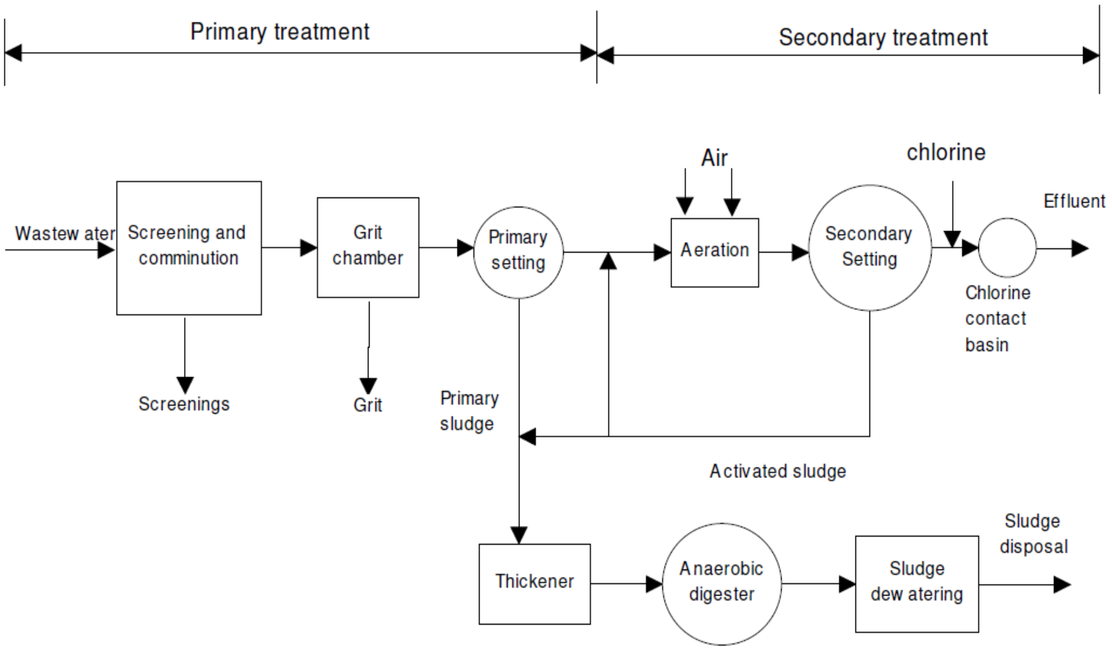
UNIT – III

LAYOUT AND GENERAL OUTLINE OF WASTEWATER TREATMENT PLANT:



FUNCTION OF EACH UNIT:

1. **Screening:** A screen is a device with openings for removing bigger suspended or floating matter in sewage which would otherwise damage equipment or interfere with satisfactory operation of treatment units.
2. **Grit chamber:** Grit chambers are provided to protect moving mechanical equipment from abrasion and accompanying abnormal wear. They reduce the formation of heavy deposits in pipe lines, channels and conduits. They also reduce the frequency of digester cleaning that may be required as a result of excessive accumulations of grit in such units.
3. **Sedimentation tank:** Sedimentation is the separation from water by gravitational settling of suspended particles that are heavier than water. In general, sedimentation is used for grit removal in grit chamber, particulate matter removal in the primary settling basin, biological – floc removal in the activated-sludge settling basin (Secondary settling tank).

4. **Aeration:** Aeration removes odour and tastes due to volatile gases like hydrogen sulphide and due to algae and related organisms. Aeration also oxidise iron and manganese, increases dissolved oxygen content in water, removes CO_2 and reduces corrosion and removes methane and other flammable gases.
    - Principle of treatment underlines on the fact that volatile gases in water escape into atmosphere from the air-water interface and atmospheric oxygen takes their place in water, provided the water body can expose itself over a vast surface to the atmosphere. This process continues until an equilibrium is reached depending on the partial pressure of each specific gas in the atmosphere.
5. **Activated sludge process:** It is aerobic biological treatment system. The settled wastewater is aerated in an aeration tank for a period of few hours. During the aeration, the microorganisms in the aeration tank stabilize the organic matter. In this process part of the organic matter is synthesized into new cells and part is oxidized to derive energy. The synthesis reaction followed by subsequent separation of the resulting biological mass and the oxidation reaction is the main mechanism of BOD removal in the activated sludge process.

PRINCIPLES AND DESIGN OF SCREENS:

Screening: A screen is a device with openings for removing bigger suspended or floating matter in sewage which would otherwise damage equipment or interfere with satisfactory operation of treatment units.

Types of Screens:

1. **Coarse Screens:**
    - Coarse screens also called racks, are usually bar screens, composed of vertical or inclined bars spaced at equal intervals across a channel through which sewage flows.
    - Bar screens with relatively large openings of 75 to 150 mm are provided ahead of pumps, while those ahead of sedimentation tanks have smaller openings of 50 mm.
    - Bar screens are usually hand cleaned and sometimes provided with mechanical devices. These cleaning devices are rakes which periodically sweep the entire screen removing the solids for further processing or disposal. Hand cleaned

racks are set usually at an angle of 45° to the horizontal to increase the effective cleaning surface and also facilitate the raking operations. Mechanical cleaned racks are generally erected almost vertically. Such bar screens have openings 25% in excess of the cross section of the sewage channel.

2. **Medium Screens:** Medium screens have clear openings of 20 to 50 mm. Bar are usually 10 mm thick on the upstream side and taper slightly to the downstream side. The bars used for screens are rectangular in cross section usually about 10 x 50 mm, placed with larger dimension parallel to the flow.
3. **Fine Screens:** Fine screens are mechanically cleaned devices using perforated plates, woven wire cloth or very closely spaced bars with clear openings of less than 20 mm. Fine screens are not normally suitable for sewage because of clogging possibilities.

The most commonly used bar type screen is shown in figure:

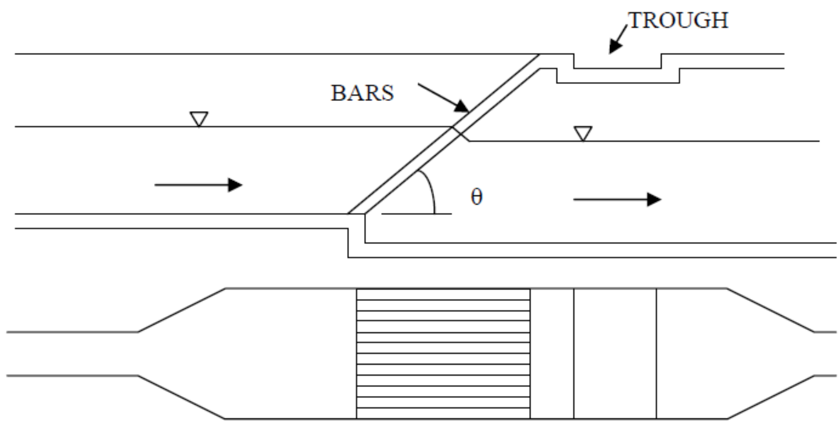


Figure 14.1 Bar Screen

Velocity:

The velocity of flow ahead of and through the screen varies and affects its operation. The lower the velocity through the screen, the greater is the amount of screenings that would be removed from sewage.

However, the lower the velocity, the greater would be the amount of solids deposited in the channel. Hence, the design velocity should be such as to permit 100% removal of material of certain size without undue depositions.

Velocities of ***0.6 to 1.2*** m/s through the open area for the peak flows have been used satisfactorily. Further, the velocity at low flows in the approach channel should not be less than 0.3 m/s to avoid deposition of solids.

Head loss:

Head loss varies with the quantity and nature of screenings allowed to accumulate between cleanings. The head loss created by a clean screen may be calculated by considering the flow and the effective areas of screen openings, the latter being the sum of the vertical projections of the openings. The head loss through clean flat bar screens is calculated from the following formula:

$$h_L = 0.0729\ (V^2 - v^2)$$

where, h_L = head loss in m

V = velocity through the screen in mps

v = velocity before the screen in mps

Another formula often used to determine the head loss through a bar rack is Kirschmer's equation:

$$h_L = \beta(W/b)^{4/3}\ h_v \sin\theta$$

where h_L = head loss, m

K = bar shape factor (2.42 for sharp edge rectangular bar, 1.83 for rectangular bar with semicircle upstream, 1.79 for circular bar and 1.67 for rectangular bar with both u/s and d/s face as semi-circular).

W = maximum width of bar u/s of flow, m

b = minimum clear spacing between bars, m

h_v = velocity head of flow approaching rack, m = $v^2/2g$

θ = angle of inclination of rack with horizontal

The head loss through fine screen is given by

$$h = (1/2g)\ (Q/CA)$$

where, h = head loss, m

Q = discharge, m^3/s

C = coefficient of discharge (typical value 0.6)

A = effective submerged open area, m^2

The quantity of screenings depends on the nature of the wastewater and the screen openings.

Problem: Design a bar screen for a peak average flow of 40 million litres per day.

Solution:

Assume manual cleaning, let us keep the bars at an inclination of 45^o with vertical.

Let us use bars of size 9 mm × 50 mm, with 9 mm dimension facing the flow.

Let us keep a clear spacing of 36 mm between the bars.

Let us assume a desired velocity through the screen as 0.8 m/s at peak flow.

Max. rate of flow = $\frac{40 \times 10^6 \times 10^{-3}}{24 \times 60 \times 60}$ = 0.4630 m^3/sec

Net area of screen = (0.4630/0.8) = 0.5787 m^2

Gross area of screen = 0.5787 × (45/36) = 0.7234 m^2

Since the screen is inclined at 45^o with horizontal, gross area of screen needed = (0.7234/sinθ) = (0.7234/sin45^o) = 1.023 m^2

Also, velocity of flow above screen = 0.8 × (36/45) = 0.64 m/s

Thus, we have V = 0.8 m/s and v = 0.64 m/s

$$hL = 0.0729 (V^2 – v^2)$$

$$= 0.0729(0.8^2 – 0.64^2) = 0.017 \text{ m} = 1.7 \text{ m}$$

This will be the head loss when the screen is clean, if however, the screen is half clogged,

$$V = 2 \times 0.8 = 1.6 \text{ m/s}$$

$$hL = 0.0729(1.6^2 – 0.64^2) = 0.157 \text{ m} = 15.7 \text{ cm}$$

if the screen is clean, the head loss is only 1.7 cm, but it is 15.7 cm (nearly nine times) when the screen is half clogged. Hence the bar screen should be frequently cleaned, in order to keep the head loss within a desirable limit.

GRIT CHAMBERS:

Grit chambers are basin to remove the inorganic particles to prevent damage to the pumps, and to prevent their accumulation in sludge digesters.

Types of Grit Chambers:

Grit chambers are of two types: mechanically cleaned and manually cleaned. In **mechanically cleaned** grit chamber, scraper blades collect the grit settled on the floor of the grit chamber. The grit so collected is elevated to the ground level by several mechanisms such as bucket elevators, jet pump and air lift. The grit washing mechanisms are also of several designs most of which are agitation devices using either water or air to produce washing action. **Manually cleaned** grit chambers should be cleaned atleast once a week. The simplest method of cleaning is by means of shovel.

Aerated Grit Chamber:

An aerated grit chamber consists of a standard spiral flow aeration tank provided with air diffusion tubes placed on one side of the tank. The grit particles tend to settle down to the bottom of the tank at rates dependent upon the particle size and the bottom velocity of roll of the spiral flow, which in turn depends on the rate of air diffusion through diffuser tubes and shape of aeration tank. The heavier particles settle down whereas the lighter organic particles are carried with roll of the spiral motion.

Principle of Working of Grit Chamber:

- Grit chambers are nothing but like sedimentation tanks, designed to separate the intended heavier inorganic materials (specific gravity about 2.65) and to pass forward the lighter organic materials.
- Hence, the flow velocity should neither be too low as to cause the settling of lighter organic matter, nor should it be too high as not to cause the settlement of the silt and grit present in the sewage.
- This velocity is called "differential sedimentation and differential scouring velocity". The scouring velocity determines the optimum **flow through velocity**. This may be explained by the fact that the critical velocity of flow 'vc' beyond which particles of a certain size and density once settled, may be again introduced into the stream of flow.
- It should always be less than the scouring velocity of grit particles. The critical velocity of scour is given by Schield's formula:

  Flow through velocity $V = 3 \text{ to } 4.5\,(g(S_s - 1)d)^{1/2}$
- A horizontal velocity of flow of 15 to 30 cm/sec is used at peak flows. This same velocity is to be maintained at all fluctuation of flow to ensure that only organic solids and not the grit is scoured from the bottom.

Types of Velocity Control Devices

1. A sutro weir in a channel of rectangular cross section, with free fall downstream of the channel.

2. A parabolic shaped channel with a rectangular weir.

3. A rectangular shaped channel with a parshall flume at the end which would also help easy flow measurement.

Design of Grit Chambers

Settling Velocity:

The settling velocity of discrete particles can be determined using appropriate equation depending upon Reynolds number.

Stoke's law: $v_s = \frac{g}{18}\left(\frac{\rho_{s-}\rho}{\mu}\right)d^2$

$$v_s = \frac{g}{18}\left(\frac{S_{s-1}}{\nu}\right)$$

For grit particles of specific gravity 2.65 and liquid temperature at 10°C, μ =1.01 x 10-6m^2/s. This corresponds to particles of size less than 0.1 mm.

Detention Period: Detention period for grit chambers may vary from 45 to 90 sec. A detention period of 60 sec is usually adopted.

Loss of head: Loss of head in grit chambers may vary from 0.06 m to 0.6 m depending upon the device adopted for velocity control.

Problem: Design a grit chamber for a maximum wastewater flow of 8000 m^3/day, to remove particles upto 0.2 mm dia. having specific gravity of 2.65. The settling velocities of these particles is found to range from 0.018 to 0.022 m/sec. maintain a constant flow through velocity of 0.3 m/sec through the provision of a proportional flow weir.

Solution:

v_h = 0.3 m/sec

Q = (8000/ 24 × 60 × 60) = 0.0926 m^3/sec

A = $\frac{Q}{v_h}$ = (0.0926/0.3) = 0.3086 sq.m

Providing a depth of 1m, the width of grit chamber is,

B = (0.3086/1) = 0.3086 m

Provide a width of 0.35 m

The settling velocity of the particles to be removed in the grit chamber varies from 0.018 to 0.022m/sec. Hence let us assume a settling velocity v_s = 0.02 m/sec

Detention time = (depth of chamber/settling velocity)

= (1/0.02) = 50 sec

Length of tank = v_h × detention time

= 0.3 x 50 = 15 m

Hence provide a grit chamber of length 15 cm, width 0.35 m and depth 1 m.

Problem: Design a grit chamber for population 50000 with water consumption of 135 LPCD.

Solution:

Average quantity of sewage, considering sewage generation 80% of water supply, is

$= 135 \times 50000 \times 0.8 = 5400\ m^3/day = 0.0625\ m^3/sec$

Maximum flow = 2.5 x average flow

$= 0.0625 \times 2.5 = 0.156\ m^3/sec$

Keeping the horizontal velocity as 0.2 m/sec (<0.228 m/sec) and detention time period as one minute.

Length of the grit chamber = velocity x detention time

$= 0.2 \times 60 = 12.0$ m

Volume of the grit chamber = Discharge x detention time

$= 0.156 \times 60 = 9.36$ m3

Cross section area of flow 'A' = Volume / Length = 9.36/12 = 0.777 m^2

Provide width of the chamber = 1.0 m, hence depth = 0.777 m

Provide 25% additional length to accommodate inlet and outlet zones.

Hence, the length of the grit chamber = 12 x 1.25 = 15.0 m

Provide 0.3 m free board and 0.25 m grit accumulation zone depth, hence total depth

$= 0.777 + 0.3 + 0.25 = 1.33$ m

and width = 1.0 m

PRIMARY SETTING TANKS:

- Primary sedimentation in a municipal wastewater treatment plant is generally plain sedimentation without the use of chemicals. In treating certain industrial wastes chemically aided sedimentation may be involved.

- In either case, it constitutes ***flocculent settling***, and the particles do not remain discrete as in the case of grit, but tend to agglomerate or coagulate during settling. Thus, their diameter keeps increasing and settlement proceeds at an over increasing velocity. Consequently, they trace a curved profile.
- The settling tank design in such cases depends on both ***surface loading*** and ***detention time***. Long tube settling tests can be performed in order to estimate specific value of surface loading and detention time for desired efficiency of clarification for a given industrial wastewater using recommended methods of testing. Scale-up factors used in this case range from 1.25 to 1.75 for the overflow rate, and from 1.5 to 2.0 for detention time when converting laboratory results to the prototype design.
- For primary settling tanks treating municipal or domestic sewage, laboratory tests are generally not necessary, and recommended design values given in table may be used.
- Using an appropriate value of surface loading from table, the required tank area is computed. Knowing the average depth, the detention time is then computed. Excessively high detention time (longer than 2.5 h) must be avoided especially in warm climates where anaerobicity can be quickly induced.

Settling: Solid liquid separation process in which a suspension is separated into two phases –

- Clarified supernatant leaving the top of the sedimentation tank (overflow).
- Concentrated sludge leaving the bottom of the sedimentation tank (underflow).

Purpose of Settling

- To remove coarse dispersed phase.
- To remove coagulated and flocculated impurities.
- To remove precipitated impurities after chemical treatment.
- To settle the sludge (biomass) after activated sludge process / tricking filters.

Principle of Settling

- Suspended solids present in water having specific gravity greater than that of water tend to settle down by gravity as soon as the turbulence is retarded by offering storage.
- Basin in which the flow is retarded is called ***settling tank***.
- Theoretical average time for which the water is detained in the settling tank is called the ***detention period***.

Types of Settling

Type I: ***Discrete particle settling*** - Particles settle individually without interaction with neighbouring particles.

Type II: ***Flocculent Particles*** – Flocculation causes the particles to increase in mass and settle at a faster rate.

Type III: ***Hindered or Zone settling*** –The mass of particles tends to settle as a unit with individual particles remaining in fixed positions with respect to each other.

Type IV: ***Compression*** – The concentration of particles is so high that sedimentation can only occur through compaction of the structure.

Types of Settling Tanks

- Sedimentation tanks may function either intermittently or continuously. The intermittent tanks also called quiescent type tanks are those which store water for a certain period and keep it in complete rest. In a continuous flow type tank, the flow velocity is only reduced and the water is not brought to complete rest as is done in an intermittent type.
- Settling basins may be either long rectangular or circular in plan. Long narrow rectangular tanks with horizontal flow are generally preferred to the circular tanks with radial or spiral flow.

1. ***Long Rectangular Settling Basin***

- Long rectangular basins are hydraulically more stable, and flow control for large volumes is easier with this configuration.
- A typical long rectangular tank have length ranging from 2 to 4 times their width. The bottom is slightly sloped to facilitate sludge scraping. A slow moving mechanical sludge.
- Scraper continuously pulls the settled material into a sludge hopper from where it is pumped out periodically.

Drag of sedimentation tank:

A long rectangular settling tank can be divided into four different functional zones:

- ***Inlet zone:*** Region in which the flow is uniformly distributed over the cross section such that the flow through settling zone follows horizontal path.
- ***Settling zone:*** Settling occurs under quiescent conditions.

- ***Outlet zone:*** Clarified effluent is collected and discharge through outlet weir.
- ***Sludge zone:*** For collection of sludge below settling zone.

Inlet and Outlet Arrangement

- ***Inlet devices:*** Inlets shall be designed to distribute the water equally and at uniform velocities. A baffle should be constructed across the basin close to the inlet and should project several feet below the water surface to dissipate inlet velocities and provide uniform flow;
- ***Outlet Devices:*** Outlet weirs or submerged orifices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. Weirs shall be adjustable, and at least equivalent in length to the perimeter of the tank. However, peripheral weirs are not acceptable as they tend to cause excessive short-circuiting.

Weir Overflow Rates

- Large weir overflow rates result in excessive velocities at the outlet. These velocities extend backward into the settling zone, causing particles and flocs to be drawn into the outlet. Weir loadings are generally used upto 300 m3/d/m. It may be necessary to provide special inboard weir designs as shown to lower the weir overflow rates.

Problem: Design a rectangular sedimentation tank to treat 2.4 million litres of raw water per day. The detention period may be assumed to be 3 hours.

Solution: Raw water flow per day is 2.4×10^6 l. Detention period is 3h.

Volume of tank = Flow x Detention period = $2.4 \times 10^3 \times 3/24 = 300\ m^3$

Assume depth of tank = 3.0 m.

Surface area = $300/3 = 100\ m^2$

L/B = 3 (assumed). L = 3B.

$3B^2 = 100\ m^2$ i.e. B = 5.8 m

L = 3B = 5.8 X 3 = 17.4 m

Hence surface loading (Overflow rate) = $\underline{2.4 \times 10^6}$ = 24,000 $l/d/m^2$ < 40,000 $l/d/m^2$ (OK)