EN301

Drinking water → Free from colour, taste, odour, turbidity
→ Free from pathogens
→ Free from toxicants

Sewage: All kinds of liquid waste produced by the community is known as sewage. It includes domestic wastewater, industrial wastewater, etc.

Sewer: An underground pipe that carries sewage (mixture of water and liquid waste) is called a sewer.

Sewerage: Network of sewers required in collection, conveyance and disposal is known as sewerage.

Domestic sewage + Industrial Sewage = Sanitary sewage (DWF Dry weather Flow)

The run-off resulting from rain storms is called storm drainage or storm sewage (WWF Wet weather Flow)

Types of Sewerage Systems

[Only one sewerage is used to carry sewage (DWF) and drainage (WWF)] → Combined System

[Drainage and sewage are taken independently in two different sets of conduits.] → Separate System

Partially Separate System: DWF is allowed to enter WWF or vice-versa.

✓ Separate system has two sets of conduits, hence costlier to set up

✓ Combined system mixes both flows, so higher capacity treatment plants are required. (Drainage is less foul than sewage)

✓ In case of backing up / flooding, combined sewage causes more foul / unsanitary condition

✓ Separate system requires : Pumping of sewage, no pumping for drainage

Combined system requires : Pumping of entire discharge, hence costly.

PRIMARY TREATMENT (Preliminary + Primary)

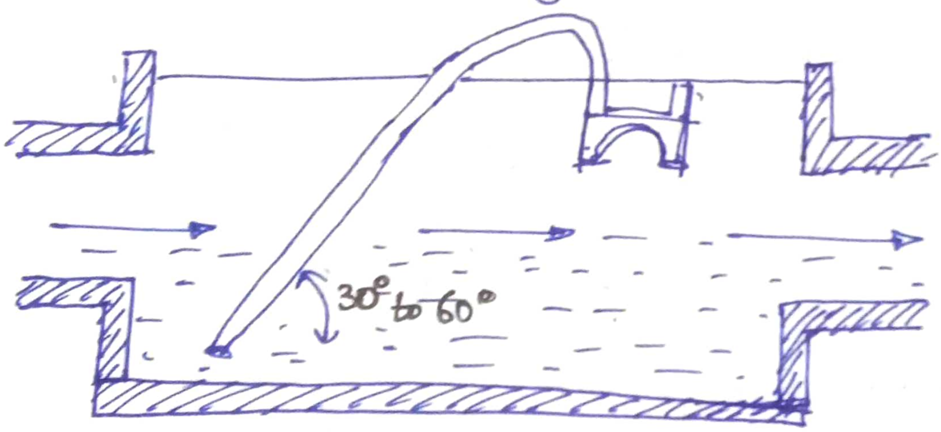
Preliminary → Screening → Grit Chambers → Skimming tanks → Primary → Settling basins

SCREENING

✓ Passing the sewage through different types of screens to trap and remove the floating matter.

- **Coarse Screens (Racks)** :
  - ✓ Spacing between bars = 50 mm or more
  - ✓ Removes large floating objects
  - ✓ Collects about 6 million litres of solids per million litre of sewage
  - ✓ Solids so collected (rags, wood, paper) → do not putrefy; may be disposed off by incineration, burial and dumping

- **Medium Screens** :
  - ✓ Spacing b/w bars = 6 mm to 40 mm
  - ✓ Collect 30 – 90 litres of material per million litre of sewage
  - ✓ The collected waste may putrefy and must be disposed by incineration or burial. (Not dumping)



Screen Design

- ✓ Openings should have sufficient total area such that the velocity through them is not more than $\boxed{0.8\,m/s \text{ to } 1\,m/s}$. This limit on velocity limits the ~~headloss~~ headloss through the screens (reduces the chance of screenings to be pushed through)
- ✓ The screenings can be removed manually or mechanically. (using manually/mechanically operated rakes)
- ✓ Screens may be fixed or movable (for cleaning purposes)

- Fine screens : ✓ Perforations of 1.5mm to 3mm.

✓ Remove about 20% of suspended solids from sewage. Help reduce loads on further treatment units.

✓ Get clogged often, require frequent cleaning.

✓ Used only for treating ~~[illegible]~~ industrial wastewaters or industry-related municipal wastewaters.

✓ Brass or bronze plates/ mesh is used.

For calculating screen design :

✓ Calculate Q (sewage discharge, which is 80% of daily demand)

✓ Assume v (flow velocity) = 0.8m/s. (velocity through screen)

✓ Calculate openings area = $\frac{Q}{v}$ $(\because, Q = A \times v)$

✓ Calculate net area = $\left(\frac{6}{5}\right) \times A_{openings}$.

✓ Calculate gross screen area = $\frac{\text{Net area}}{\sin\theta}$ θ = angle with horizontal (assume 60°)

✓ Calculate velocity above screen (V)

$= \frac{5}{6} \times 0.8 = 0.67 m/s$

Head Loss $(H_L) = 0.0729(V^2 - v^2)$ with 0.8 and 0.67

$= 0.0134m \simeq 0.013m$ (negligible)

For determining cleaning frequency.

✓ When screen gets half clogged,

velocity through screen $= 0.8 \times 2 = 1.6 m/s$

$\therefore, H_L = 0.0729((1.6)^2 - (0.67)^2) = 0.1538 m$

$\simeq 0.15 m$

(alot)

Communitors/Shredders

✓ Devices which break down larger sewage solids to about 6mm in size, when sewage is screened through them.

✓ Rotating cutters mounted on the drum shear the collected screenings against a comb until they're small enough to pass through 5mm to 10mm wide slots of the drum.

✓ Eliminate the problem of disposal of screenings.

Disposal of Screenings

→ material separated by screens

→ 85-90% moisture and other floating matter

Disposed by incineration & burial.

Dumping is avoided.

Screenings → Dried in sun's heat → Hydraulic pressed → Incinerated at 760°c-815°c

Screenings → buried in 1-1.5m deep trenches → Covered with 0.3 to 0.45m porous earth. → Becomes manure

GRIT REMOVAL BASINS

- ✓ These are sedimentation basins for removing inorganic particles like sand, gravel, grit, egg shells, bones from wastewater.
- ✓ These particles may clog channels or damage pumps, or may accumulate in sludge digestors.
- ✓ May be placed before or after fine screens.

  before → to avoid silting of screen chambers

Sedimentation → The physical separation of suspended material from a water or a wastewater by the action of gravity.

Fundamental Principle: Organic matter present in sewage has specific gravity greater than that of water.

In still sewage, these particles settle down; whereas, in flowing sewage, they are kept in suspension because of turbulence in water

Type I Settling The settlement of a particle in water brought to rest is ~~opposed by~~ dependent on the following factors :-

→ velocity of flow

→ viscosity of water (generally avoided because depends on Temp)

→ size, shape & specific gravity

Stoke's Law

$$\boxed{v_s = \frac{g}{18}(G-1)\frac{d^2}{\nu}}$$

(for $d < 0.1mm$)

[for viscous flow & small sized particles, $R_e < 0.5$]

v_s = settling velocity in m/s

d = diameter of particle in m

G = specific gravity of particle

ν = Kinematic viscosity of water in m^2/s $= \frac{\mu}{\rho_w}$ — μ = absolute/dynamic viscosity in $kg s/m^2$

R_e = Reynold's number

Derivation for Stoke's Law

Drag force $= C_D \cdot A \cdot \rho_w \cdot \frac{v^2}{2}$

↓ keeps ↑ as v ↑

C_d = coefficient of drag.

A = Area of particle

ρ_w = density of water

v = velocity of fall

At some point, when

$W - F_B = F_D$,

v becomes constant → v_s

Now, $W - F_B = \frac{4}{3}\pi r^3 \gamma_s - \frac{4}{3}\pi r^3 \gamma_w$

$= \frac{4}{3}\pi r^3(\gamma_s - \gamma_w)$

γ_s = unit weight of particle

γ_w = unit weight of water

when equal to drag,

$$C_D A \rho_w \frac{v_s^2}{2} = \frac{4}{3}\pi r^3 (\gamma_s - \gamma_w)$$

Putting $A = \pi r^2$

$$C_D \cdot \pi r^2 \rho_w \frac{v_s^2}{2} = \frac{4}{3}\pi r^3 [\gamma_s - \gamma_w]$$

$$\Rightarrow v_s^2 = \frac{4}{3} \frac{(r)(\gamma_s - \gamma_w)\cdot 2}{\rho_w \cdot C_D}$$

Put $(2r) = d$, $(\gamma_s = \rho_s g)$, $(\gamma_w = \rho_w g)$

$$\Rightarrow v_s^2 = \frac{4}{3} \frac{d(\rho_s - \rho_w)g}{\rho_w C_D} = \frac{4d}{3}\left(\frac{\rho_s}{\rho_w} - 1\right)\frac{g}{C_D}$$

$$= \frac{4}{3} \cdot \frac{d(G-1)g}{C_D}$$

For viscous flow and $d < 0.1\,mm$, $C_D = \frac{24}{Re}$.

$$v_s^2 = \frac{\frac{4}{3}g(G-1)d}{\frac{24}{Re}} = \frac{g}{18}(G-1)d \cdot Re$$

Putting $Re = \frac{v_s d}{\nu}$ $\Rightarrow v_s^2 = \frac{g}{18}(G-1)d \cdot \frac{v_s d}{\nu}$

$$\Rightarrow \boxed{v_s = \frac{g}{18}(G-1)\frac{d^2}{\nu} \quad \text{for } d < 0.1\,mm}$$

(a) For streamline or laminar settling ($d < 0.1mm$)

$$Re < 1 \quad \text{and} \quad C_D = \frac{24}{Re}$$

(b) For transition settling ($0.1mm < d < 1\ mm$)

$$1 < Re < 10^3 \quad \text{and} \quad C_D = \frac{24}{Re} + \frac{3}{Re^{0.5}} + 0.34$$

$$\text{or} \quad C_D = \frac{18.5}{Re^{0.6}}$$

(C) For turbulent settling ($d > 1mm$)

$$Re > 10^3 \quad \text{and} \quad C_D = 0.34 \text{ to } 0.4$$

GRIT CHAMBERS / CHANNELS

Grit size has nominal diameter of 0.15 to 0.20mm or more.
Quantity may vary between $0.004 - 0.037 m^3/1000 m^3$ of sewage for separate sewage system; and $0.04 - 0.180 m^3/1000 m^3$ for combined sewage system.

Grit Channels
- → Horizontal flow (Non-Aerated)
  - → Rectangular
  - → Parabolic
- → Aerated

Horizontal Flow Grit Channels

→ Flow velocity should neither be too low as to cause the settling of lighter organic matter, nor should be so high as not to cause the settlement of the ~~either~~ entire silt and grit present in sewage

$$\text{Critical Scouring velocity} = V_H = 3 \text{ to } 4.5\sqrt{gd(G-1)}$$

For Grit Basin Design:

Flow velocity = 0.25 to $\underbrace{0.3\ m/s}$

detention time = 40 to $\underbrace{60}$ seconds

Water depth = $\underbrace{1.0}$ to 1.8 metre

Theoretical Length of tank = detention time × flow velocity

Freeboard = 0.3m , Sludge zone = 0.75m

Grit chamber cleaning → manual
→ mechanical
→ hydraulic

→ Add 30% as extra length to account for inlet and outlet.

Aerated Grit Chambers

- ✓ Spiral flow aeration take
- ✓ Detention period = 3minutes.
- ✓ Length to width ratio may range from 2.5 to 7.0
- ✓ Depths b/w 2 to 5m
- ✓ width - depth ratio varies b/w 1:1 to 5:1 (typically 2:1)
- ✓ Air diffusers are located 0.45m - 0.60m above bottom of tank

Performance is a function of roll velocity and detention time.

Detritus Tanks

- ✓ Rectangular grit chambers designed to flow with a smaller flow velocity (about 0.9m/s) and longer detention periods (3-4 min)
- ✓ Separates large grit as well as very fine sand particles.
- ✓ Due to this, organic matter will also settle. It is separated from the grit by control of currents in the tank through baffles, or by controlled aeration of the flow through the tank. The rising air bubbles will separate the lighter organic matter from the descending grit.
- ✓ The grit is removed continuously by a scraper mechanism.

Tanks for Removing Oils & Grease

Skimming Tanks

→ Placed before sedimentation tanks to remove oil & grease

fats, soaps, waxes

from kitchens, restaurants, motor garages, oil refineries, factories

→ If not removed, this greasy & oily matter may form odorous scums on the surface of settling tanks, or interfere with activated sludge treatment process.

→ In a skimming tank, air is blown by an aerating device (diffusers) through the bottom. The rising air tends to coagulate and solidify the grease, and causes it to rise to the surface from where it is removed (by hand or by mechanical equipment)

→ The skimming tank has a long trough shaped structure divided into ~~two~~ two or three lateral ~~compar~~ compartments by means of vertical baffle walls for a short distance below sewage surface.

→ The baffle walls help in pushing the rising coagulated greasy material into both the side compartments.

Detention period : 3 to 5 minutes

Air Required : 300 to 6000 m^3/ million litres of sewage

Rising velocity of greasy material = 0.25 m/min

→ Efficiency of skimming tank can be increased by adding chlorine.

Vacuators

→ Grease can also be removed from the sewage by Vacuum floatation method, by subjecting the aerated sewage to a vacuum pressure of about 0-25cm of mercury for 10-to 15 min in a vacuator.

→ This causes the air bubbles to expand and move upward through the sewage to the surface, carrying the grease and lighter waste solids which are then removed through skimming troughs.

Disposal of Skimmings

→ The oil & greasy material removed as skimmings from the skimming tanks / vacuators can be ~~removed~~ disposed off either by burning or burial.

→ May sometimes be converted into soap lubricants, candles and other non-edible products.

→ If vegetable & organic matter content is high & mineral oils are less, may be digested in digestors (produces gas of high fuel value)

SEDIMENTATION

→ To remove suspended organic solids which are heavy to be removed as floating matters, and too light to be removed by grit chambers.

→ when chemical coagulants are used for flocculating the organic matter during the process of sedimentation, ~~aided with coagulation~~. the process is called 'chemical precipitation' or 'sedimentation aided with coagulation'.

→ Septic tanks and Imhoff tanks work on the principle of sedimentation. These tanks combine sludge digestion with sedimentation, whereas sludge deposited in primary as well as in secondary settling tanks, is separately digested in the sludge-digestion tanks.

Sedimentation Tanks

→ Made of reinforced concrete.
[May be rectangular or circular]

Settling tendancy depends on :

1. velocity of flow → can be decreased by increasing length of travel
2. shape & size of particle → altered by adding certain chemicals
3. viscosity of sewage (uncontrollable) → dependent on temperature

Under normal conditions, a plain sedimentation tank may remove about 60 to 65% of the suspended solids, and 30 to 35% of the BOD from the sewage.

Types of Sedimentation Tanks

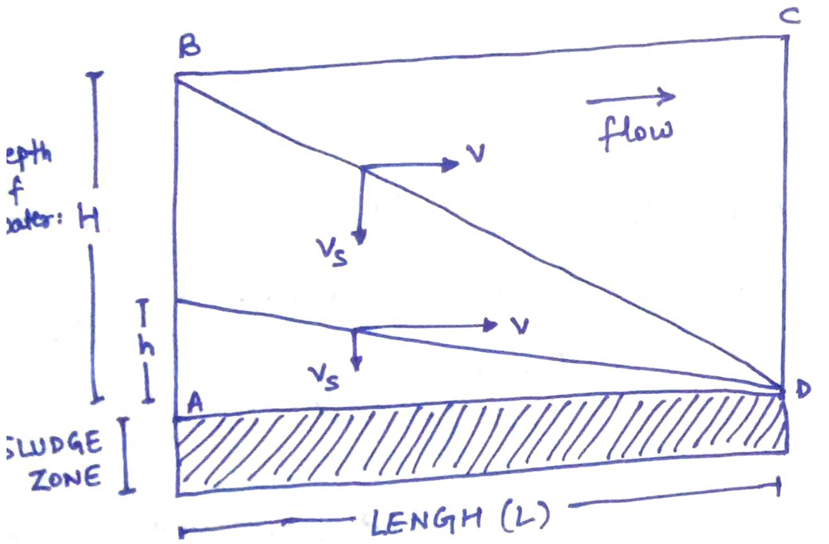
① **Intermittent Settling Tanks** –

- ✓ Store sewage for a certain period and keep it in complete rest.
- ✓ After 24hr rest, cleaner sewage from the top is drawn off, and the tank is cleaned off the settled silt. Then process repeat.
- ✓ Functions intermittently, 30-36 hrs is required to put the tank again in working condition.
- ✓ This method is not preferable because alot of time and labour is wasted and more units are required

② **Continuous Flow Type Tanks** –

- ✓ Flow velocity is only reduced, sewage is not brought to complete rest. Water enters from one end, and comes out from the other end.
- ✓ The velocity is so adjusted that the time taken by the particle to travel from one end to another is slightly more than the time required for settlement of that particle.

Design of Continuous Flow Type of Sedimentation Tank



It is assumed that the sediment is uniformly distributed as the sewage enters the basin.

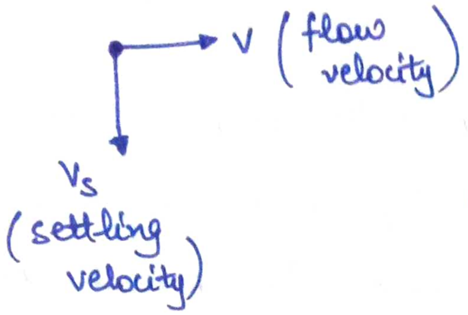
So, uniform flow velocity (V):

$$\boxed{V = \frac{Q}{BH}} \longrightarrow (1)$$

Q = discharge entering basin

B = width of tank

H = depth of sewage (water)



Assuming that all those particles whose paths of travel are above the line BD, will pass through the basin:

$$\frac{V}{V_s} = \frac{L}{H}$$

$$\Rightarrow \quad \boxed{V_s = \frac{VH}{L}} \longrightarrow (2)$$

Using (1) & (2) $\Rightarrow$

$$V_s = \left(\frac{Q}{BH}\right)\left(\frac{H}{L}\right)$$

or, $$\boxed{V_s = \frac{Q}{BL}}$$

* All particles having settling velocity equal to or greater than $\frac{Q}{BL}$ will settle down.

* Even the small particles that enter at some height 'h', will settle down if their $V_s \geq \frac{h}{H} \cdot \frac{Q}{BL}$

* $\frac{Q}{BL}$ is known as <u>overflow rate</u> OR <u>surface loading</u> OR <u>overflow velocity</u>.

* Normal ranges:
  - → For primary sedimentation tanks: 40,000 to 50,000 $l/m^2/day$
  - → For sedimentation tanks with coagulants: 50,000 to 60,000 $l/m^2/day$
  - → For secondary sedimentation tanks: 25,000 to 35,000 $l/m^2/day$

$$\boxed{\text{Efficiency of tank} \propto \frac{1}{\text{overflow rate}}}$$

overflow rate → Q/BL

* Depth has no effect

DESIGN

Effective depth (excluding sludge zone) $= 2.4m$ to $3.6m$

$\simeq 3m$

Detention time (average theoretical time required for the sewage to flow through the tank)

$$t_D = \frac{\text{Volume of tank}}{\text{Rate of flow}} = \frac{BLH}{Q}$$

For circular tank, $t_D = \dfrac{d^2(0.011d + 0.785H)}{Q}$

$d \rightarrow$ diameter of tank

$H \rightarrow$ vertical depth

Range of detention time = 1 to 2 hours

(use 2 hours)

Larger $t_D \Rightarrow$ Higher efficiency

Width of tank = 6m

Length should be 4 to 5 times of width.

Cross-sectional area of sedimentation tank should be such that it provides a flow velocity of $\longrightarrow$ 0.3 m/min

Maximum daily flow of sewage = total amount of flow from the tank.

Maximum diameter of circular tank $\simeq$ 60m.

SHORT CIRCUITING IN THE SEDIMENTATION TANKS

- ✓ For the efficient removal of sediment in the sedimentation tanks, it is necessary that the flow is uniformly distributed throughout the cross-section of the tank.
- ✓ If currents, on the other hand, permit a substantial portion of the water to pass directly through the tank without being detained for the intended time, the flow is said to be short circuited.
- ✓ Properly designed inlets and outlets near the entrance and the exit may reduce the short circuiting tendencies, and distribute the flow more evenly. Relatively narrow tanks are less affected by inlet and outlet disturbances, and by currents caused by breezes.
- ✓ In actual practice, certain amount of short circuiting will always exist, hence, the actual average time taken by a batch of water in passing through a settling tank (called flowing through period) will always be less than the detention period.

$$\text{Displacement Efficiency } (\%) = \frac{\text{Flowing through period}}{\text{Detention period}}$$

Construction Details of the Sedimentation Tanks :

① Inlet & Outlet Arrangement : To reduce short-circuiting, entry must be smooth.

- ✓ A suitable type of inlet for a rectangular settling tank is in the form of a channel extending to full width of the tank, with a submerged weir type baffle wall.
- ✓ A similar outlet arrangement is used, which consists of an outlet channel extending for full width of the tank and receiving the water after it has passed over a weir.

② Baffles :

✓ Required to prevent the movement of organic matter and its escape along with the effluent ; and to distribute the sewage uniformly through the cross-section of the tank ; and thus avoid short circuiting.

✓ Both inlets and outlets are protected by hanging baffles, 0 to 90cm in front of them, and submerged 45 to 60cm below flow line.

③ Skimming Troughs :

✓ Used in sedimentation tank itself near its outlet end, when the amount of oils and greasy matter present in a sewage is small and it is uneconomical to provide a separate skimming tank.

✓ Skimmings may be pushed into the troughs manually by hand or mechanically using scraper blades.

④ Cleaning and Sludge Removal :

✓ Sludge reduces capacity of the tank, becomes stale and leads to foul gases. Hence, needs to be cleaned frequently.

✓ Modern cleaning → Supply of sewage is stopped, the already contained sewage is drained off till the depth remains about 30cm or so. The deposited sluge is stirred and removed as a slurry through a separate pipe provided with a gate valve at the bottom of the tank.

Pick axes and pharaohs may be used for displacing hard deposits. The sludge is taken to sludge digestion tanks.

✓ Mechanical cleaning → Mechanical scrapers are used at regular intervals for cleaning out the sludge.