

Course Code: CE 4141

Course Title: Environmental Engineering

Credits: 3.0

Contact Hours: 3.0 hours/week

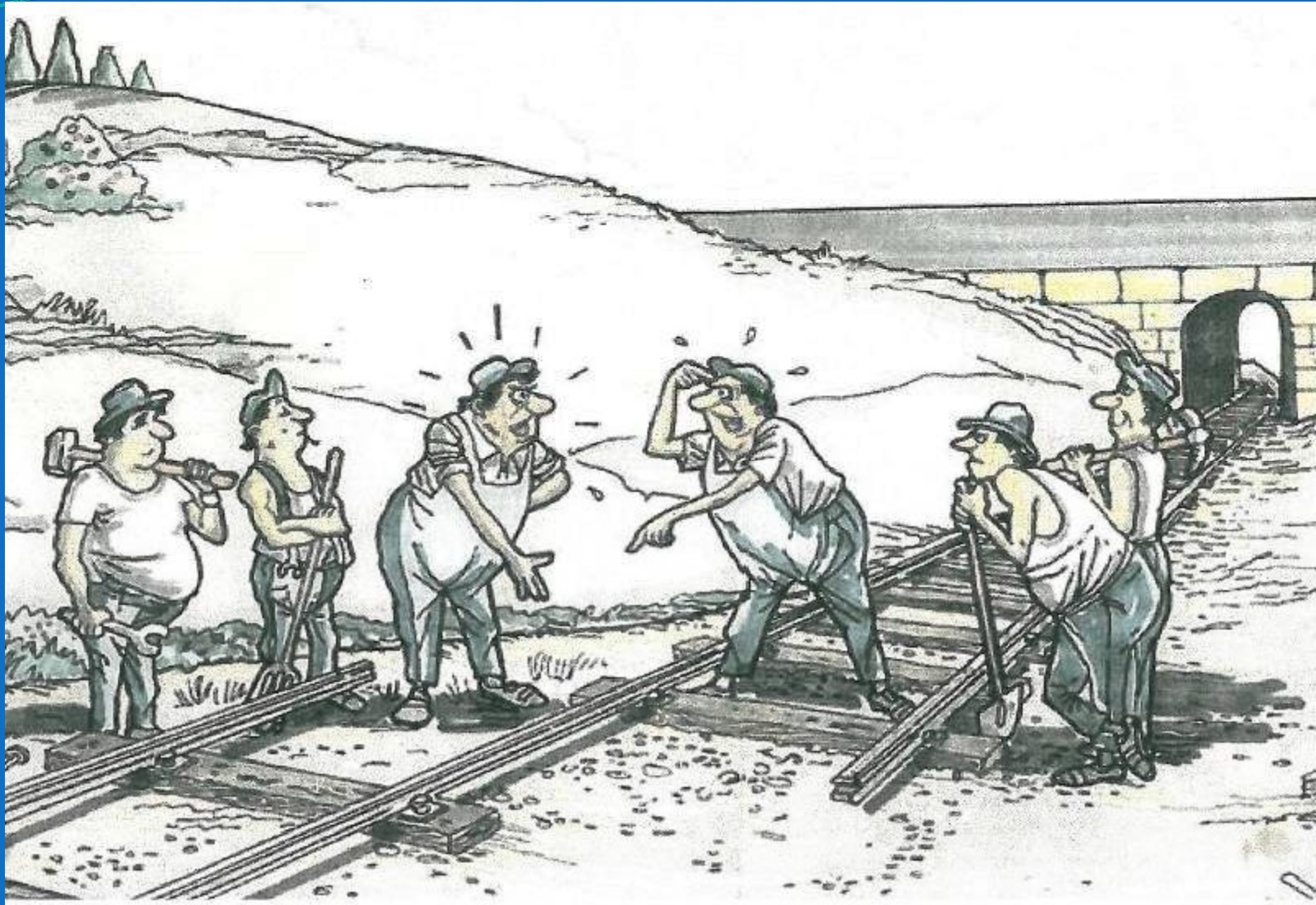
Lecture – 1

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Cycle -1, Day-C

27-04-2019

What should we do?



Conventional Sewerage System

Learning Out Come

- i. Wastewater and types of wastewater**
- ii. Terminology of wastewater engineering
- iii. Sewerage system: design, construction, etc.**
- iv. Treatment of wastewater
- v. Aquaculture and wastewater treatment**
- vi. Industrial wastewater treatment and disposal
- vii. Microbiology in wastewater treatment**
- viii. Small bore sewer system and simplified sewer system

Conventional Sewerage System

Some Important Terms

- i. Wastewater:** is the liquid waste conveyed by a sewer and may include domestic and industrial discharges as well as storm sewage, infiltration and inflow.
- ii. Domestic (Sanitary) sewage:** is the liquid waste which originates in the sanitary conveniences, e.g., water closets, urinals, baths, sinks etc. of dwellings, commercial or industrial facilities, and institutions. This is sometimes also referred to as black water.
- iii. Industrial wastewater:** includes the liquid discharges from spent water in different industrial processes such as manufacturing and food processing.

Conventional Sewerage System

Some Important Terms

- iv. Sullage:** is the liquid discharge from kitchen, wash basin etc. and excludes discharge from WCs and urinals. Sullage, also known as grey water, is less foul than domestic sewage and can be discharged through open surface drains in unsewered area.
- v. Storm water:** is the surface runoff obtained during and immediately after the rainfall, which enters sewers through inlets. Storm water is not as foul as sanitary or industrial sewage and hence can be carried through open drains or canals and disposed of in natural rivers or streams without any treatment.
- vi. Infiltration:** is the water which enters the sewer from the ground through leaks or faulty joints.

Conventional Sewerage System

Some Important Terms

- vii. Sewer:** is a pipe or conduit, generally closed, but normally not flowing full, which carries sewage.
- viii. Sanitary sewer:** carries sanitary sewage and is designed to exclude storm sewage, infiltration, and surface inflow. Industrial waste may be carried in sanitary sewers, depending upon its characteristics.
- ix. Storm sewer:** carries storm sewage and any other waste which may be discharged into the streets or onto the surface of the ground.
- x. Sewerage:** refers to the entire system of collection, treatment and disposal of sewage through a system of reticulation sewers.

Elements of Conventional Water Borne System

The essential elements of a sewerage system include:

- i. Collection:** refers to the collection of sewage from different points of generation.
- ii. Transportation:** refers to the conveying of sewage to any desired points through a network of sewers.
- iii. Treatment:** Sewage treatment includes any process which may be used to favourably modify the characteristics of sewage.
- iv. Disposal:** refers to the discharge of liquid wastes to the environment. Normally, but not always, disposal implies some degree of treatment prior to discharge.

Types of Collection Systems

There are three different collection systems:

i. Separate sewerage system: In this system sanitary sewage and storm waste are collected and conveyed separately through two different system.

Advantages:

- Sewers are of small size;
- Only sanitary sewage is treated;
- Storm water can be discharged without treatment;
- Sewage lifting is less costly because of less volume.

Disadvantages:

- Two sets of sewers may prove costly;
- Smaller sewers may be difficult to clean.

Types of Collection Systems

ii. Combined sewerage system: In this system both sanitary sewage and storm water are collected and conveyed together through a single set of sewers.

Advantages:

- ❑ Only one set of sewers might prove economical;
- ❑ Larger sewers are easy to clean;
- ❑ Strength of sewage diluted with storm water.

Disadvantages:

- ❑ Increased load on treatment plant;
- ❑ Larger volume requires to be lifted;
- ❑ Heavy rains may cause overflow and thus create a nuisance;
- ❑ Storm water is polluted unnecessarily;
- ❑ More difficult to properly treat the wastewater to high quality standards;
- ❑ Flow during the dry period may cause difficulties in maintaining minimum flow.

Types of Collection Systems

iii. Partially Combined or partially separate system: In this system only one set of sewers is laid to carry sanitary sewage as well as storm water during low rainfall. During heavy rainfall excess storm water is carried separately e.g., through open drain to natural channels.

Advantages:

- Size of sewer is not very large;
- Advantages of both separate and combined systems;
- Minimal solid deposition problem;
- Problems of storm water discharges from homes is simplified.

Disadvantages:

- Velocity of flow may be low during the dry period;
- Increased load on pump and treatment unit.

Types of Collection Systems

Suitable conditions for separate system:

- ❑ In flat areas a separate system is economical as deep excavation is not required.
- ❑ When sufficient funds are not available for two sets of sewer systems, only a sanitary sewerage system may be installed.
- ❑ Where rainfall is not uniform throughout the year a separate system is suitable.
- ❑ In areas near rivers or streams, only a sanitary system may be installed; storm water may be disposed of into rivers untreated, through open drains.
- ❑ Where pumping is required at short intervals.
- ❑ In rocky areas where large combined systems may be difficult to install.
- ❑ If sewers are to be laid before actual development of the area, a separate system is desirable.

Types of Collection Systems

Suitable conditions for combined system:

- ❑ Where rainfall is uniform throughout the year a combined system is economical.
- ❑ Where pumping is required for both sanitary sewage and storm water.
- ❑ Where sufficient space is not available for two separate sets of sewer systems.

Course Code: CE 441

Course Title: Environmental Engineering

Lecture – 2

Cycle -1, Day-D

28-04-2019

Types of Sewers

Building sewers: Also called house connection, are used to convey wastewater from the buildings to lateral or branch sewers, or any other sewer except another building sewer.

Lateral or branch sewers: Lateral sewer forms the first element of a community sewage collection system and are usually in streets. They are used to collect sewage from one or more building sewers and convey it to a main sewer.

Main sewer: Main sewers are used to convey sewage from one or more lateral sewers to trunk sewers or to interceptor sewers.

Types of Sewers

Trunk sewers: These are large sewers that are used to convey sewage from main sewers to treatment plants or other disposal facilities or to large intercepting sewers.

Intercepting sewers: These are larger sewers that are used to intercept a number of main or trunk sewers and convey the wastewater to treatment plants or other disposal facilities .

Outfall sewer: These are the segments of main or trunk or interceptor sewers which lie between connections and the final point of disposal or treatment plant.

Design of Sanitary Sewer System

The important objectives of the design of a sanitary sewer system are:

- To ensure ease of operation;
- To minimize maintenance requirements.

Two major factors to be considered in the design of a sewer system are:

- The quantity of wastewater flow;
- The flow hydraulics.

Design of Sanitary Sewer System

Estimation of wastewater flow

A sanitary sewer system is designed as a separate system, which is intended to receive domestic wastewater, commercial and industrial wastewater and groundwater infiltration. The quantity is influenced by:

- Population;
- Rate of water supply;
- Type of area served;
- Groundwater infiltration.

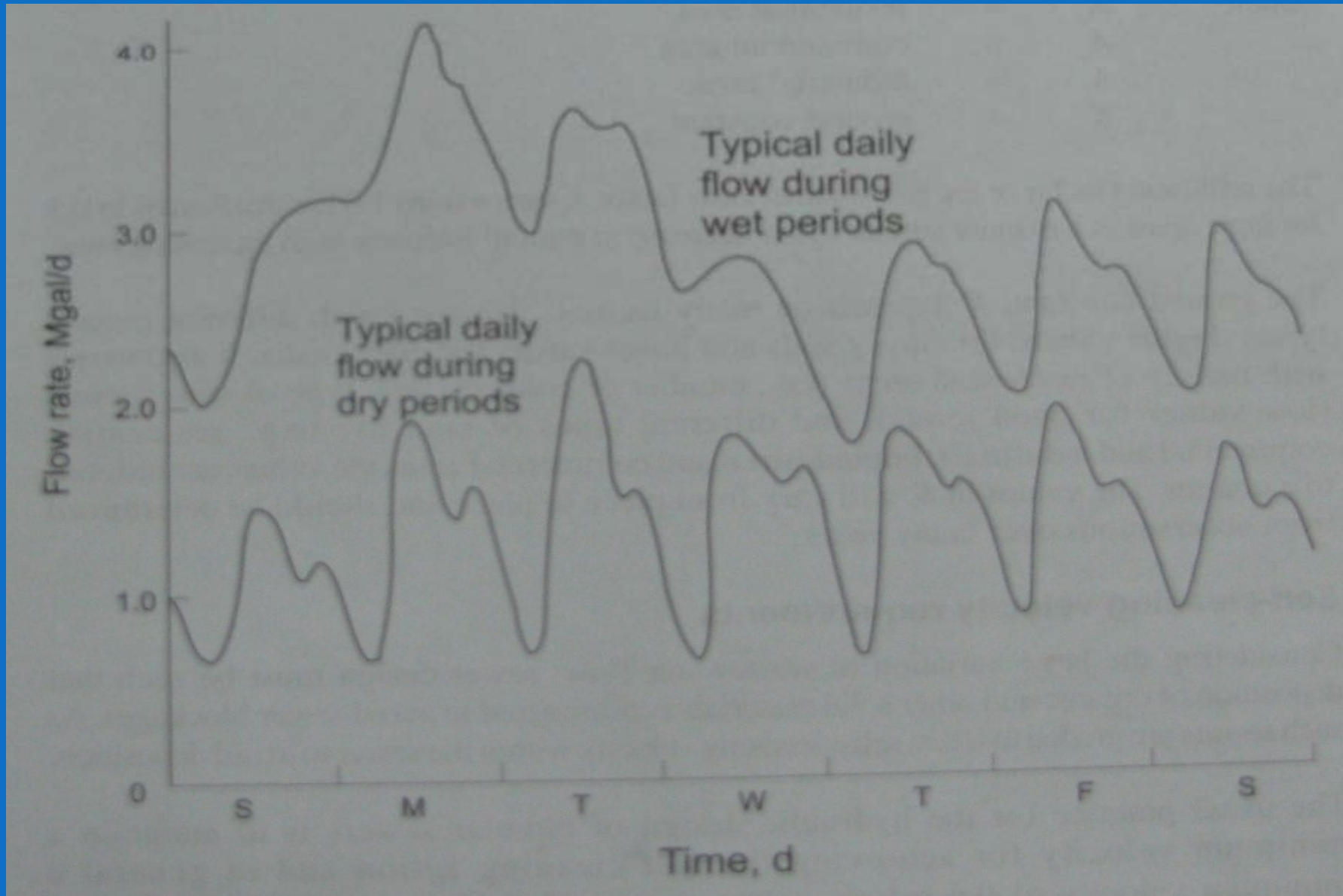
Design of Sanitary Sewer System

Component of Design Flow

The unit quantities of wastewater for which the sewer size have to be designed are called the design flows and consist of the dry weather flow and wet weather flow.

- The wastewater flow is not uniform throughout the day and throughout the year.
- It also varies during the day due to the varying use of water for domestic, commercial and industrial purposes.
- Variation throughout the year is due to seasonal variation of rainfall and its intensity.

Design of Sanitary Sewer System



Design of Sanitary Sewer System

Component of Design Flow

Due to the variation of flow, the following terms are used:

Average Dry Weather Flow (ADWF): is the average of the daily dry weather flow to the sewer system when not affected by storm infiltration and reflects the wastewater discharges from domestic, commercial and industrial fixtures.

Peak Dry Weather Flow (PDWF): During normal daily flows, two distinct peaks usually occur – the morning peak and the evening peak.

Peak Wet Weather Flow (PWWF): is the sum of the maximum PDWF plus storm contribution during wet weather period.

Design of Sanitary Sewer System

Design Flow Estimation

The design flow consists of the sum of the PDWF plus wet weather additives and may be expressed as:

$$Q = \sum D.d + \sum I.i$$

Where, $\sum D$ = the sum of all dry weather components

d = peak dry weather factor = PDWF/ADWF

$\sum I$ = basic wet weather additive

i = appropriate infiltration factor

Design of Sanitary Sewer System

Design Flow Estimation

$$\Sigma D = P \cdot q_r + A_c \cdot q_c + A_i \cdot q_i$$

q_r = residential discharge rate (say, 100 – 400 lpcd)

q_c = commercial discharge rate (say, 0.25 – 1.5 l/sec/ha)

q_i = industrial discharge rate (say, 0.25 – 0.35 l/sec/ha)

$$\Sigma I = A_r \cdot K + A_c \cdot K/4 + A_i \cdot K/4$$

K = ground constant varies from 1 to 0.5

Design of Sanitary Sewer System

Self-cleansing velocity requirement

The minimum velocity at which no solid deposition takes place in sewer section is called self-cleansing velocity.

The usual practice for the hydraulic design of circular sewers is to maintain minimum velocity for achieving the self-cleansing action and in general a minimum velocity of 0.6 m/sec.

Design of Sanitary Sewer System

Non-scouring velocity requirement

The maximum permissible velocity at which no scouring action takes place in sewer section is known as non-scouring velocity. It depends on sewer materials.

Recommended non-scouring velocities are:

2.0 – 2.5 m/sec for brick sewer

2.5 – 3.0 m/sec for concrete sewer

3.0 – 3.5 m/sec for vitrified sewer

3.5 – 4.0 m/sec for cast iron sewer

Design of Sanitary Sewer System

Hydraulic design of sewer

Manning's most widely used equation for velocity determination is:

$$V = 1/n R^{2/3} S^{1/2}$$

V = velocity, m/sec

n = Manning's roughness coefficient, 0.013 to 0.015.

R = Hydraulic radius = X-sectional area/wetted perimeter

S = Slope of energy grade line.

$$Q = AV$$

Construction of Sewerage System

The steps to be followed:

- i. Collection or preparation of map of community that to be served.
- ii. Preparation of lay out map of sewer network following the road network.
- iii. Investigation of sub-soil if necessary by excavating the bore holes along the network.
- iv. Selecting the suitable location of manhole.
- v. Setting the center line of sewer network on the ground according to map.
- vi. Mark the center line by driving pegs **at interval of 7.5 m or 15 m**
- vii. Excavating the trench following the center line.

Construction of Sewerage System

The steps to be followed:

- vii. Protecting the side of trench with timber if necessary.
- viii. Dewatering from the trench if water met during the excavation with suitable method.
- ix. Providing the concrete bedding of sewer if bottom of the trench is soft .
- x. Laying of sewer segments in the trench.
- xi. Joining the sewer.
- xii. Checking of sewer.
- xiii. Filling of trench.

Course Code: CE 441

Course Title: Environmental Engineering-II

Lecture - 3

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Cycle -2, Day-C
16-06-2019

Construction of Sewerage System

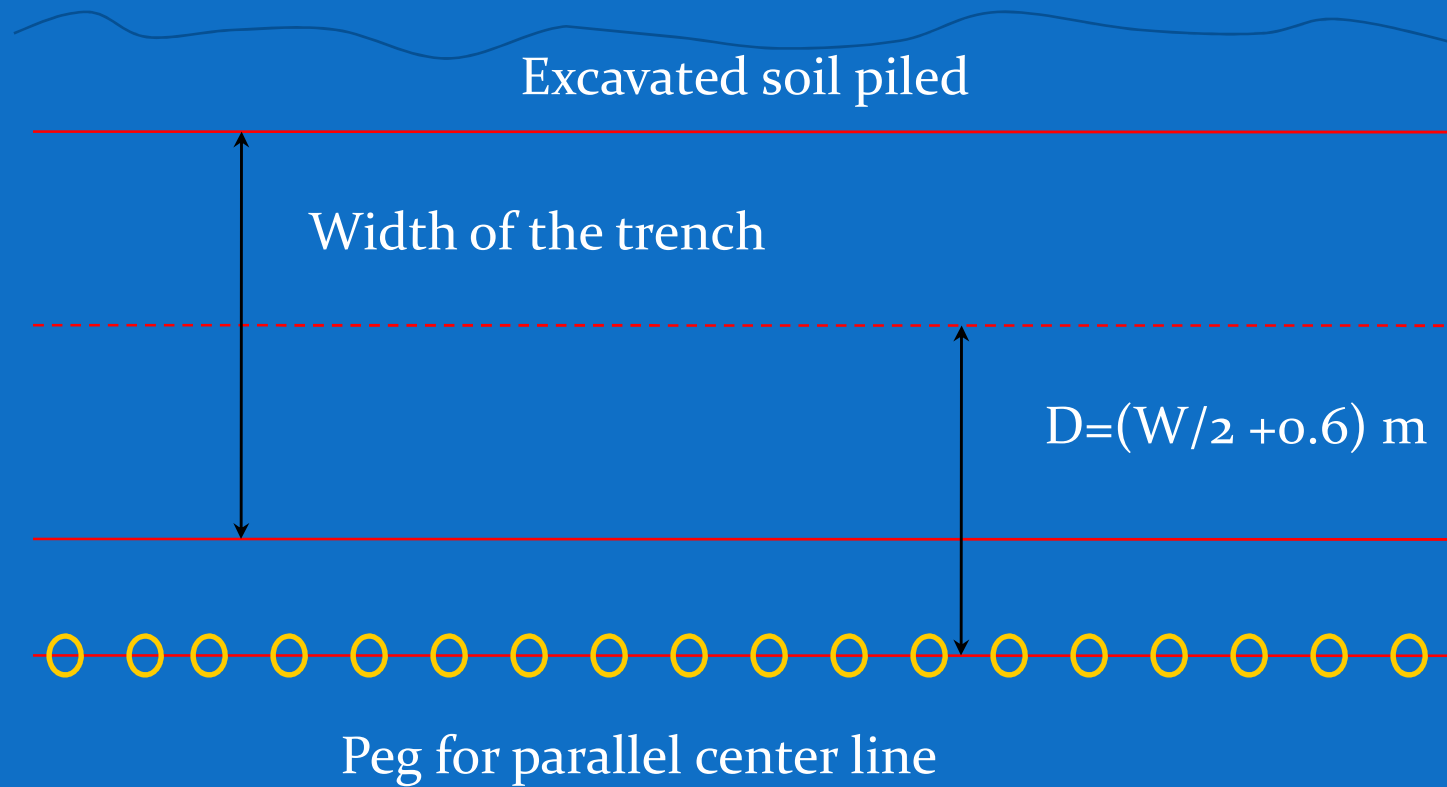
Setting of centre line

First method

- ❑ A line parallel to the sewer is marked on one side. This is known as an offset line and it is usually marked at a distance of D which is about one-half the trench width plus 600 mm.
- ❑ The temporary bench marks at the intervals of about 200 m to 300 m should be established along the offset line by carrying the levels from a permanent bench mark.
- ❑ The offset line helps in locating the sewer centre-line when excavation is carried out to lay sewers.

Construction of Sewerage System

Method of setting center line:



Construction of Sewerage System

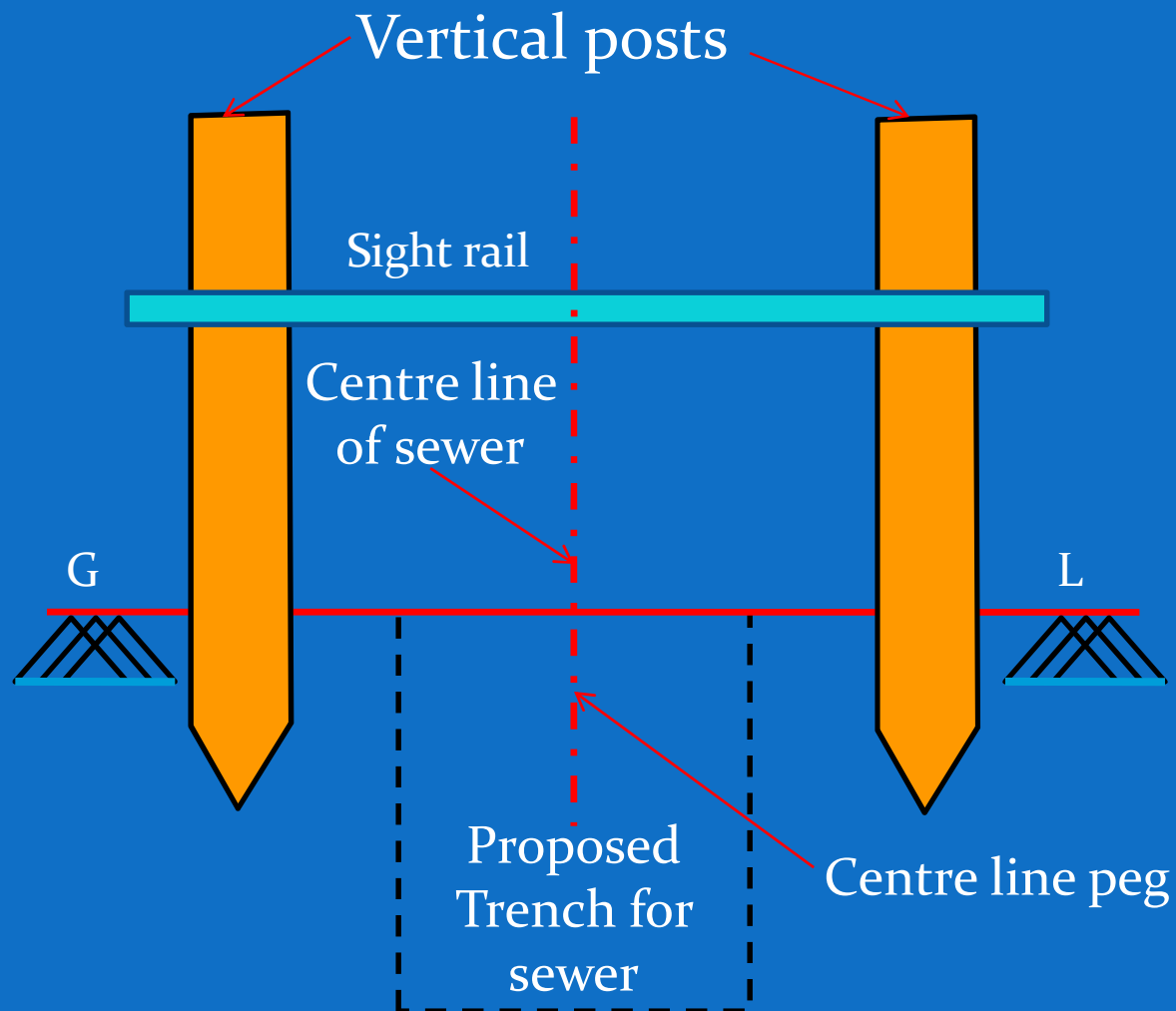
Second method

- ❑ Two vertical posts are driven into the ground at a known distance from the centre-line peg.
- ❑ One horizontal rail, known as the sight rail, is fixed between these posts at a convenient height from the ground level.

First method is adopted for short duration of work and second method is adopted for all cases.

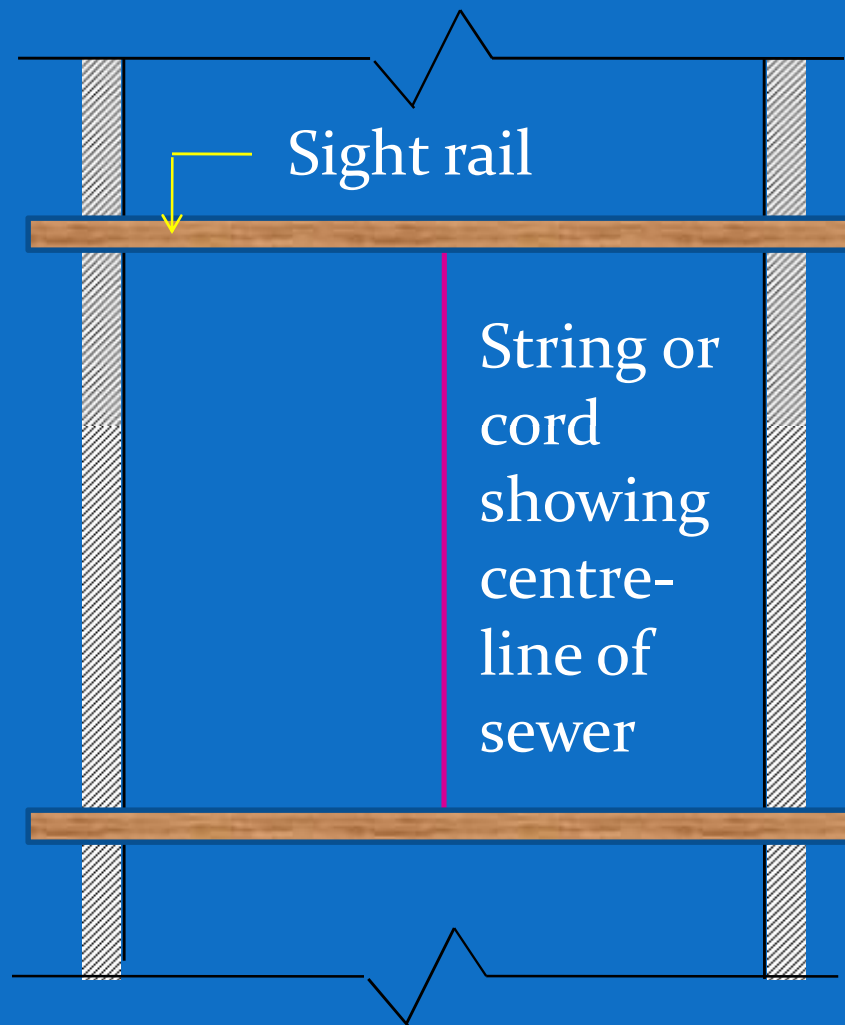
Construction of Sewerage System

Method of setting center line:



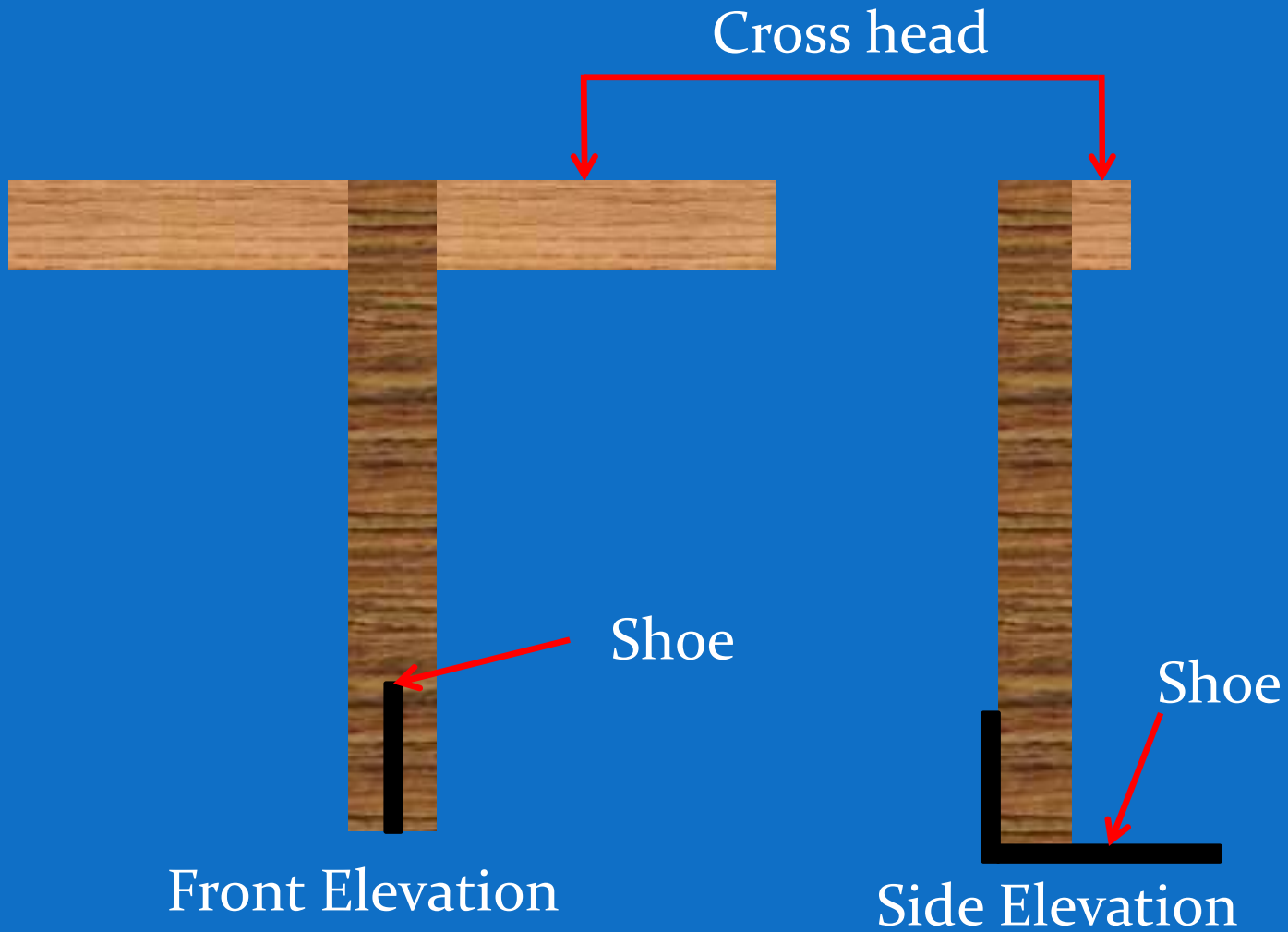
Construction of Sewerage System

Method of setting center line:



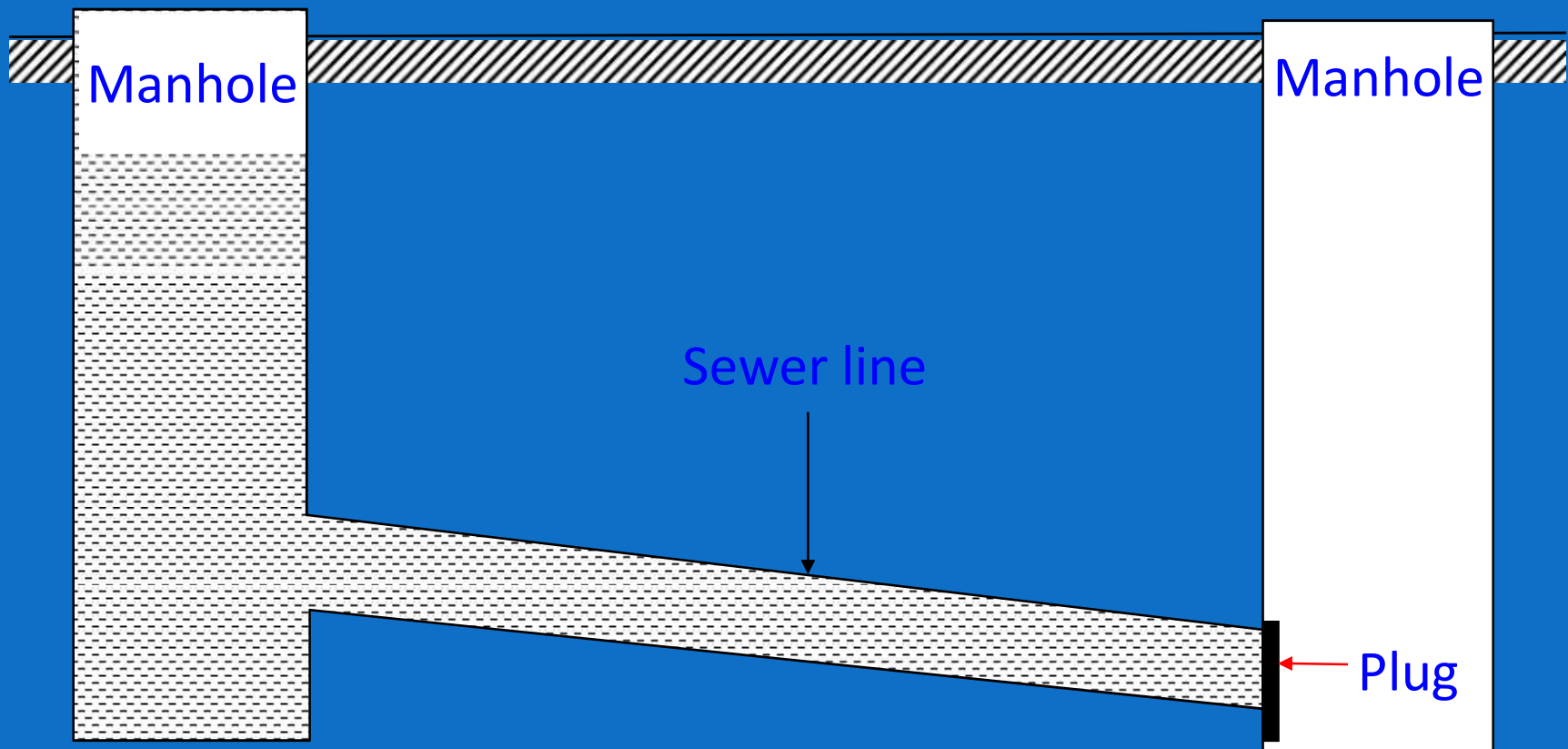
Construction of Sewerage System

Depth of excavation checking:



Construction of Sewerage System

Method of checking:



Construction of Sewerage System

Method of bedding:

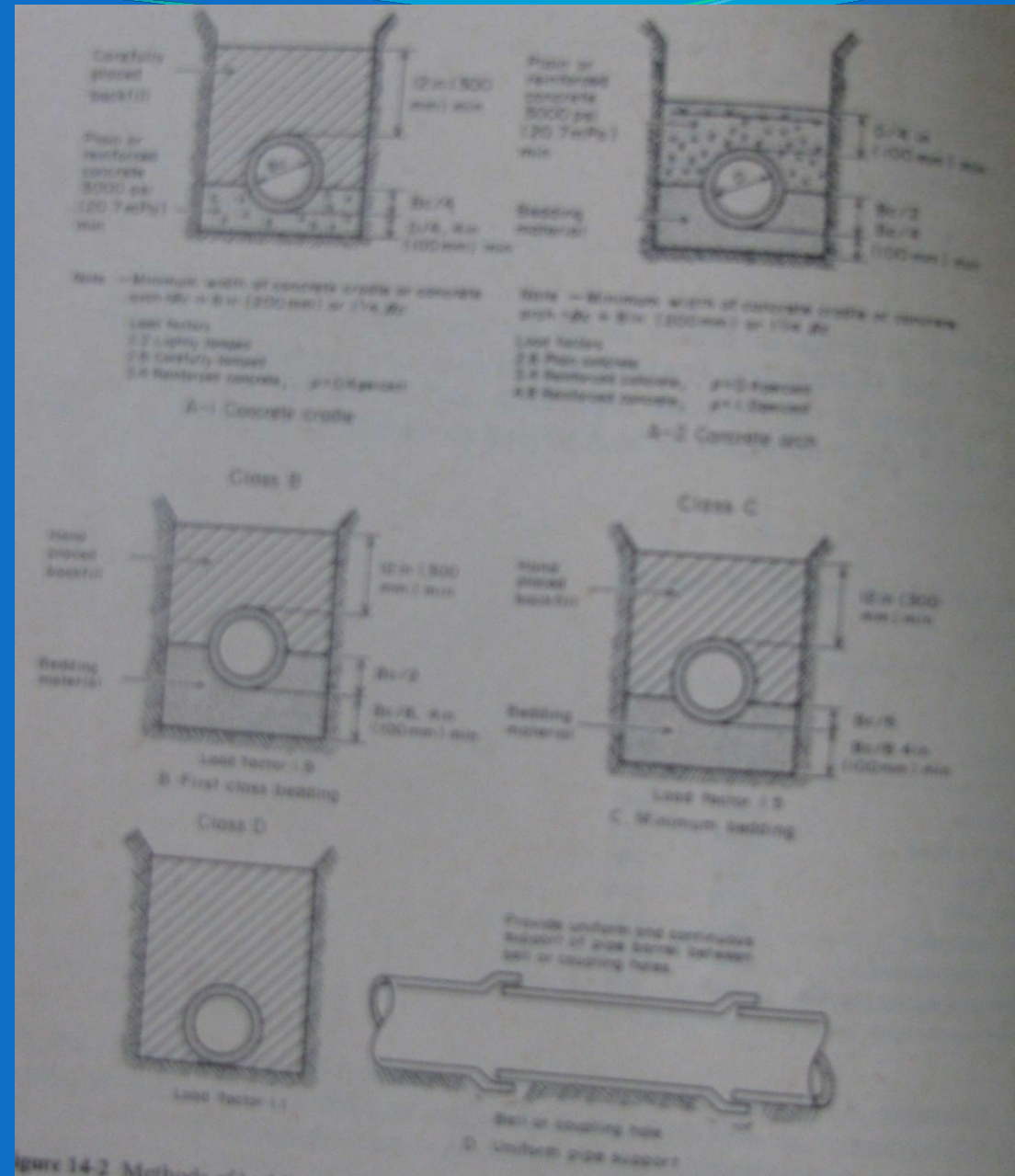


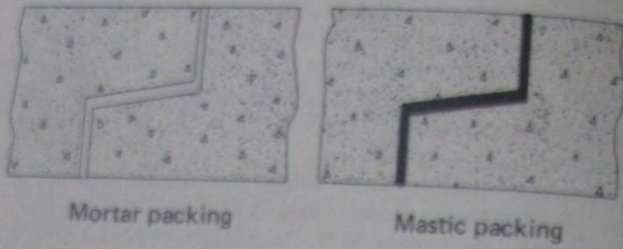
Figure 14-2 Methods of pipe bedding

Construction of Sewerage System

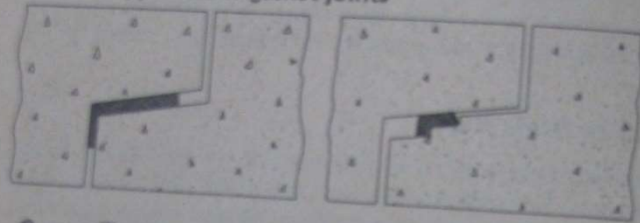
Types of sewer join:

- i. Cement mortar join
- ii. Collar join
- iii. Flexible of bituminous join
- iv. Mechanical join
- v. Open join

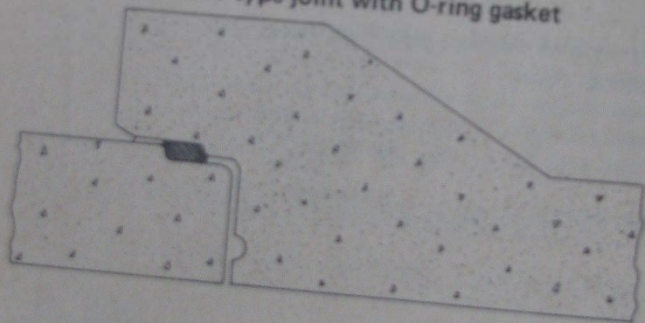
A - Typical cross sections of joints with mortar or mastic packing



B - Typical cross sections of basic compression type rubber gasket joints



C - Typical cross sections of opposing shoulder type joint with O-ring gasket



D - Typical cross section of spigot groove type joint with O-ring gasket

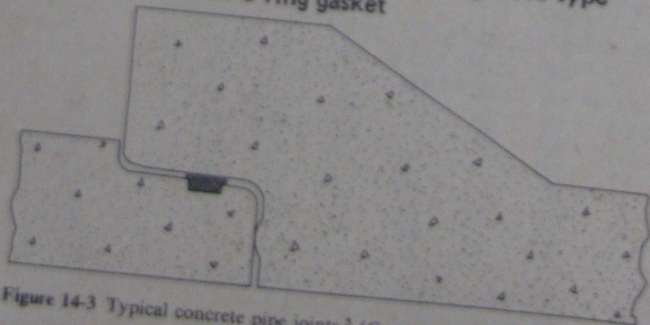
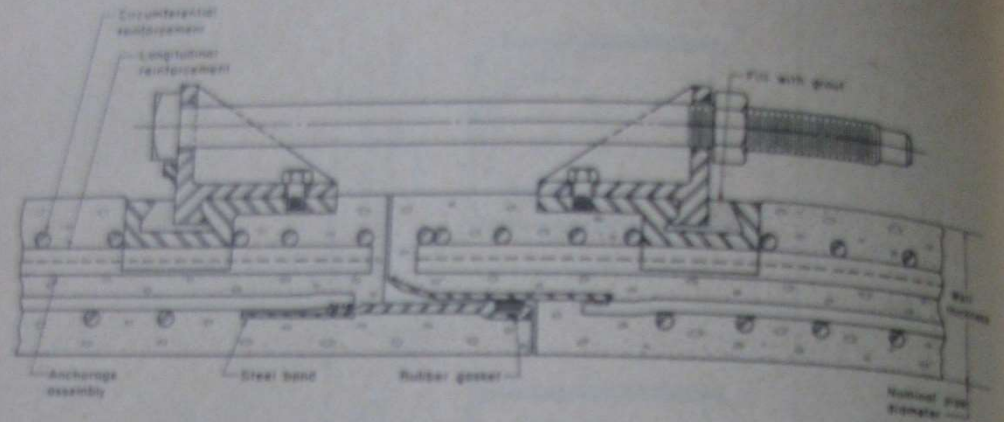
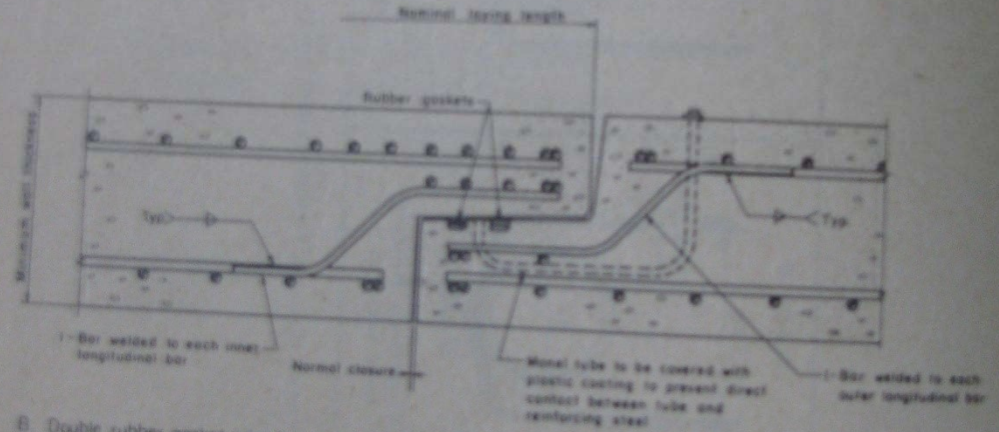


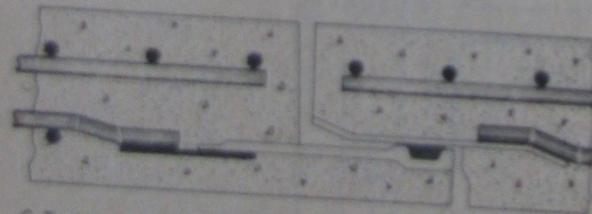
Figure 14-3 Typical concrete pipe joints. (Courtesy American Concrete Pipe Association.)



A. Subaqueous joint for concrete pipe outfall



B. Double rubber gasket joint for large-diameter concrete pipe outfall



C. Typical cross section of steel end ring joint with spigot groove and O-ring gasket

Figure 14-5 Reinforced concrete pipe joints. (Courtesy Portland Cement Association and American Concrete Pipe Association.)

Construction of Sewerage System

Selection of sewer materials:

- i. Cost
- ii. Durability
- iii. Imperviousness
- iv. Resistance to abrasion
- v. Resistance to corrosion
- vi. Strength
- vii. Weight

Construction of Sewerage System

Material of sewer:

- i. Asbestos cement sewer
- ii. Brick sewer
- iii. Cast-iron
- iv. Cement concrete sewer
- v. Corrugated iron sewer
- vi. Plastic sewer
- vii. Steel sewer
- viii. Stoneware sewer
- ix. Wood sewer

Course Code: CE 441

Course Title: Environmental Engineering-II

Lecture - 4

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Cycle -2, Day-D
17-06-2019

Construction of Sewerage System

Shape of sewer:

Basket-handle section
FIG. 4-6

Inverted egg-shaped section
FIG. 4-8

New egg-shaped section
FIG. 4-9

U-shaped section

Horse-shoe section
FIG. 4-10

Parabolic section
FIG. 4-11

Rectangular section
FIG. 4-12

Semi-circular section

Semi-elliptical section
FIG. 4-14

Standard egg-shaped section

into the sewerage for some period. Hence it becomes necessary to store the sewage for some period.

cannot be discharged immediately. Hence it becomes necessary to store the sewage for some period.

Fig. 4-9 shows an egg-shaped sewer with imaginary circles placed slightly apart from one another. The top arch is generally a semi-circle.

(*) **Semi-circular section:** The semi-circular section, as shown in fig. 4-13, gives a wider base at the bottom and hence it becomes suitable for constructing large sewers with less available headroom. Its place however at present is taken by the rectangular section which possesses better hydraulic properties.

constructing sewers in tunnels.

Treatment of wastewater

The treatment of wastewater is classified broadly into three categories:

- i. Primary treatment
- ii. Secondary treatment
- iii. Disinfection

Primary treatment

The larger solids from sewage are removed during the treatment process. The more complex compounds are broken up and converted into simple compounds by decomposition. Primary treatment unit includes screens, grit chambers, detritus tanks, skimming tanks and sedimentation tanks with or without the use of chemicals.

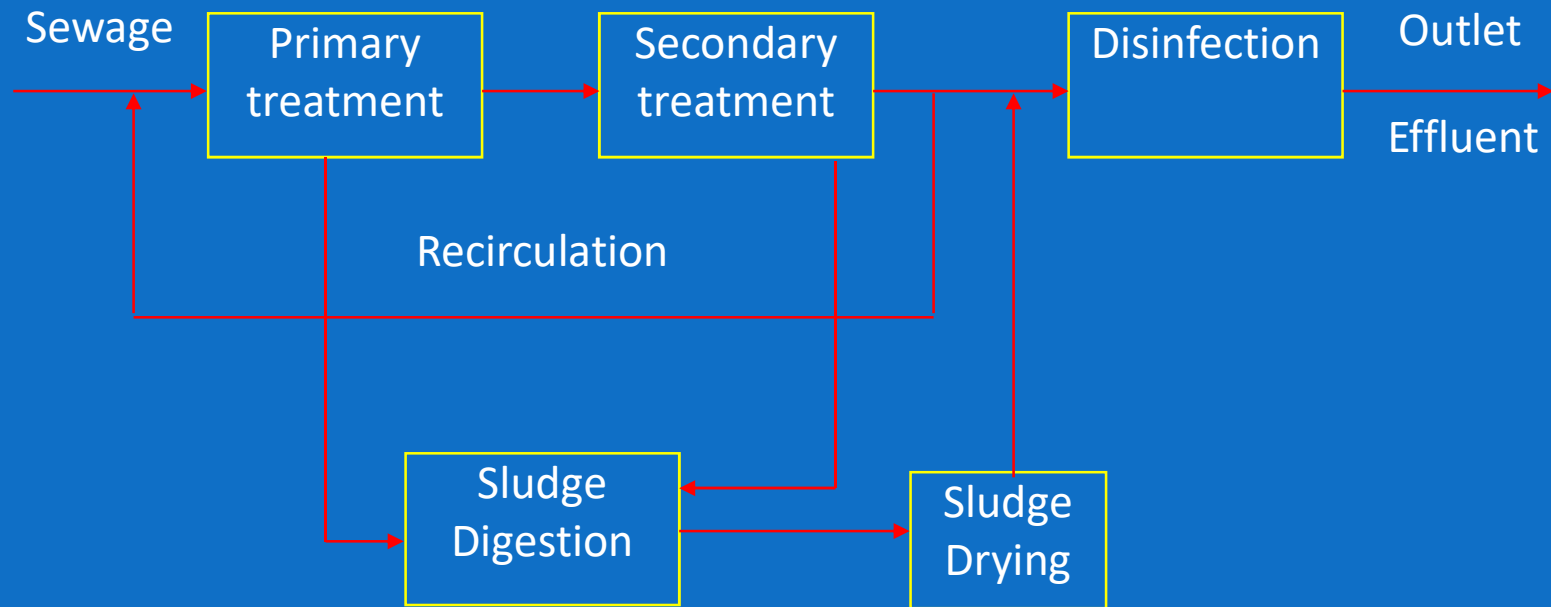
Secondary treatment

The sewage is treated exhaustively and it is completely purified by filtration or activated sludge process.

Disinfection

The disinfection is generally carried out by chlorination to kill some of the bacteria which remains in the effluent of sewage.

Treatment of wastewater

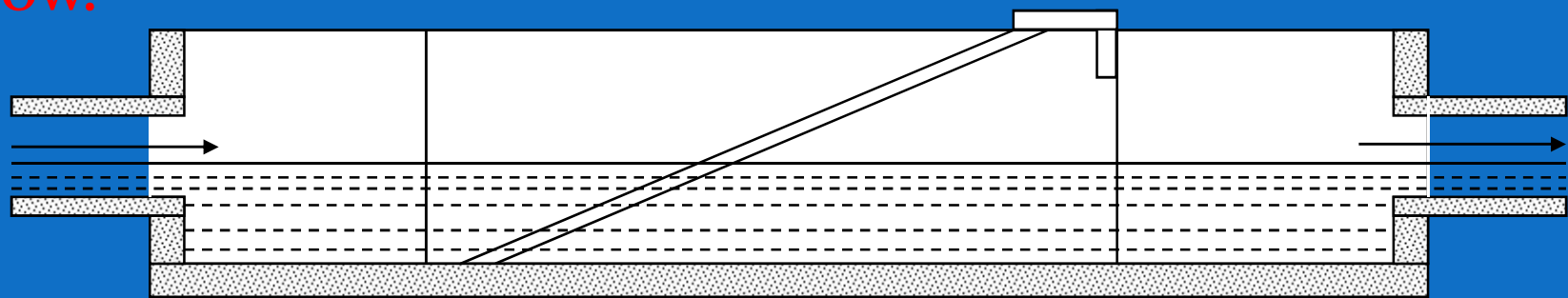


Typical Flow diagram of Sewage treatment

Primary treatment

Screens

The main purpose of the installation of screens is to remove the floating matter of comparatively large size. The screens are usually placed in an inclined position with an angle of about 30° to 60° with the direction of flow.



Sectional Elevation



Plan

Bar Screen

Primary treatment

❖ Bar Screen

- catches large objects that have gotten into sewer system such as bricks, bottles, pieces of wood, etc.



Primary treatment

Types of Screens

□ Based on size:

Course screen: spacing between bars is about 40 mm or more

Medium screen: spacing between bars is about 6 mm to 40 mm

Fine screen: Less than 6 mm

□ Depending upon the fixing arrangement:
(a) fixed or stationary and (b) movable.

□ Depending upon the method of cleaning:
(a) hand cleaning and (b) machine or mechanical cleaning.

Primary treatment

Problem-1

Design a screen for an average discharge of 0.2 m³/sec.

Solution: Assuming fluctuation factor is 2, velocity of flow is 1 m/sec.

The maximum discharge, $Q_{\max} = (2 \times 0.2) = 0.4 \text{ m}^3/\text{sec}.$

Again, , $Q_{\max} = A \times V$

Or, $A = Q_{\max}/V = 0.4/1 = 0.4 \text{ m}^2$

Keeping 100% as excess openings,

\therefore Effective area = $(2 \times 0.4) = 0.8 \text{ m}^2$

Assume depth of screen = 800 mm = 0.8 m

\therefore Effective width = $0.8/0.8 = 1 \text{ m}$

Primary treatment

Problem-1

Design a screen for an average discharge of 0.2 m³/sec.

Solution:

Use opening size of screen = 40 mm

$$\therefore \text{No. of opening} = 1/0.04 = 25$$

$$\therefore \text{No. of flats} = 25-1 = 24$$

\therefore Assume flat thickness = 5 mm and angle thickness at both ends = 25 mm

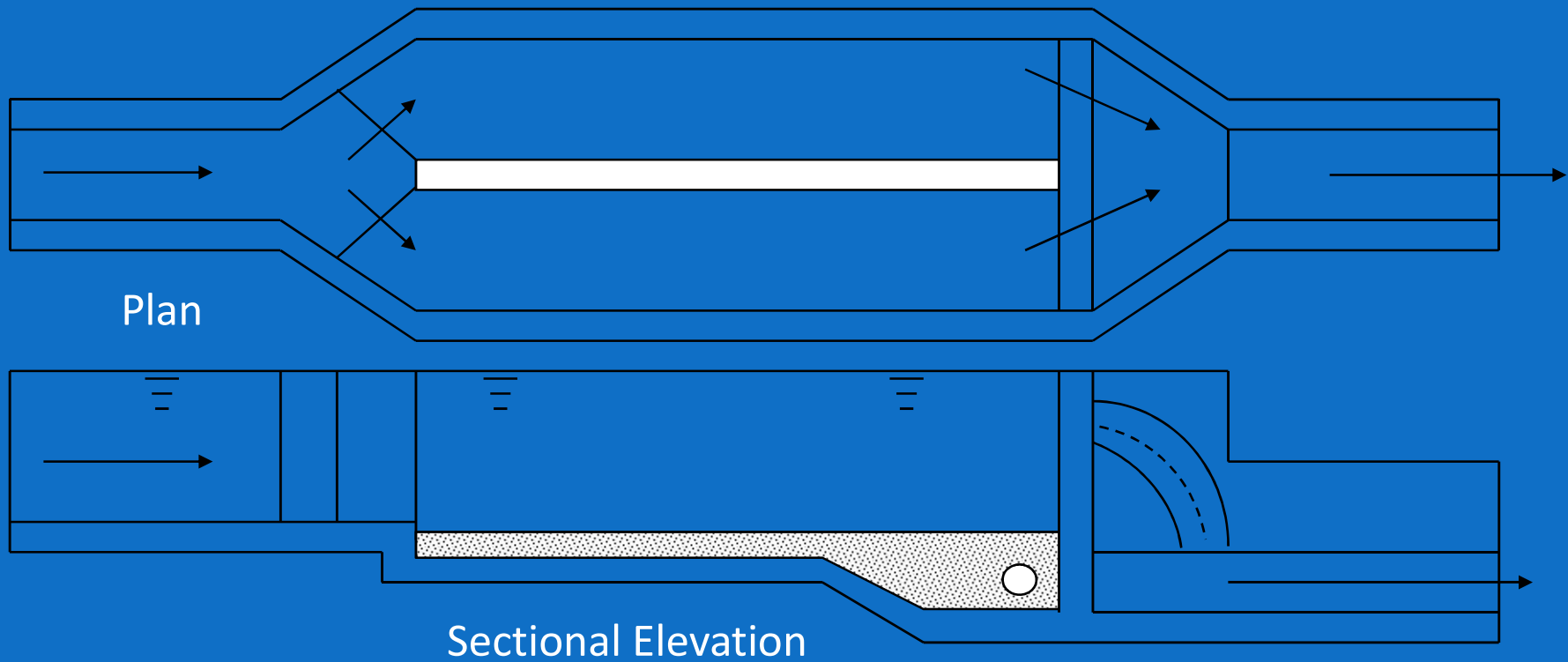
Then, total width of screen = $(25 \times 0.04) + (24 \times 0.005) + (2 \times 0.025)$

$$= 1 + 0.12 + 0.05 = 1.17 \text{ m}$$

Primary treatment

Grit chambers

The grit chamber in the sewage treatment process is used to remove grits, sand and such other inorganic matter from sewage.



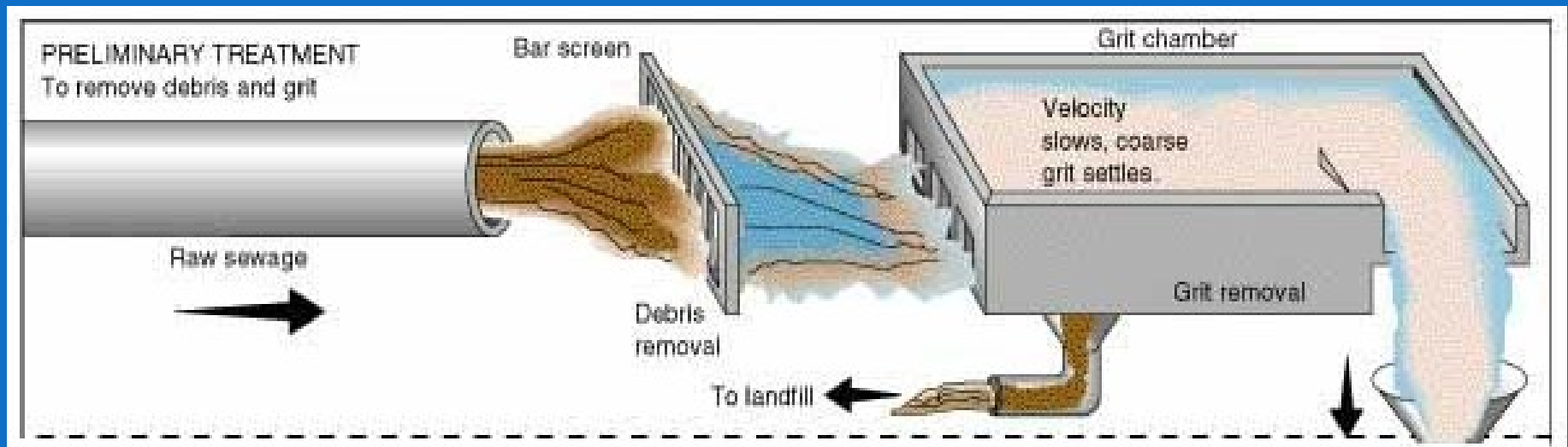
Primary treatment

❖ Grit Chamber

- removes rocks, gravel, broken glass, etc.

❖ Mesh Screen

- removes diapers, combs, towels, plastic bags, syringes, etc.



Primary treatment

Grit chambers Design specifications

Typically a grit chamber may have a depth of 3 – 4 ft and a length of about 40 – 60 ft with a detention time of 30 to 60 sec.

A chamber with a depth of 4 ft, a length of 60 ft and a detention time of 45 second would remove all particles having a settling velocity greater than 0.088 fps.

This corresponds to all particles larger than about 0.02 mm.

If the velocity in the chamber is too low, some of the organic material will settle; if the velocity is too high, the grit will not completely settle.

An average sewage will yield about 2 – 5 cft. of grit/million gallons.

Many grit chambers are provided with automatic grit removal mechanisms.

Primary treatment

Detritus Tanks

The purpose of detritus tank is the same as that of a grit chamber. In fact, a detritus tank may be considered as a grit chamber having such velocity of flow that an appreciable amount of organic matter also settles down at its bottom together with the grit.

The overall depth varies from 2.5 – 3.5 m with a detention time of 3 to 4 minutes.

The velocity of flow is kept between 200 to 400 mm/sec.

The other details of detritus tanks are similar to those of grit chambers.

Primary treatment

Problem-2

Design a detritus tank for an average flow of 200 liter per second. Make suitable assumption where necessary.

Solution

1. Width calculation:

Assume:

A detritus tank of rectangular shape with effective depth as 1.2 m.

The maximum flow to be three times the average flow, the maximum flow would be 600 l/sec or 0.6 m³/sec

The velocity of flow in the tank be 300 mm/sec

Then, $Q_{\max} = A \times V$

$$0.6 = A \times 0.3$$

$$\therefore A = 2 \text{ m}^2$$

$$\therefore \text{Width of tank} = A/\text{depth} = 2/1.2 = 1.67 \text{ m [say 1.7 m]}$$

Primary treatment

Problem-2

Solution

2. Length calculation

Assume detention period is 3 min.

\therefore Length of tank = velocity of flow \times detention period =
 $(0.3 \times 3 \times 60) = 54$ m

Making an allowance of about 6 m for inlet and outlet arrangement, the total length of tank works out to 60 m.

3. Total depth calculation

Provide the bottom depth of 500 mm for the accumulation of detritus and freeboard at top is kept as 300 mm.

The total depth = $0.3 + 1.2 + 0.5 = 2$ m.

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Course Title: Environmental Engineering-II

Lecture - 5

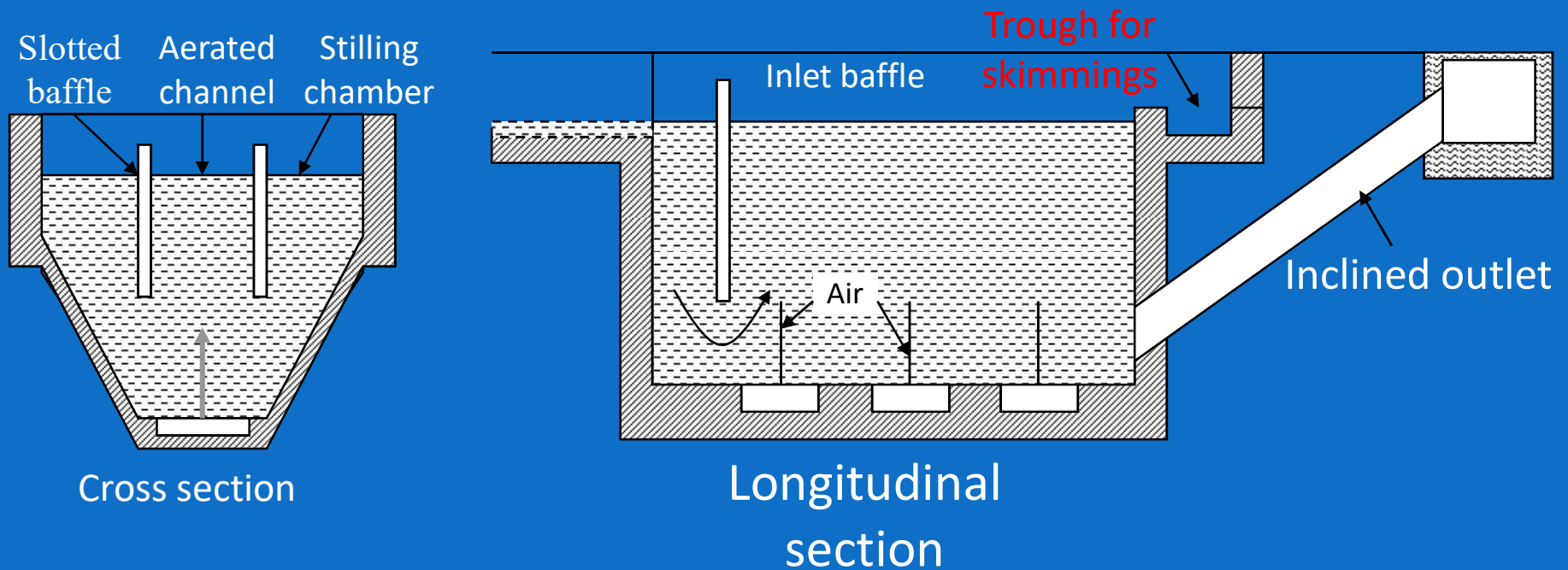
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Primary treatment

Skimming Tanks

Skimming tanks generally includes an aerating device which blows air through the sewage at rate about 0.1 cft. of air per length of sewage. The raising air tends to coagulate the grease and oils and cause them to rise to the surface where they can be removed easily either by hand or mechanically.



Primary treatment

Skimming Tanks

The depth is commonly between 1 – 2 m given detention time varying from about 300 to 500 sec.

With the greater depth and target detention periods, floatation efficiency is improved by flocculation, but due to the lower value of horizontal velocity there is also mere danger that settle out materials accumulates at the bottom of the tank.

Short detention time 300 to 500 sec and high velocity of horizontal flow are therefore commonly preferred and flocculation when necessary is promoted by the addition of chemicals such as iron and aluminum salts.

Primary treatment

Plain Sedimentation Tanks

The sedimentation tanks are also known as the settling tanks or clarifiers. Following are the objects of installing sedimentation tanks:

- i. The process of sedimentation reduces the strength of sewage to the extent of about 30% to 35%.
- ii. The quantity of settleable solids in the sewage is reduced to the extent of about 80% to 90%.
- iii. There is reduction in B.O.D. to the extent of about 30% to 35%.
- iv. The sewage after being treated in the sedimentation tanks becomes fit for further treatment processes.

Primary treatment

The sedimentation process

When velocity of flow is decreased or when sewage is allowed to stand at rest, the suspended particles carried by the sewage tend to settle at the bottom of the tanks.

The material collected at the bottom of sedimentation tanks is known as the ***sludge***.

The partially treated sewage is known as the ***effluent***.

Primary treatment

Type of sedimentation tank

According to the shape and size or direction of flow sedimentation tank may be classified as

- i. Rectangular tank
- ii. Circular tank.

According to location sedimentation tank may be classified as

- i. Primary sedimentation tanks or primary clarifier
- ii. Secondary sedimentation tanks or secondary clarifier

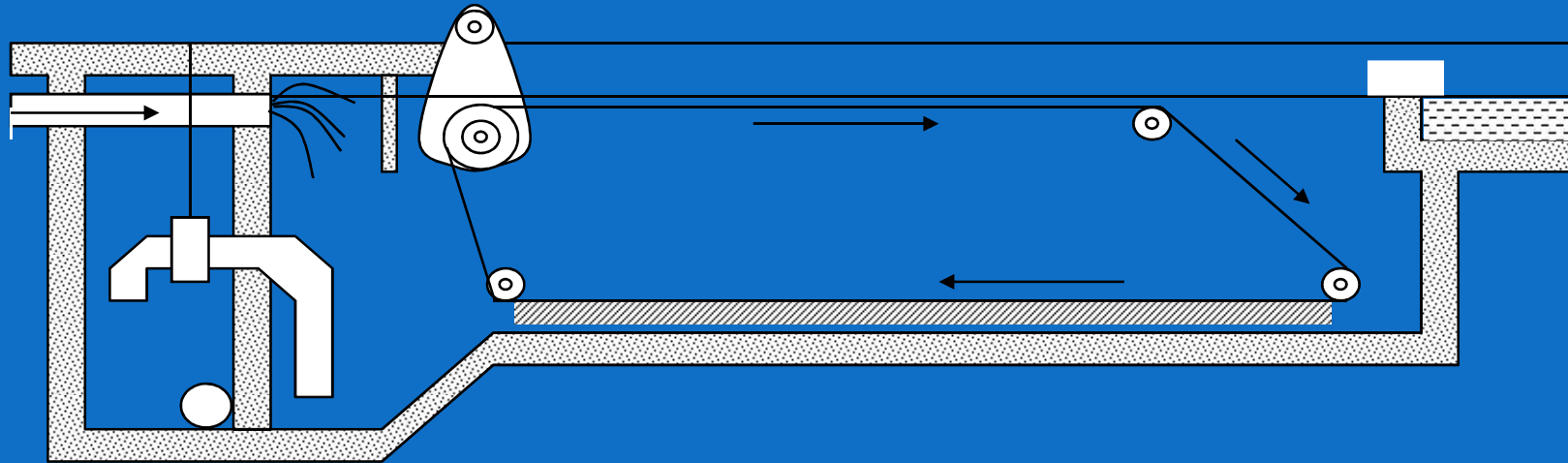
According to the nature of working sedimentation tank may be classified as

- i. Fill and draw type
- ii. Continuous flow type

Primary treatment

Rectangular sedimentation tank

In a rectangular horizontal flow tanks, the sewage enters at one end and leaves at the other end. In rectangular tank out let structure generally composed of finger launders running parallel to the length of the tank. It is shown in Figure.

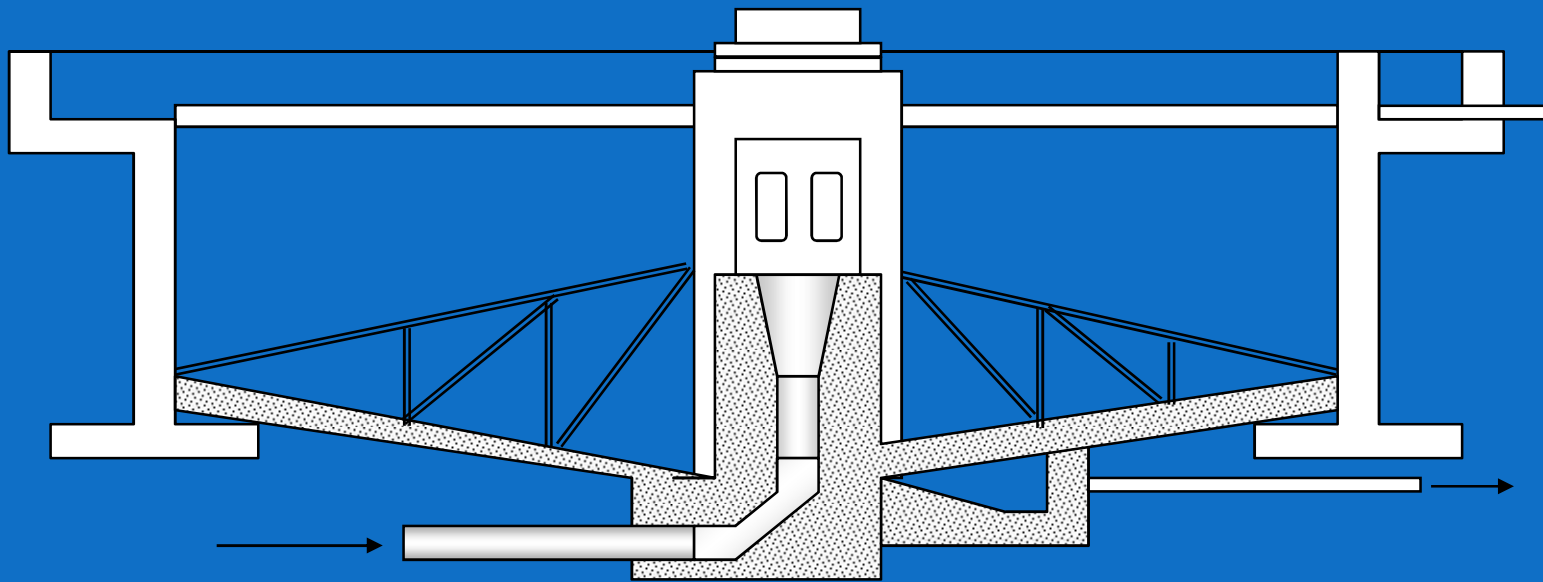


Chain carried scrapers in rectangular plain sedimentation tank

Primary treatment

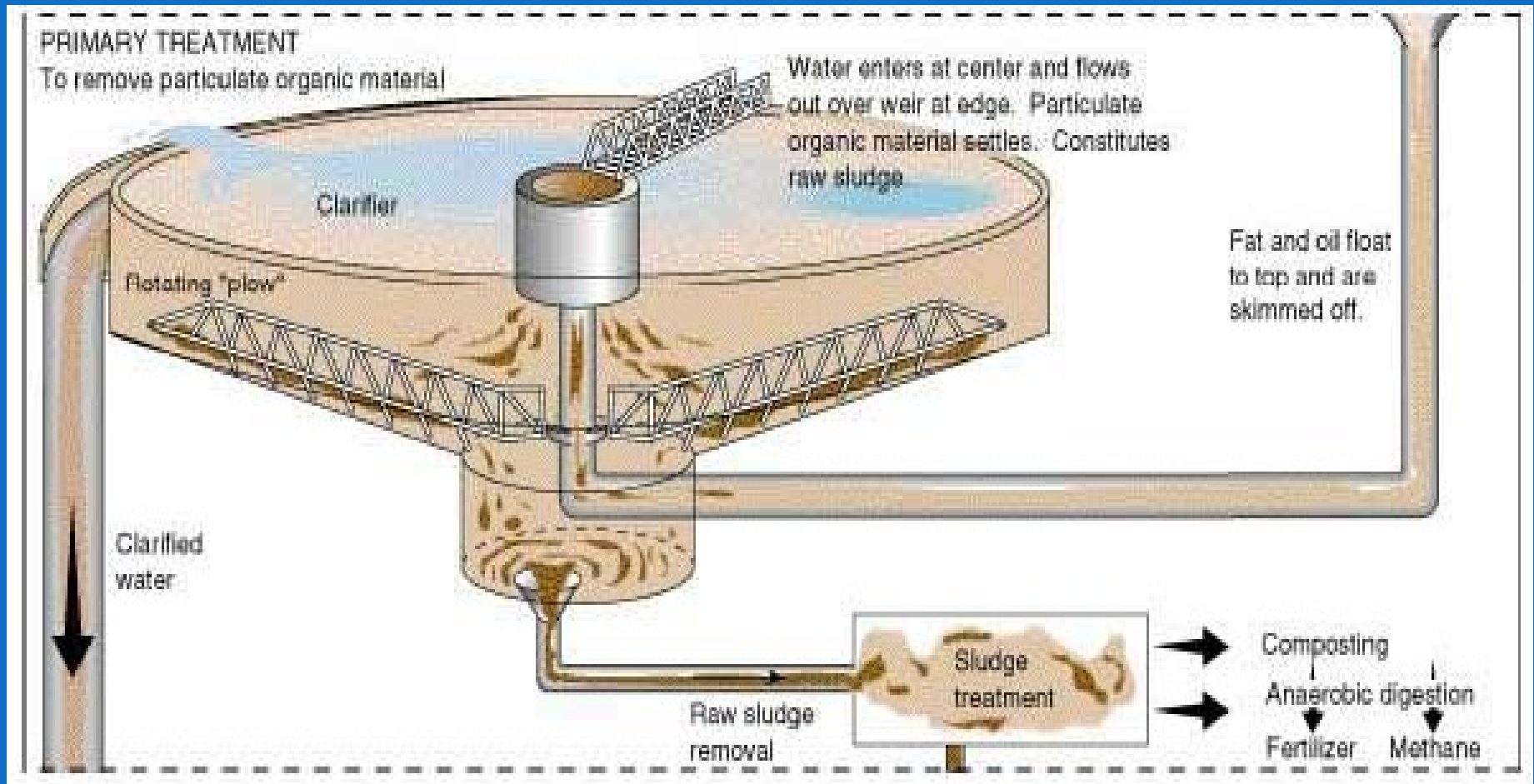
Circular sedimentation tank

Sewage enters at the centers and flows towards periphery. Practically, circular sedimentation tanks are widely used for sewage sedimentation. Circular tank can be fed from a center inlet or from multiple peripheral ports or a peripheral launder.

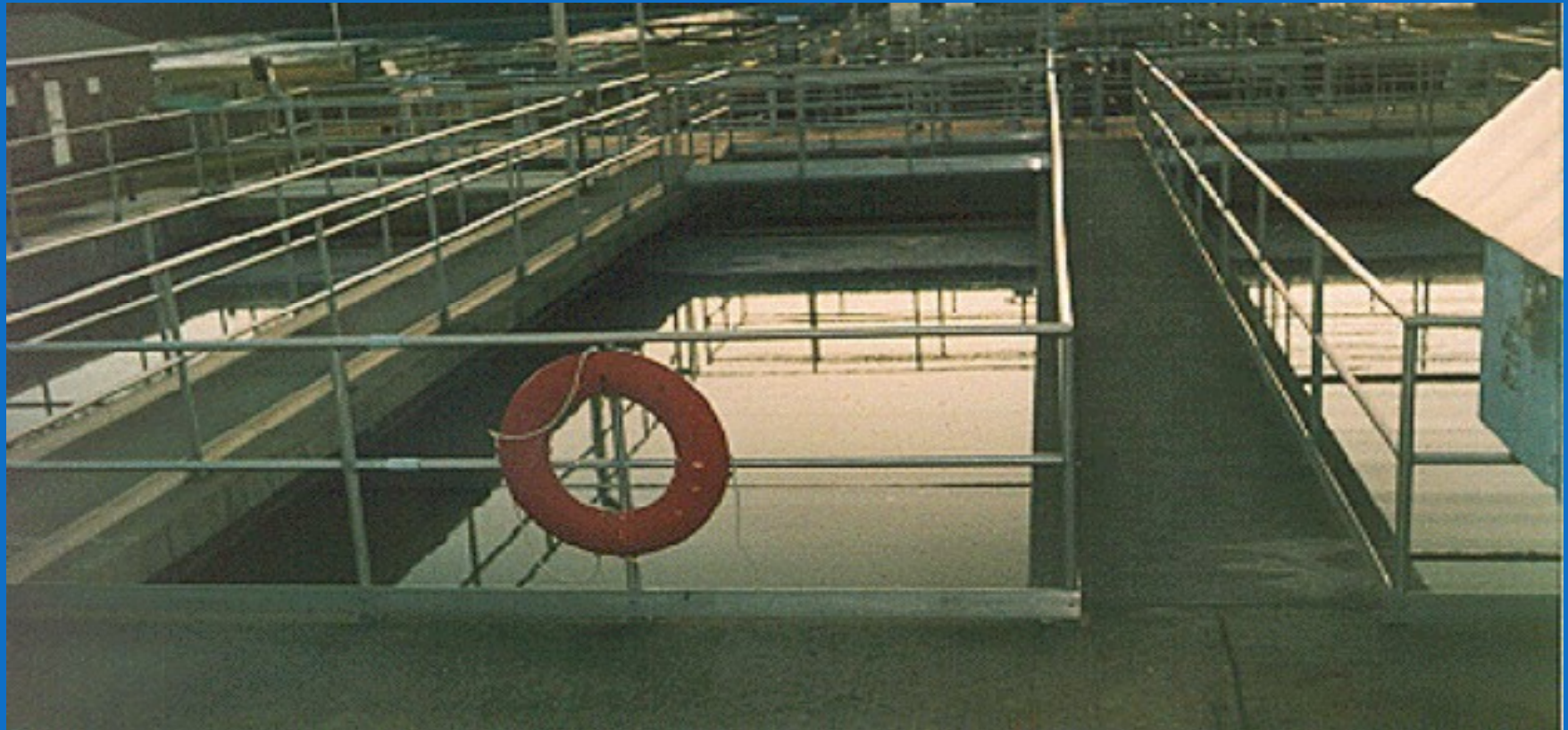


Circular sedimentation tank

Primary treatment



Primary Treatment

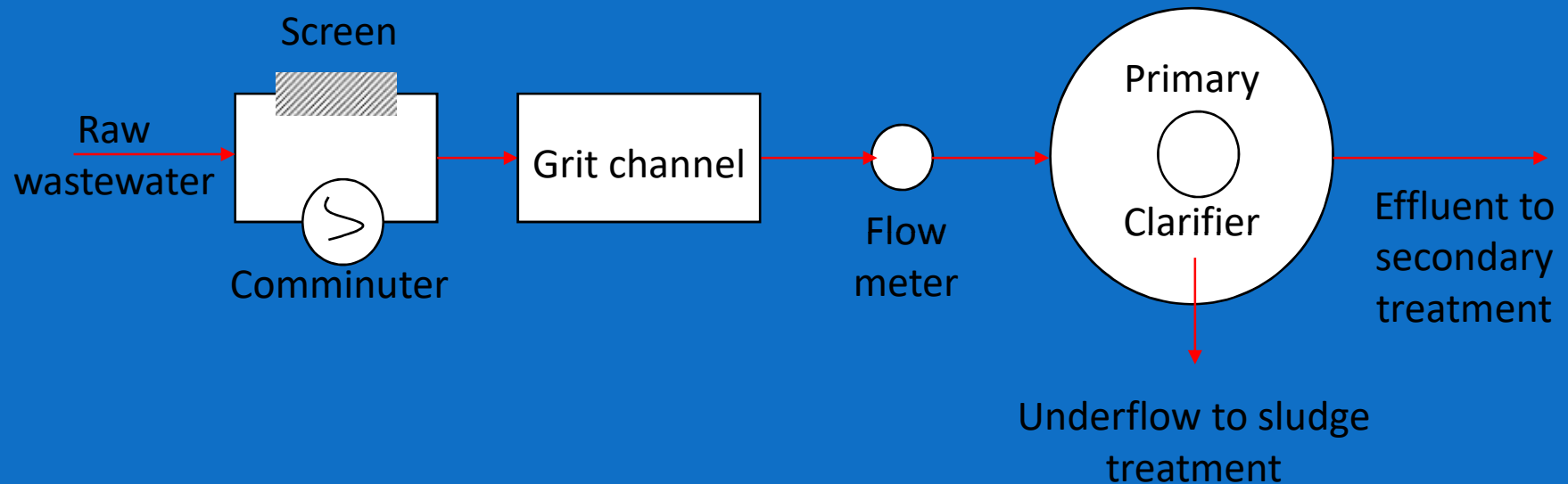


Primary Treatment



Primary treatment

Typical flow diagram of primary treatment process



Primary treatment

Problem-3

Design a primary clarifier for a town having a population of 34000. The formation of sewage may be assumed at 150 lpcd.

Solution:

Daily flow of sewage = $(34000 \times 150) = 5100000$ liters

Assume detention period of 2 hours.

Then, tank capacity = $(5100000 \times 2) / 24 = 425 \text{ m}^3$

Assume effective depth of tank = 2.5 m

Then, surface area of tank = $425 / 2.5 = 170 \text{ m}^2$

Now, $L \times B = 170$ [Assume, $L = 4B$]

$$4 B^2 = 170$$

$$\therefore B = 6.5 \text{ m and } L = 26 \text{ m}$$

Provide additional 4 m for inlet and outlet arrangement.

\therefore The total length of the tank would be 30 m

Primary treatment

Provide 1 m depth for sludge accumulation and 500 mm depth of freeboard. The total depth of tank would then be 4 m.

The dimension of the tank would then be 30 m × 6.5 m × 4 m.

If circular tank of diameter d is provided with effective depth of 2.5 m , the value of diameter can be obtained as follows:

$$\pi d^2 / 4 = 170$$

$$\therefore d = 14.7 \text{ m, say } 15 \text{ m}$$

Secondary Treatment

Secondary treatment usually consists of biological conversion of dissolved and colloidal organics into biomass that can subsequently be removed by sedimentation.

The main function of secondary treatment of sewage is to convert the remaining organic matter into stable form by oxidation or nitrification.

The secondary treatment of sewage may broadly be classified into the following two categories:

- i. Filtration
- ii. Activated sludge process

Secondary Treatment

Filtration

Filtration is the process of removing of organic matter by retaining over a filter bed while the sewage is allowed to passing through.

The filters which are used in secondary treatment of sewage are of following types:

- i. Contact beds filter
- ii. Intermittent sand filter
- iii. Trickling filter

Secondary Treatment

Contact beds filter

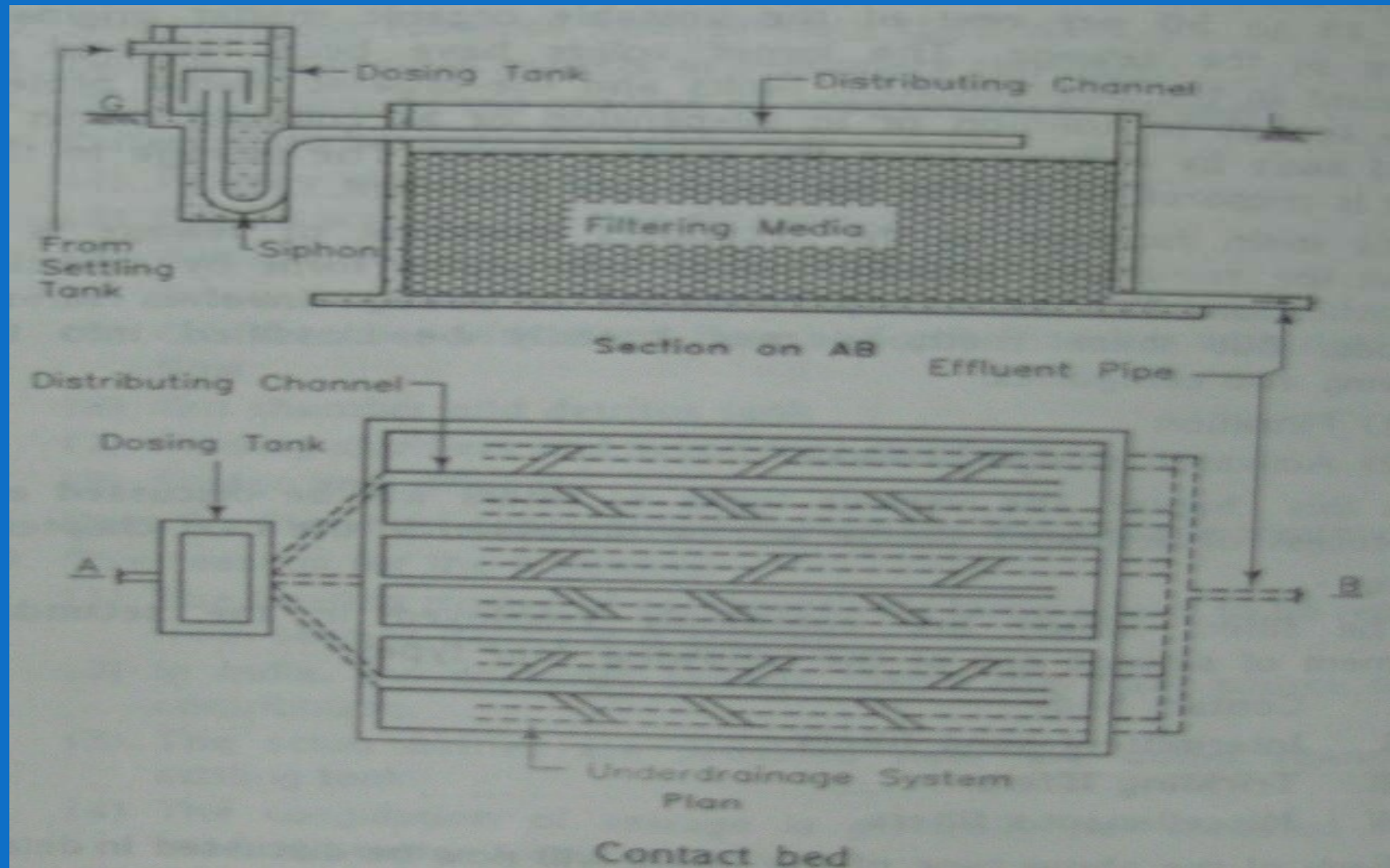
The sewage effluent is kept in contact with filtering media for some period.

As sewage effluent passes through the filtering media, an organic film is produced around the particles of filtering media. A large number of aerobic bacteria present in this film carries out the oxidation of organic matter.

In second stage, when the bed is standing empty, the filter obtained oxygen from the atmosphere and the organic matter caught in the voids of filtering media gets oxidation.

Secondary Treatment

Contact beds



Secondary Treatment

Construction of Contact beds

A contact bed is a watertight tank. It is filled with the filtering media which may be of gravel, ballast or broken stone.

- ❑ The size of particles of media varies from 15 mm to 40 mm.
- ❑ The depth of bed is about 1 m to 1.8 m and area generally does not exceed 0.2 ha.
- ❑ The beds are usually designed for a dosing rate of 300 to 500 liters per loading per m³.

Secondary Treatment

Working procedure

The tank is filled with sewage effluent which may take about 2 hours.

- ❑ The sewage effluent is allowed to stand for a period of about 2 hours.
- ❑ The tank is then emptied and the sewage effluent is allowed to flow through the effluent pipe without disturbing the organic film of the bed. It may requires about 2 hours.
- ❑ The contact bed is allowed to stand empty for a period of about 6 hours.

Secondary Treatment

Advantages

- i. It is possible to operate without exposing the sewage effluent to view.
- ii. It consume relatively small amount of head.
- iii. There is no nuisance of filter flies.
- iv. The undesirable odour is also less as compared to that in case of trickling filter.

Secondary Treatment

Disadvantages

- i. For efficient working of the contact beds, the primary treatment of sewage effluent is essential, otherwise the beds will be easily clogged.
- ii. The cost of the contact beds is more as compared to that of trickling filter.
- iii. The operation requires skill supervision.
- iv. The rate of treatment of sewage is very low.
- v. It requires long rest period.

Secondary Treatment

Intermittent sand filters

The sewage effluent is applied on intermittent sand filters at regular interval. The sewage is purified by the aerobic bacteria. During the period of rest, the atmospheric air will be carried up to the voids of sand particles so as to establish favourable conditions for aerobic bacteria.

Secondary Treatment

Construction of Intermittent sand filters

It is generally rectangular and the **ratio of length to width is about 3 to 4**. The area of one unit varies from **0.2 to 0.4 ha**.

The effective size of sand should be between 0.2 mm to 0.5 mm and uniformity coefficient should not exceed 5.

The thickness of sand layer is kept as about 750 mm to 900 mm.

A layer of about 150 mm to 300 mm depth of gravel is provided at the bottom of sand layer.

Secondary Treatment

Advantages

- i. The quality of effluent obtained from this filter is very clean and stable and it generally does not require any further treatment except chlorination in some cases.
- ii. The oxidation of organic matter of sewage is brought about by the aerobic bacteria and as the sewage is applied intermittently, there are less chances for anaerobic conditions to develop.
- iii. It does not require any skill supervision constantly.

Secondary Treatment

Disadvantages

- i. The process of sewage treatment is very slow.
- ii. The process requires relatively large area of land for the construction of filter.
- iii. These filter cannot be adopted for very cold climate as there are chances of the sand surface being frozen.

Course Code: CE 441

Course Title: Environmental Engineering-II

Lecture - 6

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Cycle -3, Day-D
24-06-2019

Secondary Treatment

Trickling filters

These are also known as the percolating filters or sprinkling filters.

The sewage is allowed to sprinkling or to trickle over a bed of coarse, rough, hard material and it is then collected through the under-drainage system.

The oxidation of the organic matter is carried out under aerobic conditions.

A bacterial film known as bio-film is formed around the particles of filtering media and for the existence of this film, the oxygen is supplied.

Secondary Treatment

Trickling filters

It may be circular or rectangular in shape.

The filter media of a trickling filter may consist of crushed rock or clinker or specially manufactured material.

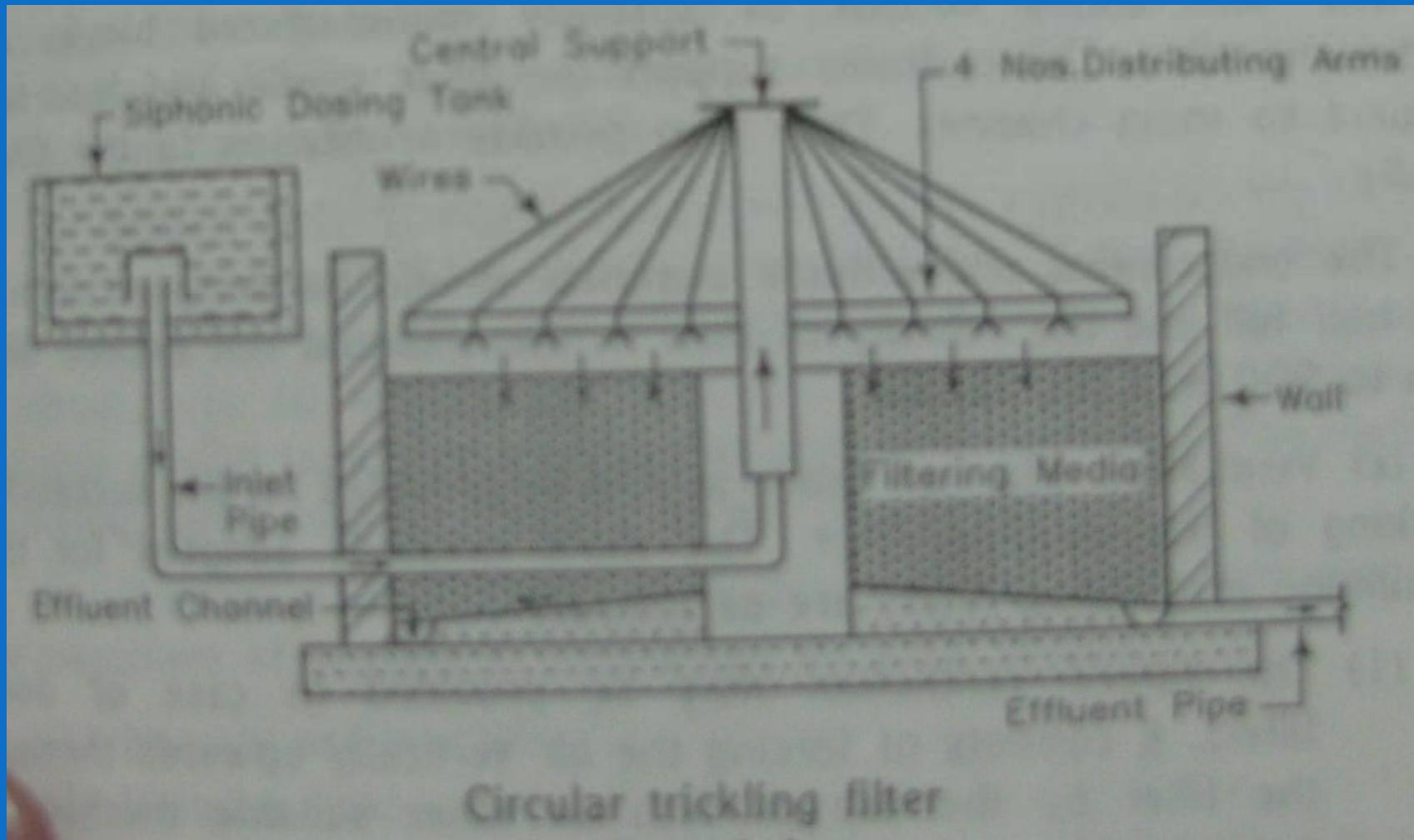
The size of the particles varies from 30 mm to 80 mm.

The floor of a trickling filter is generally made of R.C.C. and its thickness is about 100 mm to 150 mm.

The slope of the floor may be towards the central drain or toward the periphery of filter as design of the under-drainage system.

Secondary Treatment

Trickling filters



Secondary Treatment

Trickling filters

Quality of filtering material

No.	Property	Requirement
1	Crushing strength	$\leq 100 \text{ N/mm}^2$
2	Hardness	≤ 12
3	Percentage wear	≤ 4
4	Specific gravity	≤ 2.6

Secondary Treatment

Design aspects of trickling filter

- ❖ **Depth:** The effective depth of trickling filters is generally kept between 1.8 m to 2.4 m.
- ❖ **Number:** The minimum two trickling filter units.
- ❖ **Rate of filter loading:**
 - (a) Kg of BOD per volume of liter bed: 1000 to 2200 kg of BOD per hectare-meter per day.
 - (b) Kg of BOD per volume of liter media: 15 to 30 kg of BOD per day per 100 m³ of filter material.
 - (c) Surface area of filter bed: 25 – 40 million liters per hectare of surface area per day.
 - (d) Volume of filter bed: 7.5 – 22.5 million liters per hectare-meter per day.

Secondary Treatment

Ventilation of trickling filter

Ventilation should be provided for the successful working of the trickling filter. The methods are:

- ❖ The forced ventilation
- ❖ Natural draft ventilation
 - ❖ By connecting the end of under drains to a chimney for circulation of air
 - ❖ By constructing the filter above ground with open sides
 - ❖ By keeping the ends of under drains open
 - ❖ By providing vent pipes at the periphery of filter.
- ❖ The under drains and effluent channel are designed to flow partially full.

Secondary Treatment

Distribution

The function of distributor is to spread the effluent evenly on the filter media. It is two types:

- ❖ Movable distributor
- ❖ Fixed distributor

Secondary Treatment

Advantages of trickling filter

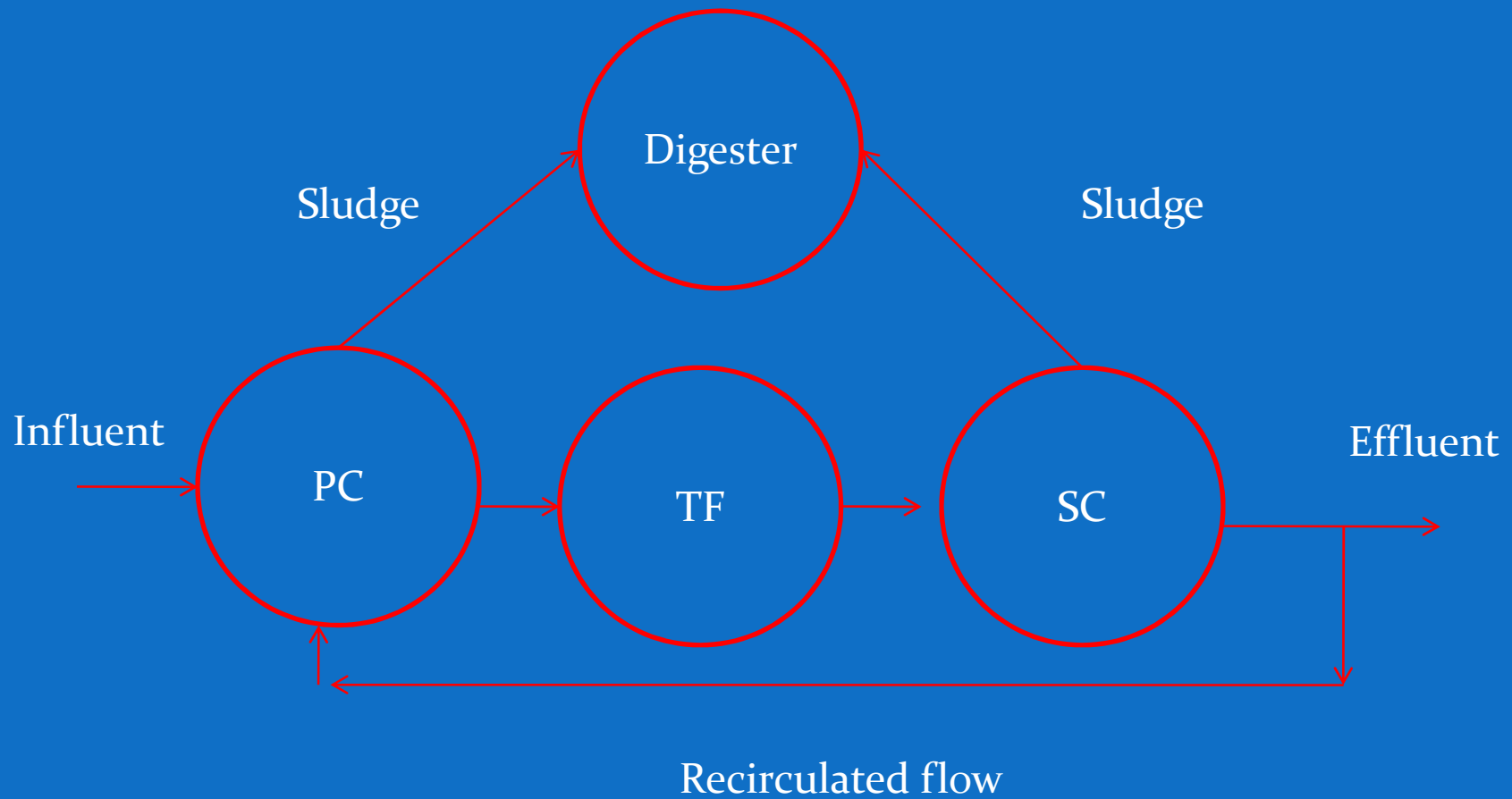
- ❖ The effluent is highly nitrified and stabilized.
- ❖ The mechanical wear and tear is small.
- ❖ The moisture content of sludge is as high as 99% or so.
- ❖ The operation requires less electrical power.
- ❖ It is flexible in operation.
- ❖ It may reduce the BOD and colloidal matter of about 75% and 80%, respectively.
- ❖ The working is simple and does not require skilled supervision.

Secondary Treatment

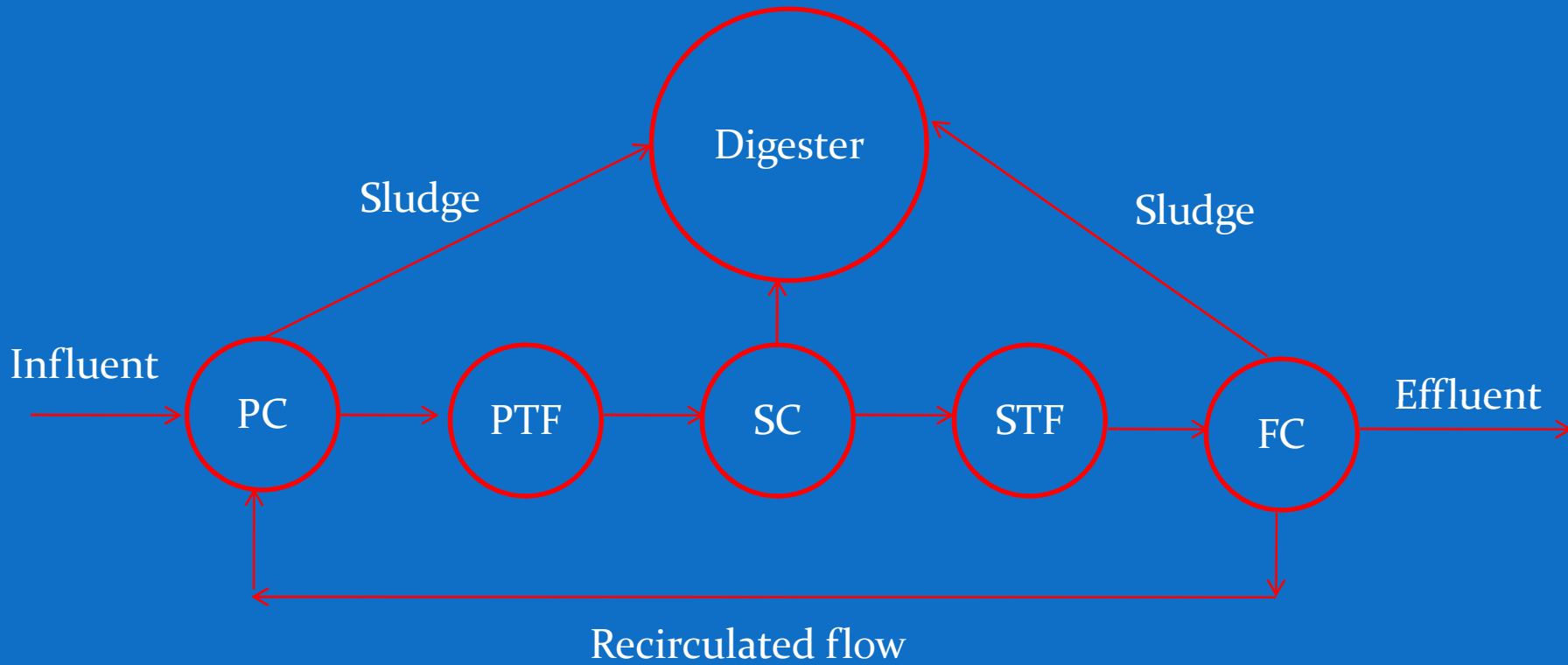
Disadvantages of trickling filter

- ❖ The construction cost is high.
- ❖ The loss of head is high and required syphonic dosing tank.
- ❖ It may develop fly nuisance and bad odour.
- ❖ The process requires primary treatment of sewage and hence raw sewage cannot be treated by this process.
- ❖ It requires large land area.

Secondary Treatment



Secondary Treatment



Secondary Treatment

Problem

Design a trickling filter for treating 6 million liters of sewage per day. The B.O.D. of sewage is 120 p.p.m.

Solution:

(1) Kg of BOD per volume of filter bed:

Total BOD = (120×6) 720 kg/day

Assume the rate of filter loading as 1440 kg BOD/ha-m/day.

\therefore Volume required = $720/1440 = 0.5$ ha-m

Assume effective depth = 1.8 m

Then surface area of filter = $(0.5 \times 10000)/1.8 = 2778 \text{ m}^2$

Secondary Treatment

Solution:

(2) Kg of BOD per volume of filter media:

Assume the rate of filter loading as 16 kg BOD/day/100 m³ of filter media.

$$\therefore \text{Volume required} = (720 \times 100) / 16 = 4500 \text{ m}^3$$

$$\text{Then surface area of filter} = 4500 / 1.8 = 2500 \text{ m}^2$$

(3) Surface area of filter bed:

Assume the rate of filter loading as 25 million liter/ha/day.

$$\therefore \text{Surface area of filter} = (6 \times 10000) / 25 = 2400 \text{ m}^2$$

Secondary Treatment

Solution:

(4) Volume of filter bed:

Total BOD = (120 × 6) 720 kg/day

Assume the rate of filter loading as 12 million liter/ha-m/day.

∴ Volume required = 6/12 = 0.5 ha-m

Then surface area of filter = $(0.5 \times 10000) / 1.8 = 2778 \text{ m}^2$

Adopt a circular trickling filter of diameter 45 m.

Area of one filter = $\pi 45^2 / 4 = 1590 \text{ m}^2$

Nos. of unit requires = $2778 \text{ m}^2 / 1590 \text{ m}^2 \cong 2$

Provide 1 stand-by unit with required 2 units.

Course Code: CE 441

Course Title: Environmental Engineering

Lecture - 7

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Cycle -4, Day-C
30-06-2019

Secondary Treatment

Activated Sludge Process

The term activated sludge is used to indicate the sludge which is obtained by settling sewage in presence of abundant oxygen. The activated sludge is biologically active and it contains a great number of aerobic bacteria and other micro-organisms which has got an unusual property to oxidize the organic matter.

Properties:

- It contains fertilizing constituents.
- Moisture content is about 95 to 97%.
- The colour of activated sludge indicates the degree of aeration.
 - Under-aerated – light brown
 - Well-aerated – golden brown
 - Over-aerated – muddy brown

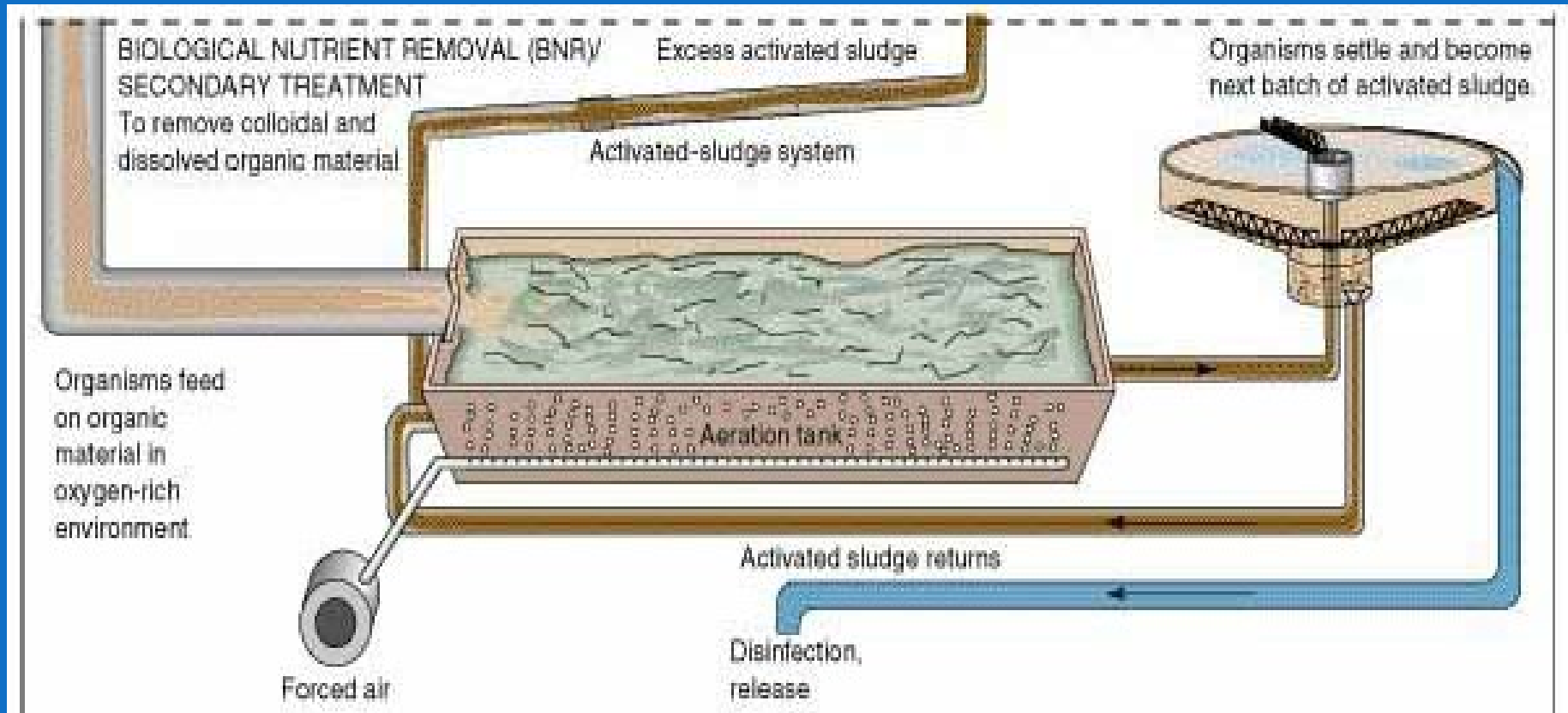
Secondary Treatment

Action of activated sludge

When activated sludge is mixed properly with sewage containing sufficient quantity of oxygen, the micro-organisms present in the activated sludge multiply rapidly. As a result of this phenomena, the following effects take place:

- Organic solids present in sewage are rapidly oxidized; and
- Suspended and colloidal matters coagulate and they form a readily settleable precipitate.

Secondary Treatment



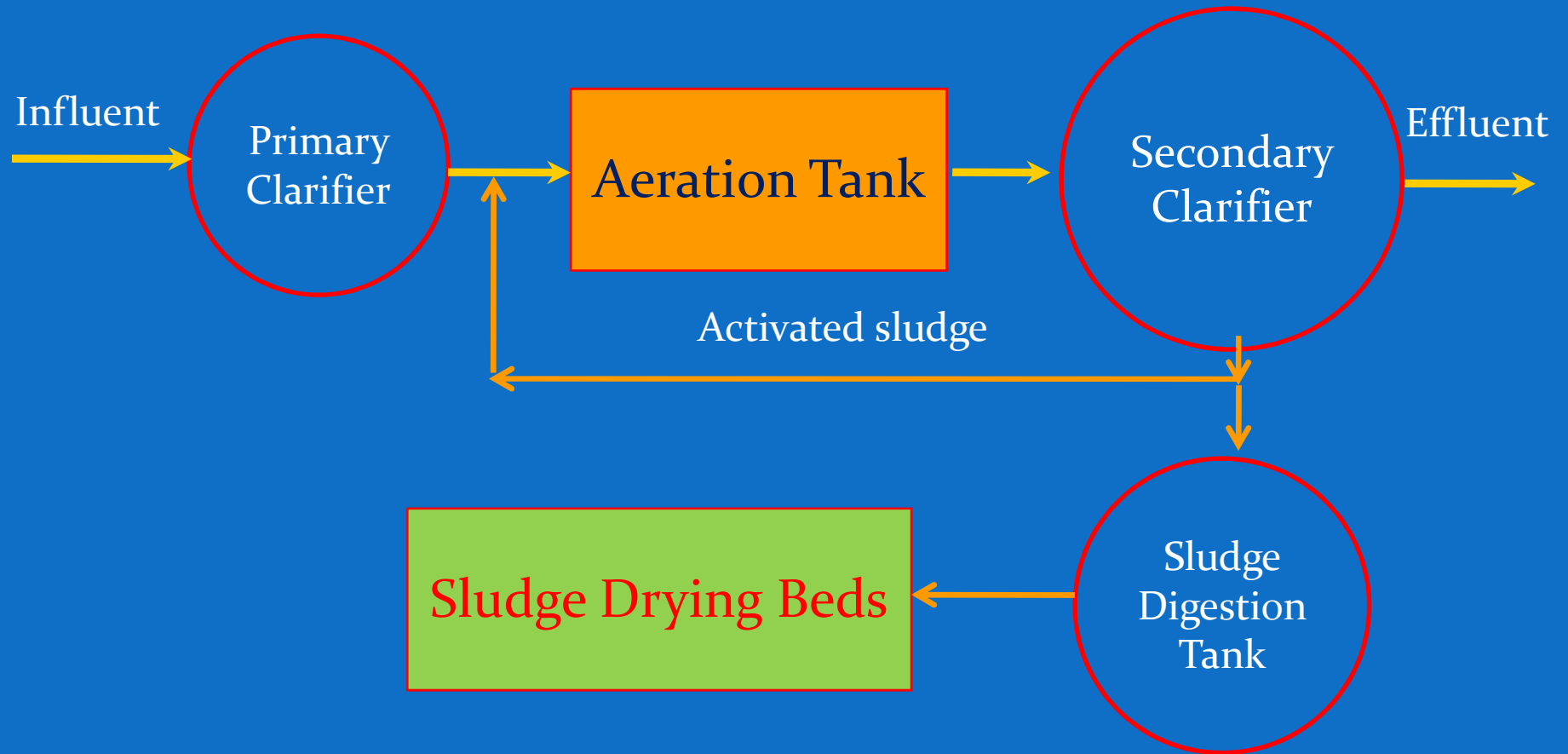
Secondary Treatment

❖ The final clarifiers remove additional sludge and further reduce suspended solids and B.O.D.



Secondary Treatment

Treatment Process Flow diagram:



Secondary Treatment

Treatment process

Mixing of activated sludge: The activated sludge is mixed properly with raw or settled sewage. The activated sludge is added to the effluent of primary clarifier.

Aeration: The mixed liquor containing activated sludge and effluent is agitated or aerated in the aeration tank or aeration chamber.

Settling in secondary clarifier: The mixed liquor after agitation is taken to the secondary clarifier. The sludge is allowed to settle in this tank. The settle sludge is the activated sludge and a portion of it is sent for circulation. The extra activated sludge is taken to the sludge digestion tank and then to the sludge drying beds for further treatment.

Secondary Treatment

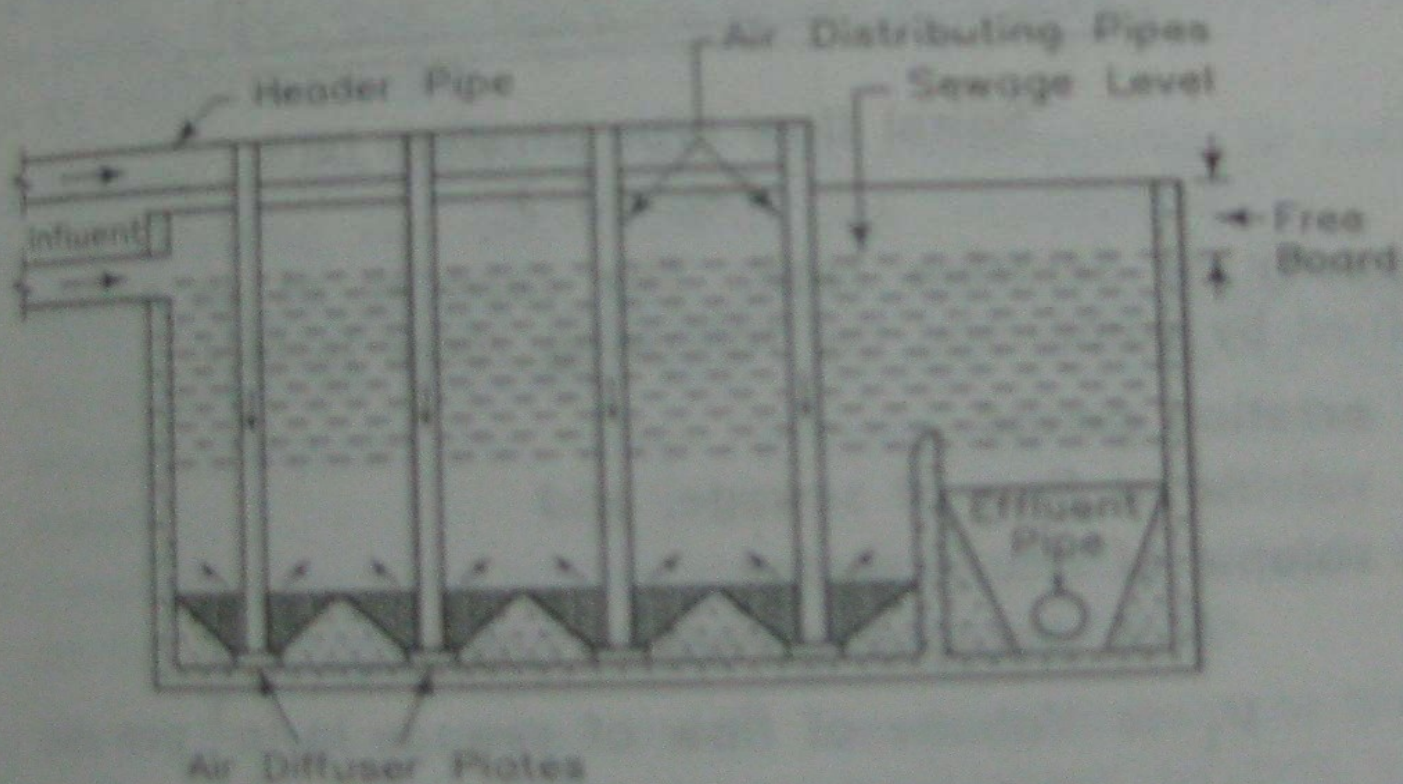
Methods of aeration

- i. Diffused air aeration
- ii. Mechanical aeration
- iii. Combination of diffused air aeration and mechanical aeration.

Secondary Treatment

Types of aeration tanks

i. Ridge and furrow type tank

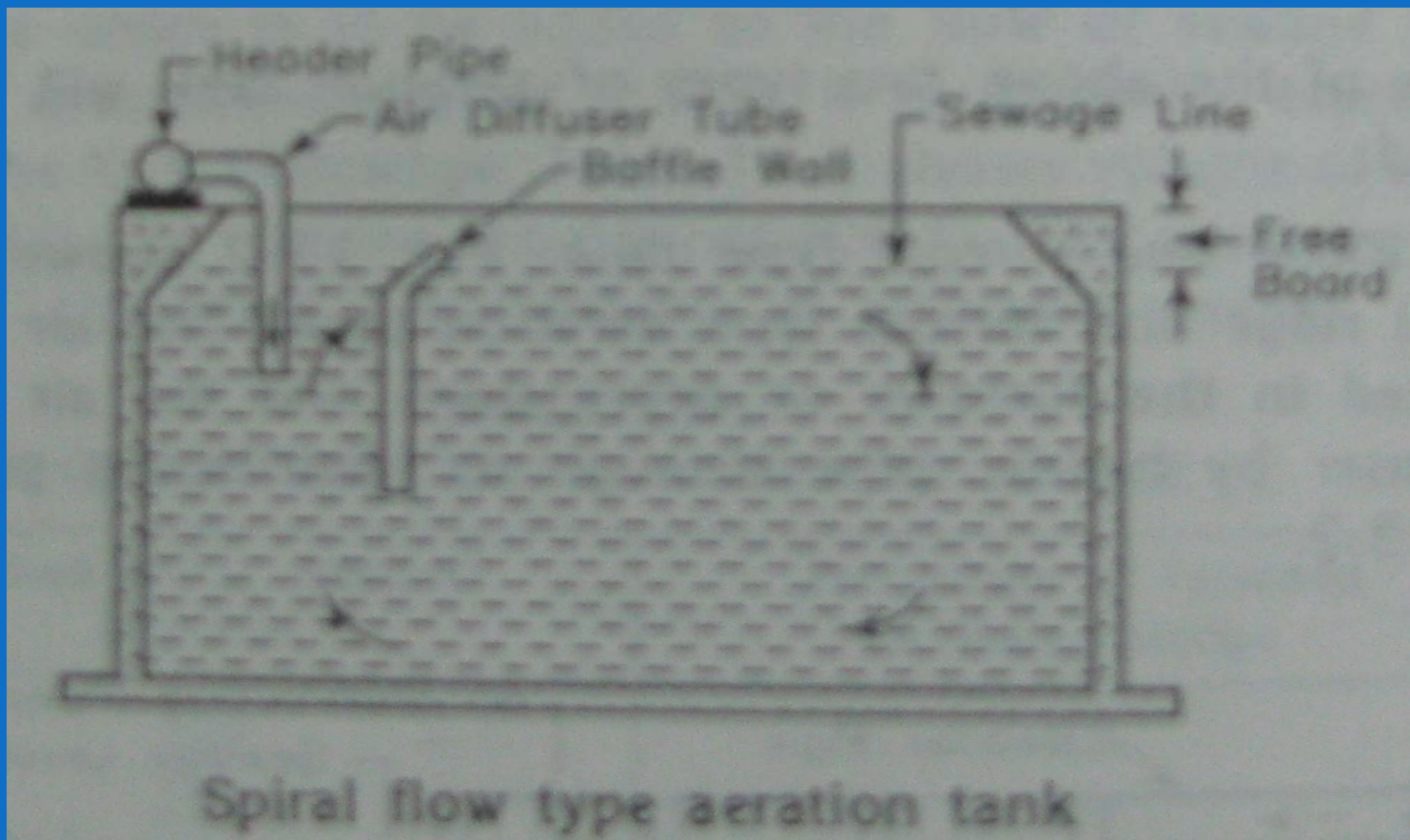


Ridge and furrow type aeration tank

Secondary Treatment

Types of aeration tanks

ii. Spiral flow type tank



Secondary Treatment

Methods of aeration

Mechanical aeration

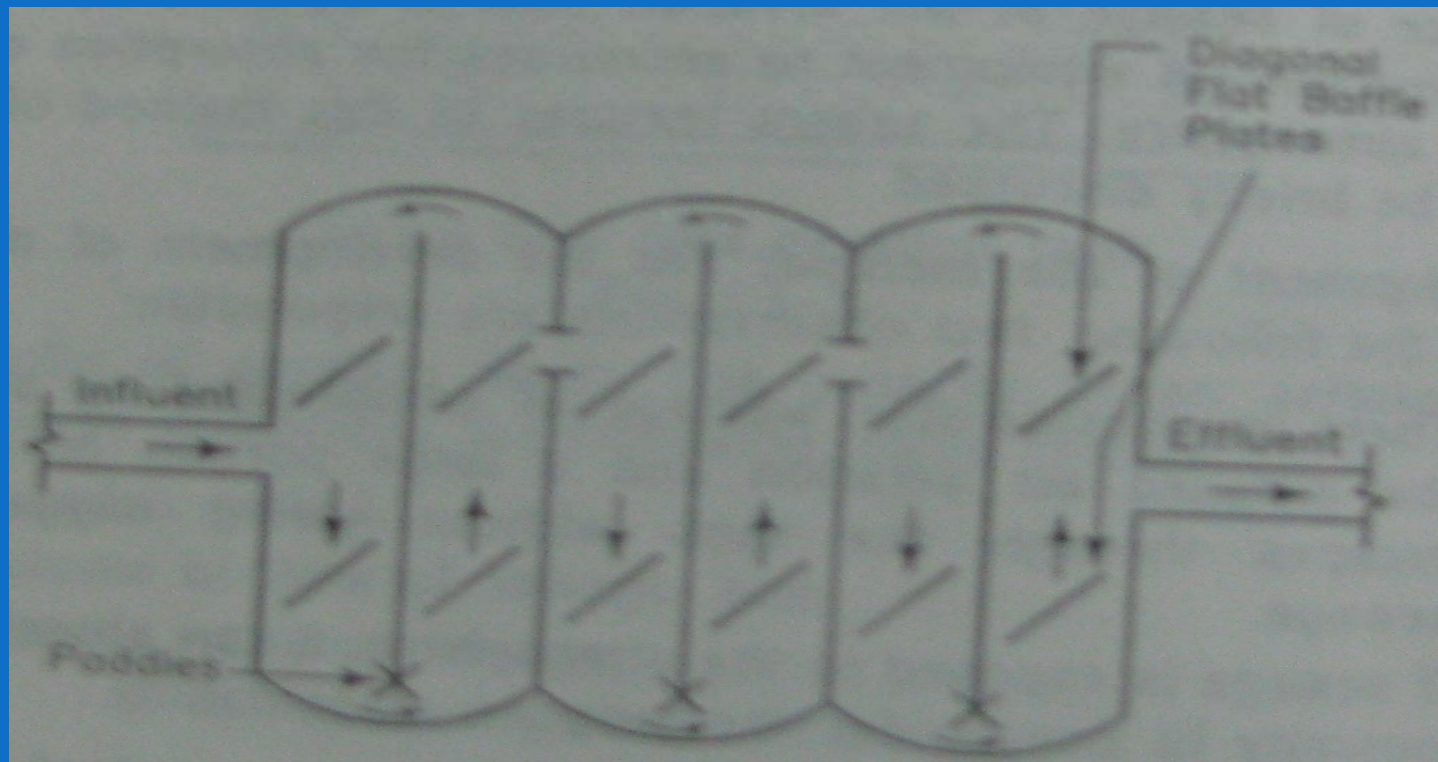
- i. Hartley process
- ii. Haworth process
- iii. Kessener process
- iv. Link-belt process
- v. Simplex process

Secondary Treatment

Methods of aeration

Mechanical aeration

i. Hartley process

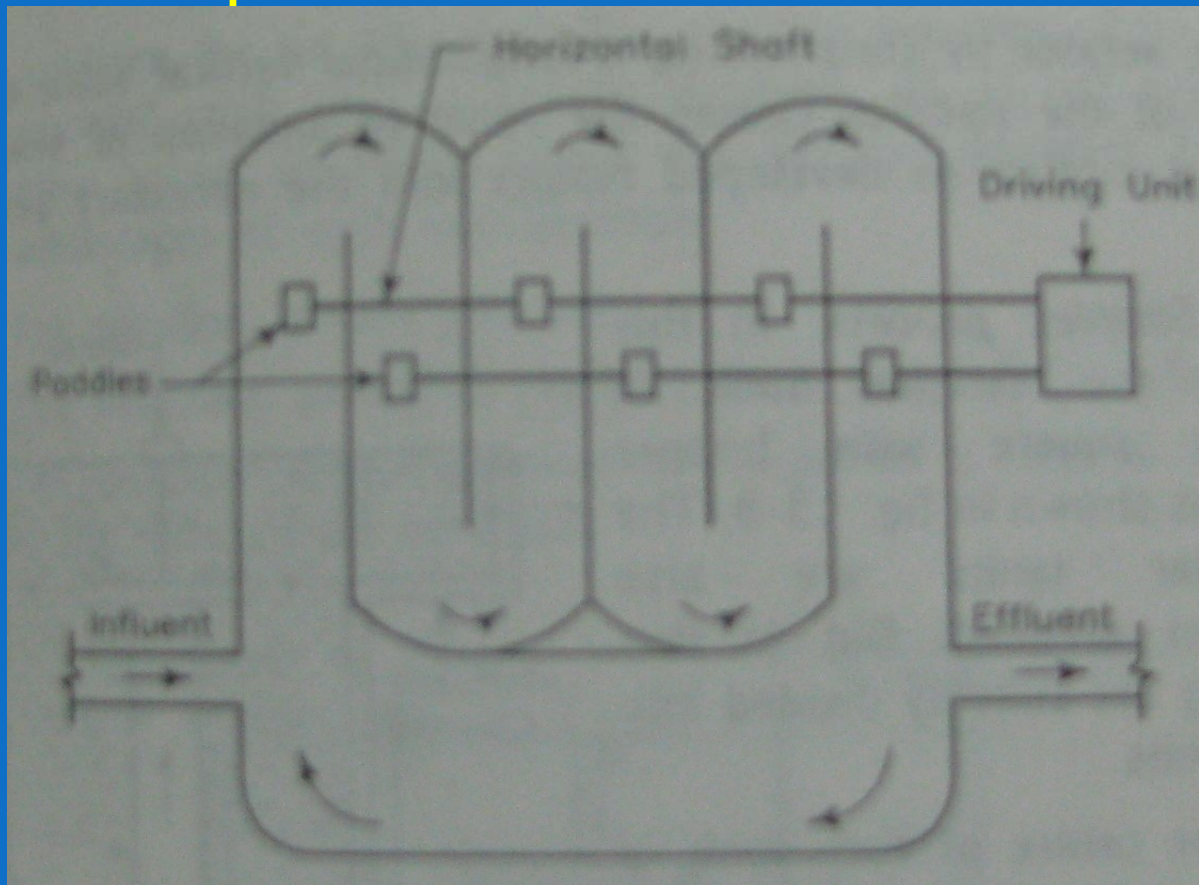


Secondary Treatment

Methods of aeration

Mechanical aeration

ii. Haworth process



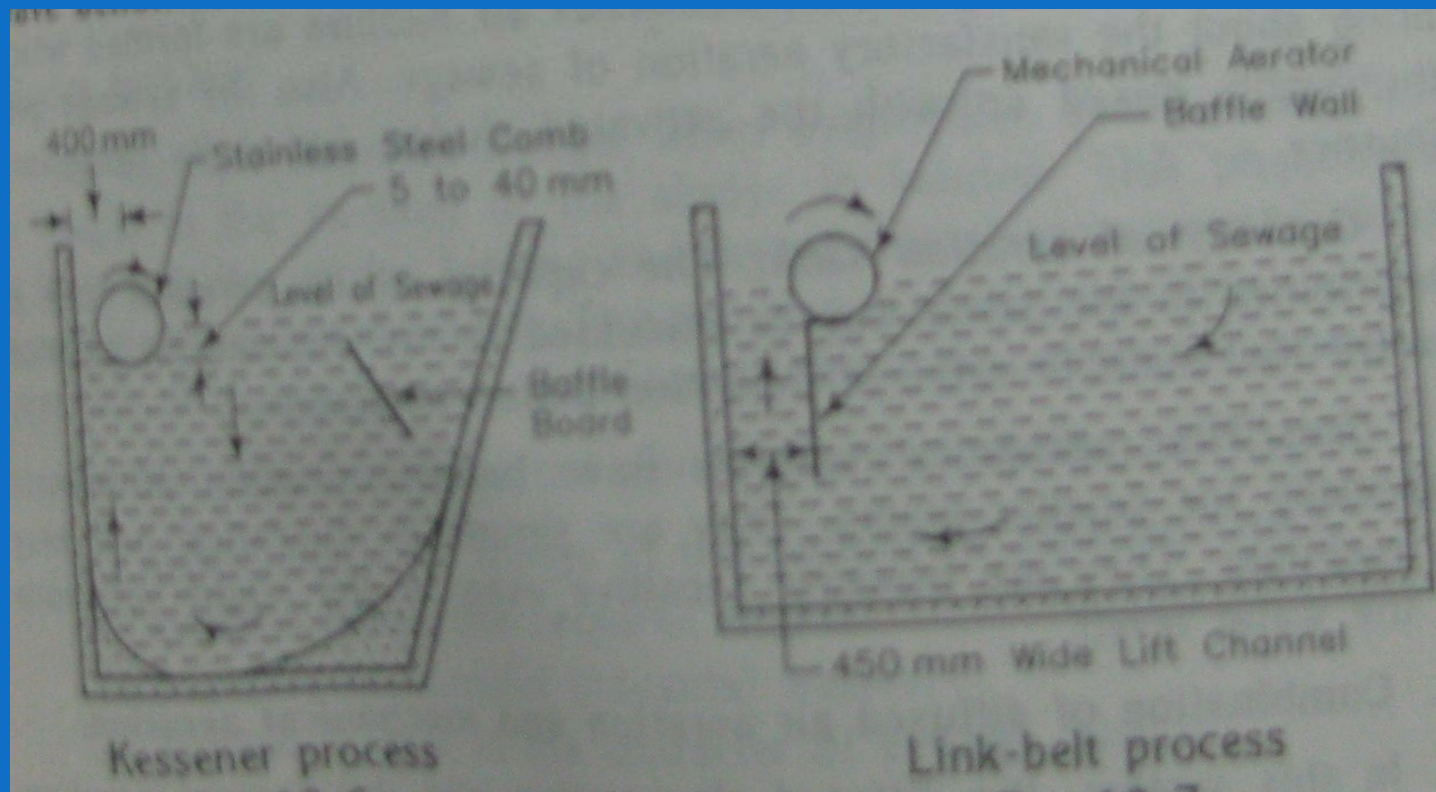
Secondary Treatment

Methods of aeration

Mechanical aeration

iii. Kessener process

iv. Link-belt process



Secondary Treatment

Methods of aeration

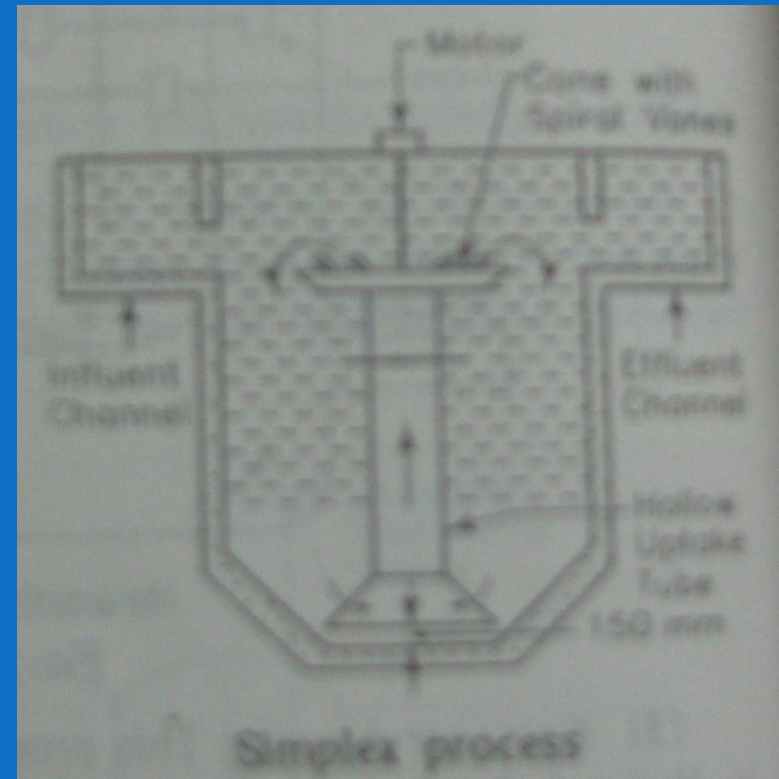
Kessener process: The tank is long and the flow of sewage take place from one end to the other. The agitating device is in the form of a stainless steel comb. It is fixed longitudinally and is partially submerged to a depth of about 5 mm to 40 mm. It rotated at a speed of about 40 to 50 rpm.

Link-belt process: The tank is rectangular and revolving paddles fixed near one side. The paddles rotates at a speed of about 45 to 50 rpm. A lift channel of width of about 450 mm is formed near the aerator by constructing a longitudinal vertical baffle wall.

Secondary Treatment

v. Simplex process

At the centre of tank, a hollow uptake tube is suspended from the top with a distance of about 150 mm from the bottom of the tank. A cone with spiral vanes is provided at the top of uptake tube and it is driven by a motor placed at the top of tank. The speed of rotation is about 60 rpm.

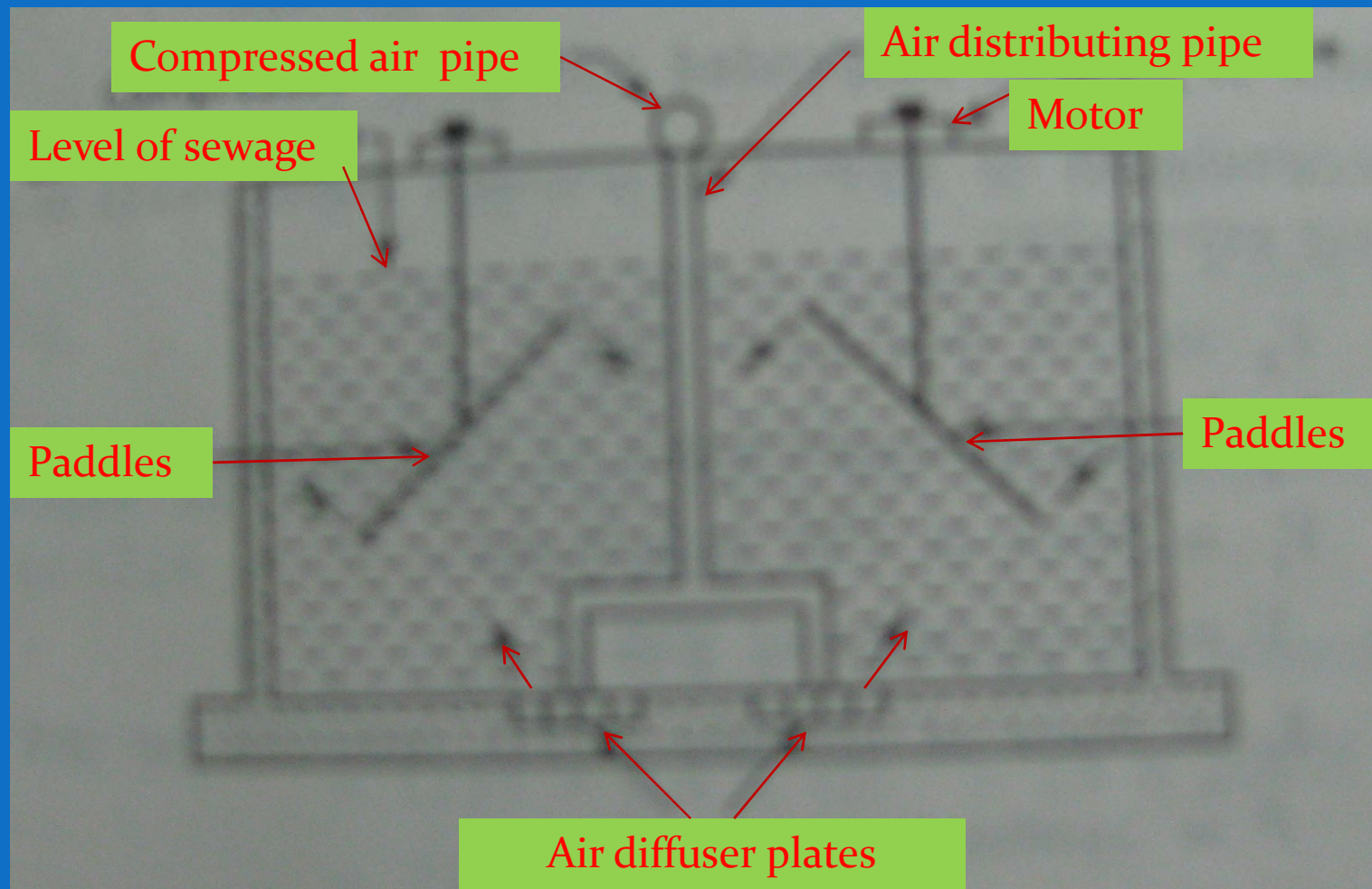


The rotation of cone causes the suction effect and the sewage is sucked through the uptake tube. The sewage then falls on the top surface and air bubbles are formed which creates sufficient aeration.

Secondary Treatment

Methods of aeration

Combination of diffused air aeration and mechanical aeration.



Course Code: CE 441

Course Title: Environmental Engineering

Lecture - 8

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Cycle -4, Day-D
01-07-2019

Secondary Treatment

Step Aeration

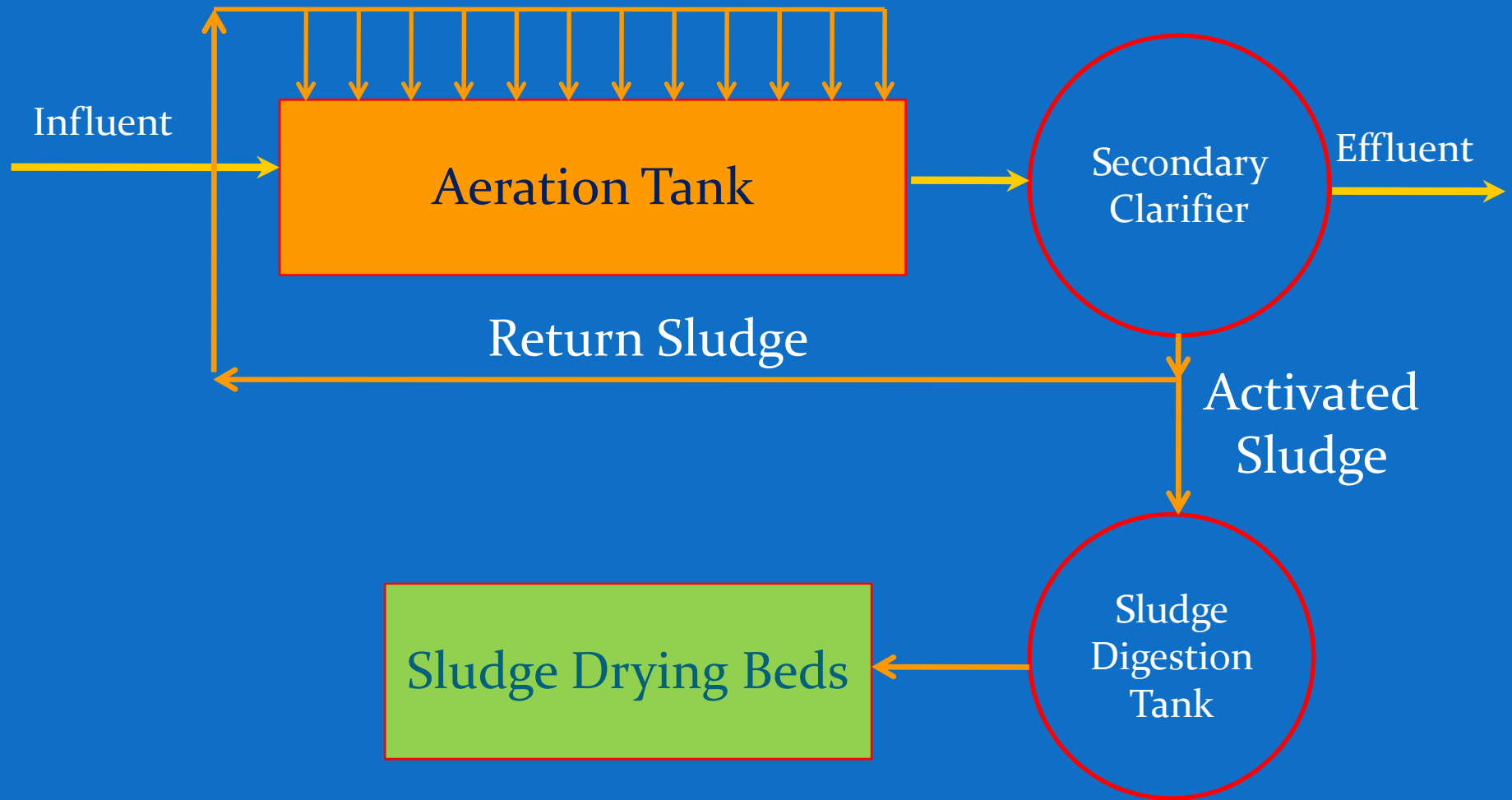
The activated sludge is brought near the inlet end of the aeration tanks. But this activated sludge is not added to the influent at a time or in a single dose as conventional procedure. It is added along the aeration tank in stages as required.

Advantages:

- i. It has considerable capacity to absorb the shock of organic loadings.
- ii. It helps in reducing the aeration tank volume appreciably without sacrificing the efficiency of B.O.D. removal.
- iii. It results in a uniform air requirement along the entire length of the tank. It is thus possible to use the uniform air supply of the conventional plants in most efficient manner.

Secondary Treatment

Step aeration



Secondary Treatment

Tapered Aeration

In this process, the compressed air is supplied at higher rates near inlet end of aeration tank and it is gradually decreased as sewage moves towards the outlet end of the aeration tank.

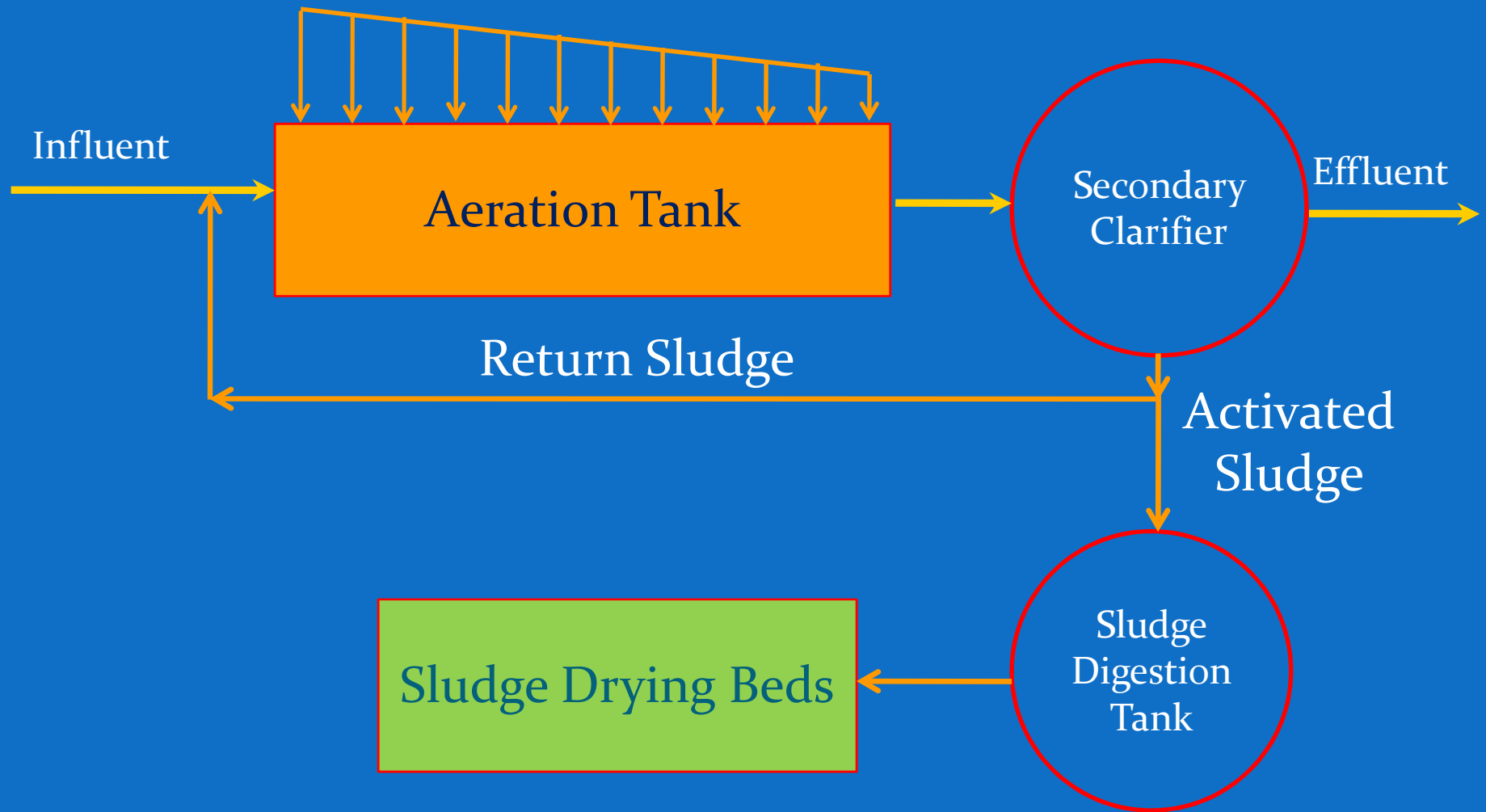
The principle involved in such an arrangement is that the rate of oxygen consumption in the aeration tank is not uniform throughout the tank. It is maximum at the inlet end of the tank and minimum at the outlet end of the tank.

The tapered aeration may consist of an arrangement by which 45% of air is supplied to first one-third length of the tank, 30% to second one-third length of tank and 25% to the remaining length of the tank.

It helps in ensuring optimum application of air in the aeration tank.

Secondary Treatment

Tapered Aeration



Secondary Treatment

Extended Aeration

- i. It uses longer aeration periods of 24 to 48 hours.
- ii. The process operates in the endogenous respiration zone which requires a relatively low organic loading and long aeration time.
- iii. The process produces less sludge volume and the digested sludge is relatively inoffensive in nature.
- iv. The sludge produced is thus capable of being taken directly to the sludge drying beds.

Secondary Treatment

Sludge Bulking

An excellent activated sludge, when overloaded, becomes sick and it results in the swelling of the sludge in volume. This phenomena is known as the sludge bulking and during this phenomena, the sludge assumes unusual great volume. The occurrence of sludge bulking indicates presence of unsatisfactory conditions in the activated sludge process.

Following factors assist the development of sludge bulking:

- Accumulation of sludge at the bottom of aeration tank;
- Aeration below the required degree;
- Presence of harmful industrial wastes;
- Sudden change in the character of sewage; and
- Unusual detention of sludge in the clarifiers.

Secondary Treatment

Sludge Bulking

When sludge bulking occurs, the sludge does not readily settle down. But it remains in suspension in secondary clarifiers and it is even seen in the effluent of the secondary clarifiers. The quality of effluent is thus seriously affected and hence following extreme care should be taken:

- Chlorination of sewage
- Prolonged aeration
- Raising of pH value of sewage to about 8, or so by adding lime
- Re-aeration of returned activated sludge
- Reduction of sewage flow to aeration tank for short period
- Reduction of suspended solids in the sewage.

Secondary Treatment

Sludge Volume Index

The term sludge volume index or S.V.I is used to indicate the degree of concentration of sludge and it reflects the physical state of sludge.

S.V.I. = % of sludge by volume / % of suspended solids by weight

Sludge Density Index

The term sludge density index or S.D.I. is sometimes used in place of S.V.I. and it is given by the following expression:

S.D.I. = (% of suspended solids by weight / % of sludge by volume) × 100

Course Code: CE 441

Course Title: Environmental Engineering

Lecture - 9

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Cycle -5, Day-C

07-07-2019

Secondary Treatment

Accumulation of volatile suspended solids

The accumulation of volatile suspended solids (VSS) is given by:

$$V_a = (rV_i + pX_r) - qV$$

Where, V_a = Accumulation of mass of VSS per unit time

V_i = Mass of VSS in influent

V = Total mass of VSS

X_r = Mass of ultimate B.O.D. removed per unit time

p = Synthesis constant

q = Endogenous respiration constant

r = Non-biodegradable fraction of VSS in influent.

For aerobic oxidation, $p = 0.55$ and $q = 0.15$ can be taken.

Secondary Treatment

Requirement of Oxygen

For supplying energy to the system for synthesis and to permit endogenous respiration, the oxygen will be required and its requirement per unit time is worked out with the help of the following equation:

$$O_2 = 0.39X_r + 1.42 qV.$$

Secondary Treatment

Advantages of activated sludge process

- i. The cost of installation is low.
- ii. The effluent of good quality is obtained.
- iii. The process require small area of land and hence the design may be made compact.
- iv. There is comparatively very small loss of head through the treatment plant.
- v. There is freedom from fly and odour nuisance due to high degree of treatment.

Secondary Treatment

Disadvantages of activated sludge process

- i. There are adverse effect on working process due to sudden increase of volume or change in characteristics of influent.
- ii. The cost of operation is relatively high.
- iii. Sludge production is huge which requires suitable method for its disposal.
- iv. The process is sensitive to certain types of industrial wastes.
- v. The process requires skilled supervision.

Secondary Treatment

Activated sludge process versus Trickling filters

The Biological oxidation is carried out either by activated sludge process or by trickling filters. The basic difference between the processes should be carefully noted:

Activated sludge process	Trickling filters
The bacterial film is contained in the fine suspended matter of the sewage and this film is kept moving by constant agitation.	The bacterial film is formed around the particles of contact materials and it is stationary.

- ❑ The activated sludge process and trickling filters help in achieving more or less the same standard of purification.
- ❑ The adoption of these processes entirely depends on local conditions and practical considerations.

Secondary Treatment

Problem

An activated sludge plant with MLVSS as 2000 mg/l treats with an ultimate B.O.D. of 900 mg/l and 300 mg/l VSS which are 86% biodegradable. If the plant effluent contains 20 mg/l ultimate B.O.D. and 15 mg/l VSS, determine the daily VSS accumulation and the oxygen requirement for a flow of 0.40 m³/s. Take synthesis constant p as 0.55 and the endogenous respiration constant q as 0.15.

Solution:

The expression for VSS accumulation is:

$$V_a = (rV_i + pX_r) - qV$$

Secondary Treatment

Given, $V_i = 300 \text{ mg/l}$

$$V = 2000 \text{ mg/l}$$

$$X_r = (900 - 20) = 880 \text{ mg/l}$$

$$p = 0.55$$

$$q = 0.15$$

$$r = (100 - 86) = 14\% = 0.14$$

Substituting,

$$\begin{aligned} V_a &= (0.14 \times 300 + 0.55 \times 880) - 0.15 \times 2000 \\ &= 226 \text{ mg/l} \end{aligned}$$

As effluent contains 15 mg/l VSS, the net accumulated mass of

$$\text{VSS} = (226 - 15) = 211 \text{ mg/l}$$

$$V_a = (211 \times 0.4 \times 1000) \text{ mg/sec} = 7292 \text{ kg/day}$$

Secondary Treatment

For oxygen requirement, the expression is

$$O_2 = 0.39X_r + 1.42 qV.$$

$$\begin{aligned} O_2 &= (0.39 \times 880) + (1.42 \times 0.15 \times 2000) \\ &= 7692 \text{ mg/l} \end{aligned}$$

$$\begin{aligned} \therefore O_2 \text{ in kg/day} &= (7692 \times 10^{-3} \times 0.4 \times 24 \times 3600) \\ &= 26584 \text{ kg/day.} \end{aligned}$$

Secondary Treatment

Problem

Compare the area requirements for trickling filters (0.14 kg B.O.D./m³-d) and activated sludge (0.65 kg B.O.D./m³-d) for the flow from a town of 30000 population. D.W.F. is 250 lpcd with 300 mg/l B.O.D. Assume a filter depth equal to 2.5 m and 3.5 m deep aeration tank. The primary sedimentation removes 40% of the applied B.O.D.

Solution

D.W.F. = 250 lpcd; population = 30000

$$\begin{aligned}\therefore \text{Total D.W.F.} &= Q = (250 \times 30000) \\ &= 7.5 \times 10^6 \text{ l/day.} \\ &= 86.80 \text{ l/sec} \cong 87 \text{ l/sec}\end{aligned}$$

Secondary Treatment

Solution

Now , Applied B.O.D. = 300 mg/l

40% of applied B.O.D. is removed in primary sedimentation.

∴ B.O.D. of effluent entering in secondary treatment unit
= (0.6 × 300) = 180 mg/l.

∴ B.O.D. in kg per day = 180 × 10⁻⁶ × 87 × 3600 × 24)
= 1353 kg/day

For Trickling filter:

Rate of B.O.D. removal = 0.14 kg/m³-day.

∴ Volume required = 1353/0.14
= 9664.29, say 9665 m³.

Now, depth = 2.5 m

∴ Area required = 9665/2.5 = 3866 m².

Secondary Treatment

Solution

For Aeration tank:

Rate of B.O.D. removal = 0.65 kg/m³-day.

$$\begin{aligned} \therefore \text{Volume required} &= 1353/0.65 \\ &= 2081.54, \text{ say } 2082 \text{ m}^3. \end{aligned}$$

Now, depth = 3.5 m

$$\begin{aligned} \therefore \text{Area required} &= 2082/3.5 \\ &= 594.86, \text{ say } 595 \text{ m}^2. \end{aligned}$$

$$\therefore \text{Area required for trickling filter} = 3866 \text{ m}^2 / 595 \text{ m}^2 = 6.5$$

*\therefore Area required for trickling filter is **6.5 times** of activated sludge process*

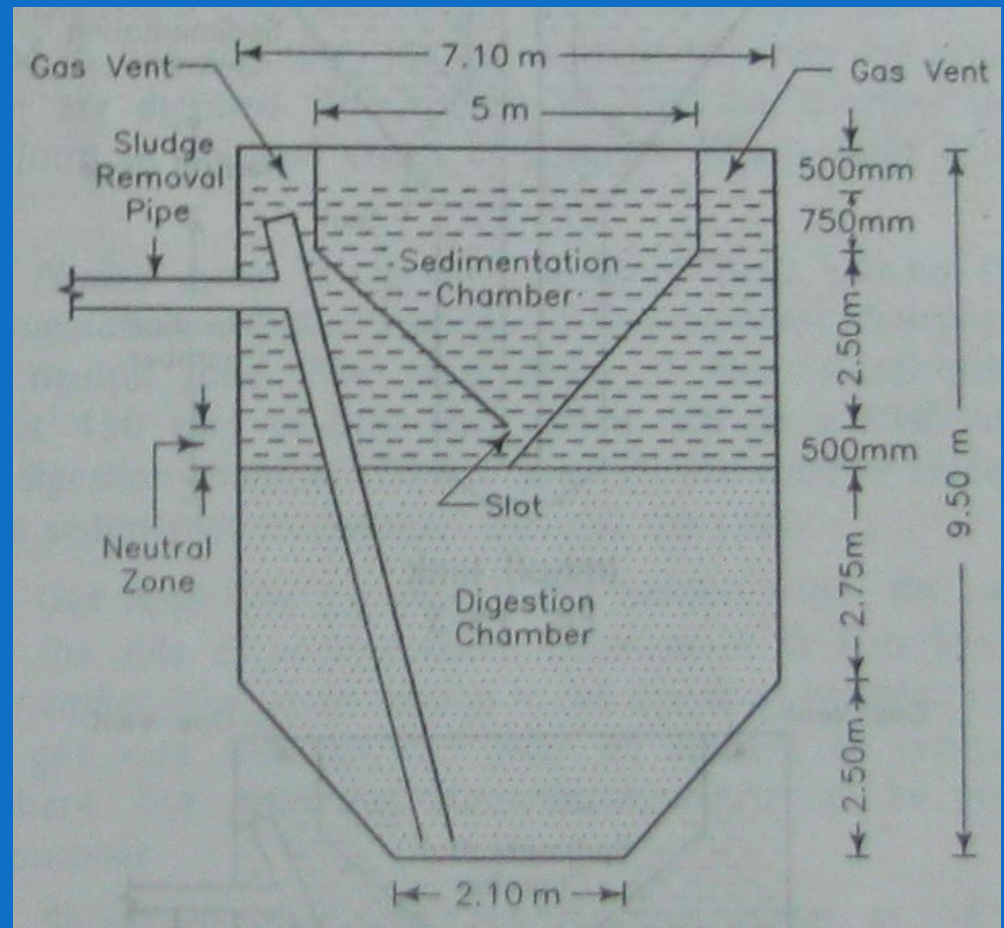
Sludge Treatment

Imhoff tanks

Imhoff tanks have two storey and some times called two storey tanks.

Component part:

- Sedimentation chamber
- Slot
- Digestion chamber
- Neutral zone
- Gas vent
- Sludge removal pipe
- Roofs



Imhoff Tank

Design aspects

Sedimentation chamber:

This has rectangular shape with length not exceeding 30 m. The ratio of length to width varies from 3 to 5.

The total depth of imhoff tank varies from 6 m to 11 m with depth of sedimentation chamber as about 3 m. The freeboard should be of 450 mm to 600 mm depth.

The velocity of flow in sedimentation chamber is kept as about 300 mm/min.

For ordinary sewage, the detention period varies from 2 to 4 hours, the common being 2 hours.

The overflow rate or surface loading should not exceed 30000 l/m²/day. But it may be increased to about 45000 l/m²/day for the effluent coming from the activated sludge plant or where recirculation is adopted.

Imhoff Tank

Design aspects

Digestion chamber:

This chamber is generally designed for a minimum capacity of 0.057 m^3 per capita. But for warm climate, it may be reduced to about 0.035 m^3 to 0.04 m^3 per capita.

The digestion chamber is generally designed to store sludge for 1 to 6 months, the common being 2 months or so.

Gas vent:

The area of scum chamber should be about 25% to 30% of total plan area of the tank with a freeboard of about 450 mm to 600 mm.

Imhoff Tank

Advantages

Following are the advantages of an Imhoff tank:

- i. It is possible to dry easily the sludge obtained from the imhoff tank.
- ii. The process of sludge digestion in the imhoff tank is better than that of the septic tank.
- iii. The tank delivers better effluent than that received from the plain sedimentation tank.
- iv. The tank does not require constant skill supervision.
- v. The tank is quite efficient in the removal of B.O.D. and settleable solids. The B.O.D. is removed to the extent of about 30 to 40% and the settleable solids are removed to the extent of about 60%.

Imhoff Tank

Disadvantages

Following are the disadvantages of an Imhoff tank:

- i. The depth of tank is more and this aspect may make its construction uneconomical in hard soils.
- ii. The tank gives out offensive odours when it is improperly operated.
- iii. The tank has a tendency to foam or boil. This leads the scum to go up to the top of tank and it also forces the sludge particles to enter the sedimentation chamber through the slot. The foaming thus affects adversely on the quality of effluent.
- iv. The tank is unsuitable and does not function properly where high acidic condition exist.

Course Code: CE 441

Course Title: Environmental Engineering

Lecture - 10

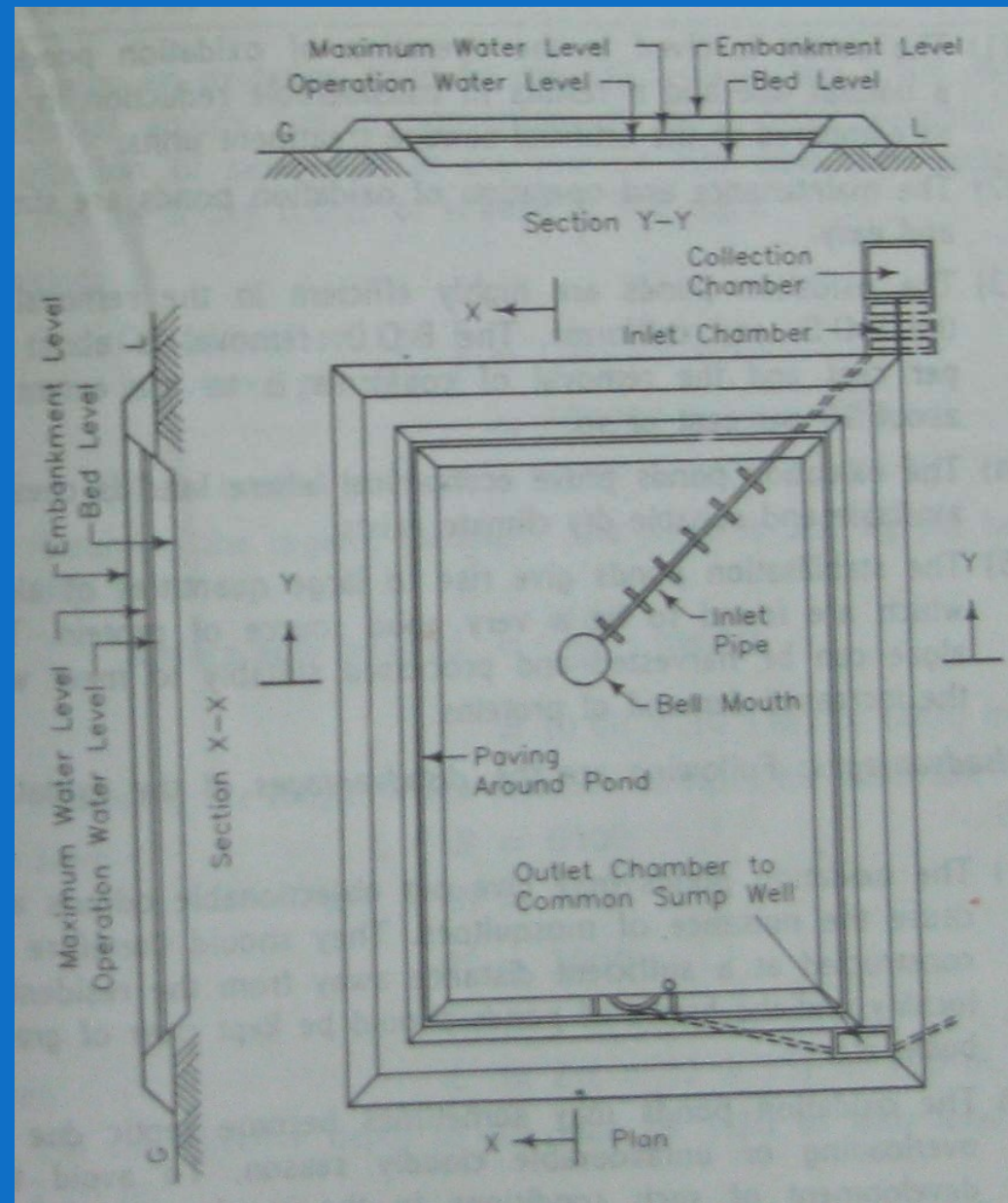
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Cycle -5, Day-D
08-07-2019

Oxidation Pond

An artificial pond of shallow depth formed for the retention of sewage for sufficient time is known as an oxidation pond or oxidation ditch or sewage stabilization pond or lagoon.

The ponds may be used to treat raw sewage or partially treated sewage.



Oxidation Pond



Oxidation Pond

Action

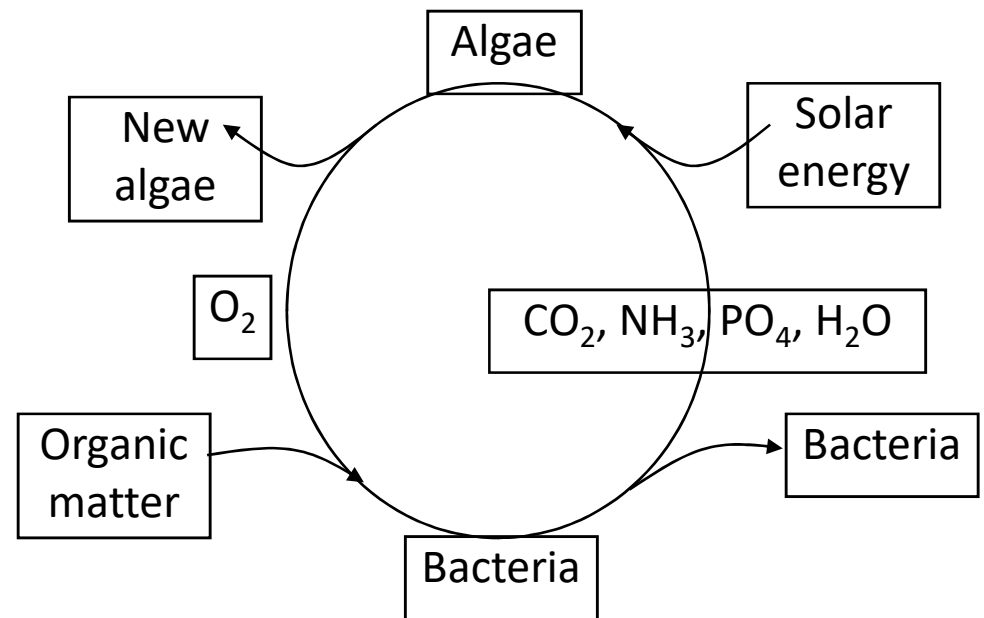
The oxidation ponds purify sewage by dual action of aerobic bacteria and algae. The sewage is stored under aerobic conditions which are favourable for the growth of algae, namely, sunshine and warmth.

The aerobic bacteria obtain oxygen from the atmosphere and use it in the decomposition of carbohydrates of sewage. Carbohydrates is also broken up by algae by the process of photosynthesis into carbon and oxygen.

The carbon is used in producing more carbohydrates and the released oxygen keeps the dissolved oxygen content of water at high level.

Algae and Bacterial Symbiosis

Algae which grows naturally in pond, where considerable quantities of both matrices and light is available. The pond bacteria utilize this algal O_2 to be oxidizing the organic waste. One of the major end products of bacteria metabolism is CO_2 which is utilized by algae. This mutual dependence of bacteria and algae in stabilization pond is known as Bacteria-algae symbiosis.



Oxidation Pond

Construction

- ❑ The oxidation ponds are constructed with shallow depth of about 900 mm to 1500 mm.
- ❑ The shallow depth permits the penetration of sunlight into the body of sewage and it thus encourages the growth of algae.
- ❑ It is desirable to provide a freeboard of about one meter or so.
- ❑ The pond is constructed into compartments of suitable sizes and the sewage is allowed to flow in zigzag manner through these compartments.

Oxidation Pond

Design Aspects

For proper development of algae, the detention period should be at least 7 days and preferably 2 to 6 weeks.

The area required for oxidation ponds varies considerably with the climatic conditions of the locality. It varies from 250 to 1000 persons per hectare.

The loading may also be expressed in terms of B.O.D. The loading on this basis varies from 150 to 300 kg per hectare per day.

Under certain circumstances, the oxidation ponds may produce no effluent because of evaporation and seepage. But in practice, most of the oxidation ponds are usually designed as unit with continuous flow.

Oxidation Pond

Classification of Stabilization Ponds

Stabilization ponds may be aerobic, anaerobic or facultative.

Aerobic ponds are shallow ponds with depth less than 0.5 m and BOD loading of 40-120 kg/ha.d so as to maximize penetration of light throughout the liquid depth. Such ponds develop intense algal growth.

Anaerobic ponds are used as pretreatment of high strength wastes with BOD load of 400-3000 kg/ha.d. Such ponds are constructed with a depth of 2.5-5 m as light penetration is unimportant.

Facultative pond functions aerobically at the surface while anaerobic conditions prevail at the bottom. They are often about 1 to 2 m in depth. The aerobic layer acts as a good check against odour evolution from the pond.

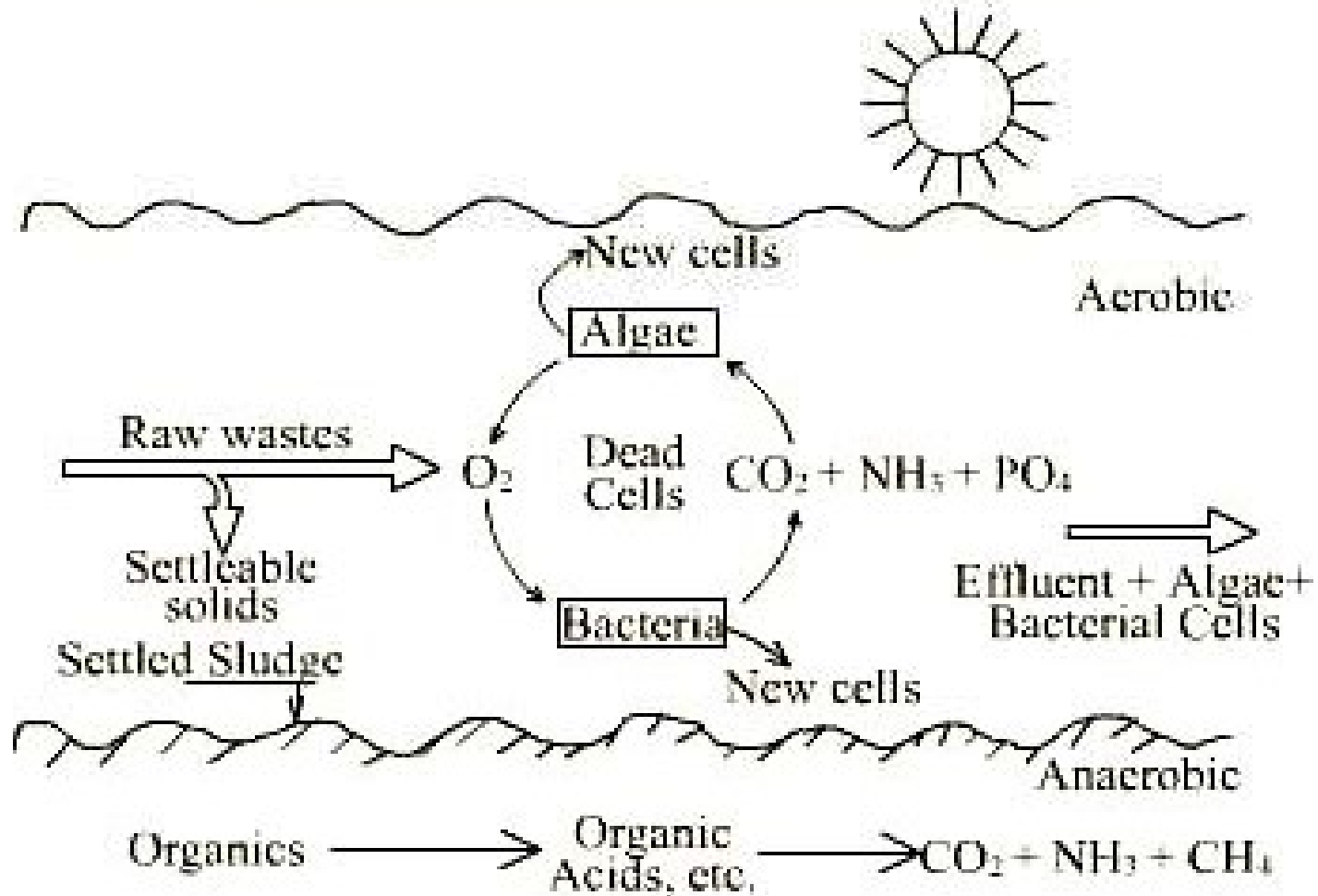
Oxidation Pond

Mechanism of Purification in Facultative Pond

The functioning of a facultative stabilization pond and symbiotic relationship in the pond are shown below. Sewage organics are stabilized by both aerobic and anaerobic reactions. In the top aerobic layer, where oxygen is supplied through algal photosynthesis, the non-settleable and dissolved organic matter is oxidized to CO_2 and water. In addition, some of the end products of partial anaerobic decomposition such as volatile acids and alcohols, which may permeate to upper layers are also oxidized periodically. The settled sludge mass originating from raw waste and microbial synthesis in the aerobic layer and dissolved and suspended organics in the lower layers undergo stabilization through conversion to methane which escapes the pond in form of bubbles.

Oxidation Pond

SYMBIOTIC RELATIONSHIP AND FUNCTIONING OF FACULTATIVE STABILIZATION POND



Oxidation Pond

Factors Affecting Pond Reactions

Various factors affect pond design:

- wastewater characteristics and fluctuations.
- environmental factors (solar radiation, light, temperature)
- algal growth patterns and their diurnal and seasonal variation
- bacterial growth patterns and decay rates.
- solids settlement, gasification, upward diffusion, sludge accumulation.

Oxidation Pond

Algal Growth and Oxygen Production

Algal growth converts solar energy to chemical energy in the organic form. Empirical studies have shown that generally about 6% of visible light energy can be converted to algal energy.

The chemical energy contained in an algal cell averages 6000 calories per gram of algae.

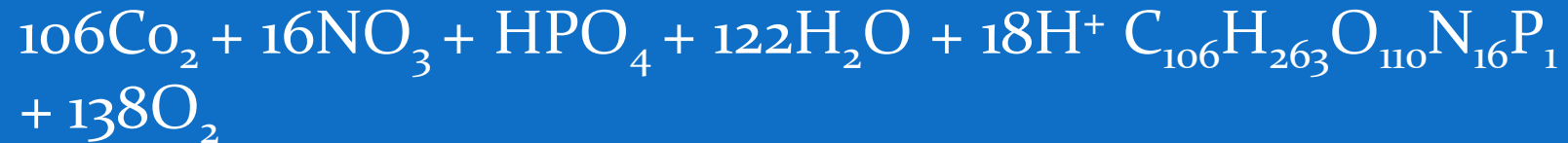
Depending on the sky clearance factor for an area, the average visible radiation received can be estimated as follows:

Avg. radiation=Min. radiation+[(Max. radiation-Min. radiation) x sky clearance factor]

Oxidation Pond

Algal Growth and Oxygen Production

Oxygen production occurs concurrently with algal production in accordance with following equation:



On weight basis, the oxygen production is 1.3 times the algal production.

Oxidation Pond

Advantages

- i. The action involved in the operation of oxidation ponds is a natural one and it results in considerable reduction in cost as compared to the artificial sewage treatment units.
- ii. The maintenance and operation are simple and easy.
- iii. The oxidation ponds are highly efficient in the removal of the B.O.D. and coliforms. The B.O.D. removal is about 90% and the removal of coliforms is to the extent of about 99% or so.
- iv. The oxidation ponds prove economical where land is chiefly available and suitable dry climate exists.
- v. The stabilization ponds give rise to large quantities of algae which are found to be a very good source of protein. The algae can be harvested and processed suitably to meet with the increased demand of proteins.

Oxidation Pond

Disadvantages

- i. The oxidation ponds may give out objectionable odours and cause the nuisance of mosquitoes. They should therefore be constructed at a sufficient distance away from the residential locality and the banks of ponds should be kept clear of grass, bush, etc.
- ii. The oxidation ponds may sometimes become septic due to overloading or unfavourable cloudy season. To avoid the development of such conditions in the ponds, the sodium nitrate may sometimes be added to the ponds.

Oxidation Pond

Problem:

Determine the size of a facultative pond needed to treat wastewater of BOD₅ of 400 mg/l

given the following data:

Effluent BOD = 60 mg/l

Wastewater flow = 2000 m³/d

Depth of pond = 1.5 m

Lowest temperature = 24° C

Removal rate constant for pond, $k_p = 0.35/\text{day}$ at 20° C.

$$(k_p)_T = (k_p)_{20} \cdot (1.05)^{T-20}$$

Oxidation Pond

Solution:

Assuming complete mixing conditions then,

$$\frac{L_e}{L_i} = \frac{1}{1 + k_p t}$$

Where

L_e = Effluent BOD = 60 mg/L.

L_i = Influent BOD = 400 mg/L.

t = Retention time, or mean hydraulic retention time, d.

k_p = Removal rate constant for waste stabilization pond, d^{-1} .

$[k_p]_{24} = [k_p]_{20} \{1.05\}^{[T-20]} = 0.35(1.05)^{[24-20]} = 0.425 /d$

Then,

$$60/400 = 1/\{1 + 0.425*t\}.$$

This yields a detention time of $t = 13.3$ days = V/Q

The volume, $V = t*Q = 13.3*2000 = 26600 \text{ m}^3$.

Surface area = Volume/depth = $26600/1.5 = 17733 \text{ m}^2$.

Oxidation Pond

Problem:

A facultative type aerated pond is to serve 10000 people and treat sewage of the following properties:

Wastewater flow = 150 l/capita.d

Influent 5-day BOD = 54 g/capita.d

Design the pond to achieve an effluent BOD of 30 mg/l.

(Assume winter temperature of lagoon to be 16° C. $k_p = 2.2$ /day at 20° C.).

Oxidation Pond

Solution:

$$[k_p]_{16} = 2.2(1.05)^{[16-20]} = 1.72 \text{ /d}$$

$$Li = 54 \times 103/150 = 360 \text{ mg/l}$$

$$\frac{L_e}{L_i} = \frac{1}{1 + k_p t}$$

$$\frac{30}{360} = \frac{1}{1 + 1.72t}$$

From which, $t = 6.4$ days

$$V = t.Q = 6.4 \times 150 \times 10000/1000 = 9600 \text{ m}^3$$

Assuming a depth of 3 m then,

$$\text{Surface area of pond} = 9600/3 = 3200 \text{ m}^2.$$

Oxidation Pond

Problem:

A maturation pond is capable of reducing the number of *e.typhi* by 99.5%. Compute pond retention time and volume needed for treating a daily sewage flow of 250m³. \9take k' (bacterial die away rate) = 0.8 /day).

Solution:

The rate of die-away of faecal organisms in a single maturation pond is given by:

$$\frac{N_e}{N_i} = \frac{1}{1 + k't}$$

Where:

N_e = Effluent bacterial number, number of bacteria/100 mL.

N_i = Influent bacterial number, number of bacteria/100 mL.

k' = Bacterial-die away rate, d⁻¹.

t = Retention time, d.

Oxidation Pond

$$\frac{N_e}{N_i} = \frac{100 - 99.5}{100t} = 5 \times 10^{-3}$$

Therefore,

$$5 \times 10^{-3} = \frac{1}{1 + 0.8't}$$

Which yields, $t = 249$ days = V/Q

$$V = 250 \text{ m}^3/\text{d} \times 249 \text{ d} = 62250 \text{ m}^3$$

Oxidation Pond

Problem:

Compute the number and size of maturation ponds needed to treat wastewater flowing at a rate of 300 m³/d containing 10⁶ *E. coli*/100 ml. The number of microorganisms emerging with the effluent is 2000/ml. (Take k' = 2 /day for the species and pond retention time of 20 days).

Solution:

For multi-celled ponds:

$$\frac{N_e}{N_i} = \frac{1}{(1 + k't)^n}$$

Where n is the number of ponds in series.

Then,

$$\frac{2000}{10^6} = \frac{1}{(1 + 2 \times 20)^n}$$

Therefore, number of ponds = 2

Total volume required = 2 x 20 x 300 = 12000 m³

Course Code: CE 441

Course Title: Environmental Engineering

Lecture - 11

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**Cycle -6, Day-C
14-07-2019**

Microbiology in Wastewater Engineering

Biological treatment is accomplished through the metabolic activities of micro-organisms within its cell. The metabolic activities within the cell of micro-organisms are explained in subject of biochemistry. Therefore, it is important to know the cell physiology and biochemistry of micro-organisms related to water and waste water treatment.

Objectives of Biological Treatment

To coagulate and remove the non-settleable colloidal solids and to stabilize the organic matter.

For domestic wastewater

- To reduce the organic content.
- To reduce the nutrients such as nitrogen and phosphorus.
- To remove the trace organic compounds that may be toxic.

Objectives of Biological Treatment

For agricultural return wastewater

To remove the nutrients, specifically nitrogen and phosphorus that are capable to stimulating the growth of aquatic plants.

For industrial wastewater

To remove or reduce the concentration of organic and inorganic compounds. Because many of these compounds are toxic to micro-organisms.

Important Micro-organisms Related to Wastewater Engineering

Bacteria

The highest population of microorganisms in a wastewater treatment plant will belong to the bacteria. They are single-celled organisms which use soluble food. Reproduce by binary fission (dividing into two).

Fungi

Fungi are multicellular, nonphotosynthetic, heterotropic organisms.

Fungi are obligate aerobes that reproduce by fission, budding, and spore formation.

Their cells require only half as much nitrogen as bacteria so that in a nitrogen-deficient wastewater, they predominate over the bacteria.

Important Micro-organisms Related to Wastewater Engineering

Algae

Photoautotrophs and may be either unicellular or multicellular.

Because of the chlorophyll contained in most species, they produce oxygen through photosynthesis.

In the presence of sunlight, the photosynthetic production of oxygen is greater than the amount used in respiration.

At night they use up oxygen in respiration.

If the daylight hours exceeds the night hours by a reasonable amount, there is a net production of oxygen.

Important Micro-organisms Related to Wastewater Engineering

Protozoa

Protozoa are single-celled organisms that can reproduce by binary fission (dividing into two).

Most are aerobic chemoheterotrophs, and they consume bacteria.

They are desirable in wastewater effluents because they act as polishers in consuming the bacteria.

Important Micro-organisms Related to Wastewater Engineering

Rotifers and crustaceans

Both rotifers and crustaceans are animals – aerobic, multicellular chemoheterotrophs.

The rotifer derives its name from the apparent rotating motion of two sets of cilia on its head.

The cilia provide mobility and a mechanism for catching food.

Rotifers consume bacteria and small particles of organic matter.

Important Micro-organisms Related to Wastewater Engineering

Crustaceans, a group that includes shrimp, lobsters, and barnacles, are characterized by their shell structure.

They are a source of food for fish and they are not found in wastewater treatment systems to any extent except in underloaded lagoons.

Their presence is indicative of a high level of dissolved oxygen and a very low of organic matter.

Classification of Microorganisms

CLASSIFICATION OF MICROORGANISMS Based on nucleus structure

Class	Characteristics	Examples
Eucaryotes	Cells contain membrane-bound nucleus and membranous organelles.	Rotifers, Crustaceans, Mosses, Ferns, Algae, Yeasts, Amoebas, Fungi.
Procaryotes	No distinct nucleus and no membranous organelles.	Bacteria: <i>Salmonella</i> <i>Escherichia</i>

CLASSIFICATION OF MICROORGANISMS

Based on kingdom

	Kingdoms	Characteristics	Examples
Eucaryotes	Animals	Multicellular, motile, exhibit tissue differentiation, heterotrophic	Rotifers, Crustaceans
	Plants	Multicellular, nonmotile, exhibit tissue differentiation, most photosynthetic	Mosses, Ferns, Some algae
	Fungi	Most multicellular, nonmotile, heterotrophic, decomposers	Mushrooms, Yeast
	Protista	Most unicellular, most motile, some heterotrophic, some photosynthetic	Amoebas, Some algae
Procarryo	Bacteria	Unicellular, some motile, some nonmotile, some heterotrophic, decomposers.	<i>Salmonella</i> <i>Escherichia</i>

CLASSIFICATION OF MICROORGANISMS

Based on energy and carbon source

Heterotrophic: If the microorganism uses organic material as a supply of carbon, it is called *heterotrophic*.

Autotrophic: If the microorganisms require only CO_2 to supply their carbon needs, it is called *Autotrophic*.

Phototrophic: Organisms that rely only on the sun for energy are called *phototrophic*.

Chemotrophic: If the microorganisms extract energy from organic or inorganic oxidation/reduction reactions, it is called *chemotrophic*.

Organotrophs use organic materials, while *lithotrophs* oxidize inorganic compounds in oxidation/reduction reactions.

Course Code: CE 4141

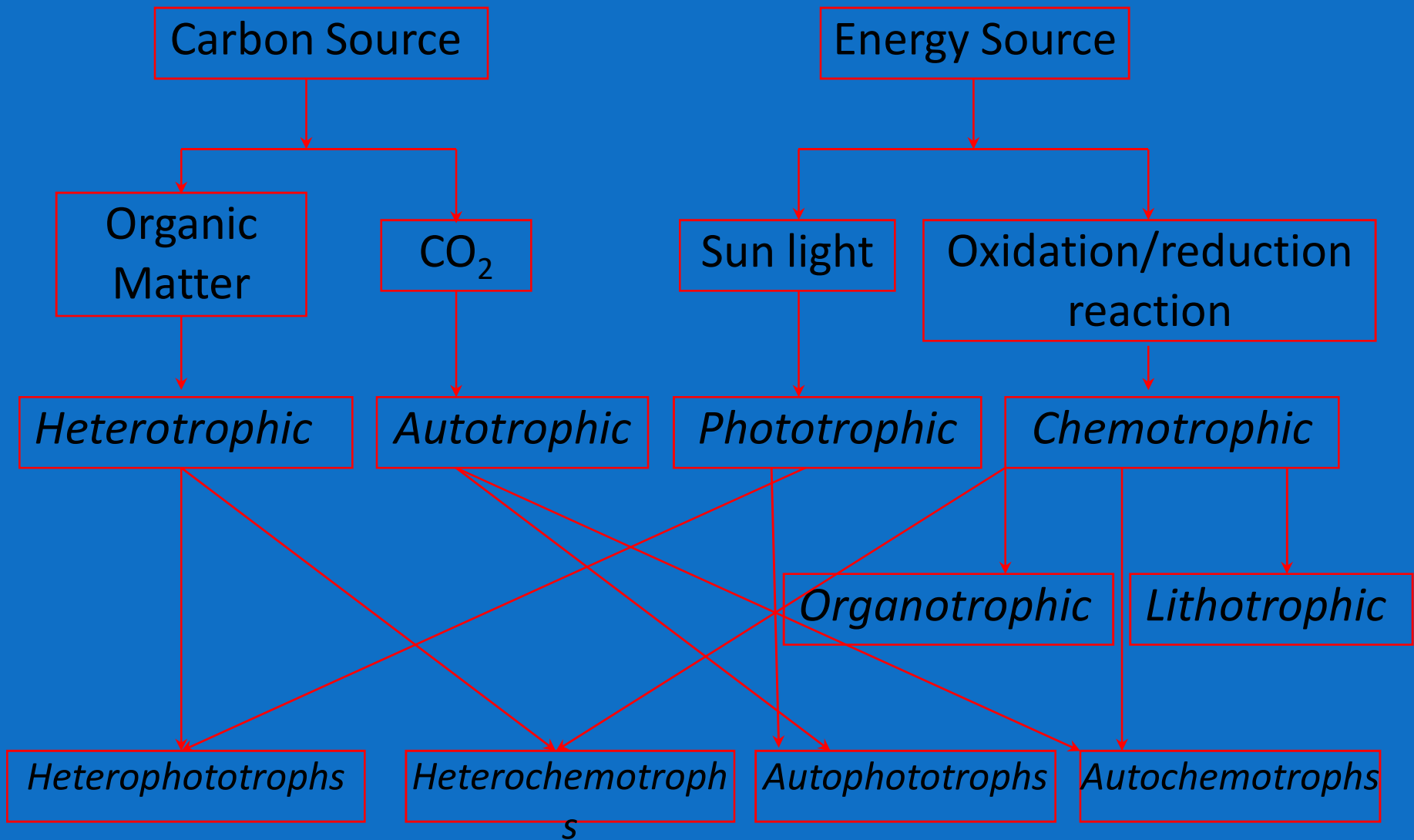
Course Title: Environmental Engineering

Lecture - 12

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Cycle -6, Day-D
15-07-2019

CLASSIFICATION OF MICROORGANISMS



CLASSIFICATION OF MICROORGANISMS

Heterophototrophs: If the microorganism uses organic material as a supply of carbon and sun light as source of energy, it is called *heterophototrophic*.

Heterochemotrophs: If the microorganism uses organic material as a supply of carbon and CO_2 as source of energy, it is called *heterochemotrophic*.

Autophototrophs: If the microorganisms require only CO_2 to supply their carbon needs and sun light as source of energy, it is called *Autophototrophs*.

Autochemotrophs: If the microorganisms require only CO_2 to supply their carbon needs and extract energy from organic or inorganic oxidation/reduction reactions, it is called *Autochemotrophs*.

CLASSIFICATION OF MICROORGANISMS

Based on relationship to oxygen

Aerobes: The microorganisms that cannot survive in absence of oxygen are classified as *aerobes*. They use oxygen as a terminal electron acceptor in oxidation/reduction reactions. When wastewater contains oxygen and can support aerobes, it is called *aerobic*.

Anaerobes: *Anaerobes* are microorganisms that cannot survive in presence of oxygen. They cannot use oxygen as a terminal electron acceptor. Wastewater that is devoid of oxygen is called *anaerobic*.

CLASSIFICATION OF MICROORGANISMS

Based on relationship to oxygen

Facultative: Facultative microorganisms can survive both in presence and absence of oxygen.

They can use oxygen as the terminal electron acceptor under certain conditions.

Under anoxic conditions, a group of facultative anaerobes called *denitrifiers* utilizes nitrites (NO_2^-) and nitrates (NO_3^-) as the terminal electron acceptor.

Nitrate nitrogen is converted to nitrogen gas in the absence of oxygen. This process is called ***anoxic denitrification.***

CLASSIFICATION OF MICROORGANISMS

Based on preferred temperature regime

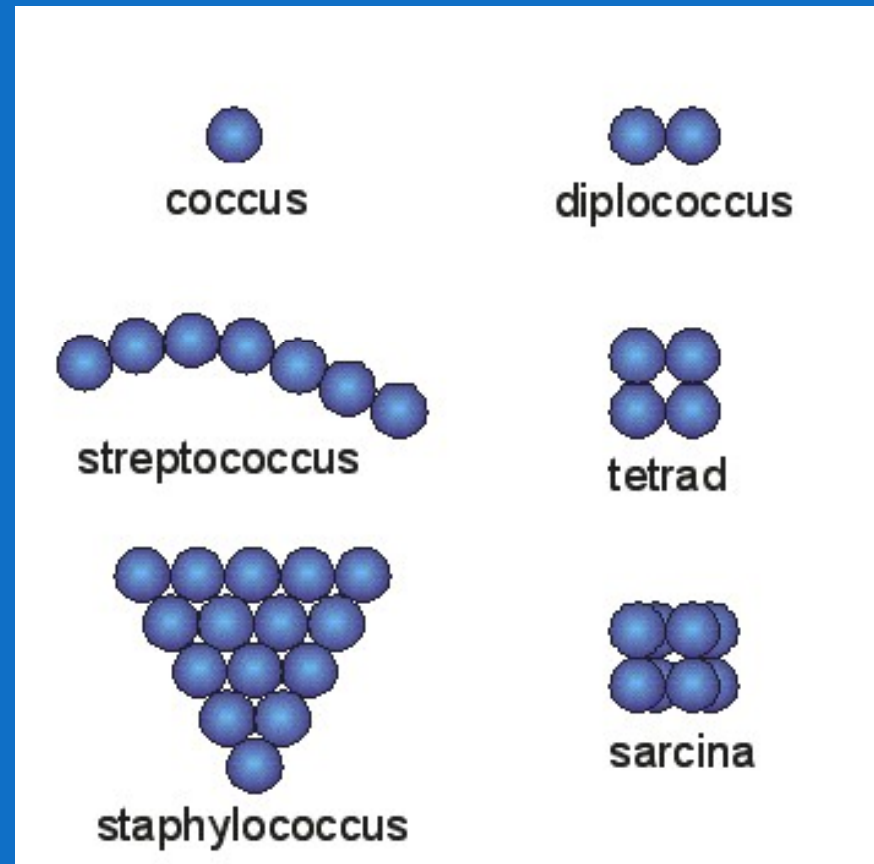
Temperature range	Class
<20°C	<i>Psychrophiles</i>
25 to 40°C	<i>Mesophiles</i>
45 to 60°C	<i>Thermophiles</i>
> 60°C	<i>Stenothermophiles</i>

CLASSIFICATION OF MICROORGANISMS

Based on shape

Spherical: The cocci are spherical or oval bacteria having one of several distinct arrangements based on their planes of division. An average coccus is about 0.5-1.0 micrometer (μm) in diameter.

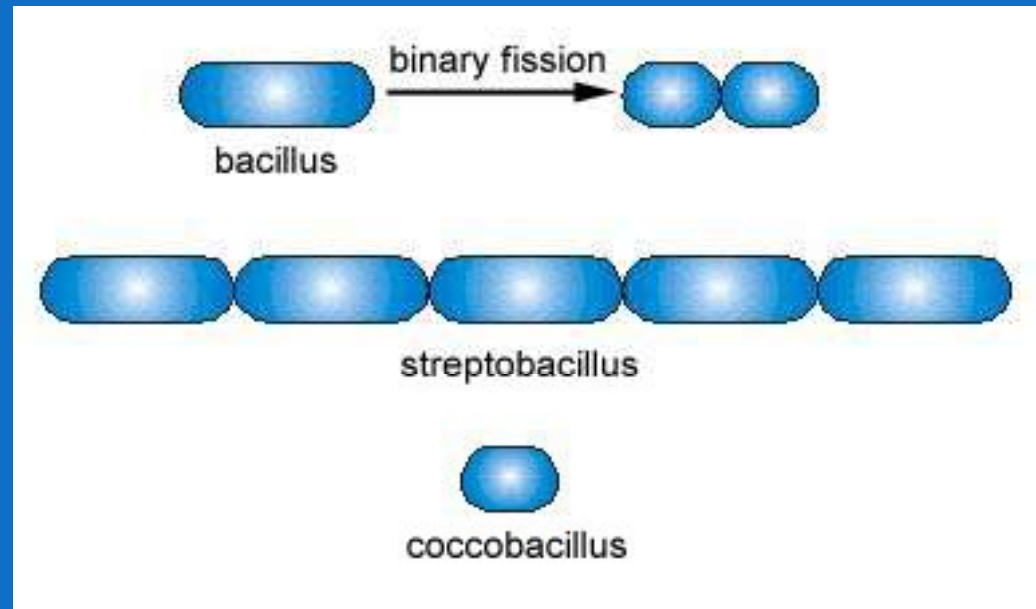
Spherical bacteria as small as 50-500 nm in diameter have been reported.



CLASSIFICATION OF MICROORGANISMS

Rod:

Bacilli are rod-shaped bacteria. Bacilli all divide in one plane producing a **bacillus**, **streptobacillus**, or **coccobacillus** arrangement. An average bacillus is 0.5-1.0 μm wide by 1.0-4.0 μm long.



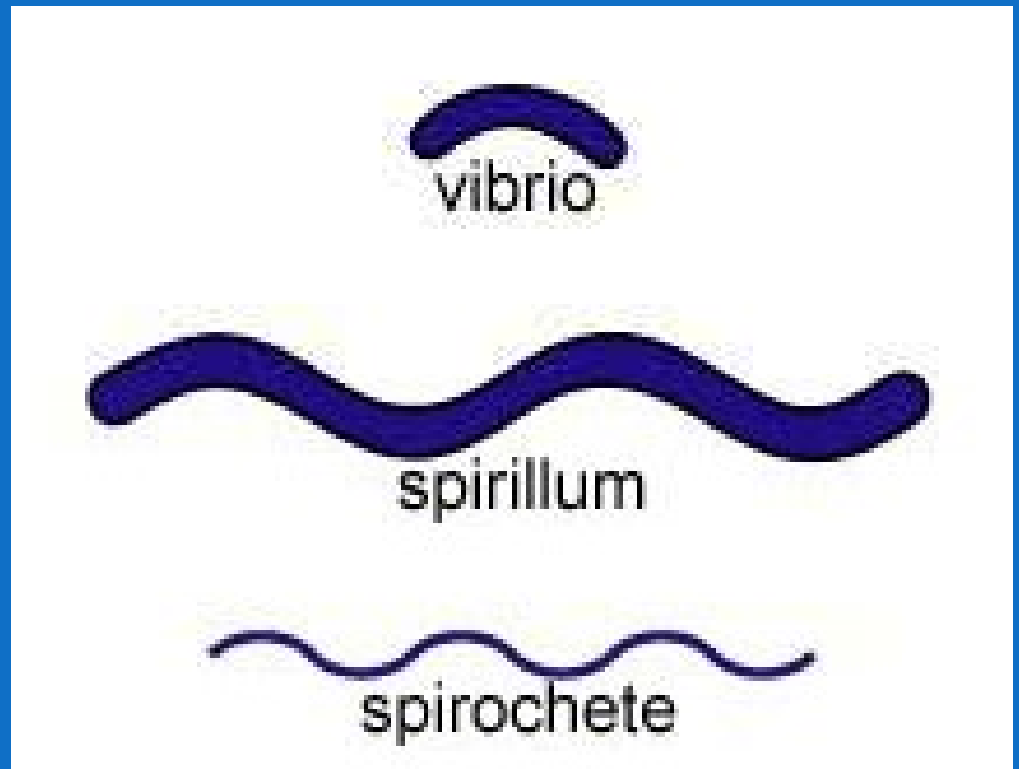
CLASSIFICATION OF MICROORGANISMS

Spiral or Helical:

Spirals come in one of three forms, a **vibrio**, a **spirillum**, or a **spirochete**.

Spirals range in size from 1 μm to over 100 μm in length.

The largest known bacterium is *Thiomargarita namibiensis*, with spheroidal diameters from 100-750 microns.



Role of Micro-organisms in Treatment of Sewage and Polluted Water

The removal of carbonaceous BOD, the coagulation of nonsettleable colloidal solids, and the stabilization of organic matter are accomplished biologically using a variety of micro-organisms, principally bacteria.

The micro-organisms are used to convert the colloidal and dissolved carbonaceous organic matter into various gases and into cell tissue.

Because cell tissue has a specific gravity slightly greater than that of water, the resulting cells can be removed from the treated liquid by gravity settling.

Microbial Metabolism

The general term that describes all of the chemical activities performed by a cell is *metabolism*.

This in turn is divided into two parts: catabolism and anabolism.

Catabolism includes all the biochemical processes by which a substrate is degraded to end products with the release of energy.

In wastewater treatment, the substrate is oxidized.

The oxidation process releases energy that is transferred to an energy carrier which stores it for future use by the bacterium.

Anabolism is the synthesis of complex molecules in living organisms from simpler ones together with the storage of energy, constructive metabolism.

Decomposition of Waste

The type of electron acceptor available for catabolism determines the type of decomposition (that is, **aerobic**, **anoxic**, or **anaerobic**) used by a **mixed culture** of microorganisms. Each type of decomposition has peculiar characteristics which affect its use in waste treatment.

Aerobic Decomposition

Molecular oxygen (O_2) must be present as the terminal electron acceptor for decomposition to proceed by aerobic oxidation through bacterial metabolism. As in natural water bodies, the oxygen is measured as DO. When oxygen is present, it is the only terminal electron acceptor used. Hence, the chemical end products of decomposition are primarily **carbon dioxide, water, and new cell material**.

Decomposition of Waste

Anoxic Decomposition

Some microorganisms can use nitrate (NO_3^-) as the terminal electron acceptor in the absence of molecular oxygen. Oxidation by this route is called **denitrification**.

The end products from denitrification are **nitrogen gas**, **carbon dioxide**, **water** and **new cell material**.

The amount of energy made available to the cell during denitrification is about the same as that made available during aerobic decomposition.

As a consequence, the rate of production of new cells, although not as high as in aerobic decomposition, is relatively high.

Decomposition of Waste

Anaerobic Decomposition

In order to achieve anaerobic decomposition, molecular oxygen and nitrogen must not be present as terminal electron acceptors.

Sulfate (SO_4^{2-}), carbon dioxide, and organic compounds that can be reduced serve as terminal electron acceptors.

The reduction of sulfate results in the production of hydrogen sulfide (H_2S) and a group of equally odiferous organic sulfur compounds called *mercaptans*.

Decomposition of Waste

Anaerobic Decomposition

The anaerobic decomposition (fermentation) of organic matter generally is considered to be a two-step process.

In the first step, complex organic compounds are fermented to low-molecular-weight fatty acids (volatile acids).

In the second step, the organic acids are converted to methane. Carbon dioxide serves as the electron acceptor.

Anaerobic decomposition yields carbon dioxide, methane and water as the major end products.

Additional end products include ammonia, hydrogen sulfide, and mercaptans. As a consequence of last three compounds, anaerobic decomposition characterized by an unbelievably horrid stench!

Decomposition of Waste

Anaerobic Decomposition

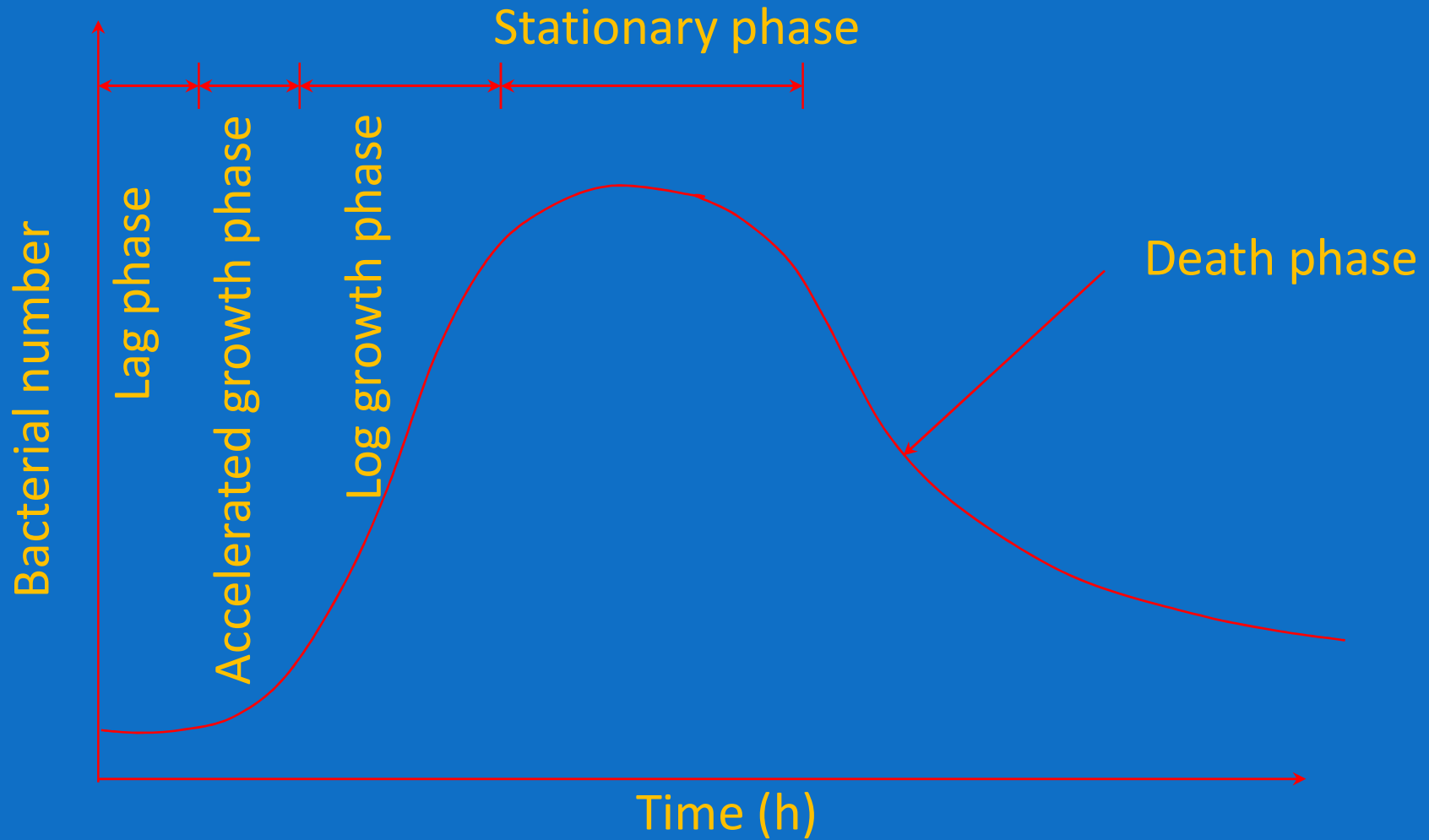
Because only small amount of energy are released during anaerobic oxidation, the amount of cell production is low.

Thus, sludge production is low.

We make use of this fact in wastewater treatment by using anaerobic decomposition to stabilize sludges produced during aerobic and anoxic decomposition.

Direct anaerobic decomposition of wastewater generally is not feasible for diluted waste.

Bacterial Growth in Pure Cultures







Thanks a Lot

Course Code: CE 4141

Course Title: Environmental Engineering-II

Lecture – 13

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Cycle -7, Day-D
22-07-2019

Small Bore Sewerage System

What is it?

Small bore sewerage system is an alternative low-cost sewerage system of high cost traditional waterborne sewerage system by introducing septic tank in between sanitation facilities and sewage collection and transportation system.

This is a recent sanitation technology that offers all the advantages of the conventional waterborne sewerage systems but at a much low cost than the conventional ones.

Small Bore Sewerage System

The SBS system collects wastewater discharges from all the fixtures in households or other premises in a similar way to the conventional sewerage system.

The basic difference between the two systems is the incorporation of septic tanks within the individual premises as part of the SBS system.

The wastewater collected in the septic tank is then transported under gravity through a network of reticulation sewers to a treatment plant comprising a series of stabilization lagoons.

Small Bore Sewerage System

Elements of SBS System

There are three basic elements to a small bore sewerage system. These are:

- Septic tank
- Small bore sewer network
- Treatment plant

Small Bore Sewerage System

Septic Tanks

Septic tanks or interceptors are required to be installed within individual premises to receive wastewater from toilets, baths, laundry and kitchens. These are designed with a view to achieve the following fundamental functions:

- ❑ Sedimentation of undissolved, settleable solids in the wastewater thus requiring sufficient retention time.
- ❑ Storage of sludge and scum for at least three to five years or more, thus requiring sufficient volume.
- ❑ Reduction of BOD of the wastewater through anaerobic decomposition of the organic matter contained in the wastewater.
- ❑ Substantial attenuation of peak flows, which is a function of the liquid surface area of the tank.

Small Bore Sewerage System

Septic Tanks

- ❑ In septic tank, suspended solids are reduced gravitationally and microbial action by about 18 to 70% and the BOD is reduced by about 46 to 60% depending on the design and performance of the septic tanks.
- ❑ The wastewater flows which reach the small bore sewers are markedly attenuated in the septic/interceptor tank from the rate at which they are discharged by the users.
- ❑ The peak discharges are attenuated by about 64% in septic tanks.
- ❑ The maximum discharge from the septic tanks can be about 25% of the peak input.

Small Bore Sewerage System

SBS Sewer Reticulation

The important parameters that bring significant changes in the design criteria of the SBS collection system, due to the presence of septic tanks in individual premises, are the design flow, sewer sizes, minimum velocity sewer grades and manholes.

Small Bore Sewerage System

Design flows

The design flow to be considered feasible in the range of 40 to 80 lpcd for yard tap supplies and 80 to 200 lpcd for multiple tap in-house supplies.

In addition to wastewater flows, estimates of groundwater infiltration and surface water inflow are also considered in the design of conventional sewer system.

It is, however, intended that in the SBS system infiltration be eliminated by using solvent jointed UPVC as sewer materials.

Small Bore Sewerage System

Sewer Diameter

In the SBS system sewer sizes are smaller because of low average flow and because of attenuation of peak flow in the septic tank.

Since most of the settleable solids are retained in the septic tank, the possibility of solids deposition and blockage in the sewer is minimized.

Estimation of storm water infiltration will also reduce the required sewer capacity.

Small Bore Sewerage System

Sewer Diameter

The minimum size of sewer most commonly used in the conventional system is 150 mm, while the SBS system can employ a minimum sewer size of as low as 50 mm.

The Australian practice uses a minimum size of 100 mm sewer.

As soon as design flows indicate that the sewer will flow more than 60% of full capacity at full development then the next higher size should be adopted.

In developing countries however, where the special equipment for cleaning smaller diameter sewers is not generally available, a minimum diameter of 100 mm may be recommended.

Small Bore Sewerage System

Sewer Gradients

In the SBS system, since the settleable solids in the wastewater are retained and the suspended solids are reduced significantly in the septic tank, it is not necessary to maintain a self-cleaning velocity in the sewer reticulation system.

As a result the grade can be substantially reduced thereby reducing the volume of excavation to a great extent.

Small Bore Sewerage System

Manholes and Flushing Points

The SBS system requires less maintenance due to minimal solid content of the wastewater. Therefore, few numbers of manholes are installed.

Flushing points are used in the system at locations where the manholes would otherwise exist. These points consist of a 100 mm PVC riser with a removable screw-cap under concrete cover at the surface to provide access for flushing.

Flushing points are preferable to manholes because they are less costly and can be more tightly sealed to eliminate most infiltration and grit which commonly enter through the lids.

Small Bore Sewerage System

Wastewater Treatment

In the SBS system, treatment of wastewater is performed in two stages, firstly, on-site treatment in the septic tanks and secondly, off-site secondary treatment in a series of stabilization lagoons.

In the septic tanks the large particles and the settleable solids are retained, and the BOD and suspended solids are significantly reduced.

Small Bore Sewerage System

Technical Advantages

The small bore sewerage system has specific technical advantages over the conventional sewerage system as listed below:

- ❑ Sewer size can be reduced because each septic tank tends to act as a balancing tank, largely eliminating surge.
- ❑ Since the wastewater contains minimum solids, self-cleansing velocities are not necessary and hence sewer grades can be substantially reduced.
- ❑ Sewer blockages are minimal as septic tanks retain most of the solids content.
- ❑ Volume of excavation is considerably reduced because of smaller sewers and lower sewer grades.
- ❑ Solid handling at the secondary treatment site is minimum.
- ❑ Rapid construction is possible because of lesser volume of excavation and fewer number of manholes to be constructed.

Course Code: CE 4141

Course Title: Environmental Engineering-II

Lecture – 14

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Cycle -8, Day-D
29-07-2019

Small Bore Sewerage System

Economic Considerations

Although the basic principles of both the SBS system and the conventional sewerage system are similar, there will be differences in the initial capital costs and the annual maintenance costs between the two systems. This is because of changes in the design criteria brought about by the presence of the septic tank in the SBS system.

Small Bore Sewerage System

Economic Considerations

The differences in the initial capital costs between the systems are a result of the following factors.

A reduction in the capital costs in the SBS system due to:

- Reduction in the sewer sizes;
- Reduction in minimum grades, thereby reducing the volume of excavation;
- Reducing in the number of manholes;
- Reduction in hydraulic and organic loading of wastewater due to the existence of the septic tank, thereby reducing the treatment plant area;
- Less costly pumps with minimum solids handling required.

Small Bore Sewerage System

Economic Considerations

An increase in the capital costs in the SBS system due to:

- Installation of septic tanks (however, if use is made of existing septic tanks then it will be an added cost advantage for the SBS system);
- Installation of flushing points.

Small Bore Sewerage System

Economic Considerations

The differences in the annual maintenance costs between the two systems are a result of the following factors.

A reduction in the maintenance costs in the SBS system due to:

- Fewer manholes;
- Less frequent cleaning of the sewers because the possibility of blockage due to solids deposition is minimum;
- No sludge handling is required at the treatment site.

An increase in the maintenance costs in the SBS system due to:

- Desludging of septic tanks 3 to 5 times per year;
- Regular flushing of sewers.

Simplified Sewerage System

Simplified Sewerage System

What is it?

- ❑ Simplified sewerage, also called shallow sewerage, is low-cost sanitation technology particularly suited to high-density, low-income urban areas in developing countries.
- ❑ It is designed to receive all household wastewater without settling in solid interseptor tanks or septic tanks as is done in the case of SBS systems.
- ❑ It is essentially similar to conventional sewerage, but without any of the later's conservative design features.
- ❑ Small diameter sewers used to convey the sewage are laid at shallow gradients.

Simplified Sewerage System

What is it?

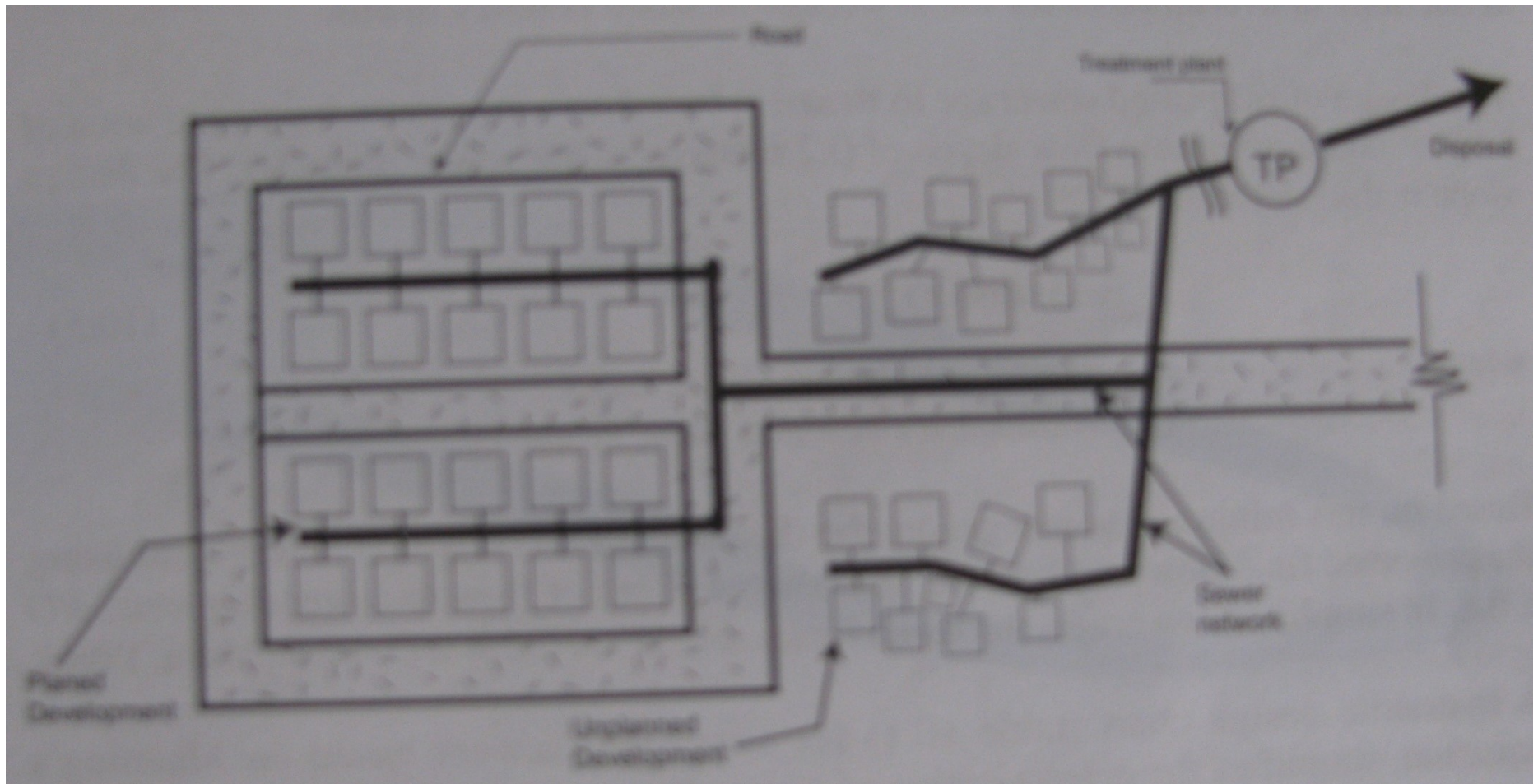
- ❑ These sewers are often laid inside housing block, where the system is known as condominial sewerage.
- ❑ They may also be laid outside the housing block, usually under sidewalk rather than in the middle of the road, as is the case with conventional sewerage.

Simplified Sewerage System

Invention?

- ❑ The system is outcome of critical review of the justification for conventional sewerage design standard.
- ❑ The change has been made in design standards for minimum diameter, minimum slopes, minimum depths, and the spacing and location of manholes.
- ❑ The changes were based on findings of research in development of lower-cost sewerage system with smaller, flatter and shallower sewers with fewer and simpler manholes.
- ❑ In addition, the system makes use of design periods that are considerably shorter than those used in conventional sewerage.

Simplified Sewerage System



Simplified Sewerage System

Design Principles?

- ❑ Sewer design must be such that deposition of organics and other materials is minimized to avoid blockage of the sewer line. As such, sewers are graded to attain self-cleansing velocity to avoid deposition.
- ❑ The usual practice for the hydraulic design of circular sewers is to maintain velocity for achieving the self-cleansing action.
- ❑ In general a velocity of 0.6 m/sec when flowing full is considered adequate for sanitary sewers.

Simplified Sewerage System

Design Principles?

- ❑ A recent trend is to apply a critical shear stress (tractive tension) approach instead of minimum velocity theory in the hydraulic design of sewer.
- ❑ The critical shear stress of sediment particles is considered as the minimum shear stress necessary for the initiation of motion of the particle.
- ❑ Its magnitude depends on a number of factors including the densities of the particle and the fluid, the size of the particle and the viscosity of the fluid.

Simplified Sewerage System

Design Principles?

- ❑ The recent minimum tractive tension approach of hydraulic design is to ensure self-cleansing of sewers by attaining sufficient shear stress on the critical area of the wetted perimeter.
- ❑ The average shear stress over the critical area of the wetted perimeter must be equal to or greater than 1.47 N/m^2 .
- ❑ The critical shear stress approach has resulted in the flattening of the grades at which smaller size sewers (up to 300 mm) are laid.
- ❑ Although larger size sewers are required to be graded more steeply.
- ❑ The flattening of smaller size sewers has resulted in substantial reduction in overall costs.

Simplified Sewerage System

Design Principles?

- ❑ The design of simplified sewerage is based on a minimum tractive tension of 1 N/m^2 and a minimum flow depth of 0.2 relative to the sewer diameter.
- ❑ The design slope is thus determined by: $I_{\min} = 0.0056Q_i^{-6/13}$

Where, I_{\min} = minimum sewer slope, m/m

Q_i = initial wastewater flow, litres/sec.

- ❑ Based on this minimum sewer grade, the diameter of the sewer is determined using the projected final flow and limiting the ratio of depth of flow to sewer diameter, $d/D \leq 0.8$.
- ❑ In simplified sewerage, the usual limits for d/D is $0.2 < d/D < 0.8$.

Simplified Sewerage System

Design Principles?

- ❑ A hydraulic design chart for simplified sewers based on Manning's equation, simplifies the determination of sewer diameter by relating d/D to $Q_f/I_{\min}^{0.5}$ and $V/I_{\min}^{0.5}$, where Q_f is the final flow in m^3 .
- ❑ The exact or a nearer value of $Q_f/I_{\min}^{0.5}$ is located in this design chart where d/D does not exceed 0.8.
- ❑ The final velocity V_f is computed from the corresponding $V/I_{\min}^{0.5}$ value in the chart.

Simplified Sewerage System

Table 10.1 Design chart for simplified sewers based on Manning's equation with $n = 0.013$, and v in m/s, I in m/m, q in m³/s and the sewer diameter D in mm.

d/D	$D=100$		$D=150$		$D=225$		$D=300$	
	$V/I^{1/2}$	$Q/I^{1/2}$	$V/I^{1/2}$	$Q/I^{1/2}$	$V/I^{1/2}$	$Q/I^{1/2}$	$V/I^{1/2}$	$Q/I^{1/2}$
0.02	0.9260	0.0000	1.2135	0.0001	1.5901	0.0003	1.9262	0.0006
0.04	1.4607	0.0002	1.9140	0.0005	2.5081	0.0013	3.0383	0.0029
0.06	1.9017	0.0004	2.4920	0.0011	3.2654	0.0032	3.9558	0.0068
0.08	2.2888	0.0007	2.9992	0.0020	3.9300	0.0059	4.7609	0.0126
0.10	2.6383	0.0011	3.4572	0.0032	4.5302	0.0094	5.4880	0.0202
0.12	2.9593	0.0016	3.8778	0.0047	5.0814	0.0137	6.1557	0.0296
0.14	3.2573	0.0022	4.2683	0.0064	5.5930	0.0189	6.7754	0.0408
0.16	3.5359	0.0029	4.6334	0.0085	6.0714	0.0249	7.3550	0.0537
0.18	3.7979	0.0037	4.9766	0.0108	6.5212	0.0317	7.8999	0.0684
0.20	4.0451	0.0045	5.3006	0.0133	6.9458	0.0393	8.4142	0.0847
0.22	4.2792	0.0055	5.6074	0.0162	7.3477	0.0477	8.9012	0.1026
0.24	4.5013	0.0065	5.8984	0.0192	7.7291	0.0567	9.3631	0.1221
0.26	4.7124	0.0076	6.1750	0.0225	8.0915	0.0665	9.8022	0.1431
0.28	4.9132	0.0088	6.4382	0.0261	8.4364	0.0769	10.2200	0.1656
0.30	5.1045	0.0101	6.6888	0.0298	8.7648	0.0879	10.6178	0.1894
0.32	5.2867	0.0115	6.9276	0.0338	9.0777	0.0996	10.9968	0.2144
0.34	5.4604	0.0129	7.1551	0.0379	9.3759	0.1118	11.3580	0.2407
0.36	5.6258	0.0143	7.3719	0.0422	9.6599	0.1245	11.7022	0.2681
0.38	5.7834	0.0158	7.5784	0.0467	9.9305	0.1377	12.0300	0.2965
0.40	5.9334	0.0174	7.7750	0.0513	10.1881	0.1513	12.3420	0.3259
0.42	6.0761	0.0190	7.9619	0.0561	10.4331	0.1653	12.6388	0.3561
0.44	6.2116	0.0207	8.1395	0.0610	10.6658	0.1797	12.9206	0.3870
0.46	6.3401	0.0224	8.3079	0.0659	10.8865	0.1944	13.1880	0.4187
0.48	6.4618	0.0241	8.4674	0.0717	11.0955	0.2094	13.4412	0.4509
0.50	6.5768	0.0258	8.6181	0.0761	11.2929	0.2245	13.6804	0.4835
0.52	6.6852	0.0276	8.7601	0.0813	11.4789	0.2398	13.9057	0.5165
0.54	6.7870	0.0294	8.8934	0.0866	11.6537	0.2553	14.1174	0.5497
0.56	6.8822	0.0311	9.0182	0.0918	11.8172	0.2707	14.3155	0.5831
0.58	6.9709	0.0329	9.1345	0.0971	11.9696	0.2862	14.5001	0.6164
0.60	7.0531	0.0347	9.2422	0.1023	12.1107	0.3017	14.6711	0.6497
0.62	7.1288	0.0365	9.3414	0.1075	12.2407	0.3170	14.8285	0.6827
0.64	7.1979	0.0382	9.4319	0.1127	12.3593	0.3321	14.9722	0.7153
0.66	7.2603	0.0399	9.5137	0.1177	12.4664	0.3471	15.1020	0.7474
0.68	7.3159	0.0416	9.5865	0.1227	12.5619	0.3617	15.2177	0.7789
0.70	7.3646	0.0432	9.6503	0.1275	12.6455	0.3759	15.3189	0.8096
0.72	7.4061	0.0448	9.7048	0.1322	12.7169	0.3897	15.4054	0.8393
0.74	7.4404	0.0464	9.7497	0.1367	12.7757	0.4030	15.4766	0.8680
0.76	7.4670	0.0478	9.7845	0.1410	12.8214	0.4157	15.5320	0.8953
0.78	7.4856	0.0492	9.8090	0.1451	12.8534	0.4277	15.5708	0.9211
0.80	7.4959	0.0505	9.8224	0.1489	12.8710	0.4389	15.5921	0.9452
0.82	7.4972	0.0517	9.8241	0.1524	12.8732	0.4492	15.5947	0.9674
0.84	7.4888	0.0527	9.8131	0.1555	12.8588	0.4585	15.5773	0.9874
0.86	7.4698	0.0537	9.7882	0.1583	12.8261	0.4666	15.5377	1.0048
0.88	7.4389	0.0545	9.7477	0.1605	12.7731	0.4733	15.4735	1.0194
0.90	7.3944	0.0551	9.6894	0.1623	12.6967	0.4786	15.3810	1.0306
0.92	7.3336	0.0554	9.6098	0.1635	12.5923	0.4819	15.2545	1.0379
0.94	7.2522	0.0556	9.5031	0.1638	12.4526	0.4830	15.0852	1.0402
0.96	7.1421	0.0553	9.3588	0.1632	12.2634	0.4811	14.8561	1.0360
0.98	6.9830	0.0546	9.1504	0.1609	11.9904	0.4745	14.5253	1.0218
1.00	6.5768	0.0517	8.6181	0.1523	11.2929	0.4490	13.6804	0.9670

Source: Mara, (1996)

Simplified Sewerage System

Operation and Maintenance

- ❑ Simplified sewerage systems have been widely adopted in Brazil and Bolivia, Colombia and Cuba.
- ❑ Information on operational problems, however, is not yet readily available.
- ❑ Experience shows that obstructions in sewer are insignificant and this supports the policy of reducing the number of manholes for maintenance purposes.
- ❑ Manholes are smaller because there is no need for maintenance personnel to enter the manholes due to shallower depths and the availability of modern cleaning equipment.

Simplified Sewerage System

Cost

- ❑ Simplified sewerage system have proven to be substantially cheaper than conventional sewer system.
- ❑ Cost saving ranging from 20 to 50%.
- ❑ The cost of simplified sewerage, however, varies from place to place depending on the varying design standards and criteria.

Simplified Sewerage System

Suitability

- ❑ Simplified sewerage system offer a new cost saving approach primarily based on rational changes in long-standing traditional conservative sewer design standard.
- ❑ Simplified sewerage could be a viable lower-cost alternative to conventional sewerage systems particularly for the developing countries.
- ❑ Design modifications in simplified sewerage are based on sound engineering principles without jeopardizing the level of service.
- ❑ Cost could be 30 to 50% less than conventional sewerage, thus service coverage could be expanded.

Thank You All

Course Code: CE 4141

Course Title: Environmental Engineering

Lecture – 15

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Cycle -9, Day-D
21-08-2019

Aquaculture

The farming of freshwater and marine plants and animals.



What is Aquaculture?

Aquaculture is the farming and husbandry of aquatic organisms under controlled or semi-controlled conditions.

These organisms may be plants, fish or shellfish — oysters, mussels, clams, shrimp, crabs, crawfish.

Aquaculture is employed for a variety of ends: fish may be raised to stock public waters for sportfishing and for commercial fishing; it may be to save an endangered species; or it may be to harvest a commercially viable crop in ponds or coastal waters.

What is Aquaculture?

In simple terms, aquaculture is agriculture: the farmer farms the water instead of the land; depending on the species, the water may be fresh or brackish or salty.

Although aquaculture is a generic term, it generally refers to the culture of plants and animals in freshwater, while culture in saltwater is commonly known as mariculture.

Why Aquaculture?

The world's oceans and rivers are fast approaching the limits of fish and shellfish production that can be harvested on a continual basis.

Farming the water is the possible solution to meet the increasing consumer demand.

In addition to the demand for seafood, there is a growing interest in sportfishing. Many public fisheries for recreational angling have had to reduce creel limits (number of fish legally allowed to be caught per day) or have imposed seasons for catching specific species of fish.

Why Aquaculture?

Aquaculture efforts can also be used to save or restore an endangered or threatened species.

These are special situations where, for various reasons, fish cannot reproduce in sufficient numbers, or the progeny do not survive well enough to maintain themselves as a population.

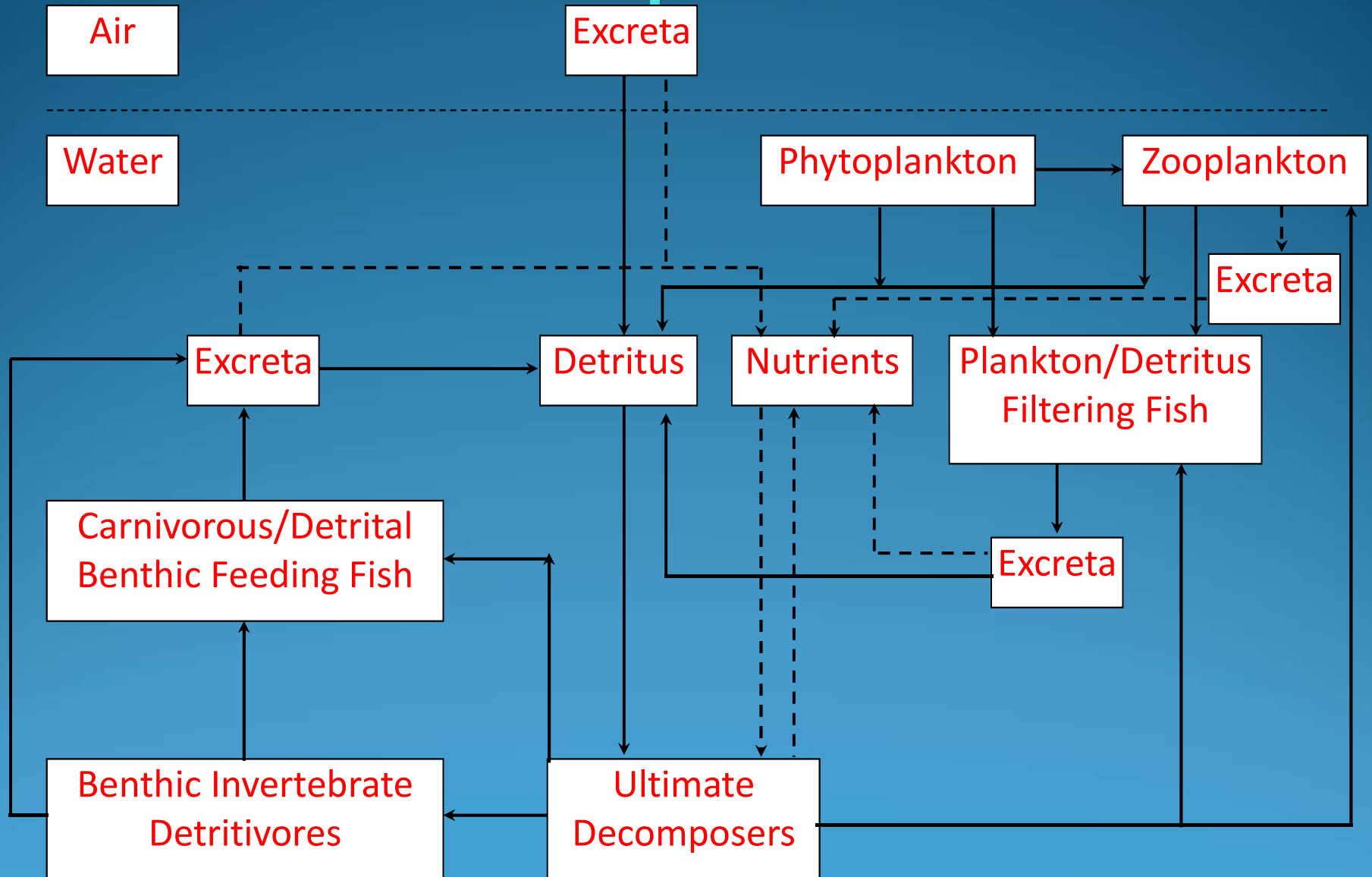
Wastewater use in aquaculture

The objective in fertilizing an aquaculture pond with excreta, nightsoil or wastewater is to produce natural food for fish.

Since several species of fish feed directly on faecal solids, use of raw sewage or fresh nightsoil as influent to fish ponds should be prohibited for health reasons.

Complex food chains in an excreta-fed fish pond as shown in Figure, involving ultimate decomposers or bacteria, phytoplankton, zooplankton and invertebrate detritivores. Inorganic nutrients released in the bacterial degradation of organic solids in sewage, nightsoil or excreta are taken up by phytoplankton.

Complex food chains in an excreta-fed fish pond



Complex food chains in an excreta-fed fish pond

Zooplankton graze phytoplankton and small detritus particles coated with bacteria, the latter also serving as food for benthic invertebrate detritivores. Plankton, particularly phytoplankton, are the major sources of natural food in a fish pond but benthic invertebrates, mainly chironomids, also serve as fish food, although they are quantitatively less important.

Fish Species

A wide range of fish species has been cultivated in aquaculture ponds receiving human waste, including

- ❑ Common carp (*Cyprinus carpio*),
- ❑ Indian major carps (*Catla catla*, *Cirrhina mrigala* and *Labeo rohita*),
- ❑ Chinese silver carp (*Hypophthalmichthys molitrix*),
- ❑ Bighead carp (*Aristichthys nobilis*),
- ❑ Grass carp (*Ctenopharyngodon idella*),
- ❑ Crucian carp (*Carassius auratus*),
- ❑ Nile carp (*Osteochilus hasseltii*),

Fish Species

A wide range of fish species has been cultivated in aquaculture ponds receiving human waste, including

- ❑ Tilapia (*Oreochromis spp.*),
- ❑ Milkfish (*Chanos chanos*),
- ❑ Catfish (*Pangasius spp.*),
- ❑ Kissing gouramy (*Helostoma temmincki*),
- ❑ Giant gourami (*Osphronemus goramy*),
- ❑ Silver barb (*Puntius gonionotus*) and
- ❑ Freshwater prawn (*Macrobrachium lanchesterii*).

Selection of Fish Species

The selection reflects local culture rather than fish optimally-suited to such environments. For example, Chinese carps and Indian major carps are the major species in excreta-fed systems in China and India, respectively.

In some countries, a polyculture of several fish species is used. Tilapia are generally cultured to a lesser extent than carps in excreta-fed systems although, technically, they are more suitable for this environment because they are better able to tolerate adverse environmental conditions than carp species.

Milkfish have been found to have poorer growth and survival statistics compared with Indian major carps and Chinese carps in ponds fed with stabilization pond effluent in India.

Aquatic Plants

Aquatic macrophytes grow readily in ponds fed with human waste. Some creeping aquatic macrophytes are cultivated as vegetables for human consumption in aquaculture ponds and duckweeds are also cultivated, mainly for fish feed. Among the aquatic plants grown for use as vegetables are

- ❖ Water spinach (*Ipomoea aquatica*),
- ❖ Water mimosa (*Neptunia oleracea*),
- ❖ Water cress (*Rorippa nasturtium-aquaticum*) and
- ❖ Chinese water chestnut (*Eleocharis dulcis*).

The duckweeds *Lemna*, *Spirodela* and *Wolffia* are cultivated in some parts of Asia in shallow ponds fertilized with excreta, mainly as feed for Chinese carps but also for chickens, ducks and edible snails

Course Code: CE 4141

Course Title: Environmental Engineering

Lecture – 16

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**Cycle -10, Day-D
28-08-2019**

Technical aspects of fish culture

Environmental factors

In a successful aquaculture system there must be both an organismic balance, to produce an optimal supply of natural food at all levels, and a chemical balance, to ensure sufficient oxygen supply for the growth of fish and their natural food organisms and to minimize the build-up of toxic metabolic products (Colman and Edwards, 1987).

Chemical balance is usually achieved through organismic balance in waste-fed ponds because the most important chemical transformations are biologically mediated.

It is now recognized that depletion of dissolved oxygen in fertilized fish ponds is due primarily to the high rates of respiration at night of dense concentrations of phytoplankton.

Technical aspects of fish culture

Romaire et al. (1978) introduced equation to cover the factors influencing waste-fed fish pond dissolved oxygen (DO) at dawn:

$$DO_{dn} = DO_{dk} \pm DO_{df} - DO_m - DO_f - DO_p$$

where:

DO_{dn} = DO concentration at dawn

DO_{dk} = DO concentration at dusk

DO_{df} = DO gain or loss due to diffusion

DO_m = DO consumed by mud

DO_f = DO consumed by fish

DO_p = DO consumed by plankton

Technical aspects of fish culture

Bacterial respiration is not specifically mentioned in this equation but is included in the mud consumption of DO and in the planktonic DO consumption.

In a well-managed waste-fed fish pond the DO in the morning should be only a few mg/l whereas in late afternoon the pond should be supersaturated with DO.

Mud respiration probably lowers DO by less than 1 mg/l overnight and a fish population weighing 3000 kg/ha would also lower DO by only about 1 mg/l overnight.

Technical aspects of fish culture

Phytoplankton photosynthesis is the major source of oxygen during daylight hours and, during the night, the major cause of oxygen depletion is respiration.

It has been estimated that respiration of plankton (bacterioplankton, phytoplankton and zooplankton) can lower pond DO by 8-10 mg/l overnight.

By far the greatest proportion of the DO depletion overnight is caused by the respiration of the phytoplankton that develop as a result of the nutrients contained in the waste.

Technical aspects of fish culture

Phytoplankton provide feed for the largest percentage of fish farmed in Asia (Edwards 1990).

They also exhibit a positive net primary productivity on a 24-hour basis and are net oxygen contributors to a fish pond.

The objective in a waste-fed fish pond should be to maintain an algal standing crop at an optimum level for net primary productivity by balancing the production of phytoplankton biomass, in response to waste fertilization, with the grazing of phytoplankton biomass by filter-feeding fish.

Technical aspects of fish culture

Fish mortality in a waste-fed pond can result from at least three possible causes.

- ❖ First, the depletion of oxygen due to bacterial oxygen demand caused by an increase in organic load.
- ❖ Second, the depletion of oxygen overnight due to the respiratory demand of too large a concentration of phytoplankton, having grown in response to an increase in inorganic nutrients, caused by an organismic imbalance.
- ❖ The third possible cause is high ammonia concentration in the waste feed.

All three causes of fish mortality have been reported in respect of sewage-fertilized fish ponds.

Technical aspects of fish culture

The sensitivity of fish to low levels of DO varies with species, life stage (eggs, larvae, adults) and life process (feeding, growth, reproduction).

A minimum constant DO concentration of 5 mg/l is considered satisfactory, although an absolute minimum consistent with the presence of fish is probably less than 1 mg/l (Alabaster and Lloyd, 1980).

Fish cultured in waste-fed ponds appear to be able to tolerate very low DO concentrations, for at least short periods of time, with air-breathing fish (such as walking catfish (*Clarias batrachus*) being the most tolerant, followed in decreasing order of tolerance by tilapia, carps, channel catfish and trout.

Technical aspects of fish culture

A wastewater fertilized aquaculture system might occasionally require a stand-by mechanical oxygenation system for use during periods when DO would otherwise be very low.

However, if the system is well managed to avoid overloading, this expense can be avoided.

Technical aspects of fish culture

Unionized ammonia (NH_3) is toxic to fish in the concentration range 0.2 - 2.0 mg/l (Alabaster and Lloyd, 1980).

However, the tolerance of different species of fish varies, with tilapia species being least affected by high ammonia levels.

Bartone et al. (1985) found that satisfactory growth and survival of tilapia was possible in fish ponds fed with tertiary effluent when the average total ammonia concentration is less than 2 mg N/l and the average unionized ammonia concentration was less than 0.5 mg N/l, with the latter only exceeding 2 mg N/l for short periods.

Technical aspects of fish culture

In ponds receiving large quantities of organic matter, sediments tend to accumulate and release anaerobic breakdown products, such as methane and sulphides, which can inhibit fish growth.

Bottom feeding fish, such as the common carp (*Cyprinus carpio*), are most affected by such conditions, especially if the macrozoobenthos disappear.

Technical aspects of fish culture

Fish Yields and Population Management

A wide range of yields has been reported from waste-fed aquaculture systems, for example: 2-6 tons/ha-yr in Indonesia, 2.7 - 9.3 tons/ha-yr in China and 3.5 - 7.8 tons/ha-yr in Taiwan.

Although the majority of waste-fed fish ponds stocks carps, research in Peru and Thailand has demonstrated the potential of tilapia for such systems.

Management of fish ponds can have a significant effect on fish yields but the maximum attainable yield in practice is of the order of 10 - 12 tons/ha-yr (Edwards, 1990).

Technical aspects of fish culture

Fish Yields and Population Management

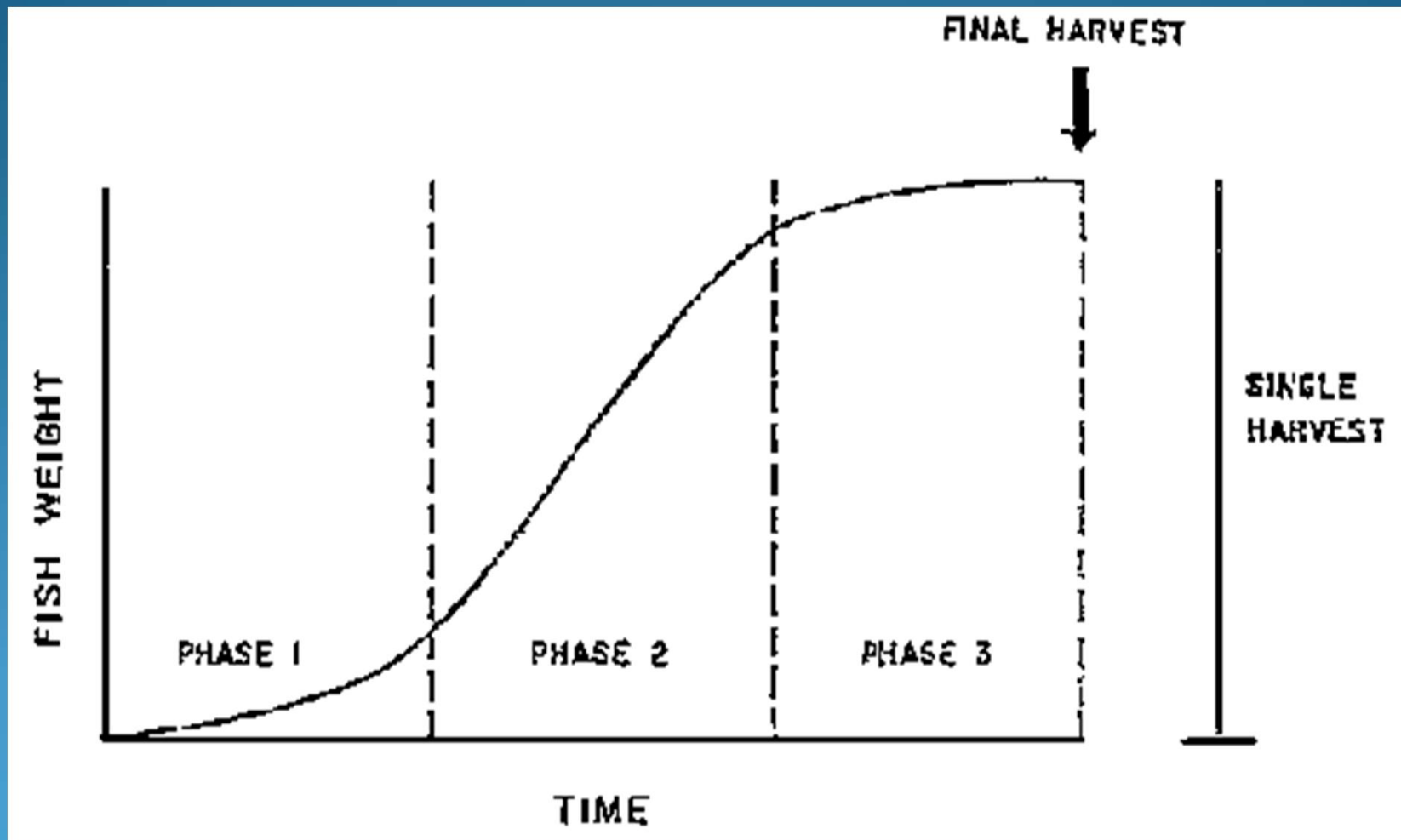
Increase in weight of small fingerlings stocked in a pond follows a sigmoidal curve. The first phase of growth (Shown in Figure) is slow, so a high stocking density can be adopted to better utilize the spatial and nutritional resources of the pond.

Alternatively, this can be achieved by stocking with larger fish having a higher initial weight, following growth in nursery ponds.

Fish yield is positively correlated with the size of the stocked fish at a given stocking density. In South China, tilapia are stocked once a year at rates of either 30 g fish and 0.15/m² or 1.3 g fish at 2.3 - 3.0/m² stocking density.

Technical aspects of fish culture

Fish Yields and Population Management



Technical aspects of fish culture

Fish Yields and Population Management

An increase in weight of fish in a pond leads initially to an increase in yield or production but there is subsequently a reduction in the growth rate of individual fish because of the limitation of natural food production in the system.

The third phase of slow growth in Figure is because the total weight of fish in the pond is approaching the carrying capacity.

Intermediate harvesting when the rapid growth ceases, at the end of phase 2, should lead to significant increases in total yield.

The high yields of tilapia reported in South China sewage-fed ponds are due to high stocking density and frequent harvesting.

Technical aspects of fish culture

Fish Yields and Population Management

Clearly, the key to achieving high yields in a waste-fed pond is to determine the carrying capacity of the pond, the maximum standing stock of fish.

This can be assessed by varying the waste load and determining the maximum production of natural food consistent with satisfactory water quality, sustainable through a fish culture cycle (Edwards, 1990).

Fish stocking density is related to carrying capacity according to the desired weight of individual fish at harvest.

Technical aspects of fish culture

Health Related Aspects of Fish Culture

Although it is good practice to limit the discharge of toxic materials to sewerage systems, inevitably some of these materials gain access and heavy metals and pesticides are frequently present in municipal sewage. This gives rise to concern about bioaccumulation when sewage effluent is used in aquaculture.

Algae are known to accumulate various heavy metals but, with the possible exception of mercury, fish raised in sewage-fed ponds have not been observed to accumulate high concentrations of these toxic substances.

Technical aspects of fish culture

Health Related Aspects of Fish Culture

It would appear that the concentrations of heavy metals in the pond water may be accumulated at slower rates than new tissues develop in rapidly growing fish, such as tilapia.

In the case of mercury, the position of fish in the food chain seems to be important in determining their mercury uptake, with carnivorous fish accumulating more than herbivores.

Technical aspects of fish culture

Health Related Aspects of Fish Culture

Fish, apparently, have the ability to regulate the heavy metal content of their tissues, except for mercury, and tend to accumulate metals in parts other than muscle tissue. There is little information on the uptake of toxics other than heavy metals but a high phenol content in the sewage fed to fish ponds in Wuhon, China caused the fish flesh to become unpalatable due to the odour of phenol. Weis et al. (1989) have reported on the effects of treated municipal wastewater on the early life stages of three species of fish and indicated that moderately toxic effluent (organic fractions) caused cardiovascular and skeletal defects, depression of heart rate and poor hatching, larval and juvenile growth rates.

Technical aspects of fish culture

Health Related Aspects of Fish Culture

Depuration was mentioned as a means to decontaminate fish grown in waste-fed aquaculture. It is generally believed that holding fish in clean-water ponds for several weeks at the end of the growing cycle will remove residual objectionable odours and pathogens and provide fish acceptable for market.

However, there is a lack of data on depuration practice and experimental assessment. What little evidence there is suggests that depuration of heavily contaminated fish with bacteria in muscle tissue will not be effective.

Relatively short depuration periods of one to two weeks do not appear to remove bacteria from the fish digestive tract.

Technical aspects of fish culture

Some Management Techniques

1. Transport and release of fingerlings are carried out during morning hours.
2. The stocked fishes are checked at the monthly intervals for their growth and health through sample netting.
3. Regular monitoring of physico-chemical parameters are undertaken.
4. Regular cleaning of pipes interconnecting the treatments pond and fish pond are done.

Technical aspects of fish culture

Advantages

1. The sewage fed fish culture uses the waste recycling process and maintains the good environment around the urban area.
2. Manuring and supplementary feeding is not required due to high content of nutrients in sewage.
3. Input cost is very low and production is very high.
4. This is the biological method of treating waste water before its final disposal in river.

Technical aspects of fish culture

Disadvantages

1. The sewage contain high load of organic and inorganic matters and toxic gases which may harm fish consumers.
2. As the raw sewage is used in fish ponds, there is a chance of infection and pollution to enter into human body through food chain. But this risk can be minimized if good managerial practice is followed.

Course Code: CE 4141

Course Title: Environmental Engineering

Lecture – 17

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Cycle -11, Day-D
07-09-2019

Industrial Effluent Treatment & Disposal

Objectives

The principal objective of industrial wastewater treatment is generally to allow industrial effluents to be disposed of **without danger to human health** or **unacceptable damage** to the natural environment

To manage water discharged from homes, businesses, and industries to reduce the threat of water pollution.



Sources of Industrial Wastewater



Sources of Industrial Wastewater

Industries use water that obtained from the water treatment system for a variety of purposes, such as

- For manufacturing foods.
- For heating.
- For cooling.
- As carrier of raw material.
- As carrier of waste matter.
- As a solvent.

The resulting water is then classified as a wastewater.

Effects

- ❑ The indiscriminate discharge of these wastewater streams into the environment can
 - ❖ Render soils "sick".
 - ❖ Pollute the receiving bodies of water.
 - ❖ Cause air pollution by generating obnoxious gases.
- ❑ Discharge untreated wastewater into the domestic sewer system makes the task of treating domestic sewage, a very difficult and costly exercise.
- ❑ To prevent any health hazards caused by discharging wastewater into the environment and protect domestic sewage, the wastewater must be treated before discharge.

Characteristics of Industrial Wastewater

1. Physical Characteristics

1.1 Total Solids

- Analytically the total solids content of a wastewater is defined as all the matter that remains as residue upon evaporation at 103 to 105°C.



Characteristics Of Industrial Wastewater

1.2 Odors

Industrial wastewater may contain either odorous compounds or compounds that produce odor during the process of wastewater treatment.

1.3 Temperature

The temperature of water is a very important parameter because of its effect on

- Chemical reactions and reaction rates in treatment process.
- Aquatic life.

Characteristics Of Industrial Wastewater

1.4 Color

Color of industrial wastewater varies according to the type of industry.

Most colored matter is in a dissolved state.

1.5 Turbidity

Turbidity, a measure of the light-transmitting properties of water, is another test used to indicate the quality of wastewater discharges and natural waters with respect to colloidal and residual suspended matter.

Characteristics Of Industrial Wastewater

2. Chemical Characteristics

2.1 Organic Matter

The presence of these substances has complicated industrial wastewater treatment because many of them either cannot be or are very slowly decomposed biologically.

Typical examples include:

- Fats, Oils, and Grease.
- Surfactants.
- Phenols.
- Volatile Organic Compounds (VOCs).
- Pesticides & Agricultural Chemicals.

2.2 Inorganic Matter

- Nitrogen & Phosphorus.
- Sulfur.
- Heavy Metals.

Characteristics Of Industrial Wastewater

3. Biological Characteristics

- Some industries have certain pathogenic organisms like slaughterhouses others have molds and fungi as starch and yeast factories.
- Biological information is needed to assess the degree of treatment of the wastewater before its discharge to the environment.

Important Contaminants of Concern in Wastewater Treatment

Suspended solids

Lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged into the aquatic environment.

Nutrients (P, N₂&C)

When discharged into the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, they can also lead to the pollution of groundwater.

Priority pollutants

Organic and inorganic compounds selected on the basis of their known or suspected carcinogenicity, or high acute toxicity. Many of these compounds are found in wastewater.

Important Contaminants of Concern in Wastewater Treatment

Refractory organics

These organics tend to resist conventional methods of wastewater treatment. Typical examples include surfactants, phenols, and agricultural pesticides.

Heavy metals

Heavy metals are usually discharged to wastewater from commercial and industrial activities and have to be removed if the wastewater is to be reused.

Dissolved inorganics

Inorganic constituents such as calcium, sodium, and sulfate are added to the original domestic water supply as a result of water use and may have to be removed if the wastewater is to be reused.

Common Types of Wastewater Treatment Methods

1. Physical Unit Operations

- ❖ Treatment methods in which the application of physical forces predominates.
- ❖ Screening, mixing, flocculation, sedimentation, flotation, filtration, and gas transfer are typical unit operations.

2. Chemical Unit Processes

- ❖ Treatment methods in which the removal or conversion of contaminants is brought about by the addition of chemicals or by other chemical reactions.
- ❖ Precipitation, adsorption, and disinfection are the most common examples used in wastewater treatment.

Common Types of Wastewater Treatment Methods

3. Biological Unit Processes

- ❖ Treatment methods in which the removal of contaminants is brought about by biological activity.
- ❖ Biological treatment is used primarily to remove the biodegradable organic substances (colloidal or dissolved) and nutrients (nitrogen & phosphorus) from wastewater.
- ❖ Basically, these substances are converted into gases that can escape to the atmosphere and into biological cell tissue that can be removed by settling.

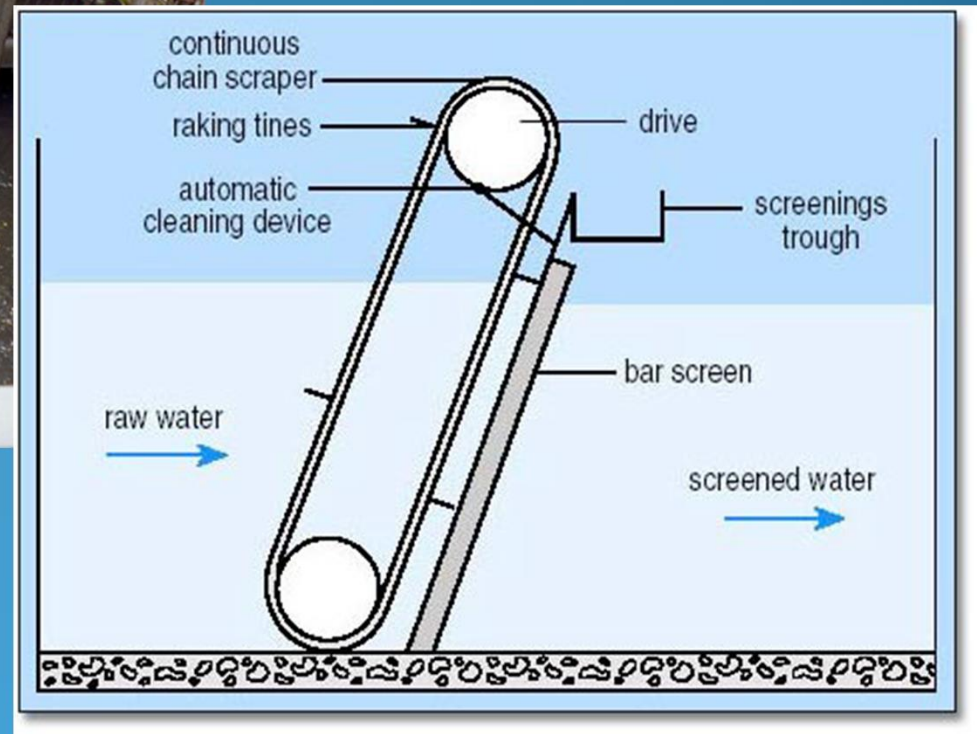
Main Treatment Technologies

1. Screening

- ❖ The first unit operation encountered in wastewater-treatment plants is screening. A screen is a device with openings, generally of uniform size that is used to retain the coarse solids found in wastewater.
- ❖ According to the method of cleaning, screens are designated as hand cleaned or mechanically cleaned.
- ❖ According to the size of openings, screens are designated as coarse or fine. Coarse screens have openings of $\frac{1}{4}$ inch or more, and fine screens have openings of less than $\frac{1}{4}$ inch.

Main Treatment Technologies

Mechanical Screen



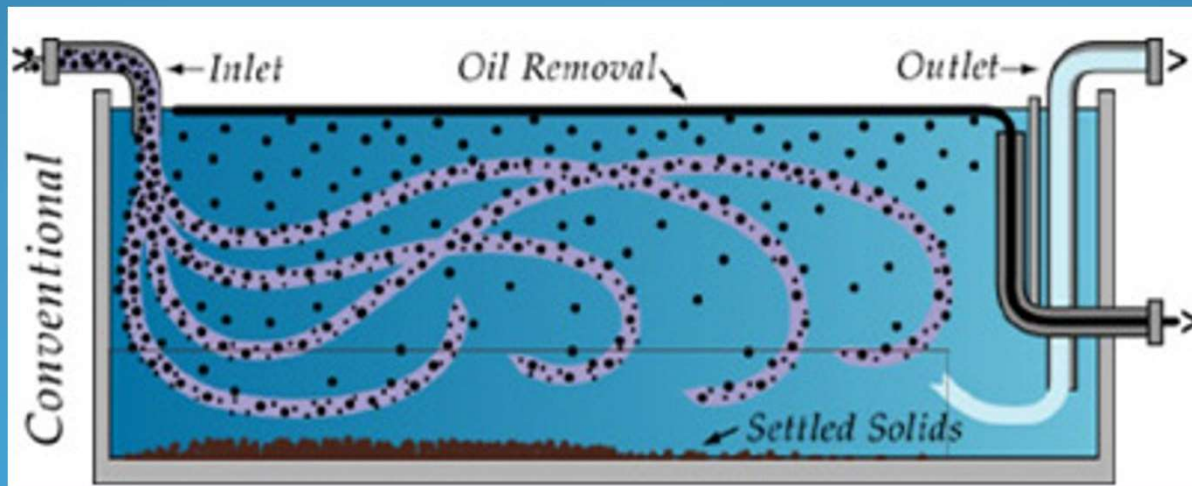
Main Treatment Technologies

2. Oil Separation

It is a process in which Floatables, namely **non-emulsified oil** and **organics** separates from wastewater.

2.1 API (American Petroleum Institute) Separators

- ❖ The design of the separator is based on the specific gravity difference between the oil and the wastewater and between the suspended solids and wastewater .
- ❖ In general, this separator can handle very large flow. However, its disadvantage is the long retention time required for efficient oil separation.

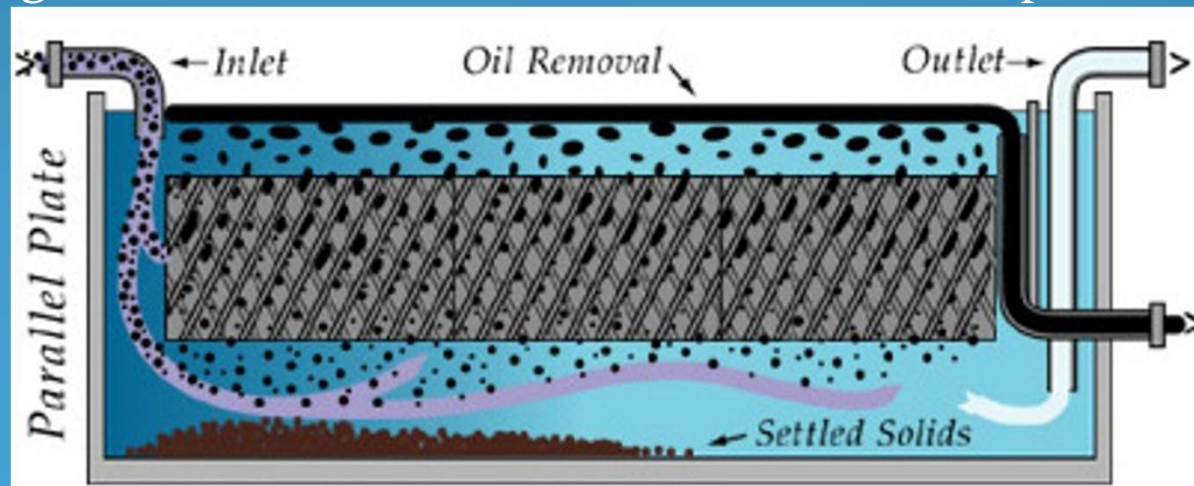


Main Treatment Technologies

2. Oil Separation

2.2 CPI (Corrugated Plate Interceptors) Units

- ❖ They consist of stacks of plates or bundles of slanted tubes, usually at 60 degrees, in a vessel or tank. It has been found that if the plates are tilted at 60 degrees, the solids will slide down the plates and be collected at the bottom.
- ❖ A CPI units can be placed in a small space but cannot take shock loads and high flows.
- ❖ They are usually more efficient than API separators and primary clarifiers in removing oil and solids, as more surface area can be provided.



Main Treatment Technologies

3 Flow Equalization

- ❖ Flow equalization is used to overcome the operational problems caused by flow variations, to improve the performance of the downstream processes, and is also used as an emergency tank to equalize wastewater effluent in case of any process failure in the treatment process.
- ❖ The design must provide for sufficient mixing to prevent solids deposition and concentration variations and also to provide aeration to prevent odor problems.
- ❖ The best location for equalization facilities to be at existing and proposed treatment plant sites. In some cases, equalization after primary treatment and before biological treatment may be appropriate.

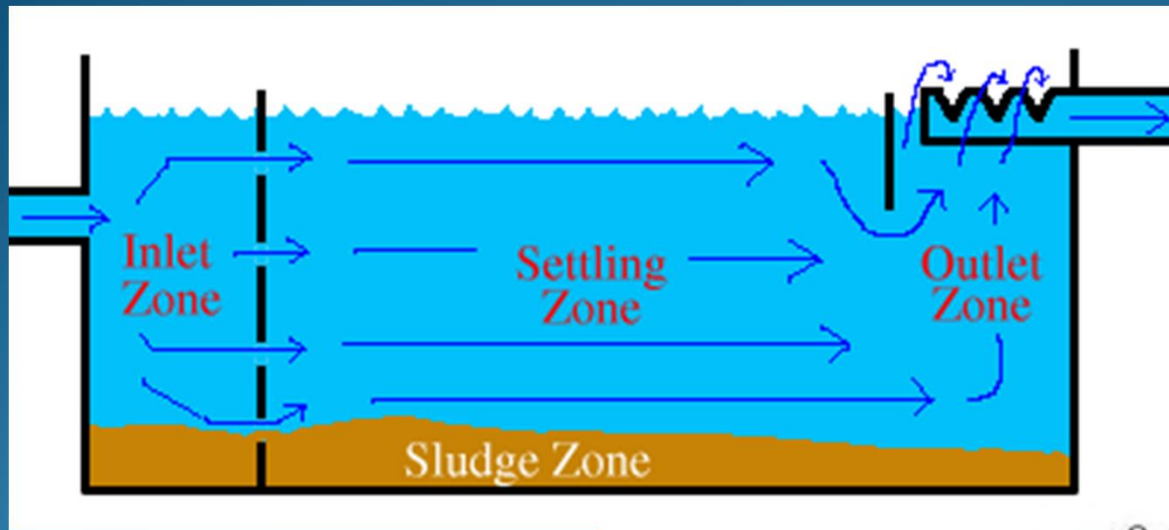
Main Treatment Technologies

Physical Treatment

1. Sedimentation

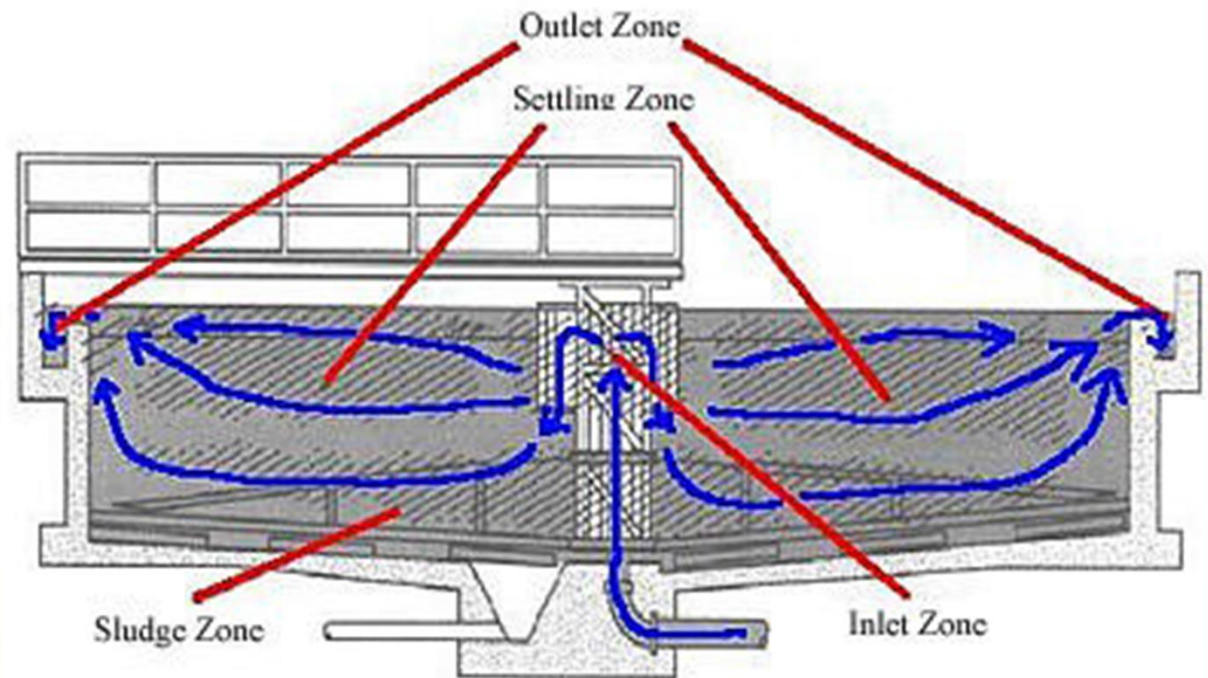
- ❑ Sedimentation is the separation from water, by gravitational settling, of suspended particles that are heavier than water.
- ❑ Sedimentation is used for separation of grit and particulate matter in the primary settling basin, separation of biological-floc in the activated-sludge settling basin, and separation of chemical-floc when the chemical coagulation process is used. It is also used for solids concentration in sludge thickeners.
- ❑ Sedimentation basins are constructed in a variety of shapes and sizes, circular tanks or rectangular tanks.
- ❑ The basin is comprised of four zones according to function:
1-The inlet zone. 2-The settling zone.
3-The sludge zone. 4-The outlet zone.

Main Treatment Technologies



Circular Type

Rectangular Type



Main Treatment Technologies



Rectangular Type



Circular Type

Main Treatment Technologies

2 Flotation

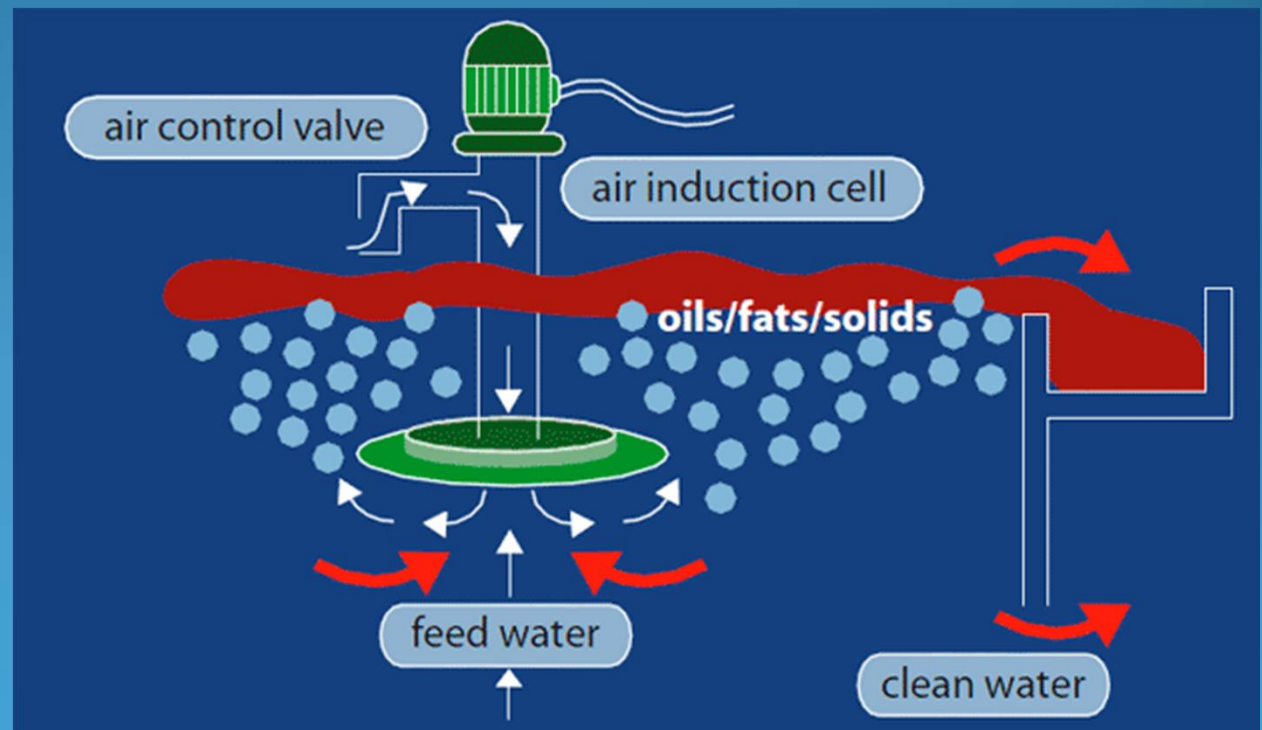
- ❖ Flotation is a unit operation used to separate solid or liquid particles from a liquid phase.
- ❖ Separation is brought by introducing fine gas (usually air bubbles) into the liquid phase. The bubbles attach to the particulate matter, and the buoyant force of the combined particle and gas bubble is great enough to cause the particle to rise to the surface to form a scum blanket, which is removed by a skimming mechanism. Grit and other heavy solids that settle to the bottom are raked to a central sludge for removal.
- ❖ Principal advantage of flotation over sedimentation is that very small or light particles that settle slowly can be removed more completely and in a shorter time.

Main Treatment Technologies

Types Of Flotation Systems

Air Flotation

In this system, air bubbles are formed by introducing the gas phase directly into the liquid phase through a revolving impeller through diffusers.

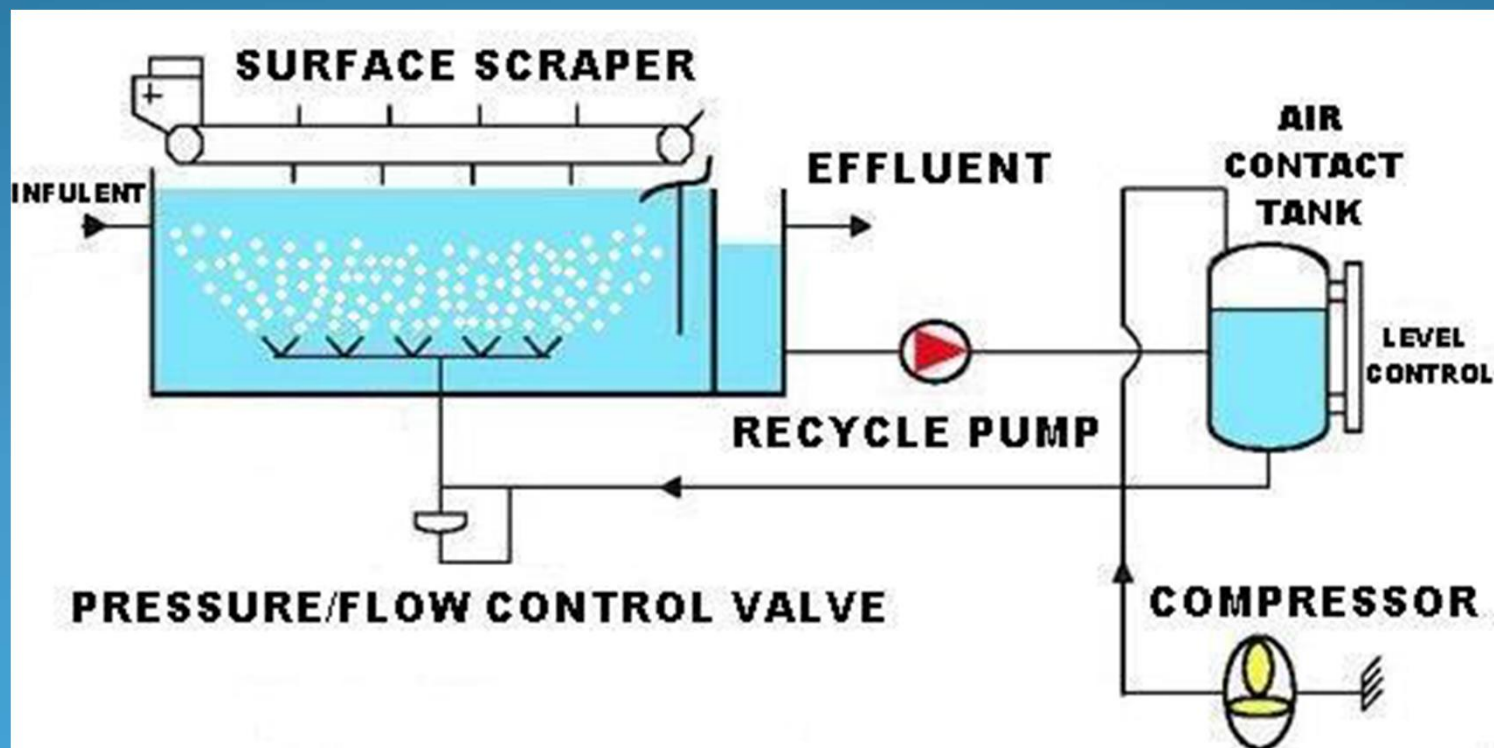


Main Treatment Technologies

Types Of Flotation Systems

Vacuum Flotation

This process consists of saturating the wastewater with air either directly in an aeration tank or by permitting air to enter on the suction side of a sewage pump.



Main Treatment Technologies

Chemical Treatment

1 Neutralization

- ❖ Industrial wastes often contain acidic or alkaline components which require neutralization before discharge or treatment.
- ❖ For wastes that are discharged to receiving waters, a pH between 6 and 9 is frequently specified by regulatory agencies. For wastes entering biological treatment processes, the pH should be maintained between 6.5 and 9 for optimum growth of the microorganisms.
- ❖ Acidic wastes are commonly neutralized with waste alkaline streams, lime, dolomite, ammonia, caustic soda, or soda ash.
- ❖ Lime is the most widely used alkaline material for neutralization acid wastes because of its low cost. Lime may be slow to react and may form insoluble precipitates.
- ❖ Alkaline wastes usually require treatment with a waste acidic stream, sulfuric acid or hydrochloric acid.

Main Treatment Technologies

2 Oxidation/Reduction

Oxidants are used in wastewater treatment as a first step in the removal of heavy metals to oxidize organics or as a last step in a treatment process, to oxidize odoriferous compounds such as hydrogen sulphide or to oxidize inorganics such as cyanide and for disinfection.

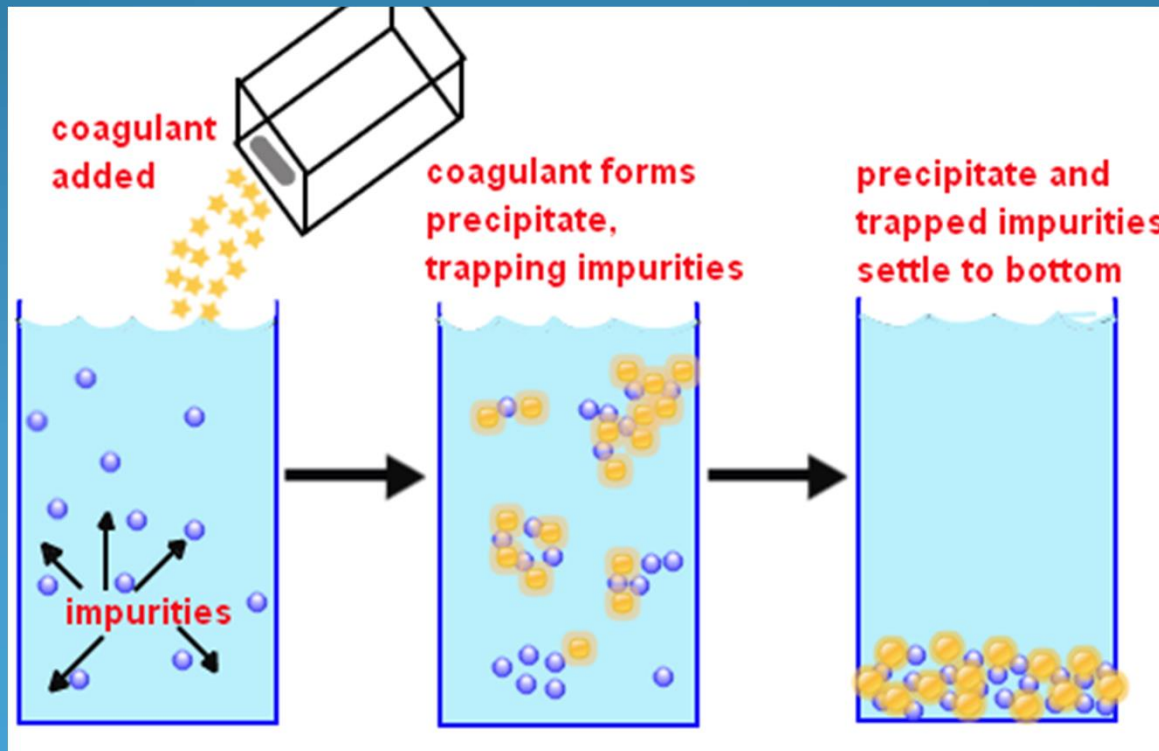
Common oxidation agents used in wastewater treatment:

- Oxygen(O_2).
- Chlorine (Cl_2).
- Sodium hypochlorite ($NaClO$).
- Calcium hypochlorite ($Ca(ClO)_2$).
- Potassium permanganate($KMnO_4$).
- Hydrogen peroxide(H_2O_2).

Main Treatment Technologies

3 Chemical Precipitation

Chemical precipitation in wastewater treatment involves the addition of chemicals to alter the physical state of dissolved and suspended solids and facilitate their removal by sedimentation.



Main Treatment Technologies

3 Chemical Precipitation

3.1 Coagulation

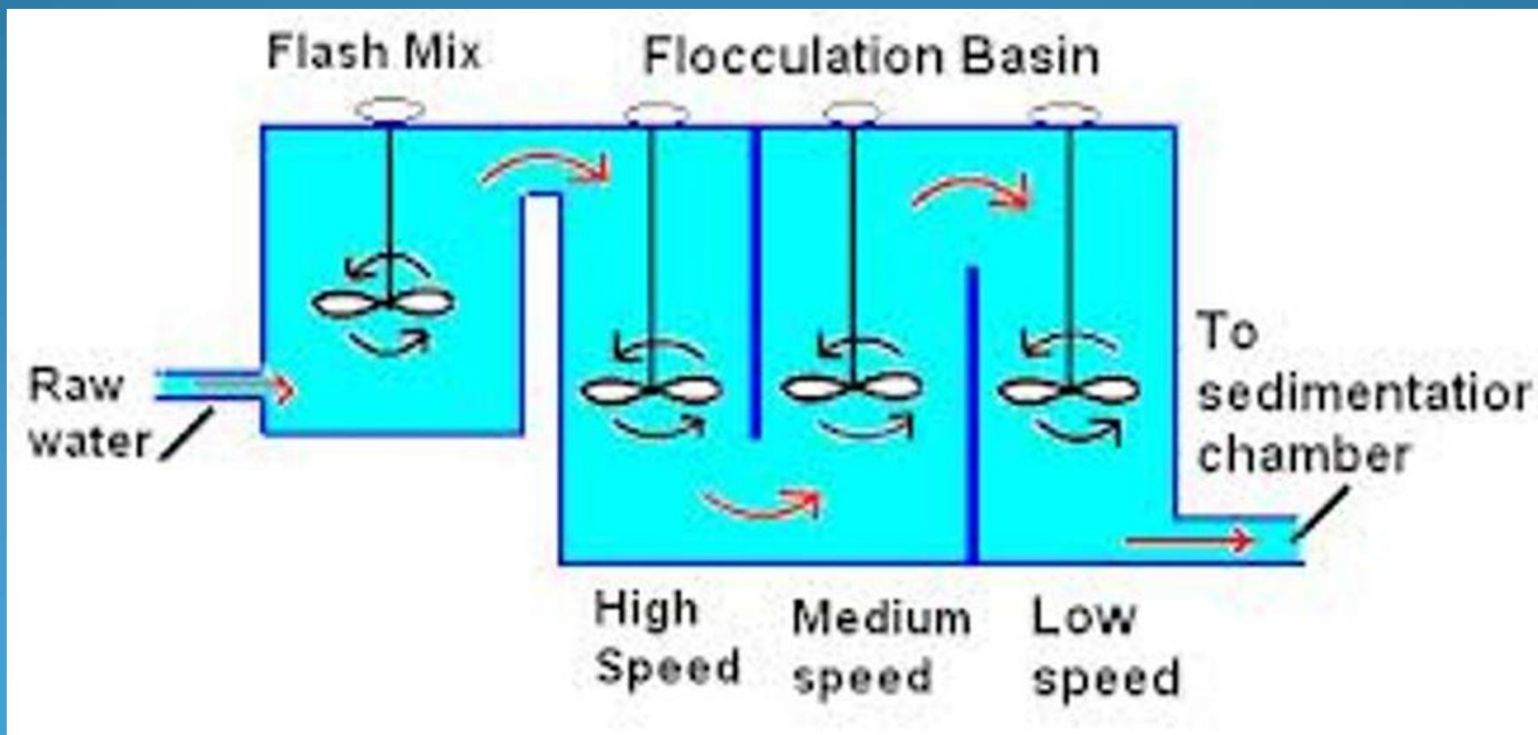
- ❖ It takes place in rapid mix, or flash mix basins which are very rapid. The primary function of rapid mix basin is to disperse the coagulant so that it contacts all of the wastewater.
- ❖ Over the years a number of different substances have been used as precipitants. The most common ones
 - Alum($\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$).
 - Ferrous Sulfate($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$).
 - Lime $\text{Ca}(\text{OH})_2$.
 - Ferric Chloride (FeCl_3).
 - Ferric Sulfate ($\text{Fe}_2(\text{SO}_4)_3$).

Main Treatment Technologies

3 Chemical Precipitation

3.2 Flocculation

The purpose of flocculation is to form aggregates or flocs from the finely divided matter. The flocculation of wastewater by mechanical or air agitation.



Main Treatment Technologies

3 Chemical Precipitation

**Chemical Precipitation for Improving Plant Performance

- From 80 to 90 percent of total suspended matter, 50 to 80% of BOD₅ and 80 to 90% of bacteria can be removed by chemical precipitation. In comparison, when plain sedimentation is used, only 50 to 70 percent of total suspended matter, 25 to 40% of BOD₅ and 25 to 75 percent of bacteria can be removed.

Main Treatment Technologies

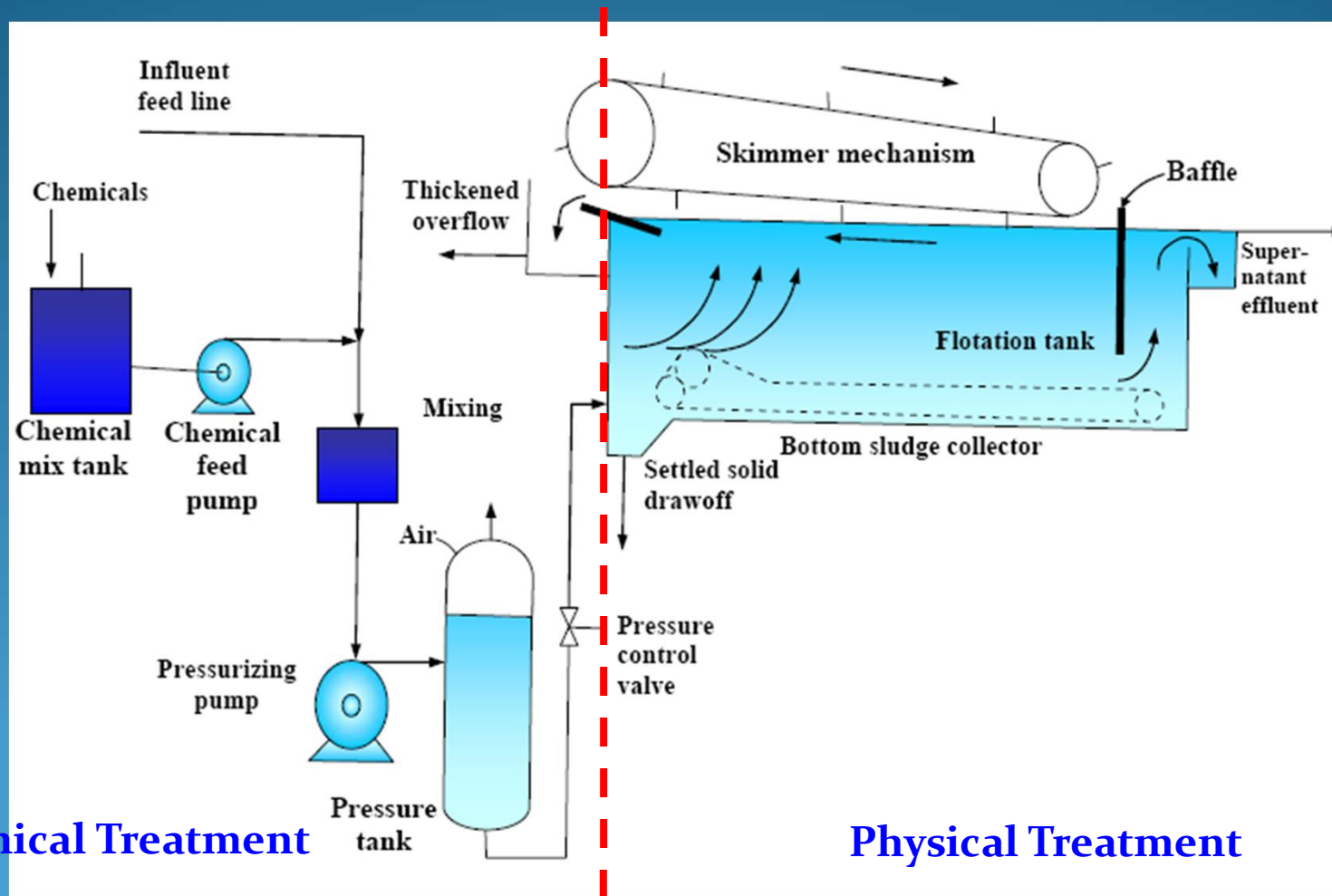
Physio-Chemical Treatment

Dissolved Air Flotation (DAF) System

- ❑ In dissolved air flotation (DAF), air is intimately contacted with an aqueous stream at high pressure, dissolving the air. The pressure on the liquid is reduced through a back pressure valve, thereby releasing micron-sized bubbles that sweep suspended solids and oil from the polluted stream to the surface of the air-flotation unit.
- ❑ Solids having a specific gravity greater than water tend to settle to the bottom and are removed by a rotating scraper arm. Attached to the same shaft is a rotating skimmer blade that removes the floating matter from the surface of the vessel into a skimming hopper.
- ❑ Clean water passes underneath a skirt and then must leave the vessel through a launder, which is located in the peripheral region.

Main Treatment Technologies

Physio-Chemical Treatment



Chemical Treatment

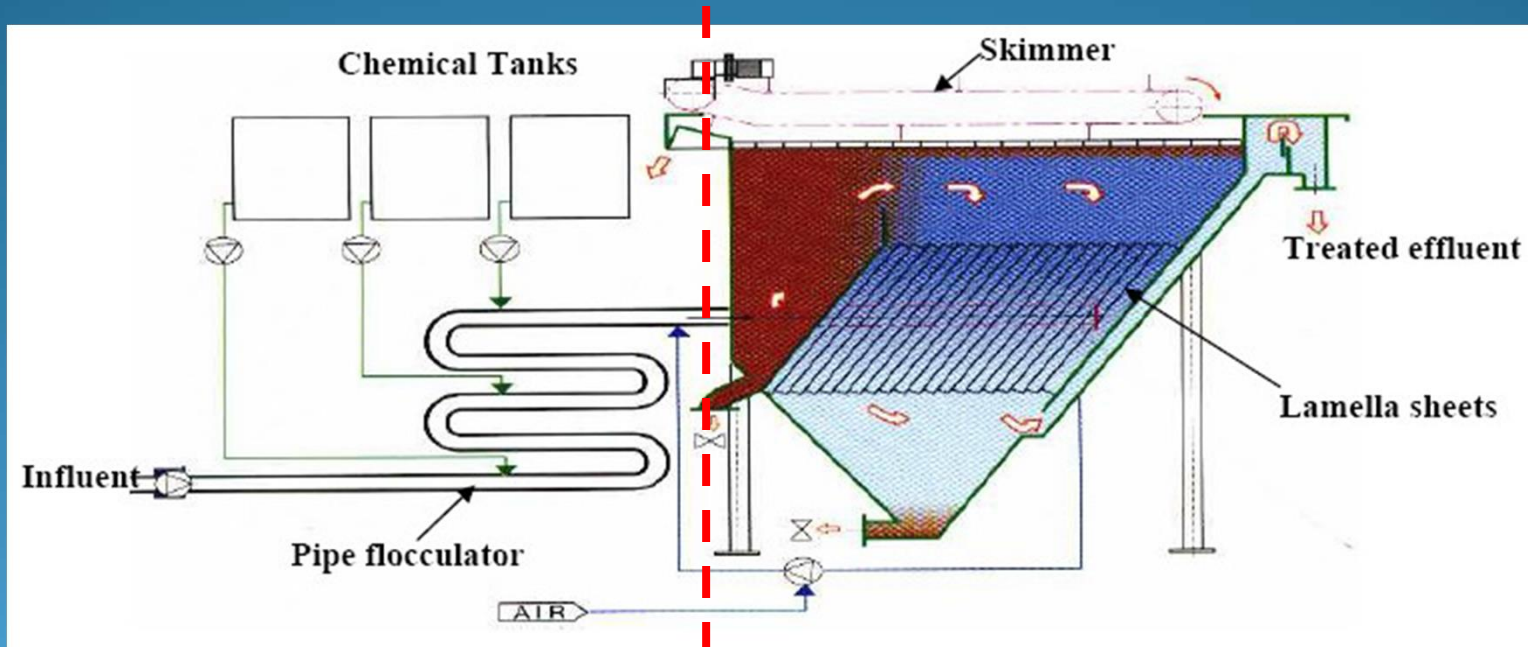
Physical Treatment

DAF system without recycling

Main Treatment Technologies

Physio-Chemical Treatment

A portion of the effluent water is recycled for pressurization. Compressed air is introduced into the discharge of the recycle pump, and intimate contact with the water is achieved in the aeration tank.



Chemical Treatment

Physical Treatment

DAF system with lamella, type flocculate & recycling

Main Treatment Technologies

Biological Treatment

1 Aerobic Biological Treatment

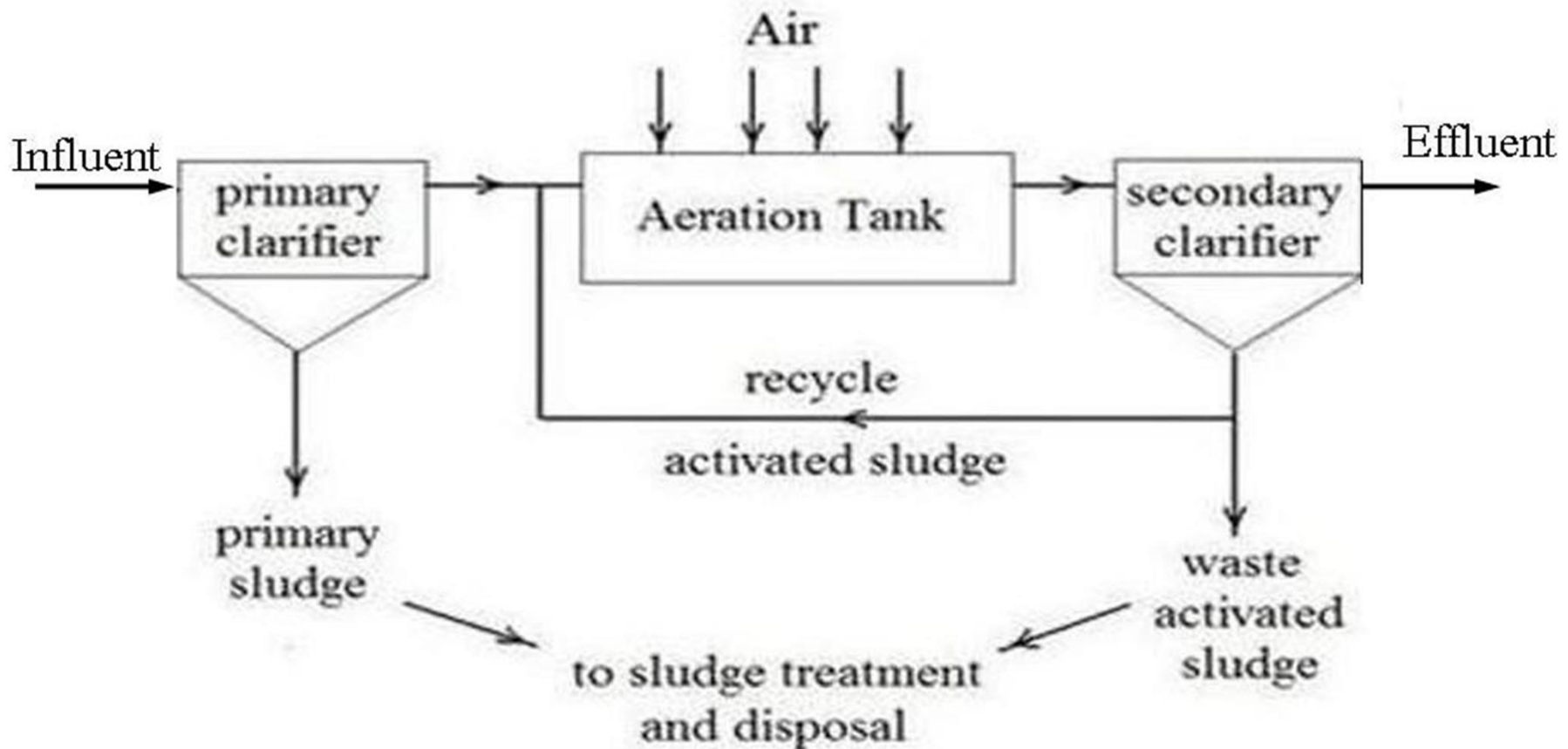
1.1 Activated-Sludge Process

1.1.1 Conventional Activated Sludge

- The conventional activated sludge system contains a tank for wastewater aeration followed by a settler and a solids recycle line.
- The wastewater flows through under constant aeration in the presence of activated sludge and exits at the end of the tank after 4-8 hours of residence time. The oxygen concentration in the reactor should be 0.5-2 mg/l throughout, where values over 2 mg/l are considered lost energy.

Main Treatment Technologies

Biological Treatment



Main Treatment Technologies

Biological Treatment

1.1.2 Extended Aeration

- This is the modified form of a conventional activated sludge process in which the production of excess sludge is minimized by oxidation and an increase in residence time, i.e. through the larger size of the aeration tank.
- The retention time is extended to 1-2 days, which results in a very low net yield of sludge due to its consumption of endogenous respiration.
- The main advantage of the extended aeration system is in having the minimum of sludge handling facilities as compared with other conventional activated sludge processes.
- The sludge in extended aeration effluents is very light, of nondegradable nature, and settles with difficulty. Therefore, settling tanks are provided with a longer retention time of approximately 4 hours versus 2 hours for the conventional treatment process.

Main Treatment Technologies

Biological Treatment

1.2 Sequential Batch Reactor “SBR”

- The unit processes involved in the SBR and conventional activated sludge systems are identical. Aeration and sedimentation/clarification are carried out in both systems. However, **there is one important difference**. In conventional plants, the processes are carried out simultaneously in separate tanks, whereas in SBR operation the processes are carried out sequentially in the same tank.

- As currently used, all SBR systems have five steps are commonly carried out in sequence as follows:

- 1- fill.
- 2- react (aeration).
- 3- settle (sedimentation/clarification).
- 4-draw (decant).
- 5- idle.

Main Treatment Technologies

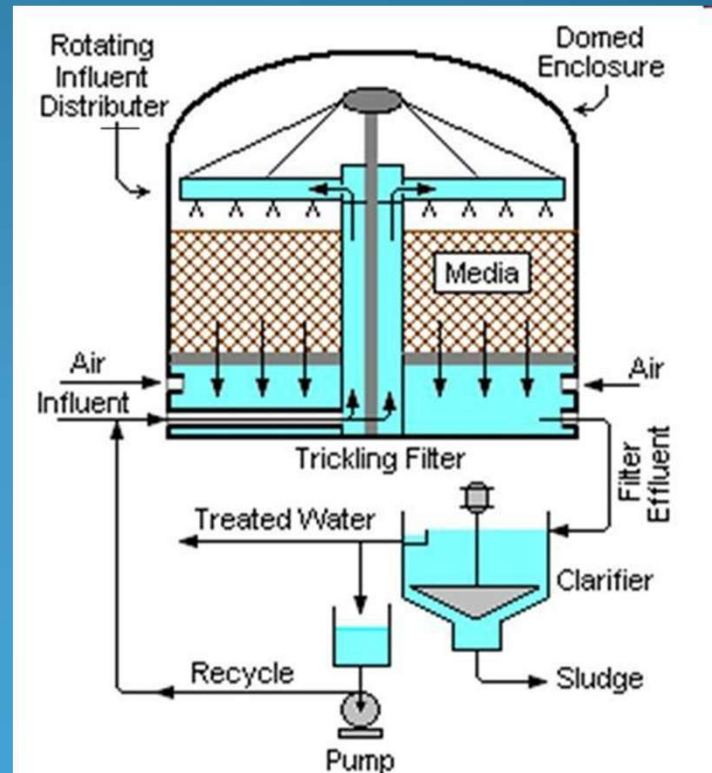
1.3 Trickling Filter “ Biological Air Filters”

- ❑ The trickling filter consists of a bed of a highly permeable medium to which microorganisms are attached and through which wastewater is percolated or trickled.
- ❑ The filter media usually consist of either rock (slag is also used) or a variety of plastic packing materials.
- ❑ Rock filter beds are usually circular and the liquid wastewater is distributed over the top of the bed by a rotary distributor, and the wastewater was allowed to contact the media for a short time.
- ❑ The collected liquid is passed to a settling tank where the solids are separated from the treated wastewater. In practice, portion of the liquid collected in the under-drain system or the settled effluent is recycled, usually to dilute the strength of the incoming wastewater and to maintain the biological slime layer in a moist condition.

Main Treatment Technologies

1.3 Trickling Filter “ Biological Air Filters”

The limitations of the trickling filter included a relatively high incidence of clogging, the long rest period required, and the relatively low loading that could be used.



Main Treatment Technologies

Anaerobic Biological Treatment

- The anaerobic process has been developed for the treatment of sludge and high strength organic load.
- The disadvantage of the anaerobic treatment as compared to aerobic treatment is that the slow growth rates require a relatively long detention time in the digester for adequate waste stabilization to occur.

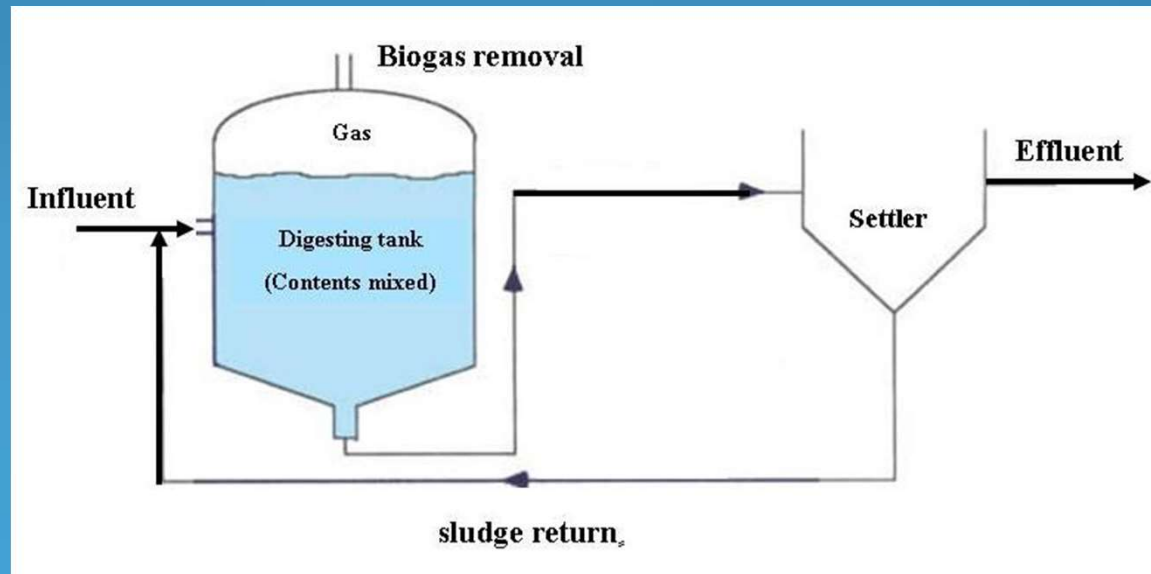
On the other hand, most of the organic waste is converted to methane gas, which is combustible and therefore a useful end product.

The high temperature necessary to achieve adequate treatment are often listed as disadvantages of the anaerobic treatment process; however, high temperatures are necessary only when sufficiently long mean cell-residence time cannot be obtained at nominal temperatures.

Main Treatment Technologies

Anaerobic Biological Treatment

- ❑ In the anaerobic process, untreated wastes are mixed with recycled sludge and then digested in a reactor sealed off from the entry of air.
- ❑ After digestion, the mixture is separated in a clarifier or vacuum flotation unit, and the supernatant is discharged as effluent, usually for further treatment.
- ❑ Settled anaerobic sludge is then recycled to seed the incoming wastewater.



Auxiliary Operations

1 Disinfection

- ❑ Disinfection refers to the selective destruction of disease-causing organisms. All the organisms are not destroyed during the process.

This differentiates disinfection from sterilization, which is the destruction of all organisms.

- ❑ Disinfection is most commonly accomplished by the use of the following agents:

- 1- Chemical Agents.
- 2- Physical Agents.
- 3- Radiation.

Auxiliary Operations

2 Reuse of Treated Effluent

- ❑ Reuse of treated wastewater in various industries is becoming very popular being a cheaper source of water supply where the industrial plant can reuse its own wastewater through recycling or after treatment or it can be used for irrigation.
- ❑ There are many possibilities that some of hazardous and toxic chemicals may pass to the treated effluents. In order to eliminate health hazards several advanced methods of tertiary treatment for industrial effluents with disinfection are available world wide to meet the standards for effluent reuse for several purposes.

Auxiliary Operations

2.1 Advanced Treatment Techniques “Tertiary Treatment”

2.1.1 Filtration

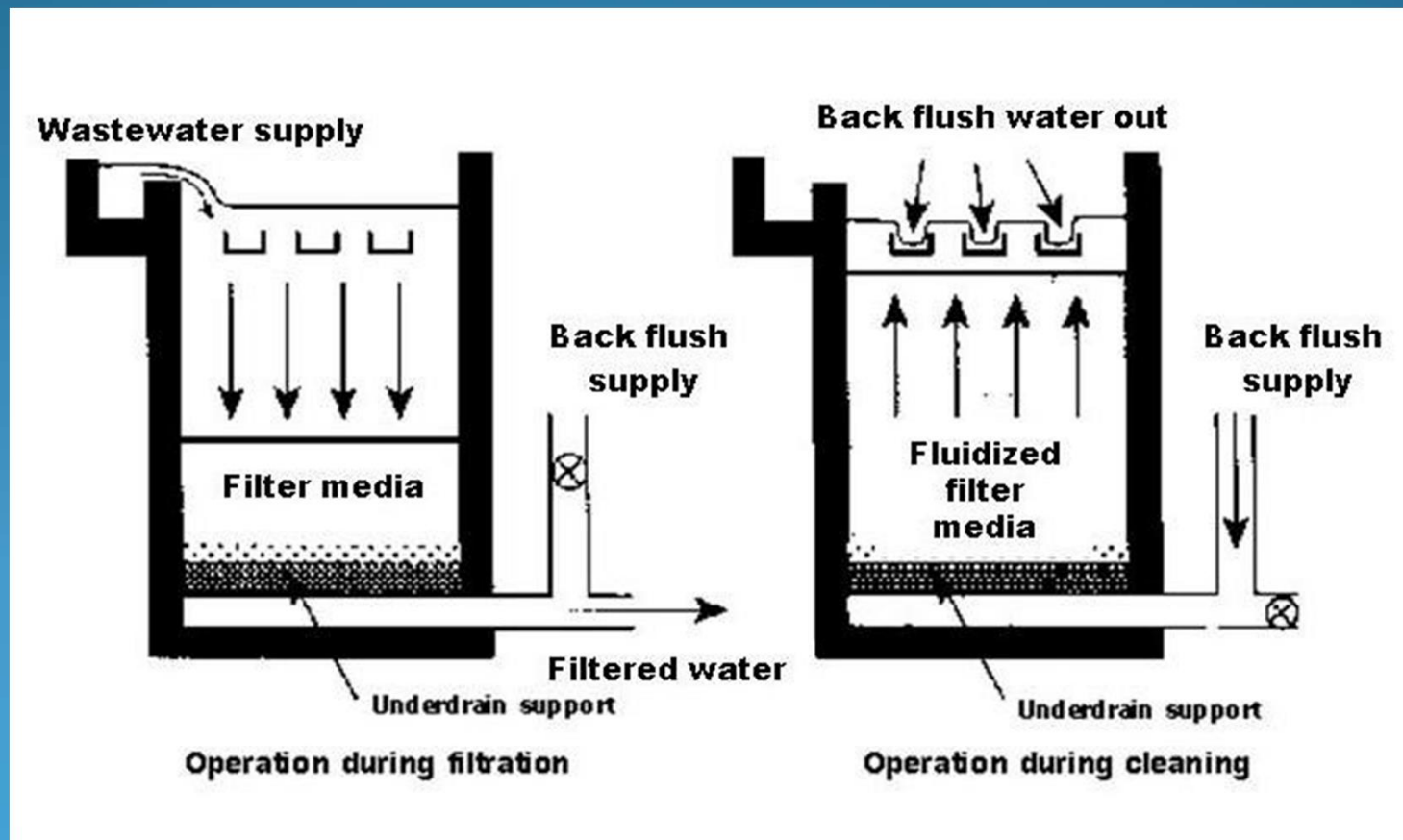
2.1.1.1 Granular Media Filters

- ❖ Granular media filters are widely used in wastewater treatment for the removal of both organic and inorganic suspended solids.
- ❖ Granular media filters can operate either by gravity flow (gravity filters) or by pressure (pressure filters).
- ❖ The most common types of filters are two and three media filters. A common design for a two media filter would have a bed of 0.5 mm sand layer below a 0.9 mm anthracite layer. A common design for a three media filter would have a 30 to 40 mesh garnet layer below the sand layer. Specialty filters could use different media with different effective sizes.

Auxiliary Operations

2.1.1.1 Granular Media Filters

Solids are captured by the bed and eventually have to be removed by scouring and backwashing.



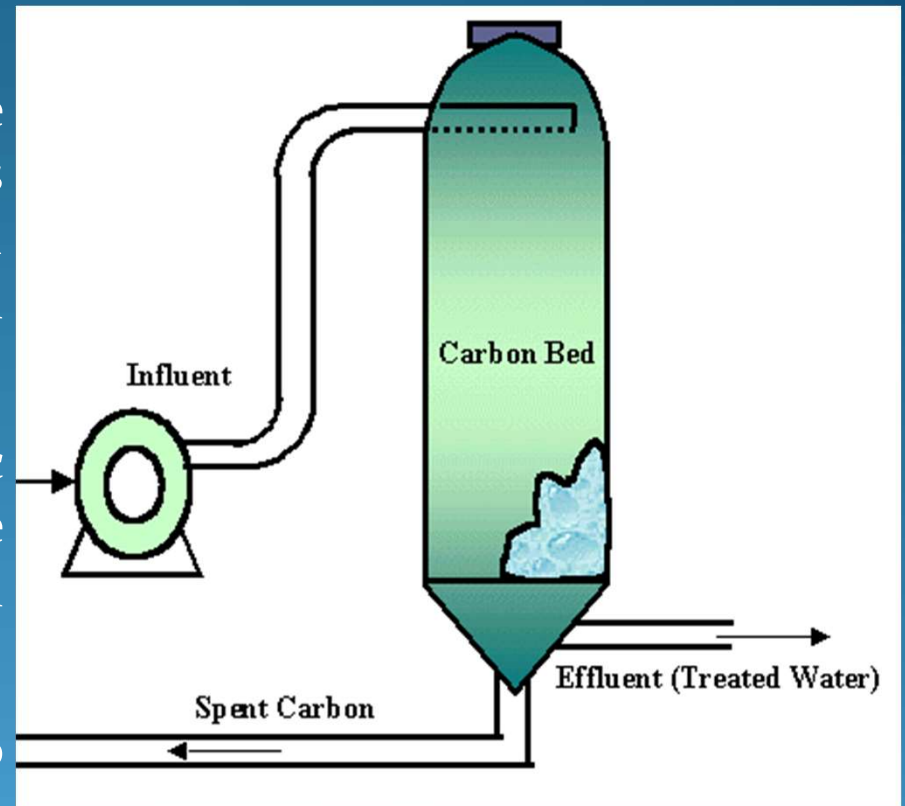
Auxiliary Operations

2.1.1.2 Carbon Adsorption

Carbon adsorption is used to remove certain types of organic contaminants that are resistant to primary and secondary treatment when such removal is required.

There are some cases where an organic stream contains contaminants that are valuable enough to recover with carbon adsorption.

Another use of carbon columns is to remove Volatile Organic Compounds (VOCs) from wastewater. All VOCs can be adsorbed onto activated carbon to a greater or lesser extent.



Auxiliary Operations

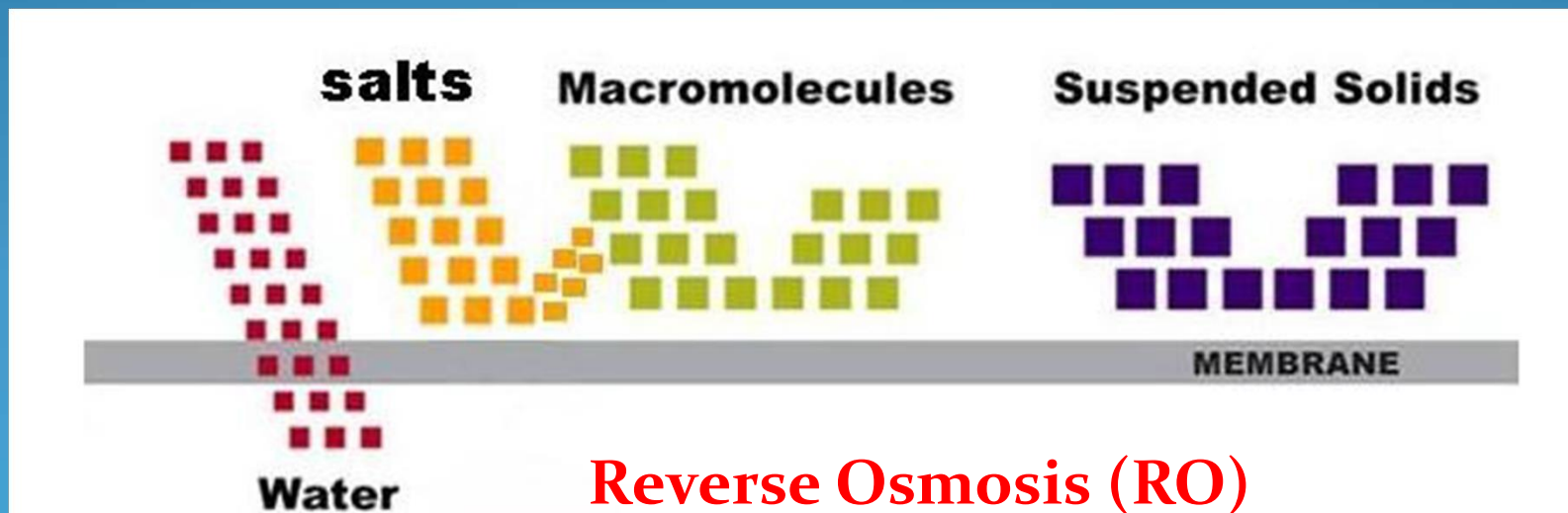
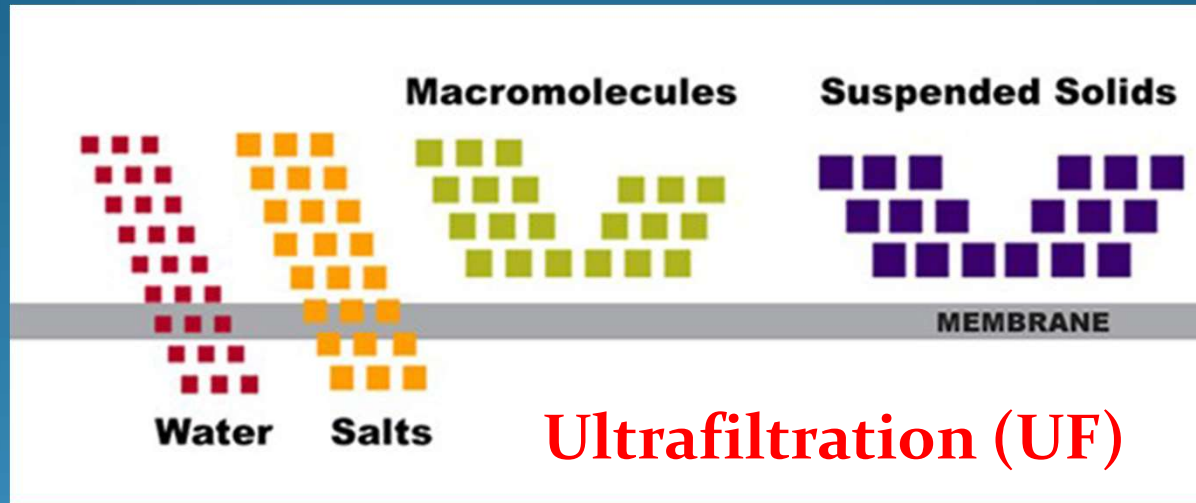
2.1.2 Membrane Separation

Membrane separation techniques are used to remove very fine particles from water, to desalinate water, and recently, membranes have been developed to remove organics from water, such as oil and other organics that have clogged and degraded membranes in the past

- ❖ Membranes are made of various materials but all have a consistent pore size that will permit particles or molecules of a given size to pass through the membrane and will prevent molecules or particles of a size larger than the pore size from passing through.
- ❖ Membrane Separation include ultrafiltration (UF) and reverse osmosis (RO).

Auxiliary Operations

2.1.2 Membrane Separation



Course Code: CE 4141

Course Title: Environmental Engineering

Lecture – 18

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15-09-2019



Sludge treatment and disposal

Sludge Treatment & Disposal

- The sludge resulting from wastewater treatment operations and processes is usually in the form of a liquid or semisolid liquid that typically contains from 0.25 to 12 percent solids by weight, depending on the operations and processes used.
- Sludge is by far the largest in volume, and its processing and disposal is perhaps the most complex problem facing the engineer in the field of wastewater treatment.
- The problems of dealing with sludge are complex because it is composed largely of the substances responsible for the offensive character of untreated wastewater. The portion of sludge produced from biological treatment requiring disposal is composed of the organic matter contained in the wastewater but in another form which can also decompose and become offensive; and only a small part of the sludge is solid matter.

Preliminary Operations

Preliminary Operations are used to provide a relatively constant, homogenous feed to sludge-processing facilities.

1 Sludge Grinding

Sludge grinding is a process in which large and string material contained in sludge is cut or sheared into small particles to prevent the clogging of or wrapping around rotating equipment.

2 Sludge De-gritting

In some plants where separate grit removal facilities are not used ahead of the primary sedimentation tanks or where the grit removal facilities are not adequate to handle peak flows and peak grit loads, it maybe necessary to remove the grit before further processing of the sludge.

Preliminary Operations

3 Sludge Blending

- Sludge from primary, secondary, and advanced processes are blended to produce a uniform mixture to enhance plant operability and performance.
- Blending tanks are usually equipped with mechanical mixers and baffles to ensure good mixing.

4 Sludge Storage

- Sludge storage is particularly important in providing a uniform feed rate ahead of the following processes: **lime stabilization**, **heat treatment**, **mechanical dewatering**, drying, and **thermal reduction**.
- If sludge is stored longer than two or three days, it will deteriorate and will be more difficult to dewater.

Sludge Thickening

Thickening is a procedure used to increase the solids content of sludge by removing a portion of the liquid fraction.

Gravity Thickening

Gravity thickening is accomplished in a tank similar in design to conventional sedimentation tank. Normally, a circular tank is used.

The supernatant flow that results is returned to the primary settling tank or to the head works of the treatment plant.

The thickened sludge that collected on the bottom of the tank is pumped to the digesters or dewatering equipment as required.

Sludge Stabilization

- Sludge is stabilized to
 - (1) reduce pathogens
 - (2) eliminate offensive odors
 - (3) inhibit, reduce, or eliminate the potential for putrefaction.
- The technologies for sludge stabilization are
 - (1) lime stabilization.
 - (2) heat treatment.
 - (3) anaerobic digestion.
 - (4) aerobic digestion.

Sludge Stabilization

lime stabilization

- ❖ In the lime stabilization process, lime is added to untreated sludge in sufficient quantity to raise the pH to 12 or higher.
- ❖ Two methods for lime stabilization used are addition of lime to sludge prior to dewatering, termed “lime pre-treatment” and the addition of lime to sludge after dewatering, or “lime post-treatment”.
- ❖ Either hydrated lime, $\text{Ca}(\text{OH})_2$, or quicklime, CaO , may be used for lime stabilization.

Sludge Dewatering

Dewatering is a physical (mechanical) unit operation used to reduce the moisture content of sludge.

1 Chemical Conditioning

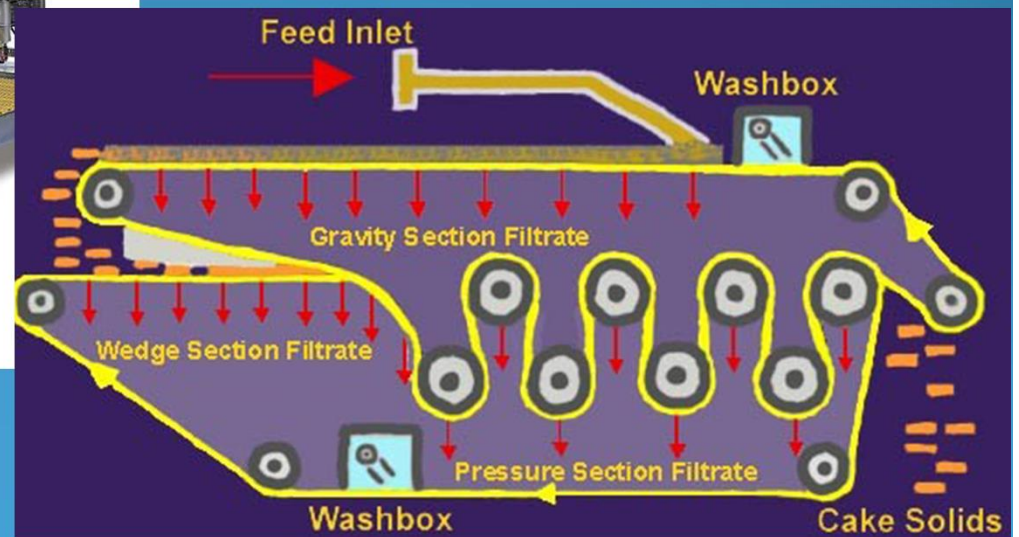
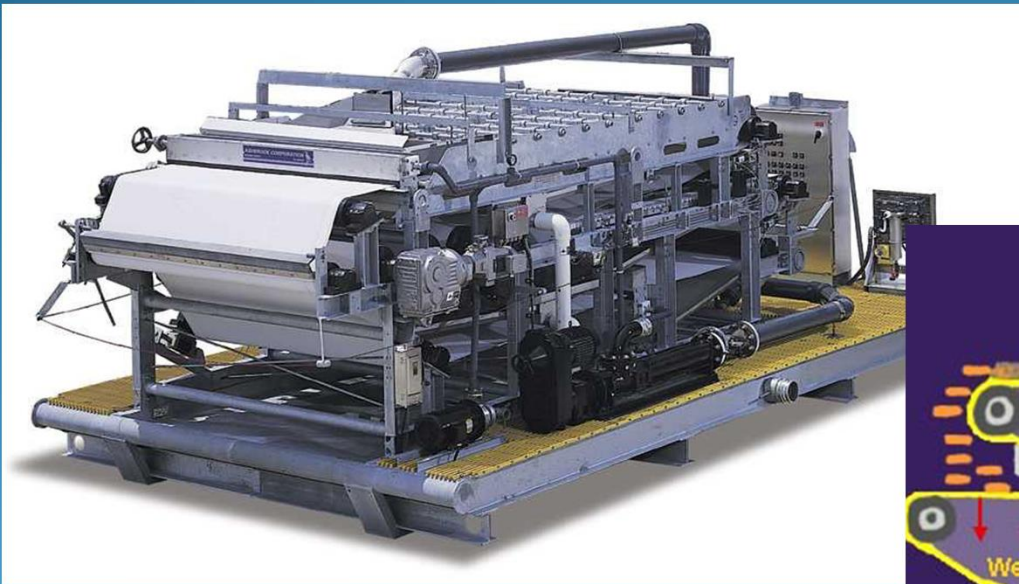
- ❑ The use of chemicals to condition sludge for dewatering is economical because of the increased yields and greater flexibility obtained. Chemical conditioning can reduce the 90 to 99 percent incoming sludge moisture content to 65 to 85 percent, depending on the nature of the solids to be treated.
- ❑ Chemicals used include ferric chloride, lime, alum, and organic polymers.

Sludge Dewatering

2 Mechanical Dewatering

2.1 Belt Press

- Belt filter presses are continuous-feed sludge-dewatering devices that involve the application of chemical conditioning, gravity, and pressure.



Sludge Dewatering

2 Mechanical Dewatering

2.2 Filter Press

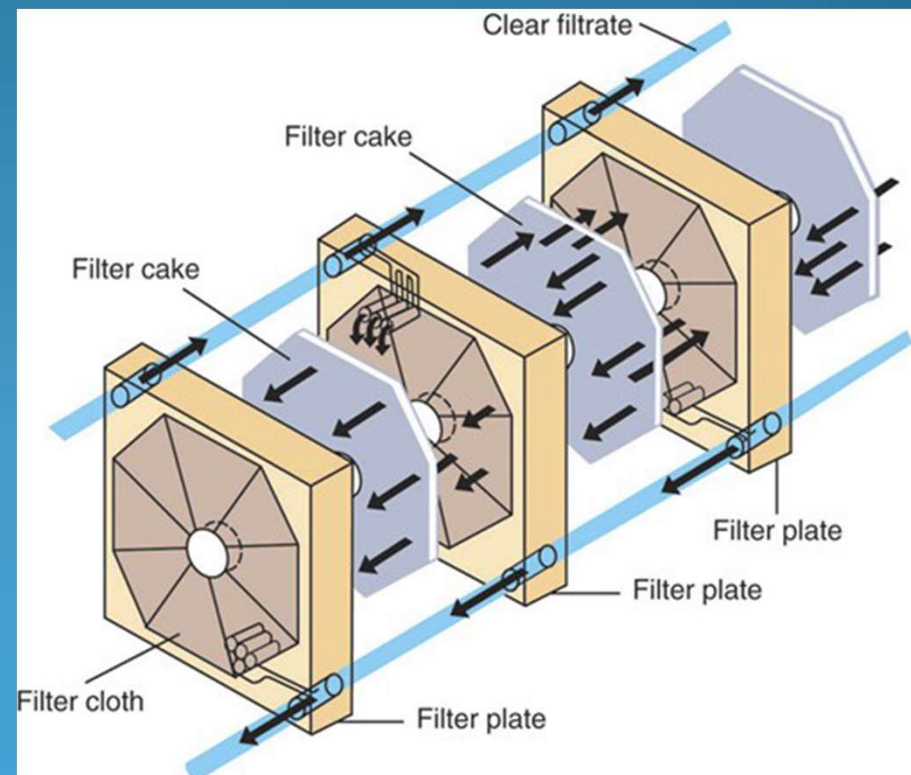
- ❑ In a filter press, dewatering is achieved by forcing the water from the sludge under high pressure.
- ❑ Filter press consists of a series of rectangular plates, recessed on both sides, that are supported face to face in a vertical position on a frame with a fixed and movable head. A filter cloth is hung or fitted over each plate.
- ❑ In operation, chemically conditioned sludge is pumped into the space between the plates, and pressure of 100 to 225 lb/in² (690 to 150kN/m²) is applied and maintained for 1 to 3 hrs, forcing the liquid through the filter cloth and plate outlet ports.

Sludge Dewatering

2 Mechanical Dewatering

2.2 Filter Press

The plates are then separated and the sludge is removed. The filtrate is normally returned to the head works of the treatment plant.



Sludge Treatment & Disposal

3 Sludge Drying Beds

3.1 Conventional sand Drying Beds

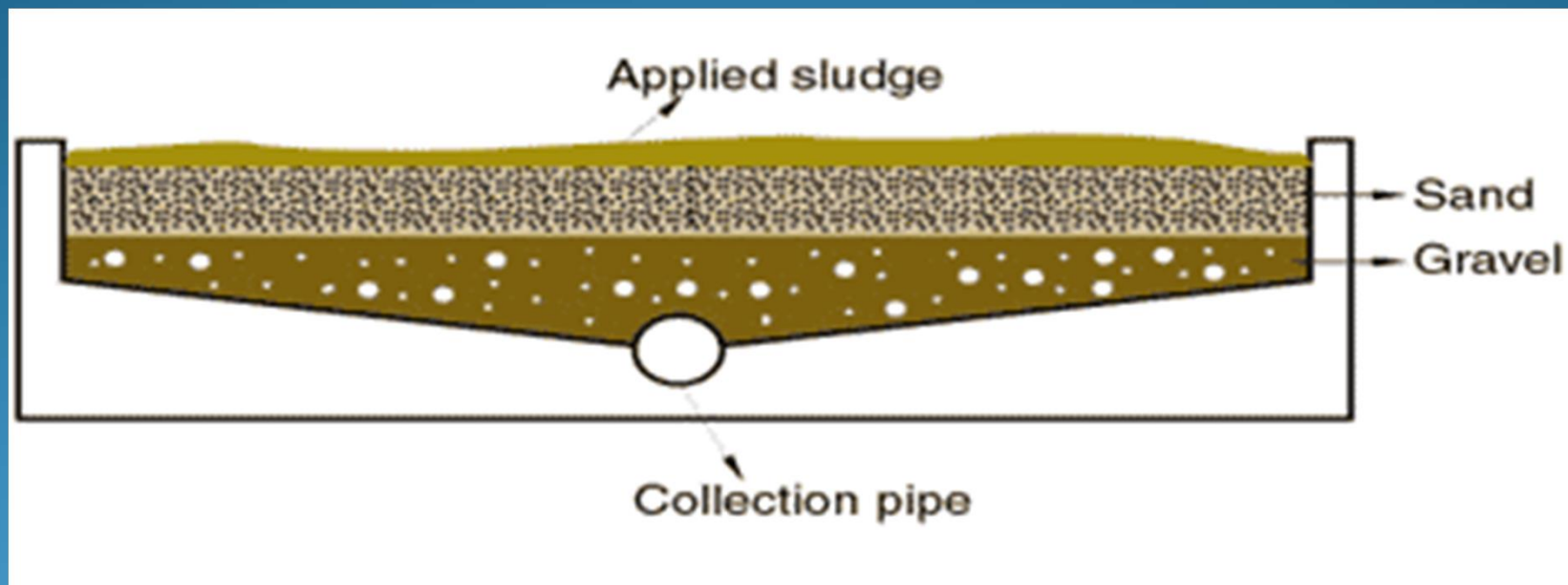
In a typical sand drying bed, sludge is placed on the bed in a 8 to 12 in (200 to 300 mm) layer and allowed to dry. Sludge is dewatered by drainage through the sludge mass and supporting sand and by evaporation from the surface exposed to the air. Most of the water leaves the sludge by drainage.

The moisture content is approximately 60 percent after 10 to 15 days under favorable conditions. Sludge removal is accomplished by manual shoveling into wheelbarrows or trucks or by a scraper or front-end loader.

Sludge Treatment & Disposal

3 Sludge Drying Beds

3.1 Conventional sand Drying Beds



Sludge Disposal and Utilization

1 Beneficial Uses of Sludge

The fertilizer value of biological sludge, which should be evaluated where the sludge is to be used as a soil conditioner, is based primarily on the content of nitrogen, phosphorus, and potassium.

2 Sludge Disposal

2.1 Landfilling

- ❑ There are two types of landfills for industrial sludge: those which accept non-hazardous wastes and those that accept hazardous wastes.
- ❑ Landfills are designed to prevent the contamination of ground water and to prevent the migration of the wastes from the landfill.

Sludge Disposal and Utilization

2.1 Landfilling

- ❑ For this reason, landfills usually have thick, 3 to 10 feet covers of clean impermeable clay or dirt on top.
- ❑ Landfill bottom and sides are also made of impermeable clays or dirt. The sump collects leachate from the landfill and is pumped to a wastewater treatment plant.
- ❑ Hazardous landfills must meet very stringent requirements. The bottoms and sides must be double contained, which is usually accomplished by installing two liquid barriers, usually plastic.
- ❑ The top of a hazardous waste landfill must be impermeable, which is usually accomplished by installing a plastic water barrier in the dirt cover.
- ❑ Liquid is collected from the space between the barriers in a leachate collection system and is properly disposed of.

Model For Industrial Wastewater Treatment Plant



Thank you All