (V_1 - V_2)\right] t$

2) With monsoon storage $V = \left[V_1 - 2/3 (V_1 - V_2)\right] t + V_2 T$

★ Monsoon storage :

When the daily digested sludge couldn't be removed due to factors such as monsoon season, winter season etc. then separate capacity for its storage should be provided in the tank. This is called Monsoon storage.

★ $V_2 \Rightarrow$ Volume of digested sludge.

$$V_2 = V_1 \left[\frac{100 - P_1}{100 - P_2}\right]$$

P_1 = moisture content of raw sludge

P_2 = moisture content of digested sludge.

Problem

1. Design a sludge digestion tank for the primary sludge with the help of following data.

- Avg. flow = 20 MLD
- Total suspended solids in raw sewage = 300 mg/L.
- Moisture content of digested sludge = 85%.

Ans. Total suspended solids = 20 MLD × 300 mg/L

$= 20 \times 10^{6} \times 300 \times 10^{-6}$

$= 6000$ kg/day

Assuming that 65% solids are removed in primary settling tank.

Mass of solids removed in primary settling tank

$= 0.65 \times 6000 = 3900$ kg/day

Assuming that fresh sludge has a moisture content of 95%.

95% moisture content means,

5 kg dry solids can produce 100 kg wet sludge.

∴ 3900 kg dry solids can produce ⇒ $\frac{3900 \times 100}{5}$

$= 78000$ kg/day wet sludge.

Assume that specific gravity of wet sludge as 1.02.

∴ Density = 1.02 × 1000 = 1020 kg/m³

∴ volume of raw sludge = $\frac{\text{Mass}}{\text{Density}}$

$V_1 = \frac{78000}{1020} = 76.47$ m³/day

Given that moisture content of digested sludge = 85%.

∴ Volume of digested sludge $V_2 = V_1 \left[\frac{100 - P_1}{100 - P_2}\right]$

$= V_1 \left[\frac{100 - 95}{100 - 85}\right]$

$= V_1/3$

$= \frac{76.47}{3}$

$= 25.49$ m³/day

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Assuming digestion period as 30 days. & change during digestion as parabolic, required capacity of digestion tank without monsoon storage;

$$V = \left[V_1 - \frac{2}{3}(V_1 - V_2)\right] t$$

$$= \left(76.47 - \frac{2}{3}\left[76.47 - 25.49\right]\right) 30$$

$$= 1274.5 \ m^3$$

Provide a depth of 6 m for the cylindrical digestion tank.

$$c/s \text{ area} = \frac{\text{volume}}{\text{depth}} = \frac{1274.5}{6}$$

$$= 212.42 \ m^2$$

$$\therefore \frac{\pi}{4} d^2 = 212.42$$

$$d = 16.45 \simeq 16.5 \ m$$

Hence provide a cylindrical sludge digestion tank 6 m deep, & 16.5 m diameter, with an additional hoppered bottom of 1:1 slope for collection of digested sludge.

SLUDGE DRYING BEDS

1. Design a sludge drying bed for drying the sludge from the digestion tank for 40,000 population. The sludge content per capita per day is 0·068 kg. The moisture of the sludge is 94 %. The specific gravity of the wet sludge is 1·02.

Ans. Dry sludge content produced by 40,000 person = 0·068 × 40000
= 2720 kg/day

Given moisture of sludge = 94% means
6 kg dry sludge can produce 100 kg of wet sludge.
∴ 2720 kg dry sludge can produce

$\Rightarrow \frac{2720 \times 100}{}$

= 45333.6 kg wet sludge.

Volume of wet sludge = $\frac{\text{Mass}}{\text{Density}}$ = $\frac{45333}{1020}$ → (1·02×1000)

= 44·4 m³/day

Let the thickness of drying bed be 22·5 cm (20–30 cm)

Area of bed = $\frac{44 \cdot 4}{0 \cdot 225}$ = 197·3 m²/day

Let 2 weeks be taken as average drying time.

∴ No. of times drying bed can be used in an year = $\frac{52}{2}$ → (52 weeks = 1 yr)

= 26 times

∴ Area of bed required per year = $\frac{197 \cdot 3 \ \frac{m^2}{day} \times 365 \ day}{26}$ → times

= 2770 m²

Making 100% allowance for space for storage, repairs and resting of beds.

Total area of bed = 2 × 2770
= 5540 m²

Using 15m x 30m bed.

$$\text{No. of beds} = \frac{5540 \;(\rightarrow \text{Total area})}{15 \times 30 \;(\rightarrow \text{area of single unit})}$$

$$= 12.3 \simeq 14$$

Let's provide 14 beds.

$$\therefore \text{Area} = \frac{5540}{14} = 395.7 \, m^2$$

Let width = 15 m

$$\text{Length} = \frac{395.7}{15}$$

$$= 26.4 \, m$$

∴ Provide 14 beds of size 26.4 m x 15 m in plan.

MODULE – VI

Sludge treatment and disposal – Methods of thickening, sludge digestion (stages & Factors affecting) – Anaerobic digestion. Design of sludge digestion tanks (Parts & working) and sludge drying beds, methods of sludge disposal.

Sludge treatment and disposal:

There are two end products obtained from various wastewater treatment plants.

(i) Effluent → Treated effluent is directly discharged either in the receiving water or on land.

(ii) Sludge → It is processed (dewatered) and disposed

Types of sludge:

(i) Raw or primary sludge → sludge from 1° settling tanks

(ii) Secondary sludge → sludge from 2° settling tanks.

(iii) Activated sludge → sludge from activated sludge process

Sludge treatment processes:

1. Thickening or concentration
   - → Gravity thickening
   - → Centrifugation
   - → Floatation thickening

2. Digestion
   - → Aerobic
   - → Anaerobic

3. Dewatering
   - → Mechanical methods
   - → Sludge Drying beds.

4. Final Disposal
   - → Incineration
   - → Lagooning
   - → Dumping
   - → Burial

Sludge thickening

It is a process used to increase the solids content of sludge by removing a portion of the liquid fraction. It is done for the following purposes.

(i) to permit increased loadings to sludge digesters.
(ii) to minimize the land requirements as well as handling costs.
(iii) to save fuel during incineration.

Sludge thickening is achieved by the following three methods.

1) Gravity thickening

→ Simplest and least expensive method.
→ It is not suitable when activated sludge exceeds 40% of the total sludge weight.
→ The tank used resembles a circular clarifier.
→ $\frac{\text{Depth}}{\text{Diameter}}$ ratio is higher, hoppered bottom has a steeper slope.
→ Diluted sludge is fed into the center feed well.
→ slowly rotating rake mechanism is provided to stir the sludge gently and opening up channels for water to escape. This promotes densification of sludge.
→ The supernatant liquor continuously overflows a peripheral weir and it is returned to primary settling tank.

→ The underflow of thickened sludge is drawn from the bottom sump in the tank.

→ Surface loading → 15 to 35 m^3 per day of sludge per m^3 of tank area.

→ Detention period → 3 to 4 hrs.

→ The volume of thickened sludge is half of its original volume.

2) Floatation thickening.

→ Air floatation units employ floatation of sludge by air under pressure or vacuum.

→ Floatation thickeners helps in thickening light sludges which have density close to that of water.

→ In dissolved air floatation unit, a portion of subnatant is pressured from 3 to 5 kg per cm^2 and then saturated with air in the pressure tank or air dissolution tank.

→ The effluent from the pressure tank is mixed with influent sludge immediately before it is released into the floatation tank.

→ Excess dissolved air then rises up in the form of minute bubbles at atmospheric pressure attaching themselves to particles which forms the sludge blanket.

→ Thickened sludge is skimmed off from the surface while the unrecycled subnatant is returned to the plant.

→ Effluent is recycled at a rate of 30–150% of the influent flow through the air-dissolution tank to the feed inlet.

→ Surface overflow rate – 10 to 15 m/day.

→ Detention time → 30 min to 1 hr

→ Efficiency of floatation units can be increased by the addition of chemicals.

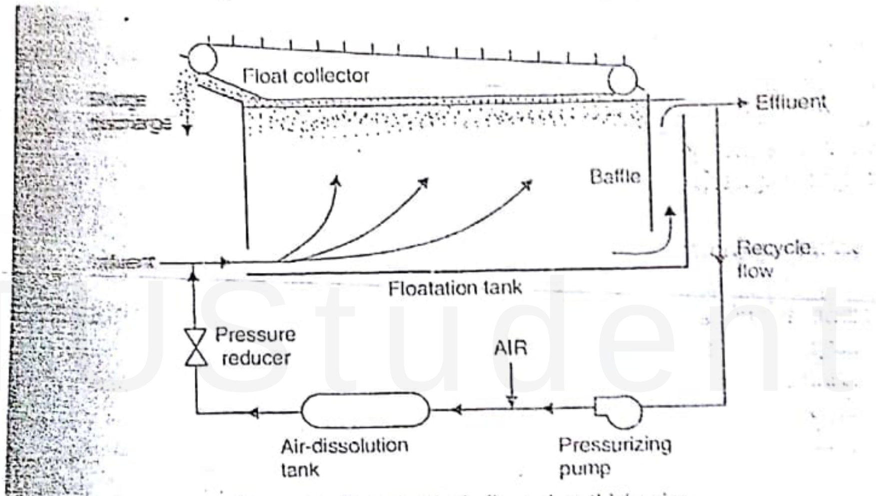


Fig. 7.15 Dissolved air floatation thickening

3) <u>Centrifugal thickening.</u>

→ They are used both to thicken and to dewater sludges.

→ This thickener is used for thickening activated sludge.

→ This method involves the settling of sludge particles under the influence of centrifugal forces.

→ This method involves high maintenance and power costs.

Sludge Digestion.

The process of decomposition of organic matter under controlled anaerobic conditions is called sludge digestion. The tank where this process is carried out is called sludge digestion tank. In a sludge digestion process, the sludge gets broken into the following three forms.

(i) Digested sludge.

- stable humus like solid matter with reduced moisture content.
- Its volume is one third of the volume of undigested sludge.
- Quality of digested sludge is better than that of undigested sludge.
- It is free of pathogenic bacteria.

(ii) Supernatant liquor.

- Liquified and finely divided solid matter.
- It has high BOD content about 2000 ppm.

(iii) Gases of decomposition

Main gases are :-

Methane – 65 to 70%

CO_2 – 30%

Traces of other inert gases – N_2, H_2S etc.

Amount of gas produced is approximately equal to 0.9 m^3/kg of volatile solids reduced in digestion.

Stages in the sludge digestion process.

(i) Acid fermentation
(ii) Acid regression
(iii) Alkaline fermentation.

Acid fermentation stage (Acid production stage)

→ Fresh sewage - sludge is attacked by anaerobic and facultative bacteria called acid formers.
→ They solubilize the organic solids through hydrolysis.
→ The products of decomposition are organic acid and gases.
→ Gases produced are CH_4, CO_2, H_2S
→ During this stage, sludge remains acidic (pH is less than 6)
→ BOD of sludge increases.
→ This stage continues for about 15 days.

Acid - Regression stage.

→ Intermediate stage.
→ The organic acids and nitrogenous compounds are attacked by bacteria and converted into acid carbonates and ammonia compounds.
→ The decomposed sludge has very offensive odour
→ It entraps the gases of decomposition and becomes foamy and tends to rise to the surface as scum.

→ The pH value rises and it remains between 6 and 7.

→ The BOD still remains high. The stage extend for several months (usually 3 months)

Alkaline fermentation stage

→ Final stage of sludge digestion.

→ The more resistant materials like proteins and organic acids are attacked and broken by bacteria (methane formers) into ammonia, organic acids and gases.

→ Liquid separates out from the solids and the digested sludge is formed.

→ Granular and stable sludge without offensive odour.

→ It is also called as ripened sludge.

→ Sludge is collected at the bottom of tank.

→ Digested sludge is alkaline in nature

→ pH value rises to a little above 7

→ BOD gets reduced

→ This stage extends for a period of one month.

Factors affecting sludge digestion

1. Temperature

* Rate of digestion is more at higher temperatures and vice-versa. There are two temperature zones:-

(i) Zone of thermophilic digestion

→ Digestion is brought about by thermophilic organisms.
→ Temperature range - 40 to 60°c.
→ Optimum temperature - 54°c
→ The digestion period can be brought down to about 10-15 days only.
→ Thermophilic range temperatures are not generally employed for digesting sewage sludge due to operational difficulties.

(ii) Zone of mesophilic digestion.

→ Digestion is brought about by mesophilic organisms
→ Temperature range (moderate temperature) - 25 to 40°c
→ Optimum mesophilic temperature - 27°c.
→ The digestion period can be brought down to about 30 days.

* The best results are obtained at about 29°c. When about 90% of digestion takes place in about 30 days.

* It is difficult to control temperature in practice.

2. pH

→ Low pH will suppress bacterial action in the initial stage.

→ pH during digester start up does not go below 6.5

→ Alkaline Conditions (optimum pH about 7.2 to 7.4) in the final stage of digestion.

3. Seeding with the digested sludge.

→ Proper seeding will help to attain quick balance conditions of reaction.

→ When a sludge digestion tank is first put in operation, it is highly beneficial to seed it with the digested sludge from another tank.

4. Mixing and stirring of the raw sludge with the digested sludge.

→ Raw sludge should be thoroughly mixed with the digested sludge, to make a homogenous mass of raw as well as digested sludge.

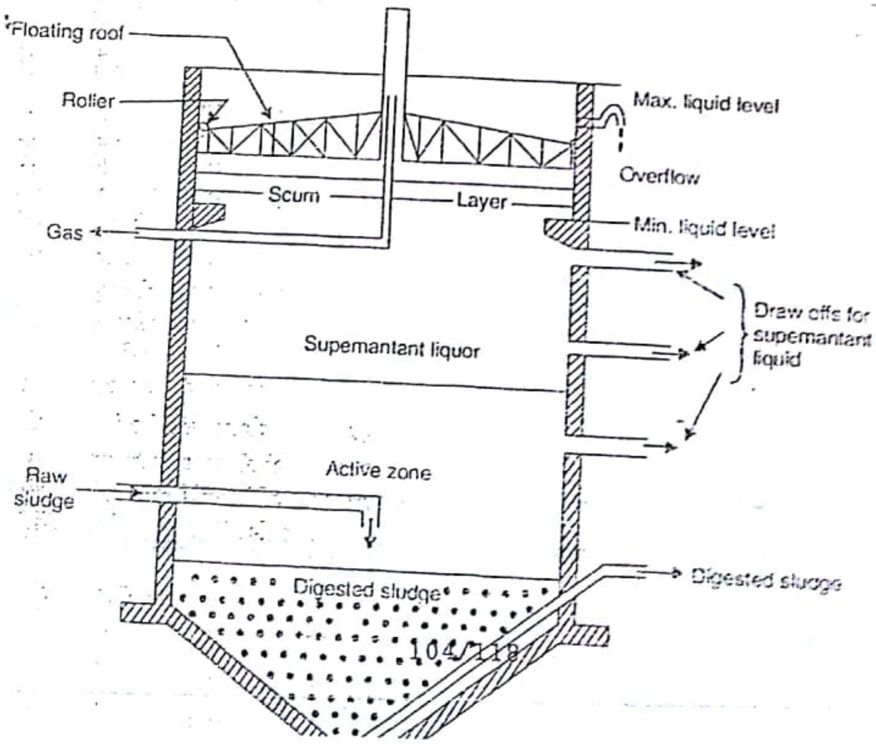
→ The mixing of raw and digested sludge is achieved by stirring the sludge in the sludge digestion tank by slow moving mechanical devices.

→ Proper stirring results in even distribution of incoming sludge.

→ Excessive stirring may kill the bacteria.

Sludge Digestion tank / Digestor

- It consists of a circular R.C.C tank with hoppered bottom and has a fixed or floating type of roof over its top.
- The raw sludge is pumped into the tank through the inlet.
- It is seeded with the digested sludge from another tank. when the tank is first put into operation.
- Sludge should be properly stirred using mechanical devices.
- During digestion process digested sludge and large amounts of CH_4 gas are formed.
- The gas is collected and used as fuel.
- The digested sludge is collected at the bottom of the tank.
- Supernatant liquor with high BOD is recycled with raw sludge and treated.



Types of digestors.
1) Conventional or low rate Digestors
2) High rate digestor

Conventional or low rate digestor

Conventional sludge digestion can be carried out in two ways.

i) Single stage digestor

sludge digestion, sludge thickening and supernatant formation takes place simultaneously in the same unit.

ii) Two stage digestor

In this two tanks are provided. The first tank is used for digestion and the second tank is used for storage, thickening and supernatant formation.

Row sludge is pumped into primary digestion tank and kept there for a period of 7-10 days. Anaerobic decomposition occurs and gas is produced. This gas is collected in the primary tank.

Partly treated sludge from primary tank is kept in secondary tank for a period of 20 days. Then the digested sludge and supernatant liquor from secondary tank are disposed off suitably in a sanitary manner.

High rate Digestor

Solids loading rate is much greater. The sludge is intimately mixed & heated to obtain optimum digestion rates.

Design Considerations of Digestion tank.

(1) Diameter – varies from 3 to 12 m.

(2) Slope of bottom hoppered floor – 1:1 to 1:3

(3) Depth of digestion tank – usually kept about 6m.

(4) Capacity of digestion tank, $V = \left(\frac{V_1 + V_2}{2}\right)t$

Where V_1 = Volume of raw sludge (m^3/d)

V_2 = Volume of digested sludge (m^3/d) $\approx \frac{1}{3} V_1$

t = digestion period (d)

* When the daily digested sludge could not be removed due to factors such as monsoon season, winter season etc. Then separate capacity for its storage should be provided in the tank. This is called monsoon storage.

∴ Monsoon storage = $V_2 \times T$

(T = No: of days for which digested sludge is stored)

* When the change during digestion is assumed to be parabolic than linear, then the avg. volume of digesting sludge will be $V_1 - \frac{2}{3}(V_1 - V_2)$

$\therefore$ Required capacity, $V = \left\{V_1 - \frac{2}{3}(V_1 - V_2)\right\} t$ → Without monsoon storage.

$$V = \left[V_1 - \frac{2}{3}(V_1 - V_2)\right] t + V_2 \cdot T$$

→ With monsoon storage.

Q. Design a sludge digestion tank for the primary sludge with the help of following data.

(i) Average flow = 20 MLD

(ii) Total Suspended solids in raw sewage = 300 mg/l

(iii) Moisture content of digested sludge = 85%.

Soln: Total suspended solids = $20 \times 10^6 \times 300 \times 10^{-6}$

$= 6000$ kg/day.

Assuming that 65% solids are removed in primary settling tanks,

Mass of solids removed in the 1° settling tank

$= \frac{65}{100} \times 6000 = 3900$ kg/day.

Assuming that the fresh sludge has a moisture content of 95%

5 kg of dry solids → 100 kg of wet sludge

3900 kg of dry solids $\rightarrow \frac{100}{5} \times 3900$

$= 78000$ kg/day of wet sludge

Assuming the specific gravity of wet sludge as 1.02

Density of sludge $= 1.02 \times 1000$

$= 1020 \text{ kg/m}^3$

Volume of raw sludge produced per day

$$V_1 = \frac{78000}{1020} = 76.47 \text{ m}^3/\text{day}.$$

The volume of the digested sludge (V_2) at 85% moisture content is given by

$$V_2 = V_1 \left[\frac{100 - P_1}{100 - P_2}\right]$$

P_1 = moisture content of raw sludge

P_2 = moisture content of digested sludge

$$= V_1 \left[\frac{100 - 95}{100 - 85}\right]$$

$$= V_1 \left[\frac{5}{15}\right]$$

$$= \frac{1}{3} V_1 = \frac{1}{3} \times 76.47 \text{ m}^3/\text{day}$$

$$= 25.49 \text{ m}^3/\text{day}.$$

Assuming the digestion period as 30 days

Capacity of required digestion tank

$= \left[V_1 - \frac{2}{3}(V_1 - V_2)\right]t$ [parabolic variation without monsoon storage]

$= \left[76.47 - \frac{2}{3}(76.47 - 25.49)\right] \times 30$

$= 1274.5\ m^3$

Providing 6m depth of the cylindrical digestion tank

Cross sectional area of the tank

$= \frac{1274.5}{6} = 212.42\ m^2$

Let D = diameter of digestion tank

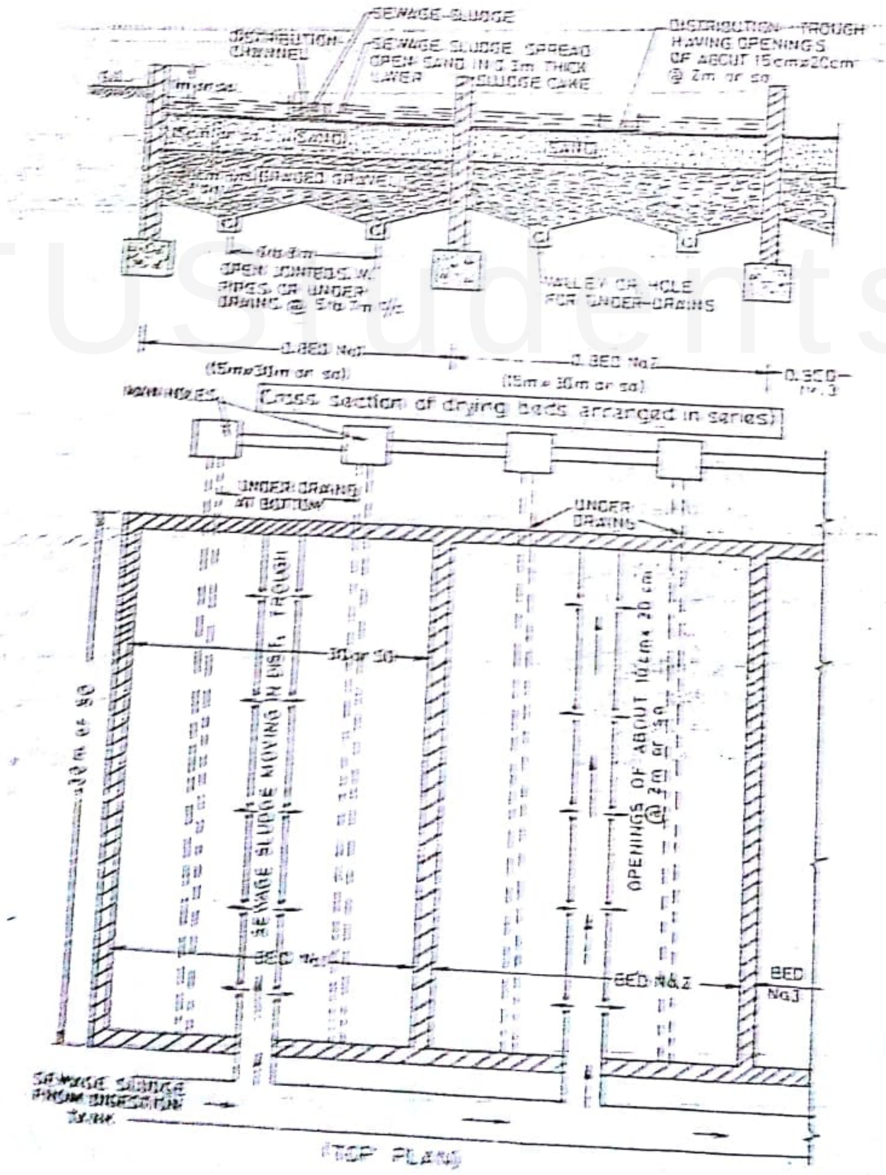
$\frac{\pi}{4} D^2 = 212.42$

$D = 16.45 \simeq \underline{16.5 m}$

Hence provide a cylindrical sludge digestion tank, 6m deep and 16.5 m diameter, with an additional hoppered bottom of 1:1 slope for collection of digested sludge.

Sludge Drying beds

→ In this, sludge is dried on open beds of land.



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→ Sludge drying beds are open beds of land 45 to 60 cm deep.

→ It consists of :-

(1) Gravel or crushed stone layers of 30 to 45 cm thick with varying size from 15 cm at bottom to 1.25 cm at top.

(2) coarse sand layer of 10 to 15 cm thick.

(3) Open jointed under-drain pipes (15 cm in dia) @ 5 to 7m c/c spacing laid below the gravel layer.

→ The beds are about 15×30m in plan. It is surrounded by brick walls rising about 1m above the sand surface.

→ The sewage sludge is distributed to the top of drying beds to a depth of about 20 to 30 cm through distribution troughs having openings of about 15 cm × 20 cm at a distances of about 2m or so.

→ A portion of moisture drains through the bed, while most of it is evaporated to the atmosphere.

→ It takes two weeks to two months for drying the sludge depending on the weather and condition of bed.

→ sludge drying beds are generally arranged in series and they are not covered at top.

→ Required area of sludge drying beds
→ 0.05 to 0.2 sq.m per capita.

→ Normally sludge is removed from the beds after a period of about 7-10 days. Within this period, about 30% of the moisture goes away and the surface of sludge gets cracked.

→ The sludge cakes are removed and they are dumped into a pit for further drying.

→ Dried sludge can be used as manure or it is disposed of by burning.

1. Design a sludge drying bed for drying the sludge from the digestion tank for 40,000 population. The sludge content per capita per day is 0.068 kg. The moisture of the sludge is 94%. The specific gravity of the wet sludge is 1.02.

Soln:- Dry sludge content produced by 40,000 persons.

$$= 0.068 \times 40{,}000 = 2720 \text{ kg/day}.$$

94% moisture content means that 6 kg of dry sludge will produce 100 kg of wet sludge.

∴ 6 kg of dry sludge produces wet sludge = 100 kg

2720 kg of dry sludge produces wet sludge

$$= \frac{100}{6} \times 2720 = 45333 \text{ kg}$$

$$\text{Volume of wet sludge produced} = \frac{\text{Mass of sludge}}{\text{Density of sludge}}$$

$$= \frac{45333}{1.02 \times 1000}$$

$$= 44.4 \text{ m}^3/\text{day}$$

Assume thickness of sludge bed as 22.5 cm [Range 20 to 30c

$$\text{Area of bed} = \frac{44.4}{0.225} = 197.3 \text{ m}^2/\text{day}$$

Under tropical Indian conditions, the beds get dried out in about 10 days and hence 2 weeks is taken as average drying time.

No: of times the drying can be used in an year

$= \frac{52}{2} = 6$ times

Area of bed required per year

$= \frac{197.3 \times 365}{26} = 2770 m^2$

Making 100 percent allowance for space for storage, repairs and resting of beds:

Total area of bed $= 2 \times 2770$

$= 5540 m^2$

Using 15x30m sized beds

No: of beds $= \frac{5540}{15 \times 30} = 12.3$

Use 14 No. of beds, Area $= \frac{5540}{14} = 395.7 m^2$

Using 15m width,

length $= \frac{395.7}{15} \approx 26.4 m$

Use 14 beds of size 15m x 26.4m in plan.

Final disposal of sludge.

Sludge can be finally disposed off by the following methods:

1) Spreading on farm land
2) Dumping
3) Land felling
4) Sludge Lagooning.
5) Disposal in water or sea.

Spreading on farm land.

→ Dewatered sludge may be disposed of by spreading over farm land and ploughing under after it has dried.

→ Wet dewatered sludge can be incorporated into soil directly by injection.

→ Shallow trenches of 50 to 90 cm wide, 0.3 to 0.4 m deep are provided about 1 to 1.5 m apart, and wet sludge is discharged into it.

→ After a sludge cake is formed due to evaporation of water, it is covered with dry earth. After about a month, the whole land is ploughed and used for cultivation.

Dumping:

Dumping in an abandoned mine quarry can be resorted to only for sludges and solids that have been stabilized so that no decomposition or nuisance conditions will result. This method can be safely adopted for digested sludge, clean grit and incinerator residue.

Disposal by land filling:

→ A sanitary landfill can be used for disposal of sludge, grease, grit and other solids, whether stabilised or not.

→ Dewatering is recommended before such disposal.

→ The wastes are deposited in the designated area, compacted in place with a tractor or roller and covered with 30cm layer of clean soil.

Sludge lagooning.

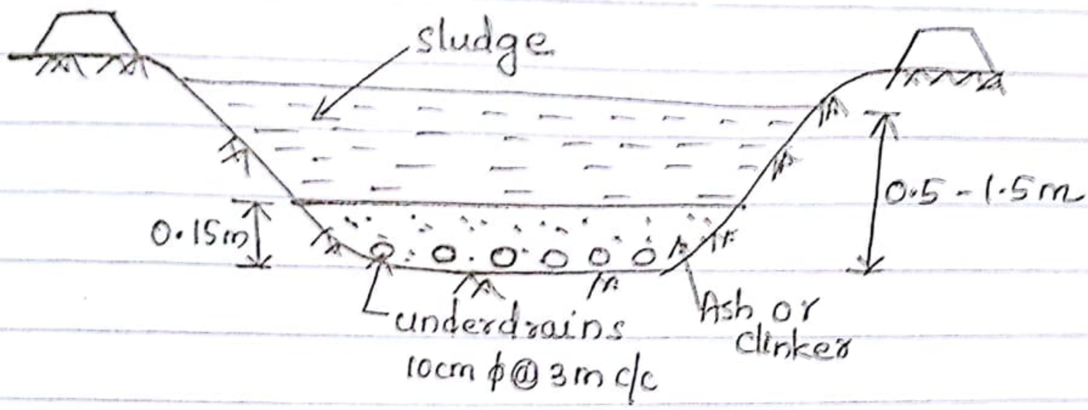
→ A lagoon is a shallow earth basin into which untreated or digested sludge is deposited.

→ Untreated sludge lagoons stabilize the organic solids by anaerobic and aerobic decomposition.

→ The depth of the lagoon vary from 0.5 to 1.5m.

→ Detention time – 1 to 2 months.

→ After the sludge has been stabilized and the moisture is drained/evaporated, the contents of the lagoon are dug out to about half of its volume and used as manure.



Disposal in water or sea.

The sludge either raw or digested is barged to sea far enough to make available the required dilution and dispersion. The method requires careful consideration of all factors for proper design and siting of outfall to prevent any coastal pollution or interference with navigation.