EWCE 333
Wastewater Engineering and Sanitation

Lecture 1

Instructor

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Lecture details

Topics	References
• Water, sanitation and health • Objectives of environmental sanitation • Classification of Wastes	1. Water Supply and Sanitation- Feroz Ahmed and Mujibur Rahman ITN - BUET

Environmental Sanitation

According to WHO (World Health Organization, 1950), environmental sanitation refers all condition that affect health, including –

- the control of water supply, excreta and wastewater disposal,
- refuse disposal,
- housing condition,
- food protection,
- atmospheric conditions and
- the safety of the working environment.

Definition of Sanitation

Sanitation may be defined as the science and practice of effecting healthful and hygienic conditions and involves the study and use of hygienic measures such as:

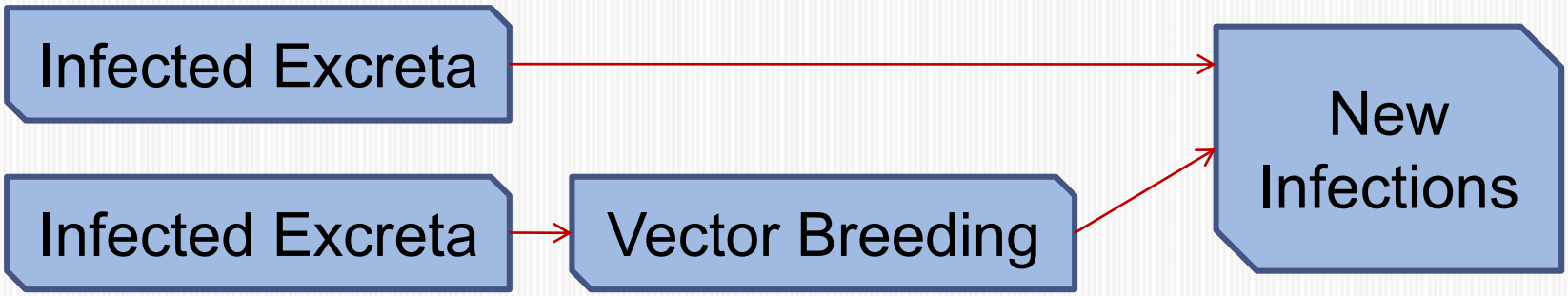
- Safe, reliable water supply;
- Proper drainage of wastewater;
- Proper disposal of all human wastes;
- Prompt refusal of all refuse.

Objectives of Sanitation

The principal objectives of providing sanitary facilities are:

- To have improved public health
- To minimize environmental pollution

Transmission of diseases



Direct way:

Pathogens in the excreta of an infected person reach another person and initiate infection. These are the excreted infections.

Indirect way:

Infection in other persons are caused by transmission of excreted pathogens via insects such as flies and mosquitoes and rodents such as rats, which act as vectors.

Effects of Sanitation

Sanitation prevents infection, which may occur in different forms through different transmission media such as:

- Ingestion of food or drinking water contaminated with faeces
- Ingestion of beef infected with tapeworms
- Contact with contaminated water
- Contact with contaminated soil
- Insect vectors

Water, Sanitation and Health

- Improvement of health is not possible without sanitary disposal of human wastes.
- However, neither sanitation nor water supply alone is good enough for health improvement.
- Health education or hygiene promotion must accompany sufficient quantities of safe water and sanitary disposal of excreta to ensure the control of water and sanitary related diseases.

Water, Sanitation and Health

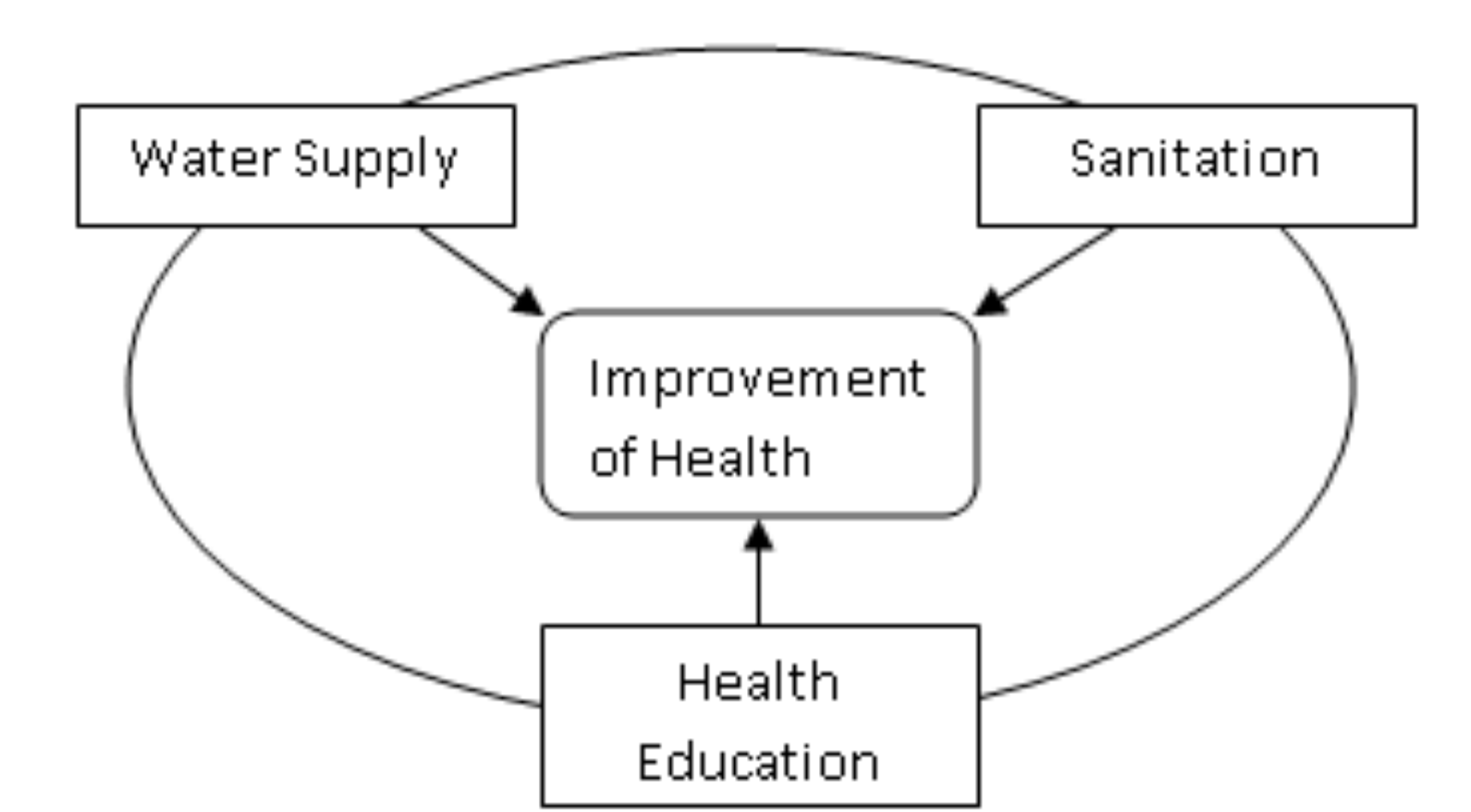


Figure: Interrelationship between water, sanitation and health education

Classification of Waste

Human Wastes or Human Excreta:

- Refers to only human faeces and urine.
- Usually not combined with other liquid or solid wastes.
- Also known as night soil, when collected without dilution in large volumes of water.

Municipal Sewage/ Wastewater:

- Liquid waste conveyed by a sewer.
- May include domestic and industrial discharges as well as storm water, groundwater, infiltration and inflow.

Classification of Waste

Domestic Sewage:

- Liquid wastes, which originate in the sanitary conveniences, e.g., water closets, urinals, bath, sinks etc. of the dwellings, commercial facilities and institutions in a community.

Sullage:

- Liquid discharges from kitchens, wash basins etc. and excludes human excreta.
- Less foul than domestic sewage.
- Can be discharged through open surface drains in unsewered areas.

Classification of Waste

Industrial Wastes:

- Include the liquid discharges from spent water in different industrial processes such as manufacturing and food processing.

Storm Water:

- It is the surface runoff during and immediately after rainfall, which enters sewer through inlets.
- It is not as foul as sanitary or industrial sewages.
- It can be carried through open drains or channels and disposed of in natural rivers or streams without any treatment.

Classification of Waste

Solid Wastes:

- It include all materials which are normally solid and are discarded as useless or unwanted during human activities.

- Domestic solid waste is a composition of organic food wastes, paper and paper products, wood, plastics, leather and rubber, textile products, glass, metals, inert stone and other bulky wastes.

- Solid wastes from factories and industries often consist of packaging, spoiled material and unwanted by-products.

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Lecture 2

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Lecture Details

Topics	Reference
• Functions of sanitation system • Types of sanitation system • Criteria for a good sanitation system • Appropriateness of sanitation system	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Functions of Sanitation System

With respect to human waste management, sanitation systems may be considered to have the following functions -

- **Excretion and storage**
- **Collection and transportation**
- **Process / Treatment**
- **Disposal / Recycle**

Types of Sanitation System

Whether the waste is stored, treated and disposed of at the point of generation or transported to somewhere else for treatment and disposal –

- On-site systems
- Off-site systems

Types of Sanitation System

Based on the methods of collection and conveyance–

- Dry systems
- Wet systems

Types of Sanitation System

Whether the systems allows infiltration or not–

- Permeable / Unconfined systems
- Confined systems

On-Site Sanitation Systems

- Wastes are collected, treated and disposed of at the point of generation.
- Examples – pit latrines and septic tank systems.
- Widely used in rural areas of both developed and developing countries, even in urban areas in absence of costly sewerage systems.
- Modification of this system includes ventilated pit latrine, pour-flush single and double-pit latrines, aqua privies, septic tanks and so on.

On-Site Sanitation Systems

The principles of on-site system are-

- Infiltration of liquids into the soil.
- Solids are retained, digested aerobically and have to be removed or a new pit has to be dug at regular intervals.
- It is primarily designed to dispose of human excreta.
- Wastewaters from cooking, clothes washing and bathing are collected in small drains & disposed of in soakaways for infiltration.

On-Site Sanitation Systems

- This system is most suitable for sparsely settled rural areas with low population density and low water consumption because of the system's dependence on the infiltration capacity of the soil for the disposal of the liquid portion of excreta.

- This system is not feasible for areas with high population density, high water consumption, and low infiltration rate of soil or high groundwater table.

Off-Site Sanitation Systems

- Waste is collected and transported to somewhere else for treatment and disposal.
- E.g. bucket latrine systems and conventional sewerage systems.
- The basic elements of this system are collection, transportation, treatment and disposal and/or reuse.
- The waste is collected either through house sewers or manually using buckets or vaults; transported either by cart, truck or sewer system to a suitable distant place where it is treated prior to disposal or reuse.

Off-Site Sanitation Systems

- Collection and transportation of the wastes through a sewer reticulation system requires that the waste be diluted by water. It is essential, piped water supply be available in areas where this system is to be applied.

- This waterborne system is by far the most satisfactory system of waste disposal provided sufficient funds are available for its construction and maintenance.

Dry Sanitation Systems

- In dry systems no water is used for dilution of the wastes.

- They are usually applied in unsewered areas with no piped water supply, e.g., pit latrine systems (on-site) and bucket latrine systems (off-site).

Wet Sanitation Systems

- In the wet system, the waste is diluted with flushes of water

- Suitable where piped water supply systems are available, e.g., septic tank systems (on-site) and conventional sewerage systems (off-site)

Permeable/ Unconfined Systems

- The liquid part of the wastes is allowed to infiltrate.
- Cause potential pollution of the groundwater.
- Example - pit latrines.

Confined Systems

- The liquid portion of the wastes is not allowed to infiltrate into the ground.
- No potential for groundwater pollution.
- Example – aqua privies, septic tanks etc.

Criteria for Good Sanitation Systems

- Simple and inexpensive in construction and operation
- Should not contaminate surface soil, surface water or groundwater
- Minimum handling of excreta and free from odour and unsightly conditions
- No access to flies, insects and animals

Criteria for Good Sanitation Systems

- Should use little or no water
- Should require little supervision and maintenance
- Should handle all waste and wastewater
- Should use little or no mechanical equipment

Appropriateness of Sanitation Systems

Purpose of sanitation:

- Health
- Privacy
- Convenience
- Cleaner Environment
- Prestige/Status

A good sanitation system should, therefore, be able to meet all the different requirements of the people.

Appropriateness of Sanitation Systems

Suitability of Sanitation System from the perspectives of -

- Level of Water supply
- Population Density

Appropriateness of Sanitation Systems

Level of Water supply:

---- On site pit latrine system would not be appropriate with piped water supply.

---- Water borne sewerage system (e.g., conventional sewerage system) is not a feasible option with bucket carried or hand-pump water supply.

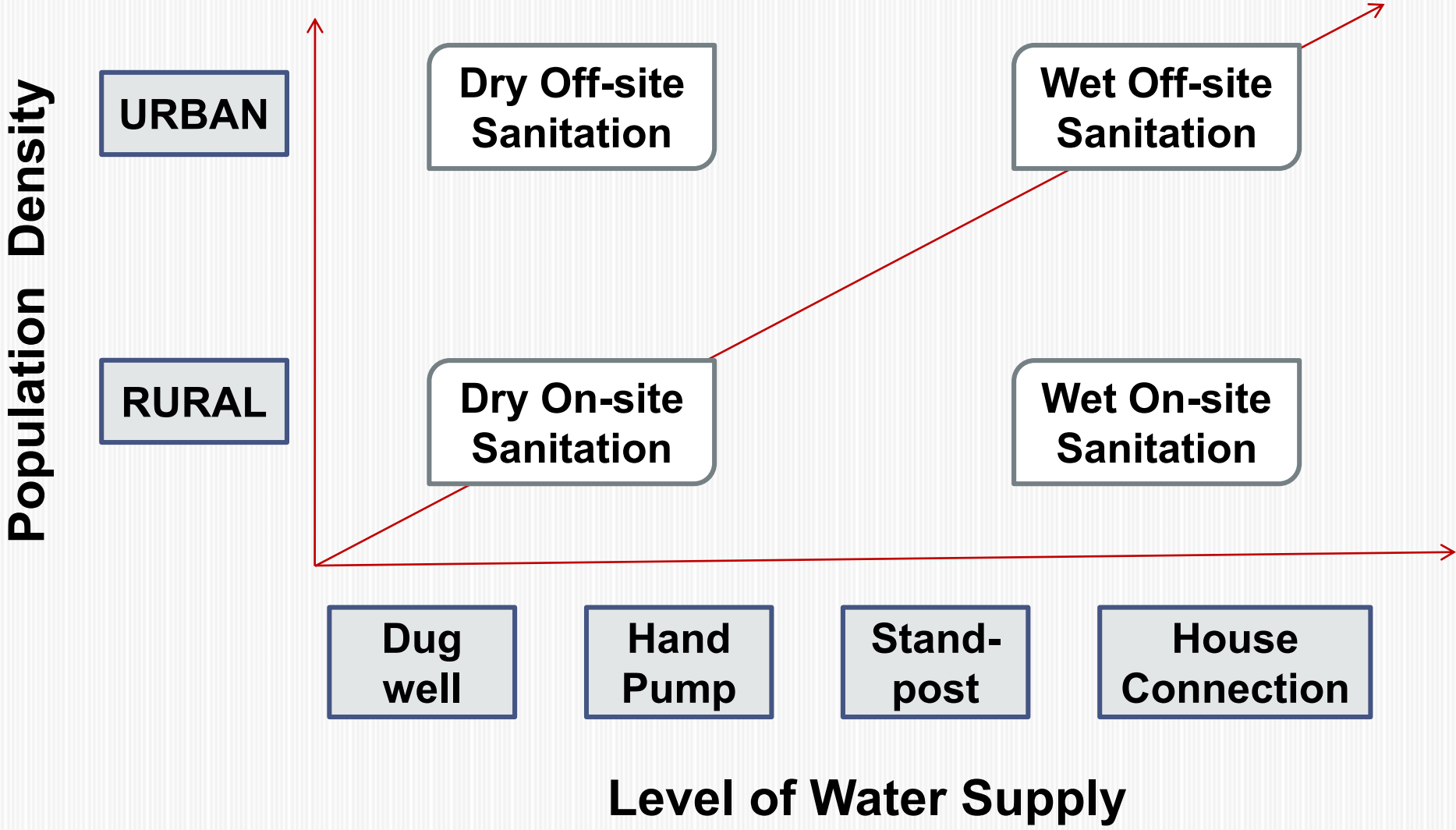
Appropriateness of Sanitation Systems

Population Density:

----- On site system is more appropriate for low-density rural setting.

----- Off-site systems more suitable for high density urban centers.

Appropriateness of Sanitation Systems



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Wastewater Engineering and Sanitation

Lecture 3

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Lecture Outlines

Topics	Reference
• On-site sanitation systems for rural & low income urban communities • Simple pit technology – design considerations and design • Two pit latrine systems – design considerations and design	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Low Cost Sanitation Technologies

- **Pit Latrine**

- **Pour-flush Latrines** (where a water seal is maintained with low-volume of flushing)

All forms of pit latrines are not fully sanitary.

With slight modifications in design and with some interventions, conventional pit latrines could be improved to be hygienic.

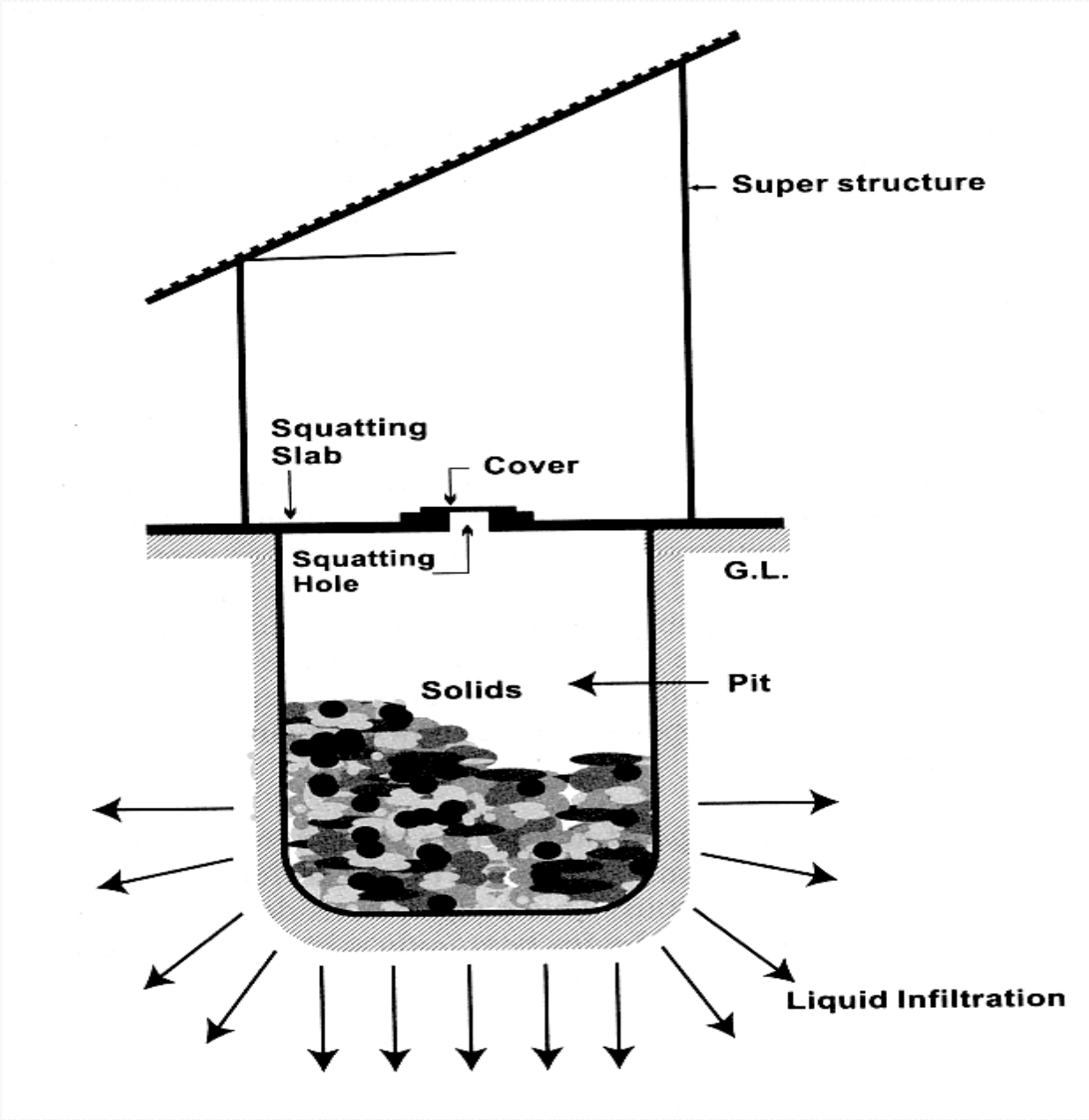
Pit Latrine Technologies

The major types of pit latrines include:

- Simple or Home-made pit latrines
- Ventilated Improved Pit (VIP) Latrines
- Reed Odorless Earth Closet (ROEC)

Pit Latrine Technologies



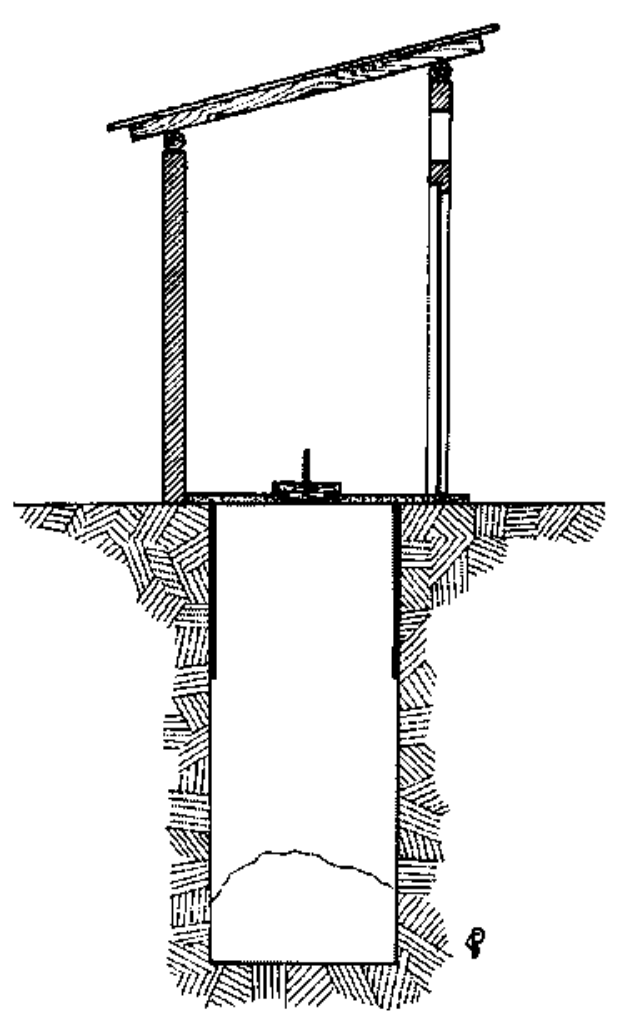


Pit Latrine Technologies

- Most common and simplest form of excreta disposal in developing countries
- Consists of a manually dug or bored hole into the ground, an appropriate seat or squatting slab and a shielding superstructure
- Urine and other liquids soak into the ground and solid materials are retained and decomposed in the pit

Types of Pit Latrines

- **Direct pit latrine-** Excreta falls directly into a pit underneath the user



Types of Pit Latrines

- **Off-set pit latrine**- Excreta pass through a short pipe or a channel to a pit a few meters away

- **Partly off-set pit latrine**- When part of the pit is under the shelter and part is outside

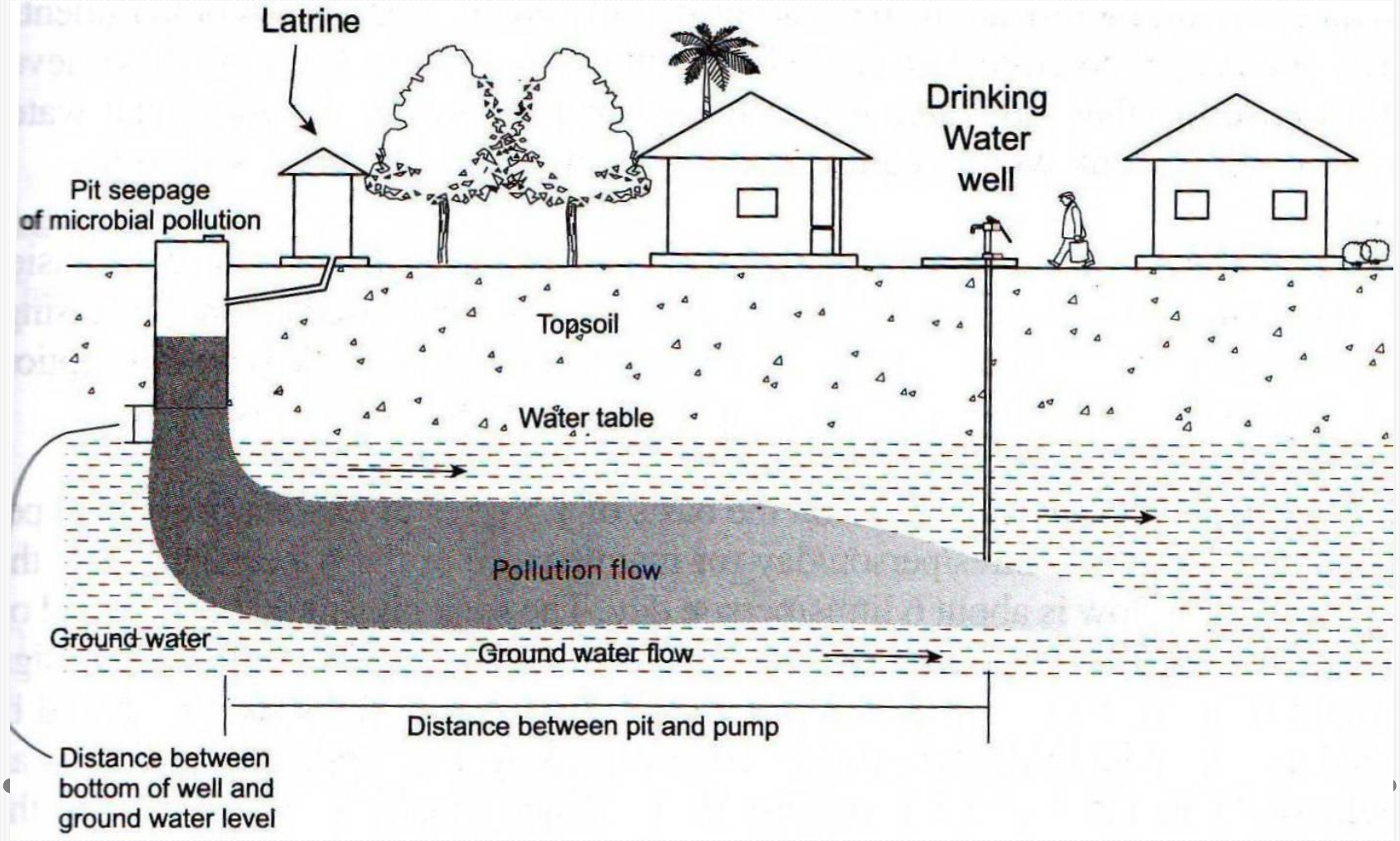
Design Considerations for Pit Latrines

- Pit width - ≤1.5 m (commonly 1.0-1.5 m), to avoid expensive construction of cover slab
- Soils with permeability ≥ 2.5 mm/hour to allow liquid infiltration into soil.
- Pits in unstable soils must be fully lined (otherwise, collapse of superstructure).

Materials used: concrete blocks, bricks, cement-stabilized soil blocks, masonry, perforated oil drums etc.

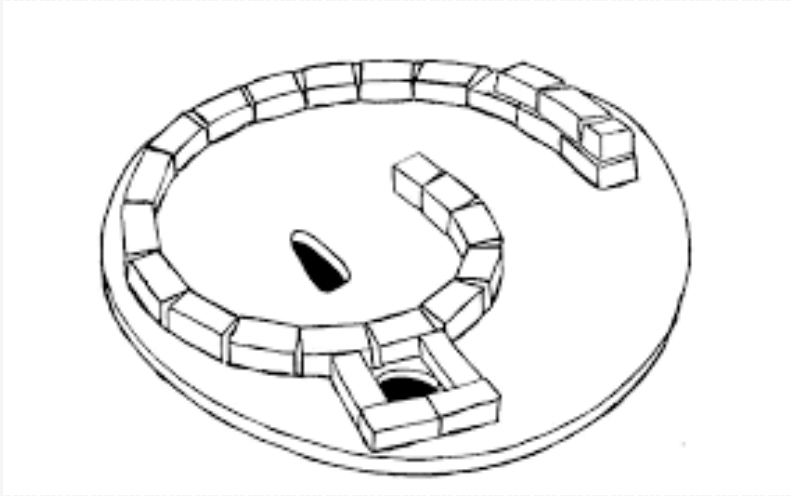
Design Considerations for Pit Latrines

- Distance between pit and a source of drinking water ≥10.0m should be provided (to avoid possible contamination).



Design Considerations for Pit Latrines

- Distance between pit bottom and water table ≥2m.
- Adequate ventilation by leaving openings above and below door or by constructing a spiral wall without door.



Design Considerations for Pit Latrines

- Pit depth: depends on ground water table, soil condition.

- 5-ring pits (@ 1 ft. per ring) are common.

Design of Pit Latrines

Effective Pit Volume:

$$V = C \times P \times N \quad \ldots\ldots (1)$$

where, V = Effective volume of the pit, m^3

C = Solids accumulation rate, m^3/person/year

P = Number of persons, (expected to use the latrine)

N = Design life, years

Design of Pit Latrines

Typical values of C:

- Wet pit: 0.04 m^3/person/year (0.02 - 0.04)

- Dry pit: 0.06 m^3/person/year (0.03 - 0.06)

Note: Accumulation rate is lower for wet pit (i.e., pit below GWT) because biodegradation is faster under wet condition

Design of Pit Latrines

Effective Pit Volume, $V = (\pi d^2/4)\, h$ ..... (2)

where, d = diameter of pit, m

h = effective depth of pit, m

Assuming a suitable d (maximum permissible d is 1.5 m) of pit, h can be obtained.

Usually a free space of 0.5 m is kept at top of the pit.

Total depth of pit, $H = h + 0.5$ ..... (3)

Advantages of Pit Latrines

- Low investment for construction.
- No expert inputs are required during construction.
- Design is readily available; local materials can be used
- Free from the risk of falling a child into it and hence suitable for children.

Advantages of Pit Latrines

- Excrements are better contained than in open defecation.
- Unit can serve one or several households.
- Easy operation and maintenance.
- Pit latrines use no water for flushing.

Disadvantages of Pit Latrines

- Potential odor and flies problem in simple pit latrine.
- Require access to open ground and digging of new pits or emptying of existing ones every few years.
- Emptying of pits can be very difficult (may require manual labor, pits may collapse). Also manual desludging poses health hazard

Disadvantages of Pit Latrines

- Toilets cannot be situated in houses, hence lack of privacy and safety concerns especially during night time.
- Re-location of individual leach-pits difficult in densely populated areas
- They cannot be used at all in crowded areas, on rocky ground, where the groundwater level is high or in areas periodically flooded

Design Problem for Pit Latrines

Problem 1:

Local authority in a village is offering pre-cast concrete rings of 1.0 m diameter and 0.3 m depth of concrete slab to cover it at a subsidized rate.

Design a simple pit latrine for a family of 7.

The soil is unconsolidated/loose and the GWT is 5.0 m below the ground surface.

The family wants the latrine to serve for 4 years.

(Note: Change design parameter as you find appropriate.)

Design Problem for Pit Latrines

Solution:

Effective Pit Volume

$V = C \times P \times N$

$= 0.06 \times 7 \times 4 = 1.68\ m^3$

Cross sectional area of pit = $(\pi d^2/4)$

$= 0.785\ m^2$

Effective Pit depth = 1.68/0.785 = 2.14 m

Design Pit depth = 2.14 + 0.5 = 2.64 m (free board/space =0.5m)

No. of rings required = 2.64/ 0.3 = 8.8 ≈ 9 rings (Height of ring = 0.3m)

But to use more than 5-6 rings is not realistic.

Design Problem for Pit Latrines

Considering N = 3 yrs

$V = 0.06 \times 7 \times 3 = 1.26\ m^3$

Effective Pit depth = 1.26/0.785 = 1.61 m

Design depth = 2.11 m

Rings required = 2.11/ 0.3 = 7 rings

Possible but construction could be difficult.

Actual depth of pit = $7 \times 0.3 = 2.1 + 2 = 4.1$m

Design Problem for Pit Latrines

Considering N = 2 yrs
V = 0.84 m^3

Effective Pit depth = 1.07 m

Design depth = 1.57 m

Rings required = 1.57/ 0.3 = 5.23 ≈ 6 rings

Actual depth of pit = 6 × 0.3 = 1.8 m
1.8 + 2 = 3.8 < 5m (ok)

Check for Gw allowance

Design Problem for Pit Latrines

Also recommended:

1) A vent pipe for the pit
(150 mm dia. PVC pipe, top of the vent pipe is 500mm higher than highest point of roof)

2) Use of suitable cover for the squatting hole, when latrine not in use

Design Problem for Pit Latrines

Problem 2:
Repeat the problem 1,
if the latrine has to serve 2 families, each with 7 members.

GWT is high, located 4.0 m below the ground surface.

Design life cannot be less than 2 years and a 2.0 m gap must be provided between the pit bottom and GWT.

Design Problem for Pit Latrines

Problem 3:

A farmer excavated 1.5 m x 2.0 m x 2.5 m (depth) pit for construction of a room which he now wants to convert into a pit latrine.

(2.5 m - 0.5 m)

Requirements/ constraints are:
(i) Water availability is limited
(ii) Excreta cannot be seen through squatting hole.

Design a suitable latrine and find design life for 6 persons. Consider low GWT.

The pit is to be constructed as a permanent one with brick lining.

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Lecture 4

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Lecture Outlines

Topics	Reference
• Ventilated Improved Pit (VIP) Latrine • Reed Odorless Earth Closet (ROEC)	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Ventilated Improved Pit Latrine (VIP)

Scope of use

- Families that use solid materials like news paper, stone, etc. for anal cleansing are not recommended to use pour-flush latrines as water seal is likely to become blocked or broken.

- In such cases a latrine direct access to the pit is more appropriate and therefore, ventilated improved pit (VIP) may be a good solution.

Ventilated Improved Pit Latrine (VIP)

Basic difference from other pit latrines

The basic difference of VIP Latrine from pit latrine is,

(i) it requires a vent pipe and

(ii) design should be such that it maintains continuous airflow.

This also increases the cost of super structure.

Ventilated Improved Pit Latrine (VIP)

Elements of ventilated pit Latrines:

- Pit
- Cover slab
- Vent pipe - large enough ≥ 150mm dia. to allow free passage of air with fly screen
- Super structure.

Types of VIP

(1) Single Pit VIP Latrine

-Suitable where mechanical emptying is possible when the pit is full

-Manual emptying is not recommended as the excreta at the top are fresh and potentially dangerous for the emptier

-Usually designed for longer life (e.g., 10 years) where feasible and act as permanent structure.

-When a single pit VIP latrine becomes full, there are two options-

- Constructing a new one
- Emptying the existing pit

Types of VIP

(2) Twin Pit VIP Latrine

-Two separate pits, with the superstructure located centrally over the off-set pits.

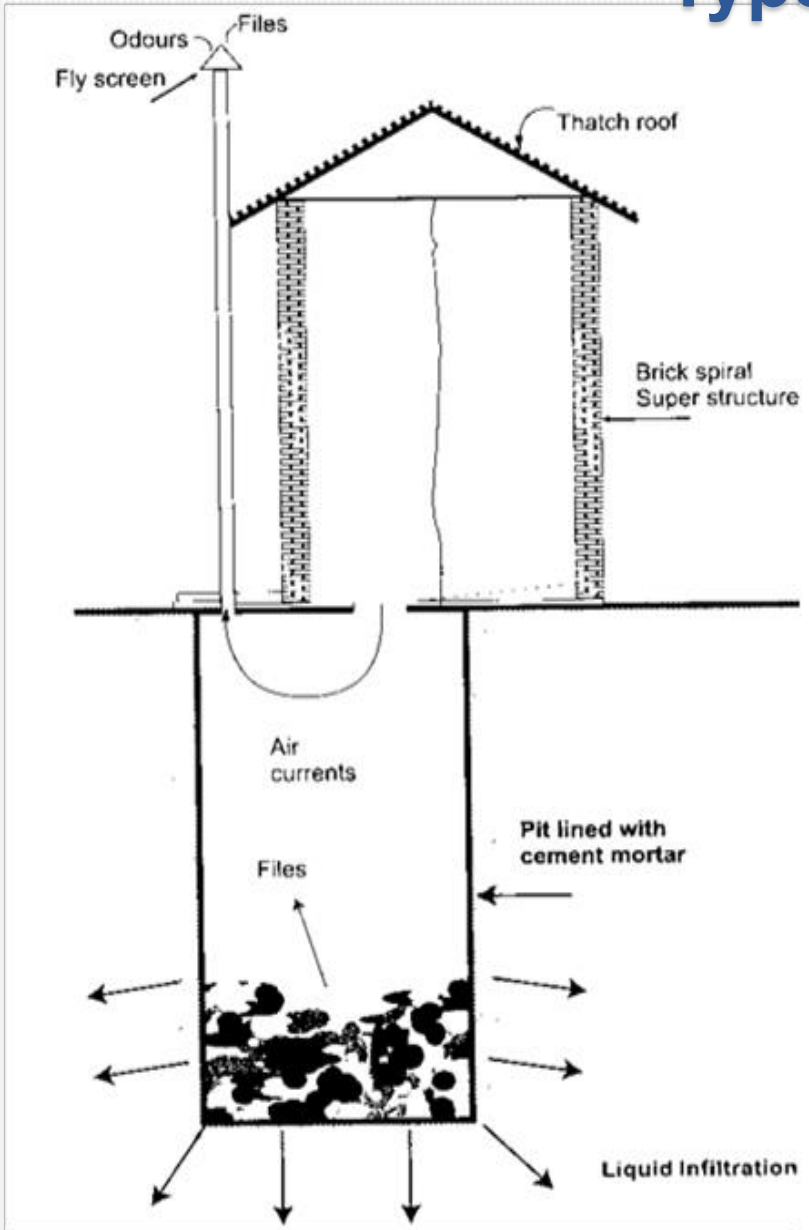
-The slab covering the pit has two squat holes, one over each pit.

-Only one hole and pit are used at a time.

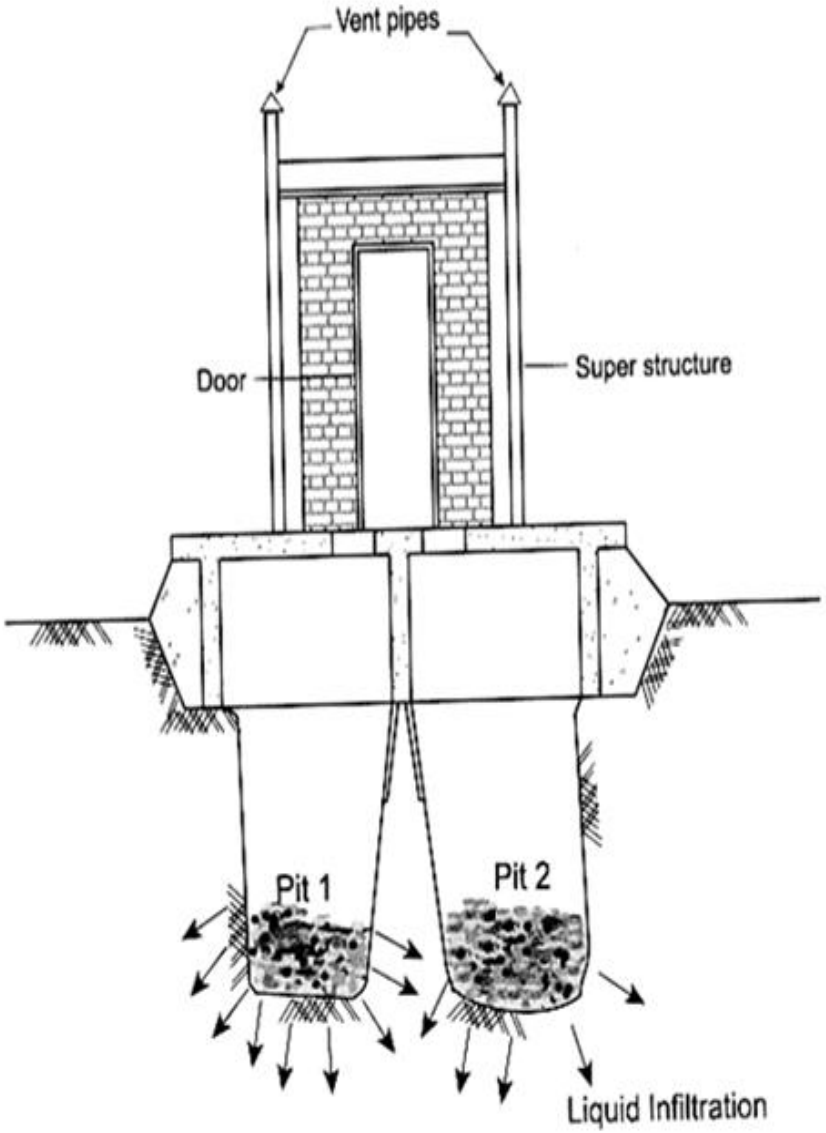
-When the pit is full (e.g., in 1-3 years), its squat hole is covered up and the second pit is put into service.

-When the second pit is full, the contents of the first pit are removed and it is put back into service. This cycle continues.

Types of VIP



Single Pit VIP Latrine



Twin Pit VIP Latrine

Advantages of VIP

- Minimum water requirement
- Control odor and insects
- Low-cost
- Easy to construct and maintain

Major Problems of VIP

- Requirement of unobstructed ventilated pipe (even 0.5m higher than surrounding building) makes the latrine more suitable for low-density area than high-density urban area
- Improper design / climatic condition may not allow sufficient air flow
- Potential for groundwater pollution.

Design of VIP

Problem:

Design a VIP latrine for a family of eight. The family uses water for anal cleansing. The ground water table is 2.0 m below the ground surface.

(Ref: Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman, ITN –BUET)

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Lecture 5

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Lecture Outlines

Topics	Reference
• Pour-Flush Latrine Latrine - design considerations and design	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Water Seal (Pour-Flush) Technologies

- A further improvement to the pit latrine can be obtained with a water-seal.
- The pour-flush latrine has three major components parts: (a) the superstructure, (b) The latrine pan with its integral water seal and (c) a single or altering twin leach pits.
- Water-seal is a U-pipe filled with water, attached below the squatting pan that completely prevents passage of flies and odor.

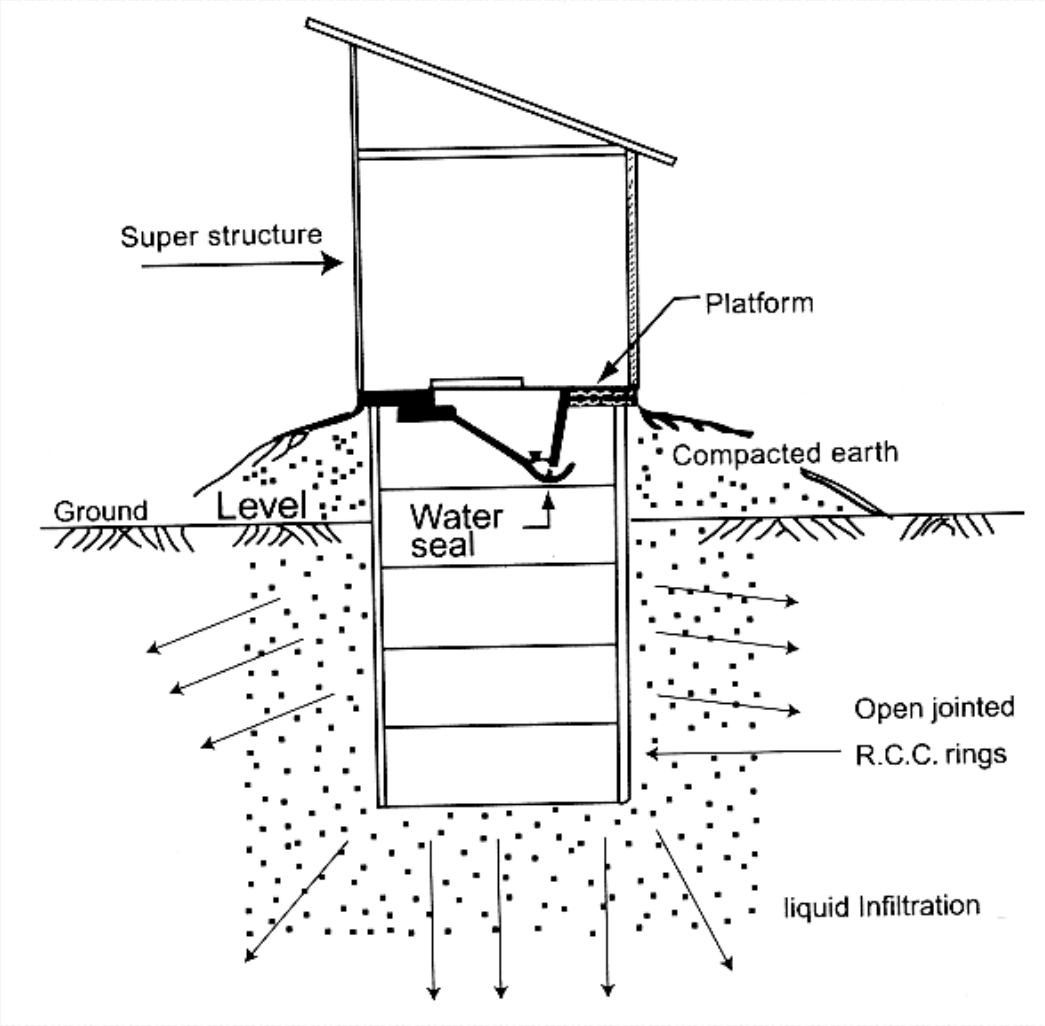
Pour-Flush Technologies

- The water-seal is only 15-25 mm deep and the latrine can be flushed by hand using 1.5 to 2.0 litres of water.
- The latrine can also be located, if desired inside the house with off-set pit.
- Small quantity of water used in a pour flush toilet is sufficient to carry the excreta to a soakage pit up to 80m away.

Types of Pour-Flush Technologies

(1) **Direct Pit Pour-flush Latrine**

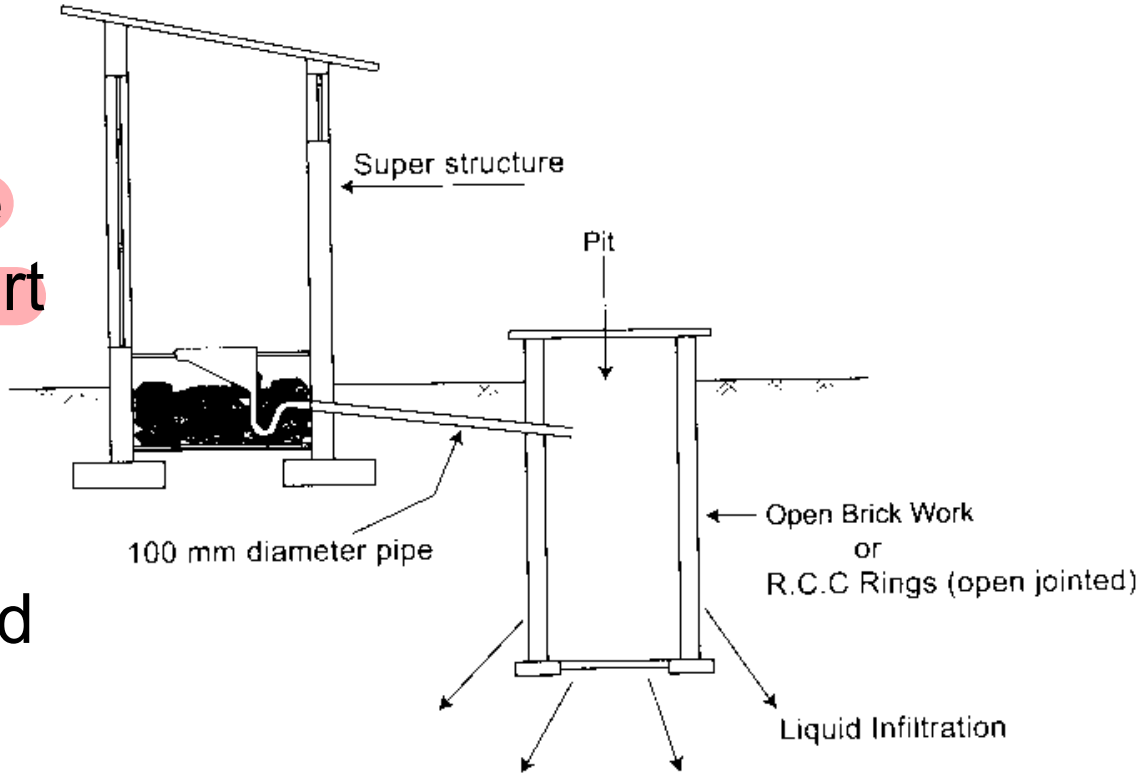
- Modification of simple pit latrine where the squatting plate is provided with a 25 mm water seal and is placed directly over the pit.



Types of Pour-Flush Technologies

(2) Off-set Pit Pour-flush Latrine

- Completely off-set pit
- Pit is connected to the pour-flush pan by a short length of 100 mm diameter pipe.
- Latrine can be installed inside the house



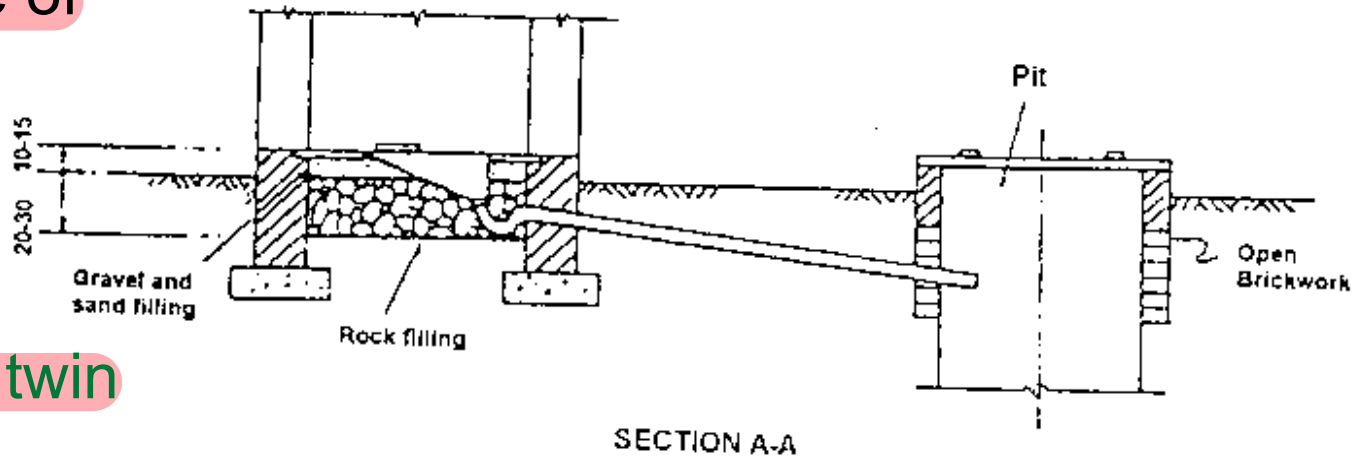
- Free from fecal odor and insect problems
- No need for a separate superstructure.

Types of Pour-Flush Technologies

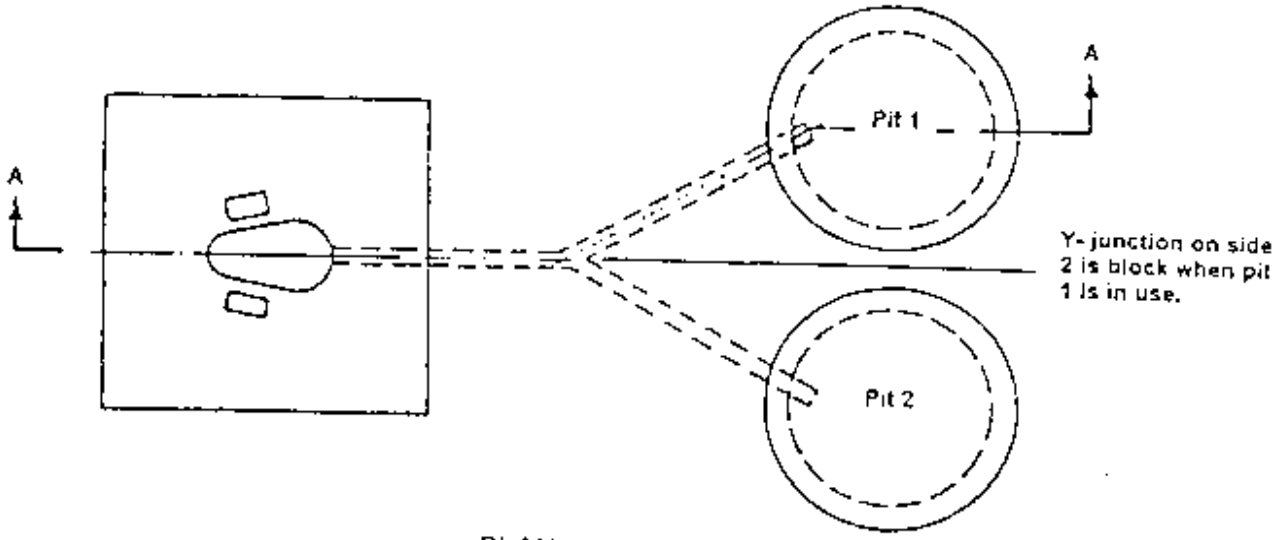
Off-set pit pour-flush latrines can be of two types –

(a) single

(b) alternating twin off-set pit.



SECTION A-A



PLAN

Alternating Twin Off-set Pit Pour-Flush Latrine

- The alternating twin-pit system comprises –
  (i) a squatting pan and
  (ii) a Y-junction for directing excreta from squatting pan to either of the two leach pits.

- The pits are used alternately and at a given time only one pit is in use.

- When the first pit is full, the flow of excreta is directed to the second pit through a Y-junction and contents of the first pit are left to decompose.

Alternating Twin Off-set Pit Pour-Flush Latrine

- The contents of the first pit decompose to safe, pathogen-free humus within 18 to 24 months.

- The contents of the first pit may then be dug out and the pit is kept ready for reuse.

Functions of Pour-Flush Latrine

- After each use, the latrine is manually pour-flushed with about 2-3 liters of water (compared to 10-20 liters used in conventional toilets)

- The water seal provides a barrier against odour and insect.

- From excreta, flush water and wash water around 10-20 liters/capita/day (lpcd) of wastewater enter into the pit.

Functions of Pour-Flush Latrine

- The pit has to provide sufficient volume for solids storage, as well as sufficient area for the wastewater to infiltrate into the soil.

- It requires that the soil has sufficient long term infiltrative capacity.

- If the soil is unsuitable for infiltration, the liquid effluent can be removed by other means e.g., by connection to the sewerage system if available.

Suitability of Pour-Flush Latrine

- Pour-flush latrines may be used in both rural and urban areas provided they are appropriately designed and that they can rely on water availability for flushing, and for maintaining the water seal.

- Single pits may be appropriate in urban areas only if they can be desludged mechanically by a vacuum tanker, since their contents are not pathogen free.

- Twin-pits are recommended if the pits are to be desludged manually, as the resting period ensures that the contents to be removed are substantially free of pathogens.

Design of Pour-Flush Latrine

Table 1: Design Values for Long-term Infiltration Rates for Wastewater into Various Soils

Soil Type	Long term infiltration rate, I (L/m^2-day)
Sand	50
Sandy loam	30
Porous loam, porous silty clay loam	20
Compact silty loam, clay	10

Design of Pour-Flush Latrine

The side wall area required for infiltration, (A_i, m^2) is given by:

$$A_i = Q / I \quad \ldots\ldots\ldots (1)$$

where, **Q** = waste water flow rate (L/day)

I = long-term infiltration rate (L/m^2 - day)

- The wastewater flow (Q) depends on the number of users, frequency of flushing, flush volume, urine volumes and amount of water used for anal cleansing.

- Generally Q varies between 5-20 Lcd.

Design of Pour-Flush Latrine

The pit volume, V_i (m^3) corresponding to the sidewall area can now be calculated. For a circular pit of diameter, D,

$$V_i = \pi D^2 h/4 \text{ ..... (2)}$$

Now, side wall area for a cylinder, $A_i = \pi Dh$

where h= the height of the sidewall area

$= A_i / \pi D$ …… (3)

Replacing the value of h (from eqn 3) in equation 2

$$V_i = (\pi D^2/4) * (A_i / \pi D)$$
$$= A_i D/4$$
$$= (Q/I) * (D/4) \text{ (from eqn 1)}$$

i.e., $$V_i = QD / 4I \text{ ..... (4)}$$

Design of Pour-Flush Latrine

For alternating twin-pits, the effective volume of each pit is calculated –

- ✓ either using **equation 4** (**$V_i = QD / 4l$**)
- ✓ or **$V_s = C \times P \times N$**, whichever is greater.

For single pit pour-flush latrines, the effective volume is given by:

$$V = V_s + V_i \quad \text{..... (5)}$$

Advantages of Pour-Flush Latrine

- Less expensive compared to conventional latrines.
- Offers appropriate and hygienic solution for excreta disposal.
- Requires less volume of water for flushing (1-3 lit/flush only).
- Can be upgraded to connect to a sewerage system or septic tank system.
- Eliminates odor release, insect and fly breeding.

Advantages of Pour-Flush Latrine

- Safe for children.
- Can be located inside the house.
- Potential for resource recovery using the sludge as soil conditioner.
- Easy construction and maintenance.
- Twin pit latrine can serve as a permanent structure because of its pits is used alternatively.

Disadvantages of Pour-Flush Latrine

- Requires separate sullage disposal facilities.
- Water (at least 4 liters / person / day) must be available throughout the year.
- Water seal may be clogged easily if garbage is thrown into it.
- Construction is difficult and expensive in areas with high ground water and shallow soil overlying hard rock.

Disadvantages of Pour-Flush Latrine

- Risk of polluting ground water and/or nearly water sources.
- Construction and maintenance of twin pit pour-flush latrine is difficult.

Design of Pour-Flush Latrine

Problem:

Design leach pits for both – (a) single pit and (b) twin offset pit pour – flush latrine for a family of 7 members for a design period of 2.5 years.

The X-section of the pits has to be square.

The average waste water flow rate is 12 liters per person per day.

The soil is porous silty loam with long – term infiltration rate of 20 L/m^2-day.

In sketch, show the designed latrine and pit arrangement.

Design of Pour-Flush Latrine

Solution:

Given,

Family Members = 7

Design Period, N = 2.5 years

Pit X-section Shape = square

Avg. Wastewater flow rate, q= 12 lpcd

Soil type = Porous silty loam

Long term infiltration rate, I = 20 L/m^2-day

Design of Pour-Flush Latrine

Now,
Total waste water flow, Q = 12×7 = 84 l/d

Area required for infiltration, A_i = Q/I m^2
= 84/20
= 4.2 m^2

Assuming, pit width = 1.2 m

Therefore, Pit Volume, V_i = QD/4I
= (84×1.2)/(4×20)
= 1.26 m^3

Design of Pour-Flush Latrine

Pit volume with respect to solid storage

Let, solid accumulation rate, C = 0.04 m^3/person-yr

N = 2.5 years

Therefore, pit volume, V_s = CPN

=0.04×7×2.5

= 0.7 m^3

Design of Pour-Flush Latrine

Case – 1 : single pit pour – flush system :

The effective volume, $V = V_i + V_s$

$=1.26+0.7$

$=1.96m^3 \approx 2m^3$

Considering, pit width = 1.2m

For square pit, effective depth, $h=V/1.2^2$

$=2/1.2^2=1.39m$

$\approx 1.5m$

Assuming 0.5m clear space, total depth=1.5+0.5

=2m

Design of Pour-Flush Latrine

Case II: alternating twin pit pour flush system

Governing volume of pit $=1.26m^3$

Pit width= 1.2m

Depth of pit= $v/1.2^2$

$=1.26/1.2^2$

$= 0.875m^2$

Let, Clear depth = 0.5m

Therefore, total depth $=0.875+0.5$

$=1.375m \approx 1.5m$

EWCE 333
Wastewater Engineering and Sanitation

Lecture 6

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Lecture Outline

Topics	Reference
• **Septic Tank - design considerations and design**	**Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman** ITN -BUET

Septic Tank

- A key component of the septic system, a small-scale sewage treatment system
- Common in areas with no connection to main sewage pipes
- The term "**septic**" refers to the anaerobic bacterial environment that develops in the tank and that decomposes or mineralizes the waste discharged into the tank
- A septic tank is a buried watertight receptacle.

Septic Tank

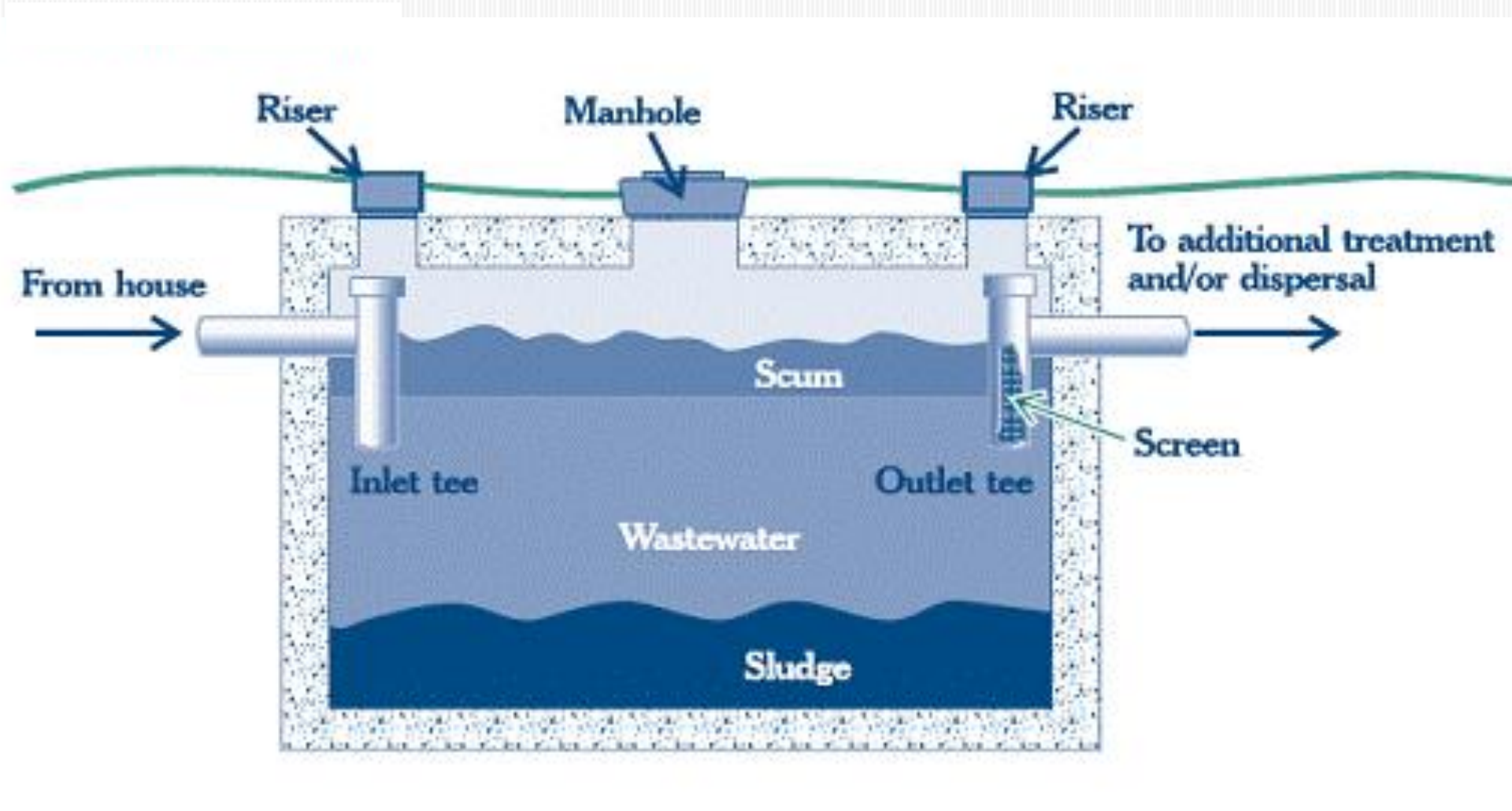
- Scope of use: Wherever the conventional sewerage system has not been feasible due to technical or economic reasons.

- It is designed and constructed to -
  - ✓ receive wastewater from a home
  - ✓ separate the solids from the liquid
  - ✓ provide limited digestion of organic matter
  - ✓ store solids
  - ✓ allow the clarified liquid to discharge for further treatment and disposal

Septic Tank

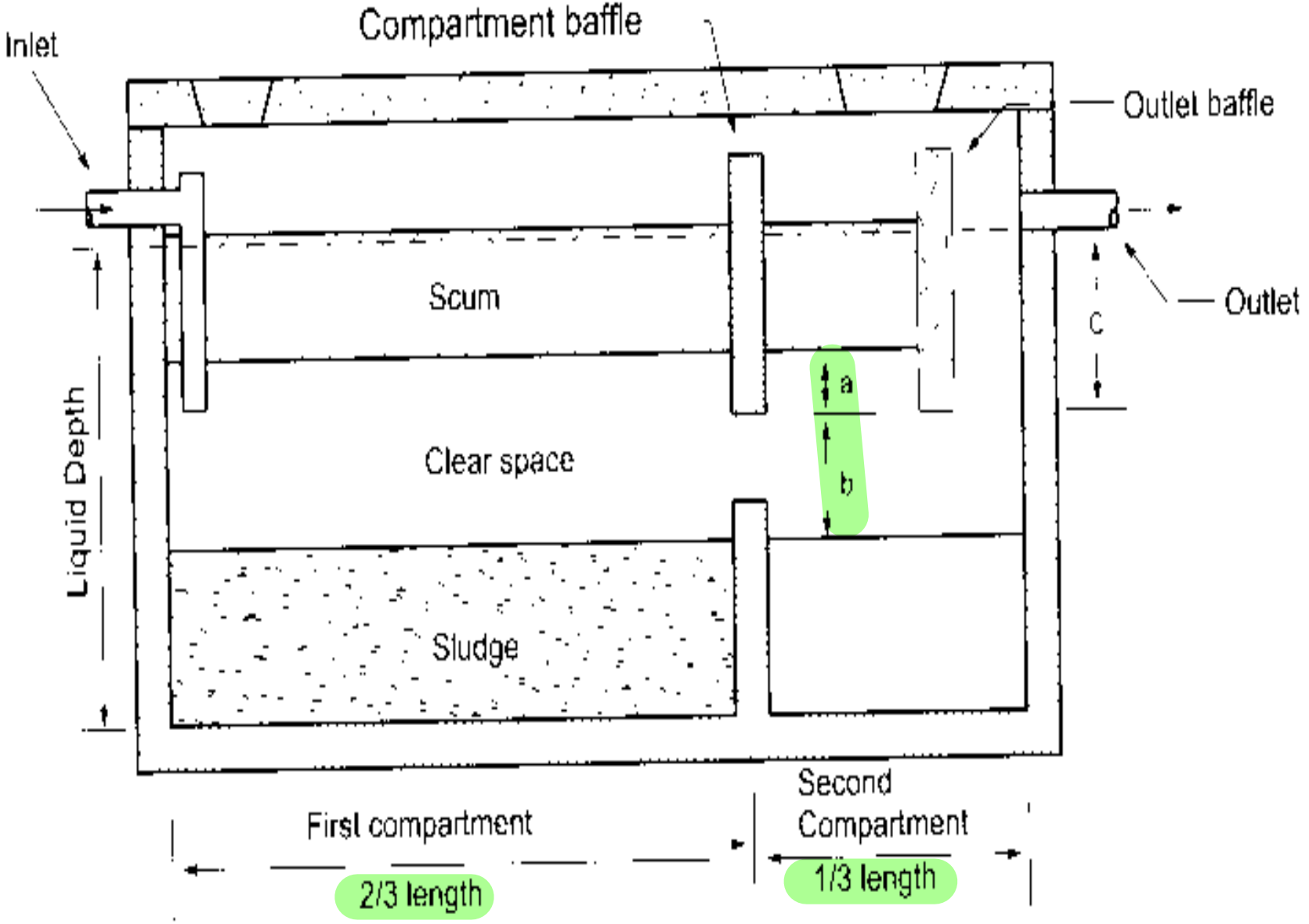
- Settleable solids and partially decomposed sludge settle to the bottom of the tank and gradually build up.
- A scum of light-weight material including fats and greases rises to the top.
- The partially treated effluent is allowed to flow through an outlet structure just below the floating scum layer.
- Partially decomposed liquid can be disposed of through soil absorption systems, soil mounds, evaporation beds or anaerobic filters depending upon the site conditions.

Components of a Septic Tank



Single compartment septic tank

Components of a Septic Tank



Double compartment septic tank

Processes in Septic Tank

The most important processes that take place within the tank include –

- separation of suspended solids,
- digestion of sludge and scum,
- stabilization of the liquid and
- growth of microorganisms.

Processes in Septic Tank

(a) **Separation of suspended solids**

- results in three distinct layers in the septic tank - a layer of sludge at the bottom, a floating layer of scum on the top and a relatively clear layer of liquid in the middle.

(b) **Digestion of sludge and scum**

- Anaerobic bacteria degrade the organic matter in the sludge and scum
- volatile acids are formed at the first instance
- eventually these acids are converted mostly to H_2O, CO_2 and CH_4.

Processes in Septic Tank

(c) **Stabilization of the liquid**

- Organic materials in the liquid are stabilized by anaerobic bacteria

- Bacteria break down complex substances into simpler ones in a process similar to the one that take place in the sludge layer.

Processes in Septic Tank

(d) **Growth of microorganisms**

- A large variety of microorganisms grows, reproduce and die during the biodegradation processes in the tank.

- Most of them are attached to organic matter and are separated out with the solids.

- Although there is an overall reduction in the number of microorganism, a large number of bacteria, viruses, protozoa and helminths survive through the processes in the tank and remains active in the effluent, the sludge and the scum.

Processes in Septic Tank

As the influent enters into an anaerobic Septic Tank, it separates into 3 distinct layers:

- the sludge layer at the bottom
- the floating layer of scum on the top
- a relatively clear zone of liquid in the middle

Performance of Septic Tank

Under normal design conditions-

- reduction in BOD is 25-50%
- reduction in suspended solids is up to 70%

The factors affecting the performance of a septic tank are –

- Retention time
- Ambient temperature
- Nature of the influent wastewater e.g., organic content of the wastewater
- Positions of the inlet and outlet devices in the tank

Design of Septic Tank

- Based on Brazilian septic tank code.
- The tank is considered to be made up of four zones, each of which serves a different function:
  - Scum storage zone
  - Sedimentation zone
  - Sludge digestion zone
  - Digested sludge storage zone

Design of Septic Tank

(a) Scum storage

- Scum accumulates at approximately 30-40 % of the rate at which sludge accumulates,

- therefore the tank volume for scum storage (V_{sc}) can be taken as 0.4 times the volume for sludge storage (V_{sl}).

i.e.. $V_{sc} = 0.4\, V_{sl}$ ..... **(1)**

Design of Septic Tank

(b) Sedimentation

- Time required to allow sedimentation of settleable solids decreases with the number of people served, according to the following equation:

$$t_h = 1.5 - 0.3 \log (Pq) \quad \text{.....(2)}$$

where, t_h = minimum mean hydraulic retention time for sedimentation, day

P = contributing population

q = wastewater flow per person, Lpcd

Design of Septic Tank

- Retention times in septic tanks are longer than those in raw sewage sedimentation tanks.

- Because septic tanks intercept solid from waste inflow, which rise up from sludge layers through flotation by the gases produced during anaerobic digestion.

- Often a minimum mean hydraulic retention time of one day is used. The value of t_h used should not be less than 0.2 days.

The tank volume for sedimentation, V_h (m^3) is given by:

$$V_h = 10^{-3} P q t_h \quad \text{.....} \quad \textbf{(3)}$$

Design of Septic Tank

(c) Digestion

- The time needed for the anaerobic digestion of the settled solids (t_d, days) varies with temperature (T °C) and is given by the equation:

$$t_d = 30(1.035)^{35-T} \quad \text{.....} \quad \textbf{(4)}$$

- Volume of sludge digestion zone, V_d (m^3), is given by:

$$V_d = 0.5 \times 10^{-3} P\, t_d \quad \text{.....} \quad \textbf{(5)}$$

Design of Septic Tank

(d) Sludge storage

- The volume of the sludge storage zone depends on the rate of accumulation of digested sludge (C, m^3 per person per year) and the interval between successive desludging operations (N, years).

- Design values for sludge accumulation rates are taken as:

  C = 0.06 m^3/person year for N < 5

  C = 0.04 m^3/person year for N > 5

$$V_{sl} = C \times P \times N \quad \text{.....} \quad \textbf{(6)}$$

Design of Septic Tank

Overall design capacity

$$V = V_{sc} + V_h + V_d + V_{sl}$$
$$= V_h + V_d + 1.4V_{sl}$$

Check for clear space depth:

- The clear space depth, which is the minimum acceptable depth of the sedimentation zone just prior to desludging, comprises the submerged scum clear depth and the sludge clear depth.

- The submerged scum clear depth is the distance between the underside of the scum layer and the bottom of the outlet ‘tee’ and should be at least 75 mm.

Design of Septic Tank

- The sludge clear depth is the distance between the top of the sludge layer and the bottom of the outlet ‘tee’.

- The minimum value of the sludge clear depth is related to the tank surface area, A, as follows:

$$d_{sc} = 0.82 - 0.26\,A \quad \text{..... (10)}$$

  subjected to a minimum value of 0.3 m.

- Thus the minimum total clear space calculated as (0.075 + d_{sc}) must be compared with the depth required for sedimentation, i.e., (V_h /A) and the greater depth chosen.

Design of Septic Tank

Compartmentation:

- A two compartment tank is reported to be better than a single compartment tank of equal capacity for the removal of BOD, suspended solids and organic colloids.
- One of the reasons for this is trapping action of the second compartment.
- First compartment (inlet side) being 2/3 of the total length and second compartment being 1/3 of the total length.

Treatment and Disposal

(a) Sludge and scum

- sludge and scum must be removed from the tank when they occupy 2/3 of tank capacity.

- sludge disposal should be done with caution because of survival of pathogens.

- desludging is usually carried out in every 2-5 years.

- in some tropical countries septic tank sludge is used as soil conditioner and fertilizer for fish ponds.

Treatment and Disposal

(b) Tank effluent

- Effluent from septic tank is only partially treated and still contains high concentration of microorganisms, BOD, Phosphorus, Nitrogen etc.

- Effluent should not be directly discharged into public water course or land.

- Sub-surface soil absorption is usually the best method of septic tank effluent disposal (concern: groundwater contamination).

Disposal of Tank Effluent

Sub-surface soil absorption:

a) Absorption trenches

b) Absorption pits or soakage pits (Soakways)

c) Disposal to nearby sewer (e.g., SBS)

Disposal of Tank Effluent

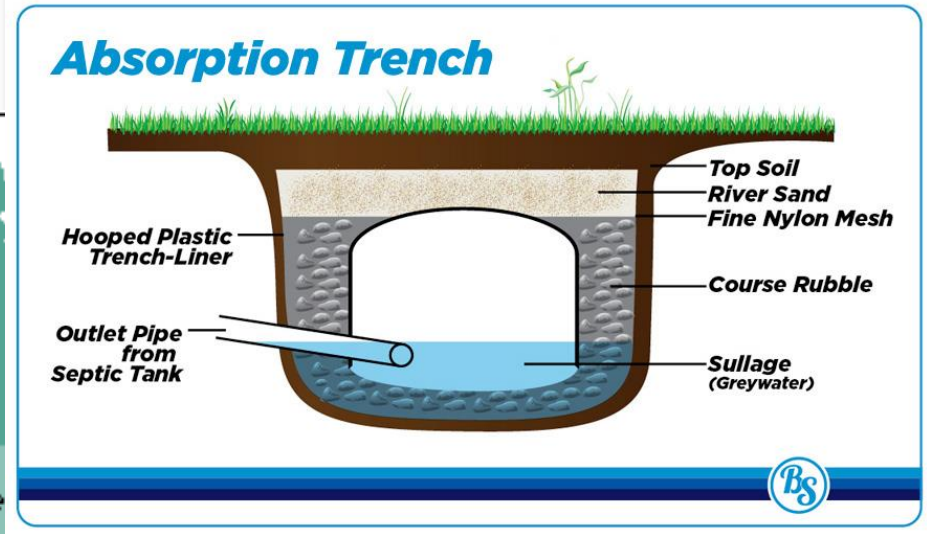
(a) Absorption trenches

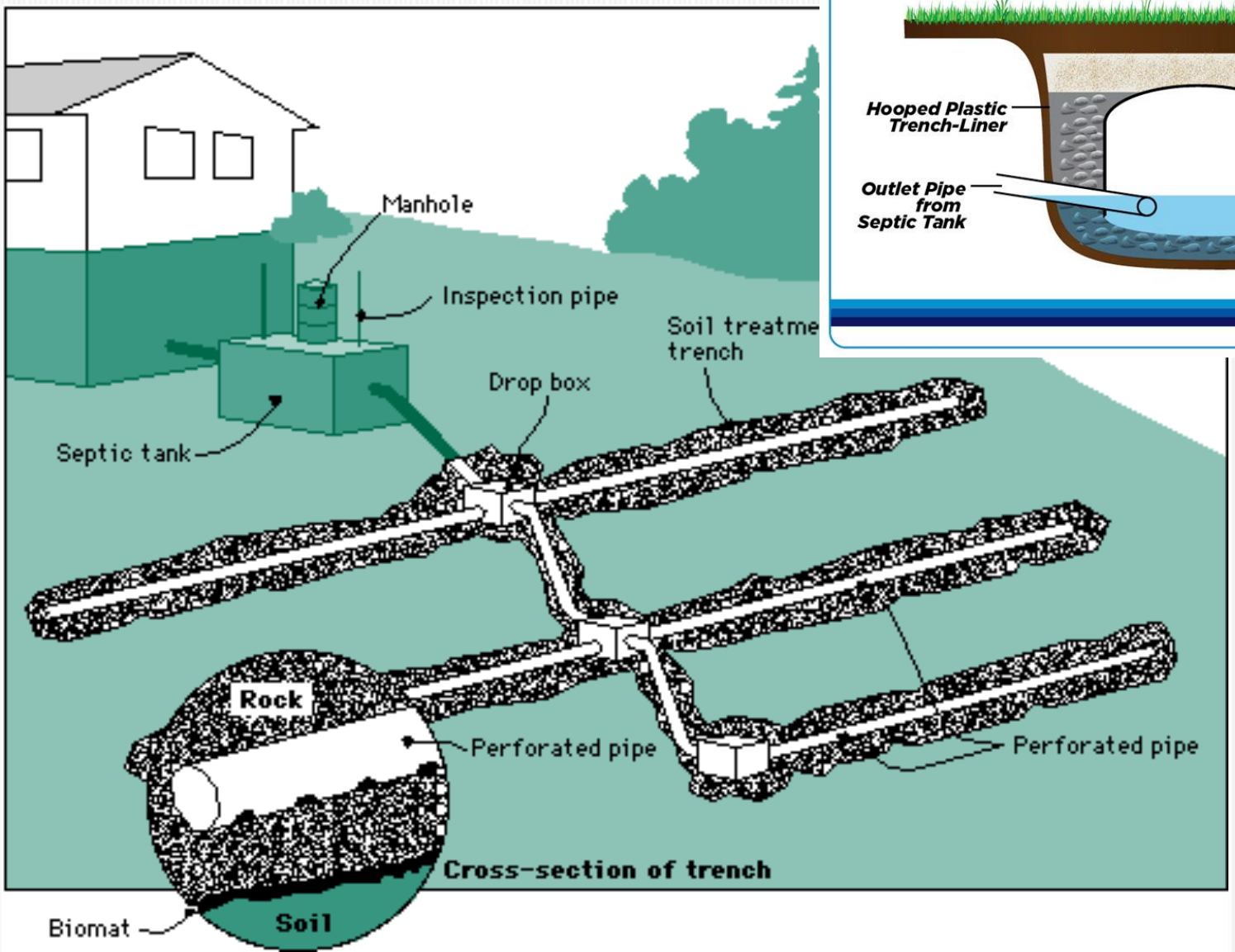
- Effluent flows by gravity from septic tank through a closed pipe and distribution box into perforated pipes in trenches.

- Bacteria in the soil help to purify the effluent.

Disposal of Tank Effluent

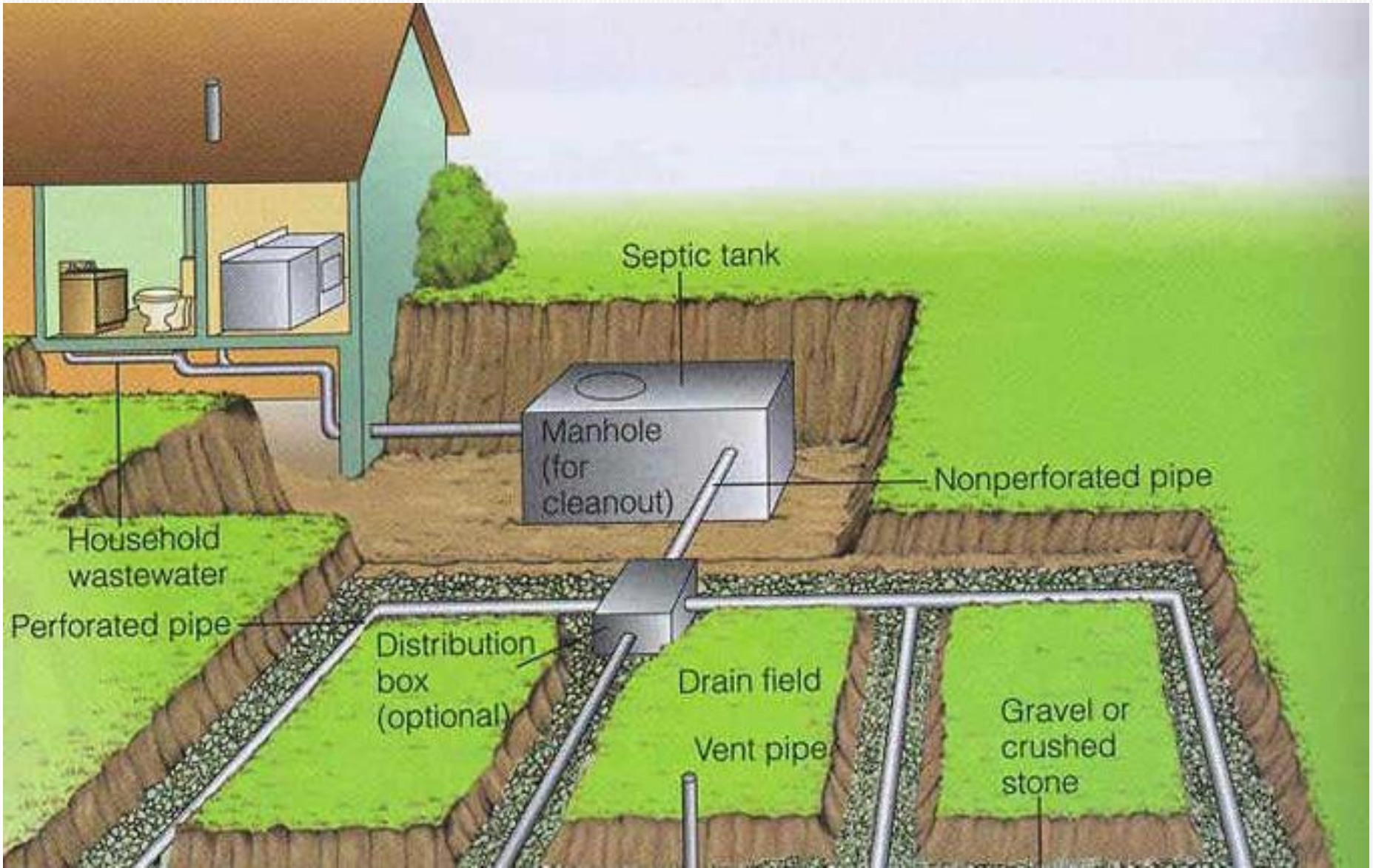
(a) Absorption trenches





Disposal of Tank Effluent

(a) Absorption trenches



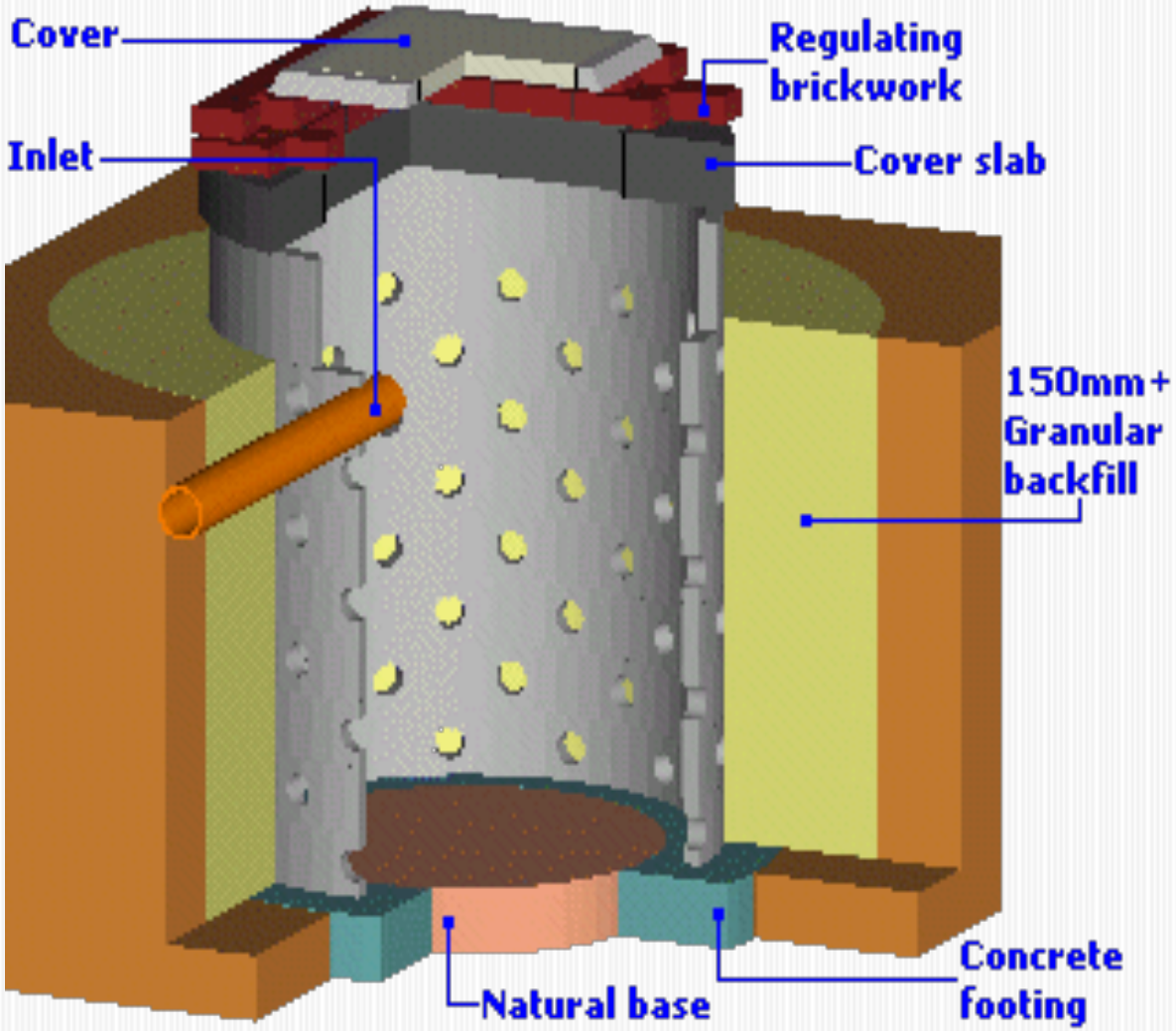
Disposal of Tank Effluent

b) Absorption pits or soakage pits (Soakways)

- Waste from the toilet, and generally domestic wastewater, is flushed into the settling chamber of septic tank.
- Waste is retained in septic tank for at least 24hrs to allow settlement and biological digestion.
- Partially treated liquids then pass out of the tank and into the subsoil drainage/soakaway system.
- Digested sludge gradually builds up in the tank and requires eventual removal by tanker.

Disposal of Tank Effluent

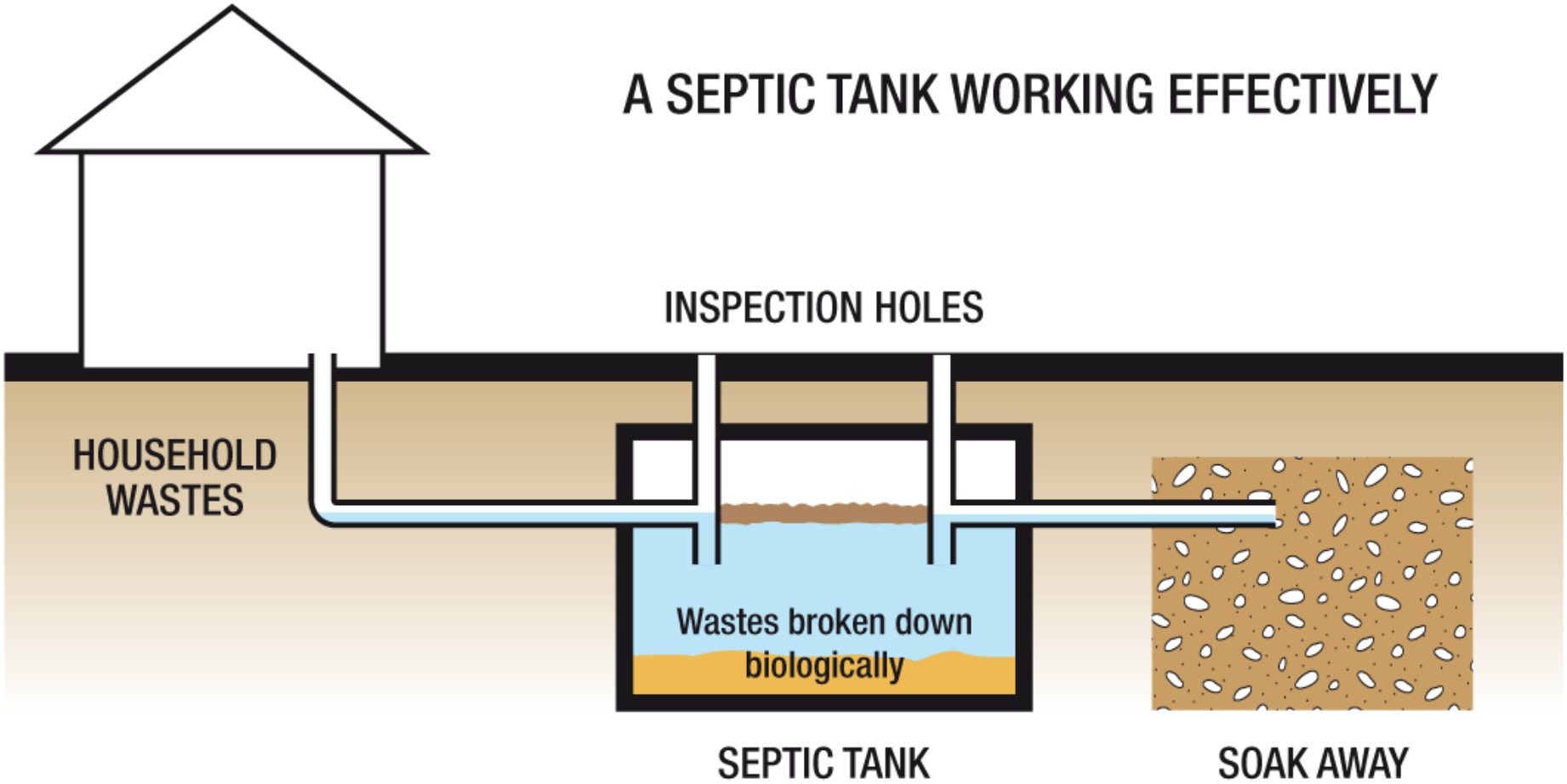
b) Absorption pits or soakage pits (Soakways)





Disposal of Tank Effluent

b) Absorption pits or soakage pits (Soakways)



Disposal of Tank Effluent

b) Absorption pits or soakage pits (Soakways)

- Deep excavations are used
- Recommended as an alternative when absorption fields or trenches are not practicable and where the topsoil is underlain with porous soil or fine gravel.
- Effluent flows through pit walls made of open jointed bricks, into the surrounding soil.
- Typical diameter of pit 2 to 3.5 m, and depth 3 to 6 m depending upon the amount of wastewater flow, infiltration capacity of soil and level of GWT.

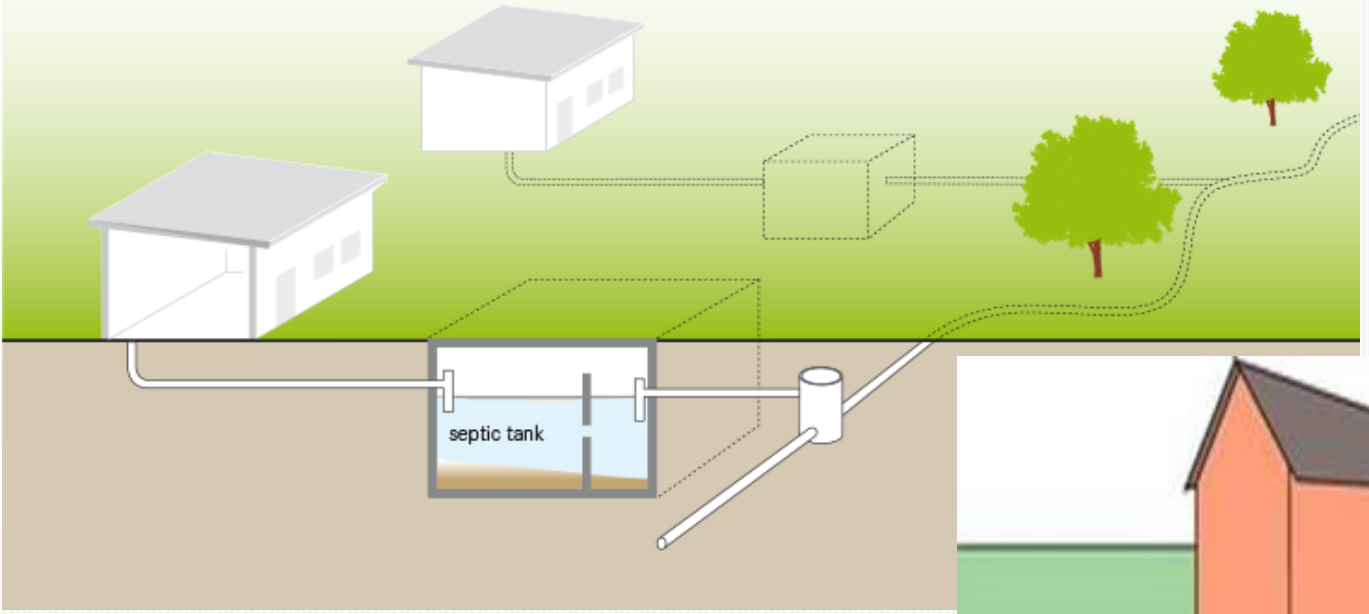
Disposal of Tank Effluent

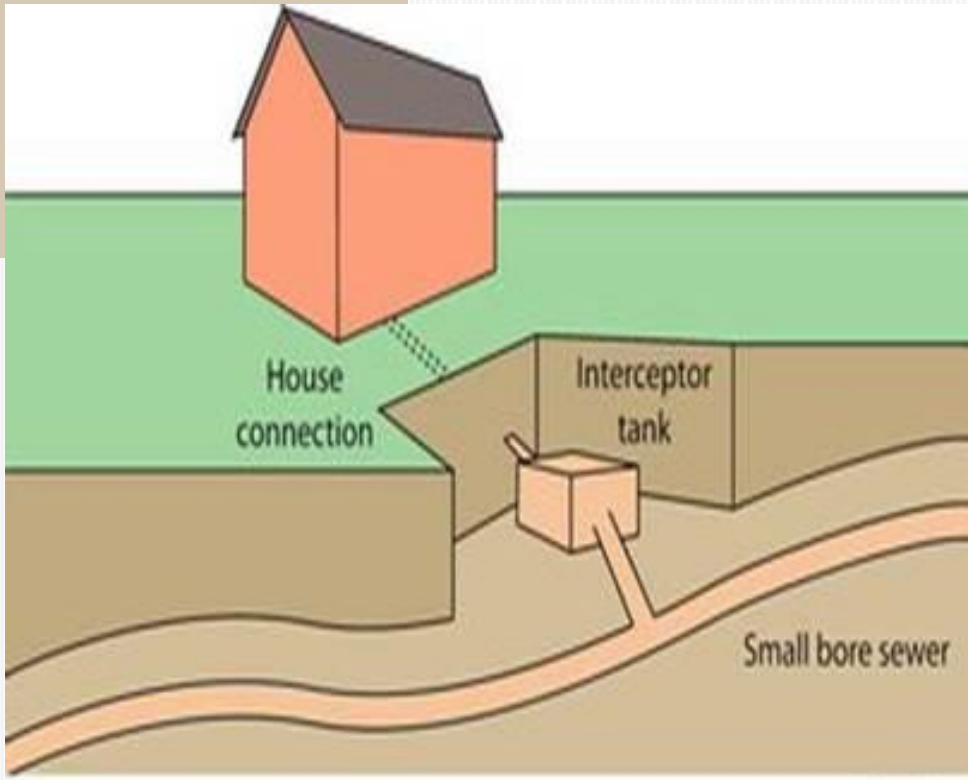
c) Small bore solid-free sewer

- Liquid effluent from septic tank is conveyed by a system of small-diameter pipes to a communal treatment point
- It may be off-site treatment works reached either via existing sewerage or by tanker

Disposal of Tank Effluent

c) Small bore solid-free sewer





Septic Tank Design

Design ***a septic tank*** to serve 3 families, each with a family size of 6. The average wastewater flow rate is 85lpcd and the tank is to be desludged every two years.

To ensure acceptable effluent quality, the minimum hydraulic detention time for the tank should be 0.8 days.

The condition of the field is such that the effective area of the septic tank cannot exceed $3.5m^2$.

In net sketch show the different components of the designed septic tank, including details of chambers, and depth of different zones.

Septic Tank Design

Solution:

Given,

Family no.= 3

Each family size = 6; therefore, P=3×6=18

Avg. wastewater flow rate, q = 85 lpcd

Design period N = 2years

Area, A = 3.5m^2

Minimum hydraulic retention time, t_h = 0.8days

Septic Tank Design

Sedimentation Zone:

$V_h = 10^{-3} \times pqt_h = 10^{-3} \times 18 \times 85 \times 0.8$

$= 1.224\ m^3$

$d_h = v_h/A = 1.224 / 3.5$

$= 0.35m$

Here,
q = 85 lpcd
t_h = 0.8 days
A = 3.5 m^2

Digestion Zone:

$t_d = 30\ (1.035)^{\wedge(35-T)}$

$= 42.32$ days

Here,
p=18
Let, T= 25°C

$V_d = 0.5 \times 10^{-3} \times pt_d$

$= 0.5 \times 10^{-3} \times 18 \times 42.32$

$= 0.38m^3$

$d_d = v_d/A = 0.38 / 3.5$

$= 0.11m$

Septic Tank Design

Sludge storage zone:

v_{sl}= CPN =0.06×18×2 = 2.16m^3

d_{sl} =v_{sl}/A=2.16/35 = 0.62m

Here,
p=18
N=2years
for N <5,
C=0.06m^3/person/year

Scum storage zone:

v_{sc} = 0.4× v_{sl}
= 0.4×2.16
= 0.864 m^3

d_{sc}= v_{sc}/A = 0.864/3.5
=0.25m

Here,
p=18
Let, T= 25^{o}c

Septic Tank Design

Overall design capacity:

$V = v_h + v_d + v_{sl} + v_{sc}$

$= 1.224 + 0.38 + 2.16 + 0.864$

$= 4.628\ m^3$

Here,
For N <5,
$C = 0.06 m^3$/person/year
p=18
N=2 years

Clear space depth:

Scum clear depth =0.075m

Sludge clear depth=0.82-0.26A ≥0.3m

=0.82-0.26*3.5 ≥0.3m

=-0.09m

=0.3m

Here,
p=18
Let, T= 25^oC

Septic Tank Design

Total clear space =0.3+0.075=0.375m
But sedimentation depth =0.35m
Therefore, clear space depth=0.375m

Total effective depth= clear space depth+d_{sl}+d_{sc}+d_d
= 0.375+0.62+0.25+0.11
= 1.35m ≈ 1.5 m

Let, tank length = L and width = W
Now, A = L×W = 3W×W = 3.5
Therefore, W = 1m and L = 3.5 m

Hence, suitable internal dimension of septic tank
=**1m×3.5m×1.5m**

Septic Tank Design

Length of 1st compartment = (2/3)×3.5 = 2.33 m

Length of 2nd compartment = (1/3)×3.5 = 1.17 m

Soakage pit design:

The design is similar to leach pit design(single pit).

Now, $A_i = (Q/I)$

$= (1530/40)$

$= 38.25 m^2$

Here,

Q =18×85

=1530 L/day

I = 40L/m^2-day

Septic Tank Design

Assuming, a circular soak pit with 1.25m dia.

Therefore, effective depth of soak pit $=(A_i/\pi d)$

$= (38.28/\pi*1.25)$

≈ 9.8m.

If the ground water table is too high then two soak pits of 1.25m dia and 4m deep may be provided.

EWCE 333
Wastewater Engineering and Sanitation

Lecture 7

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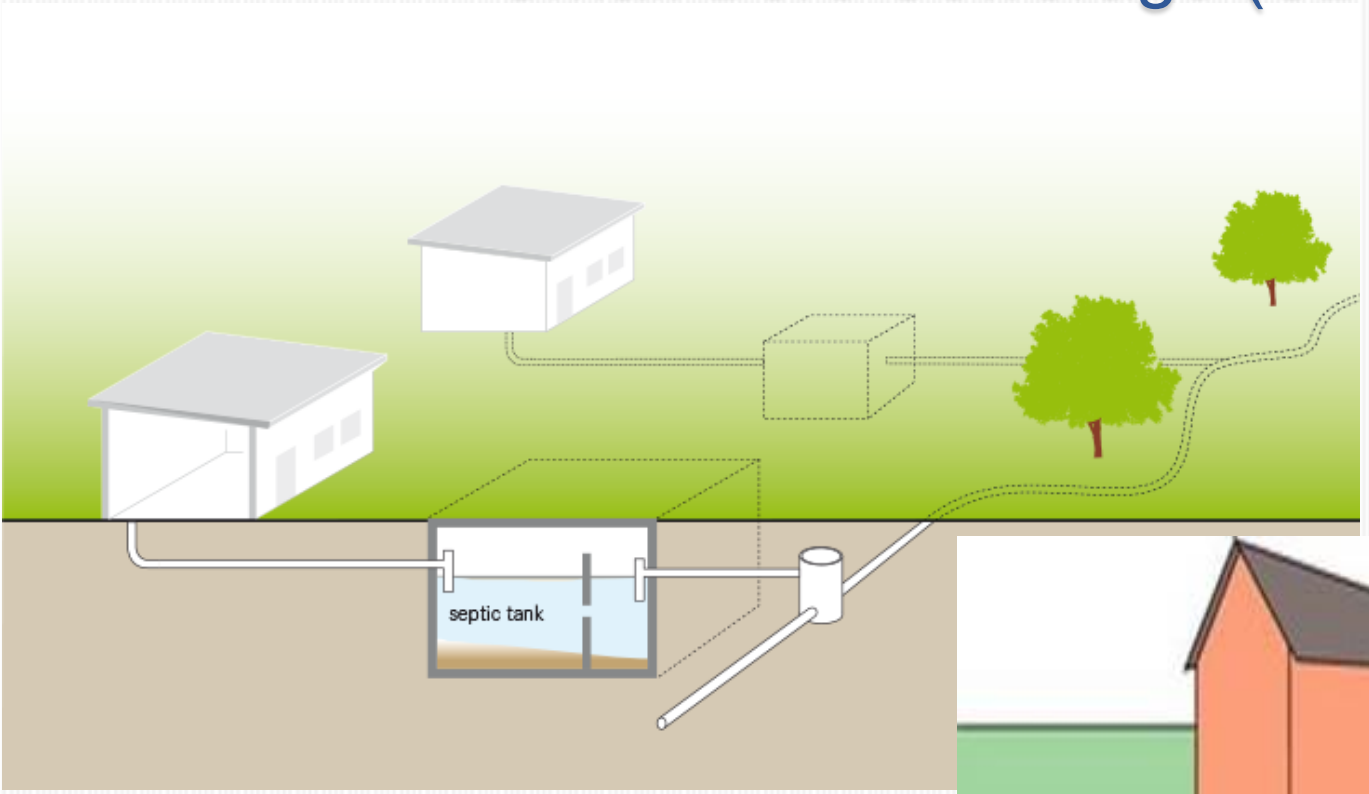
Lecture Outline

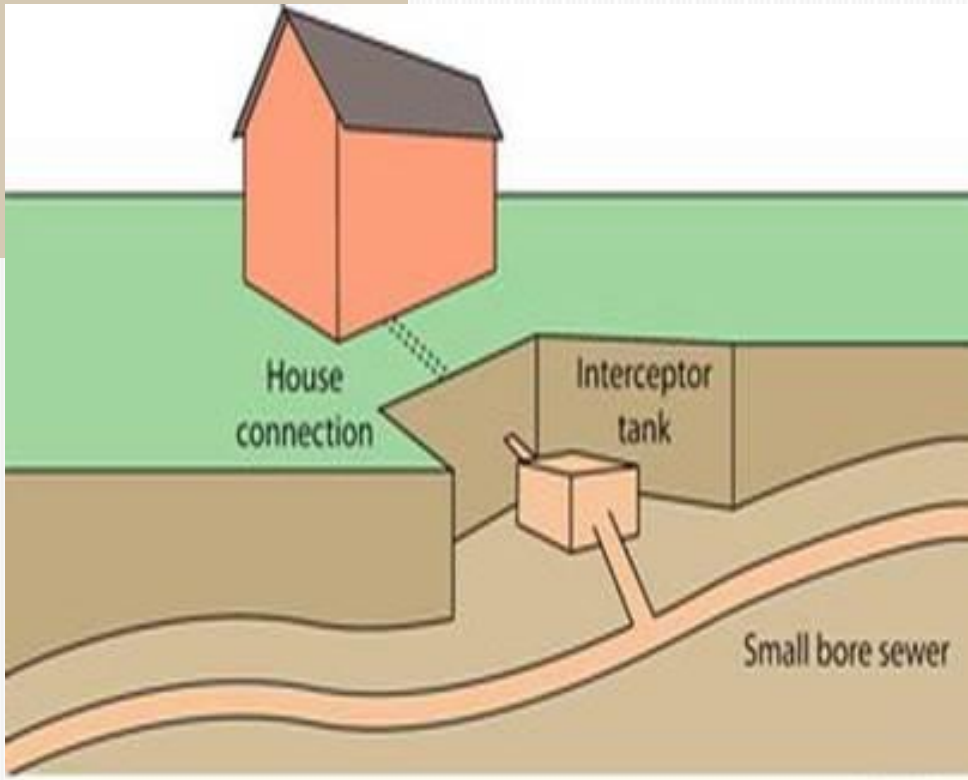
Topics	Reference
Small Bore Sewerage (SBS) system	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Small Bore Sewerage (SBS)

- High cost of traditional waterborne sewerage has stimulated interest in alternative low-cost proposals
- SBS is aimed to extend adequate sanitation services to medium and low-income communities.
- This system offers all the advantages of conventional waterborne sewerage systems but at a much lower cost than the conventional ones.

Small Bore Sewerage (SBS)

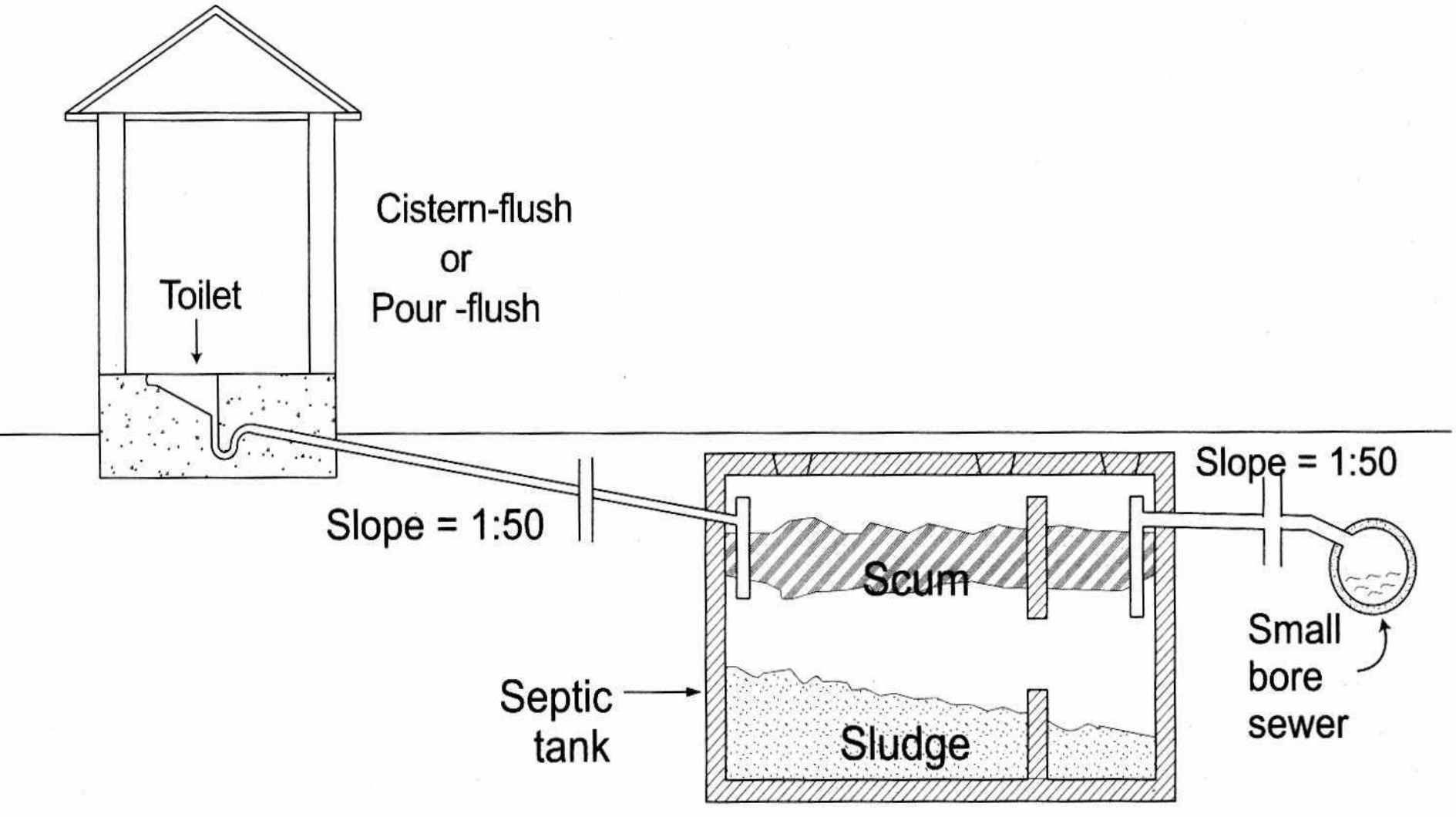




Elements of SBS

- septic tank
- small bore sewer network
- treatment plant

Small Bore Sewerage (SBS) Elements



SBS and Conventional Sewerage

Basic differences:

- 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 sewers to a treatment plant comprising a series of stabilization lagoons.

- In the case of an existing septic tank system the sewer installation commences immediately downstream of the existing septic tank and new developments must install septic tanks to be able to connect to the SBS system.

Technical Advantages of SBS

Compared to Conventional Sewerage:

- Sewer sizes can be reduced due to attenuation of flow in the septic tank
- 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.

Technical Advantages of SBS

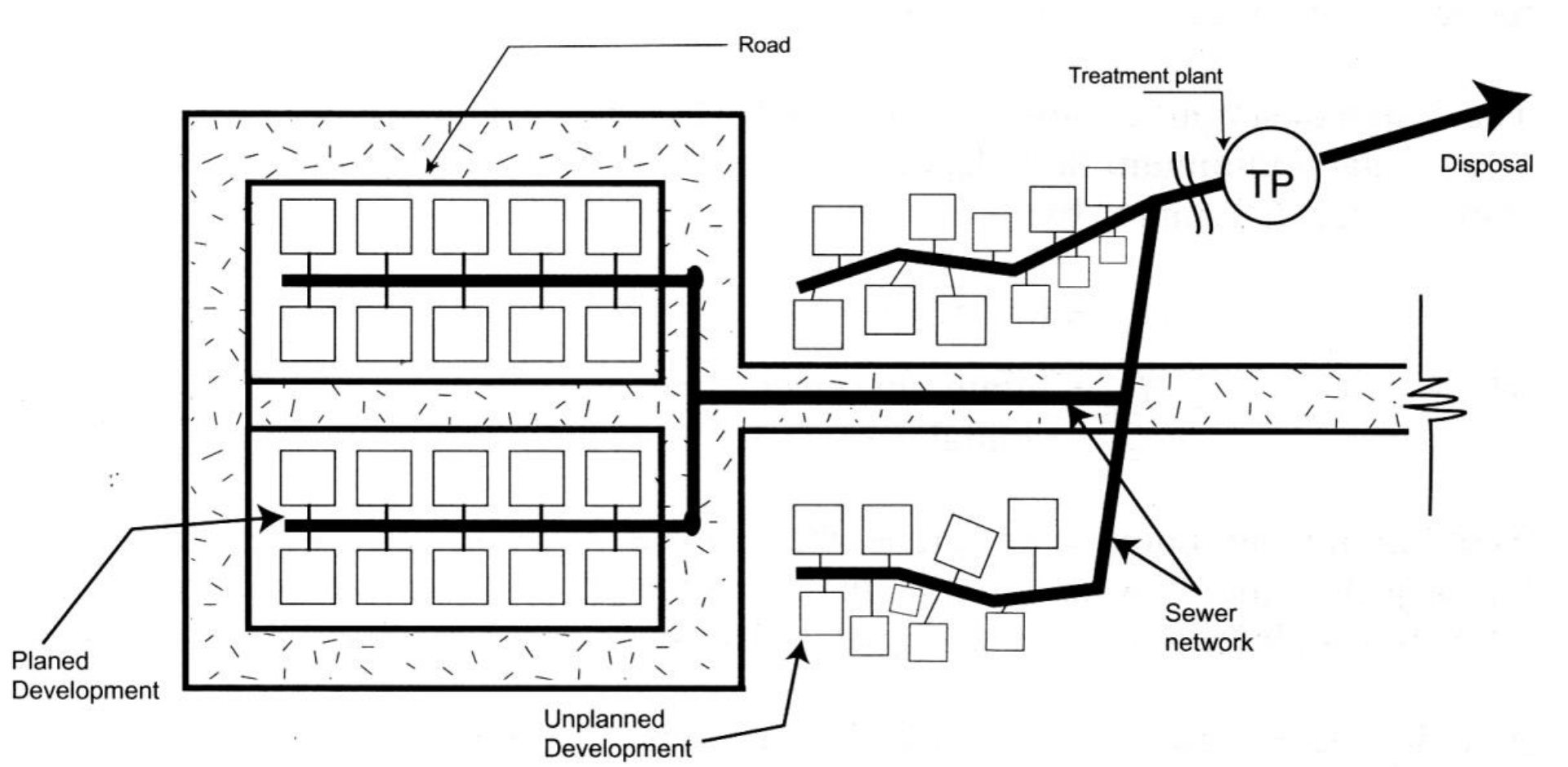
Compared to Conventional Sewerage:

- Volume of excavation is considerable 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 numbers of manholes to be constructed as requiring minimal inspection.

Simplified Sewerage (SS)

- Also called shallow sewerage
- Low-cost sanitation technology particularly suited to high-density, low-income urban areas in developing countries.
- Receives all household wastewater without settlement in solids interceptor tanks or septic tanks
- Similar to conventional sewerage, but without any of the latter's conservative design features

Simplified Sewerage (SS)



Design Standards of Simplified Sewerage

Changes in design standards for Simplified Sewerage System compared to the conventional sewerage system are in terms of –

- Minimum diameters,
- Minimum slopes,
- Minimum depths, and
- Spacing and location of manholes.
- Shorter design period

Design Standards of Simplified Sewerage

The changes were based on –

- findings of research in hydraulics
- satisfactory experience and redundancy
- development of a lower-cost sewerage system with smaller, flatter and shallower sewers with fewer and simpler manholes.

EWCE 333
Wastewater Engineering and Sanitation

Lecture 8

Instructor

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Associate Professor

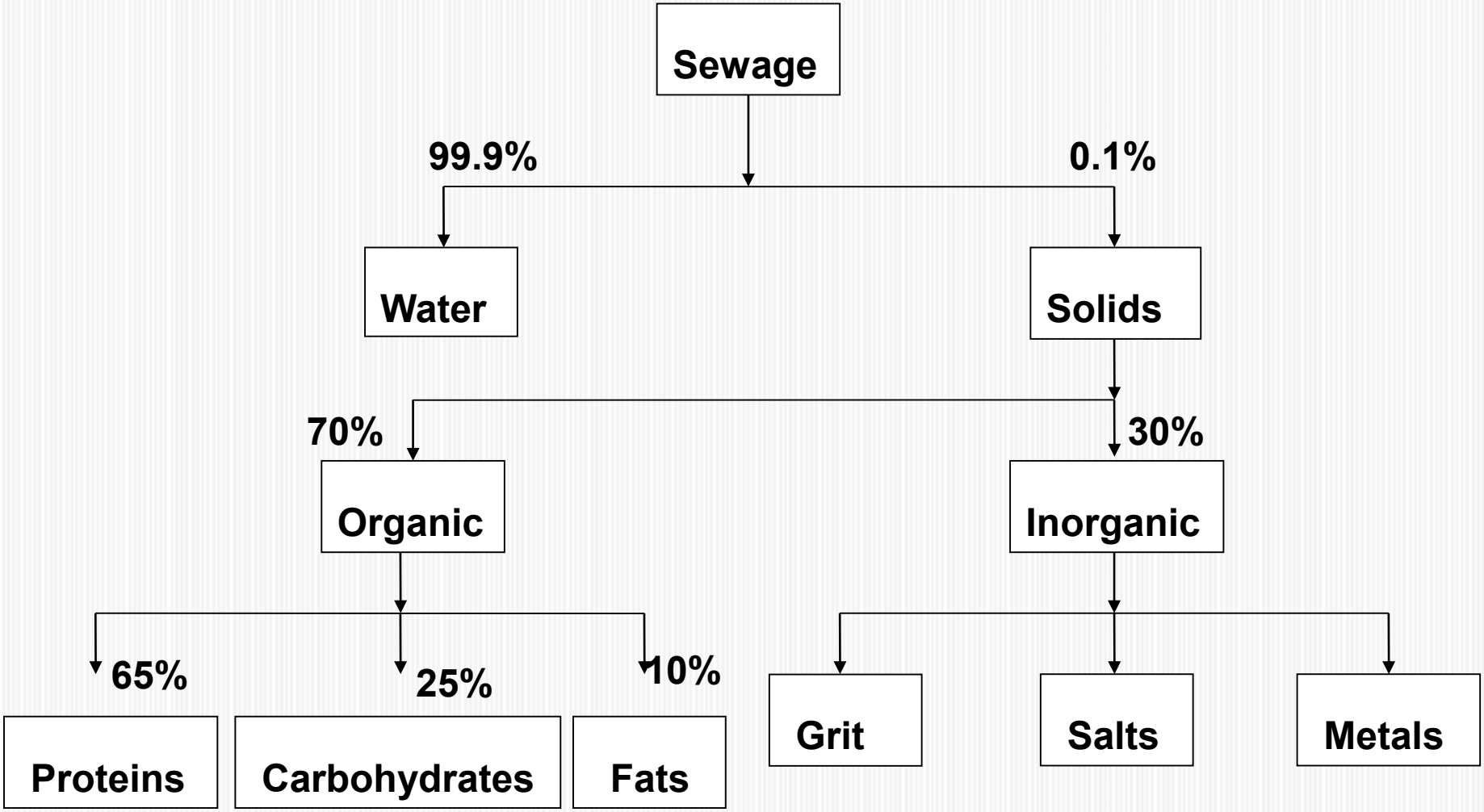
Department of EWCE, MIST

Lecture Outline

Topics	Reference
• Composition and types of sewage • Physical, chemical and biological characteristics of sewage • Environmental significance of contaminants • Sewage treatment – purpose, phases and unit operations	1. Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN –BUET 2. Environmental engineering - Howard S. Peavy

Sewage Composition

Sewage is the wastewater of a community



Types of Sewage

Domestic Sewage:

- Also called sanitary sewage
- Results from residences, public buildings
- Composed of human wastes and sullage, which is the wastewater resulting from personal washing, laundry, food washing and cleaning of kitchen utensils.

Industrial Sewage or Industrial Waste:

Results from the manufacturing or industrial processes

Storm Sewage or Storm Water:

Surface runoff, resulting during and following a period of rainfall

Physical Characteristics of Sewage

Color

- Color indicates the freshness of sewage
- Domestic sewage is initially greyish brown
- Becomes stale when entire oxygen is exhausted
- Dyeing industries sewage may add various color

Source: Dyeing industries, natural decay of organic matters

Odor

- Fresh sewage has an earthy but inoffensive odor
- When oxygen is completely depleted, hydrogen sulphide (H_2S) is produced as a by-product of anaerobic decomposition

Source: decomposing wastewater

Physical Characteristics of Sewage

Turbidity

- Stronger the sewage, higher the turbidity

Source: soil erosion, domestic and industrial substances

Solids

- Solids may be in solution or suspension
- Include organic matter

Organic and inorganic solids - total solid (TS)

Suspended solids (TSS) can be filtered out

Dissolved solids (TDS) can be removed by evaporation

Settleable solids settle down in the sedimentation basin

Physical Characteristics of Sewage

Temperature

- Slightly higher temperature then normal supply water
- More temperature, less dissolved oxygen

Has affect on-

- ✓ Biological activity
- ✓ Solubility of gases
- ✓ Viscosity of sewage

Source: Bathroom/kitchen hot water, cooling water

Contaminants	Environmental Significance
Biodegradable organic	Deletion of dissolved oxygen May add color, odor May cause undesirable condition
Suspended solids	Effect on natural aquatic life Sludge deposition causes decomposition (O_2 depletion)
Pathogens	Transmit diseases
Nutrients (P, N)	Eutrophication (Algal bloom)

Contaminants	Environmental Significance
Refractory organics	Resistant to biodegradation Lead to persistent foam in water Toxic Cause Odor and Taste problem
Heavy metals	Toxic, Effluent Reuse problem
Color and turbidity	Aesthetic problem

Contaminants	Environmental Significance
Oil, floating material	Produce unsightly condition
Volatile materials	Cause air pollution
Dissolved inorganic solids	Reuse problem of effluent

Sewage Treatment Process

- Sewage treatment is an artificial process -
  - ❑ to remove or alter the objectionable constituents from sewage and
  - ❑ to render it less dangerous or offensive

- Sewage treatment is a combination of physical and biological processes; occasionally chemical processes are employed additionally.

Purpose of Sewage Treatment

- To stabilize the sewage without causing odor or nuisance and without endangering public health
- Removal of suspended and floatable materials
- Reduction of biodegradable organics
- Elimination of pathogens

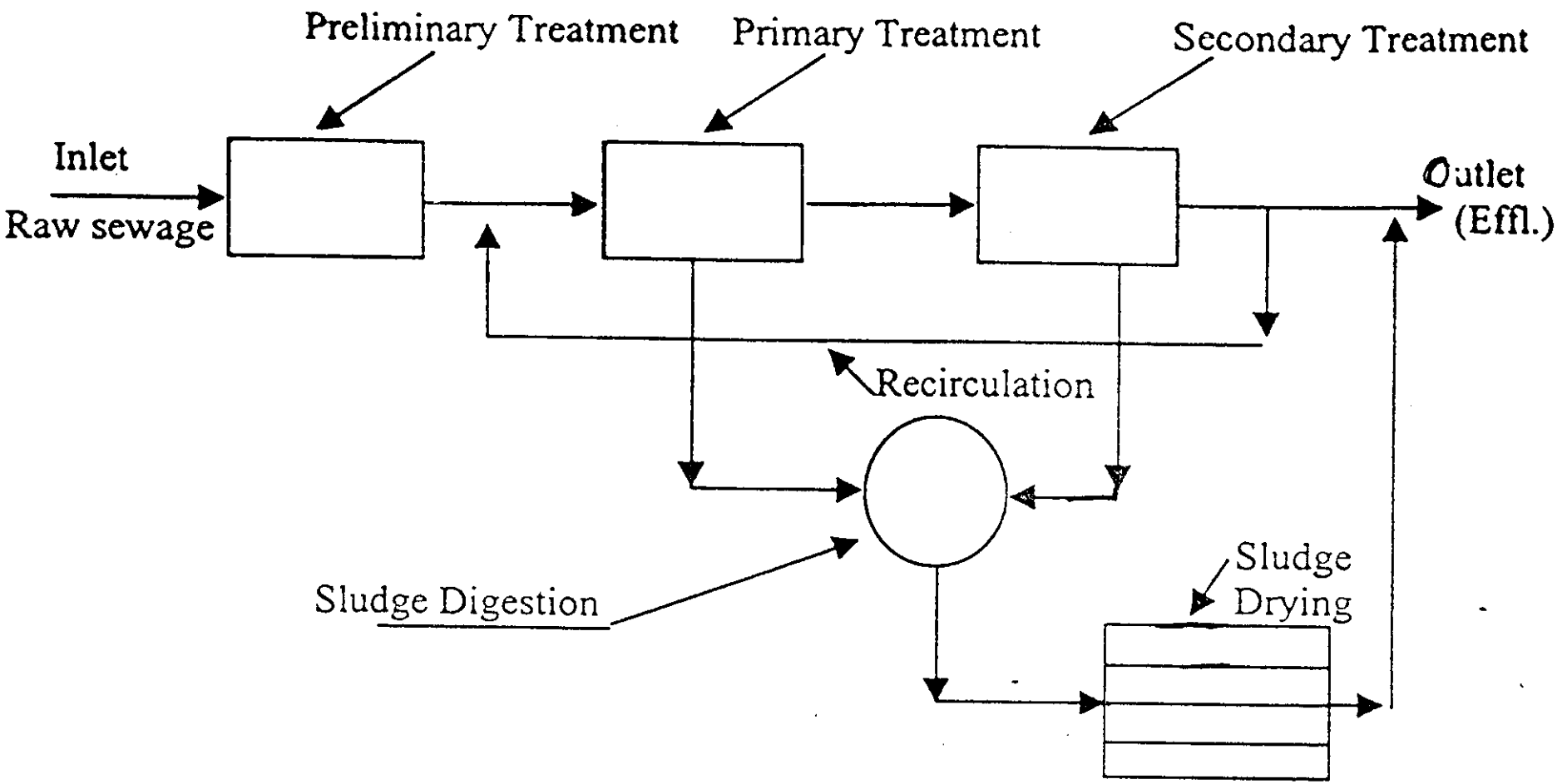
Purpose of Sewage Treatment

- Removal of N_2, P and toxic compounds
- Removal of refractory organics, heavy metals and inorganic dissolved solids
- To prevent the damages to receiving water i.e., rivers, canals, coastal waters or tidal estuaries etc.

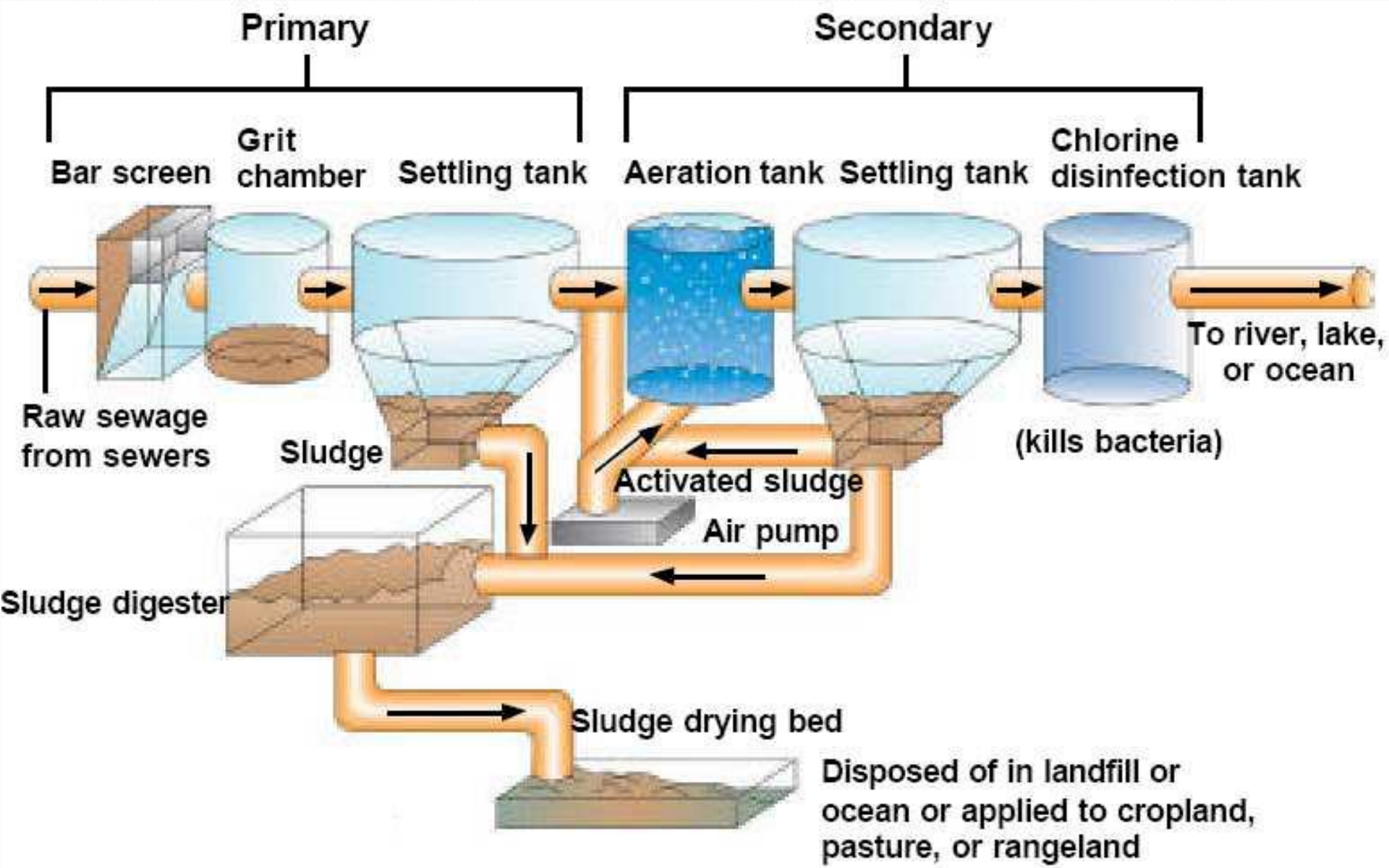
Phases of Sewage Treatment

- Preparatory / Preliminary treatment: To remove coarse suspended and floating matters, oil or grease.
- Primary / Physical treatment: To remove settleable and suspended solids.
- Secondary / Biological treatment: To remove organic solids through biological process.
- Tertiary /advanced treatment: To achieve additional removal of suspended solids, colloidal particles, removal of nutrients, refractory organics and further reduction in faecal coliform.

Sewage Treatment Plant – Typical Flow Diagram



Sewage Treatment Plant – Typical Flow Diagram



Unit Operations in Sewage Treatment

Physical Unit Operations:

- Treatment methods, in which the application of physical forces predominates, are known as physical unit operations.

- These operations remove coarse solids, suspended and floating solids and grease.

- Sedimentation, floatation, filtration are typical physical unit operations.

Unit Operations in Sewage Treatment

Chemical Unit Operations:

- Removal or conversion of contaminants is brought about by the addition of chemicals or by chemical reactions.

- These unit operations remove suspended and colloidal solids, eliminate pathogens and control odor.

- Precipitation, adsorption and disinfection are the most common chemical unit processes.

Unit Operations in Sewage Treatment

Biological Unit Operations:

- Removal of contaminants is brought about by biological activity.
- These unit operations remove biodegradable organics and nitrogen.
- Activated sludge process, trickling filter, waste stabilization ponds are important biological unit processes.

Dasherkandi Sewage Treatment Plant



The eco-friendly Dasherkandi Sewage Treatment Plant in Khilgaon, Dhaka, is the largest of its kind in South Asia. Photo: TBS

- Sewage treatment capacity of 5,00,000 tons per day.
- The largest individual sewage treatment plant in South Asia.
- First modern large-scale sewage treatment plant in Bangladesh incorporating sludge incineration plant.

EWCE 333
Wastewater Engineering and Sanitation

Lecture 9

Instructor

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Lecture Outline

Topics	Reference
• Preliminary treatment methods – ✓ Screening ✓ Grit chambers ✓ Cutting screen or comminutors ✓ Skimming tank ✓ Pre-aeration ✓ Flow equalization	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Purpose of Preliminary Treatment

- To remove large floating objectives such as rags, pieces of wood, kitchen refuse and heavy materials like sand and clay
- To protect the equipment used in the subsequent stages of treatment
- To prevent formation of scum in settling and aeration tanks and
- To prevent clogging sprinkler-nozzle, or on the surface of trickling filter, pumping machineries and siphons etc.

Preliminary Treatment Methods

(a) Screening

(b) Grit chambers

(c) Cutting screen or comminutors

(d) Skimming tank

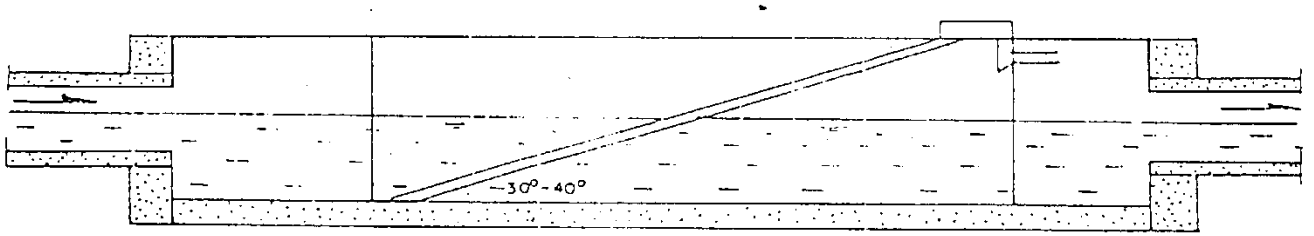
(e) Pre-aeration

(f) Flow equalization

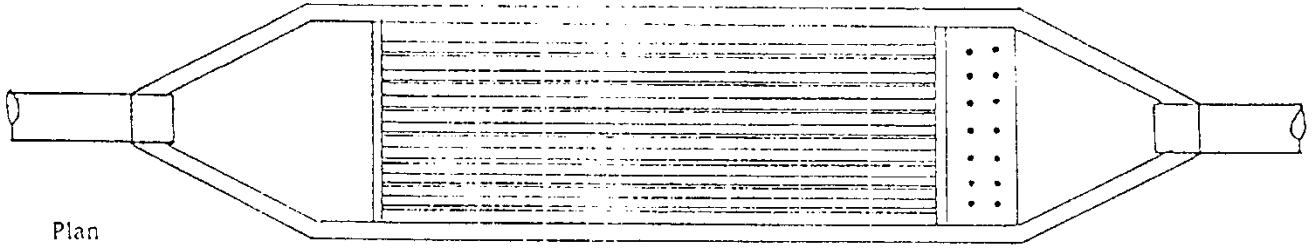
Screening

- Coarse solids are removed by a series of closely spaced mild steel bar placed across the flow.
- The bars are intended to remove only fairly large suspended solids.
- Minimum velocity through the screen - 0.3 m/s, to prevent the deposition of grit
- Maximum velocity - 1 m/s, so that the solids already trapped on the screen are not dislodged.
- The velocity is generally restricted to 0.6 m/s in order to prevent grit deposition and dislodgement of screenings.

Preliminary Treatment - Screening



Sectional Elevation



Plan

Figure:1 Bar Screen





Disposal of Screening

- Screenings are particularly obnoxious in both appearance and content and should be disposed off as soon as possible.

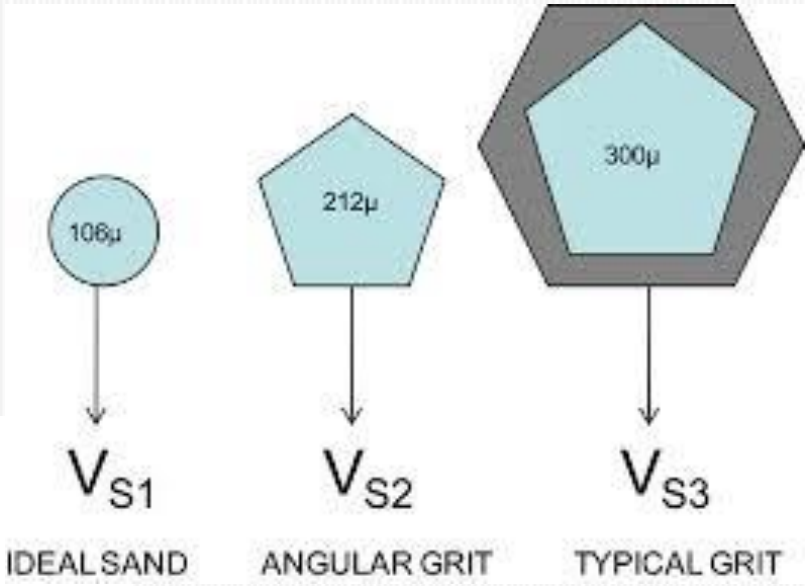
- For small works – Burial in a small piece of land

- At larger works – either dewatered in a hydraulic press and then incinerated, or macerated (softened) in a disintegrator and then returned to sewage flow under the screens.

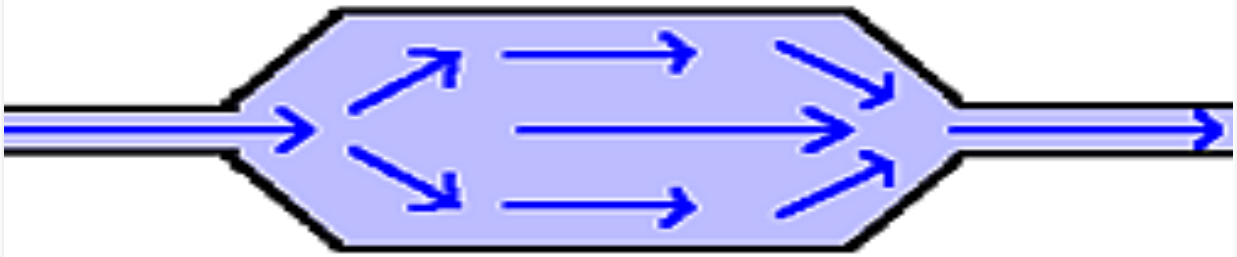
Grit Chambers

- Grit (also called detritus) is the heavy inorganic fraction of sewage solids.
- It includes road grit, sand, eggshells, ashes, charcoal, glass and pieces of metal
- It may also contain some heavy organic matter such as seeds, coffee grounds, etc.
- Grit has an average relative density of about 2-5 and thus has a much higher settling velocity than organic sewage solids (about 30 mm⁄s as against of 3 mm⁄s).

Grit Chamber

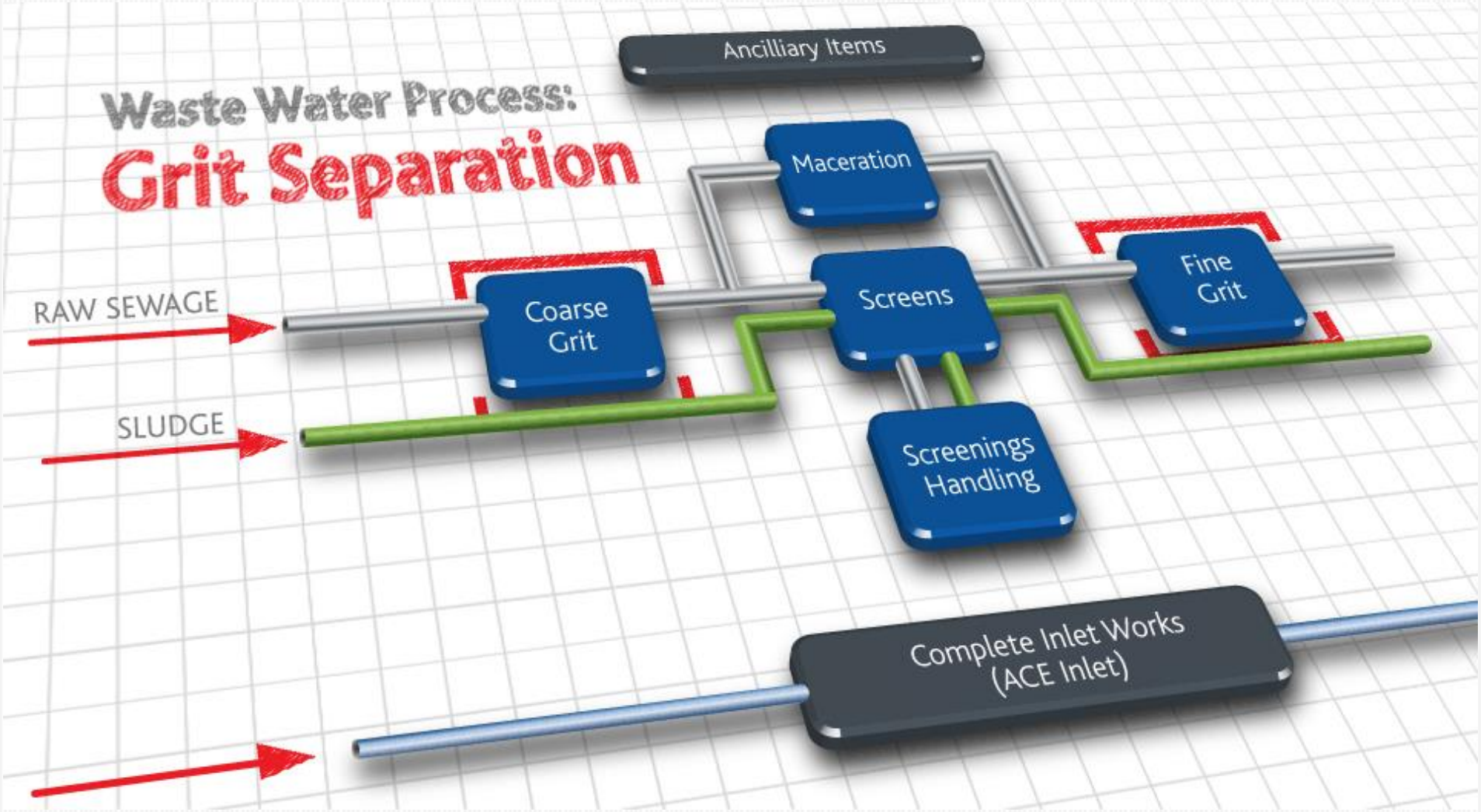


From above:



From the side:




Waste Water Process:
Grit Separation
Ancilliary Items
Maceration
Coarse Grit
Screens
Fine Grit
RAW SEWAGE
SLUDGE
Screenings Handling
Complete Inlet Works (ACE Inlet)

Grit Removal Plants

1. Constant velocity grit channel

- A constant velocity of about 0.3 m⁄s is maintained
- At this velocity, grit particles settle out but organic solids do not
- The geometry of the channel is such that its cross-sectional area is proportional to the flow and hence the velocity of the flow will be constant throughout the channel at all flows.

Constant Velocity Grit Channel



Feed inlet

Recirculation pipe

Inclined grit auger removed for transit

Grit collection box

Grit horizontal auger drive counter flow

Grit Removal Plants

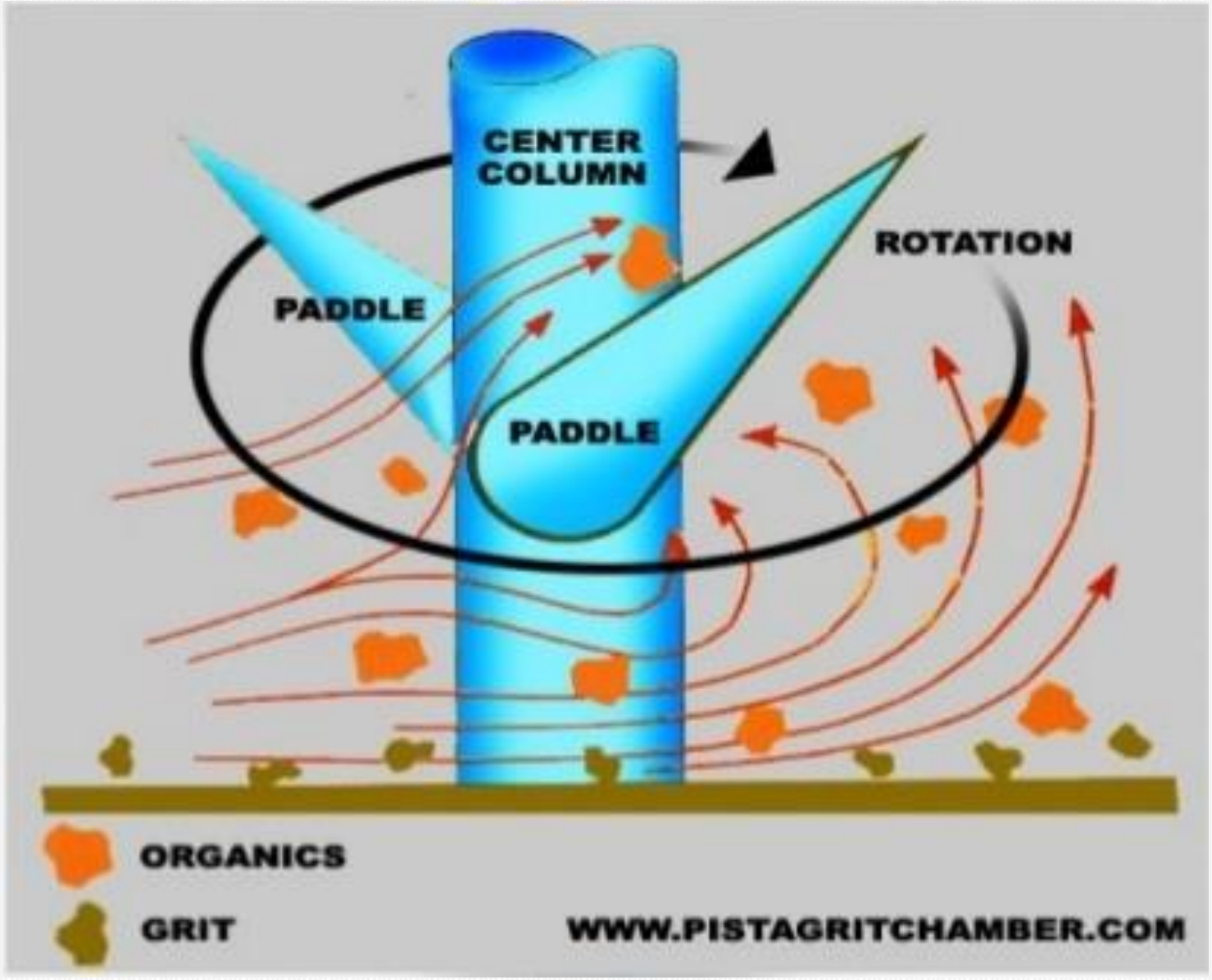
2. Propriety tanks or traps

- For flows > 5000 m^3/d proprietary grit separators are often more economical than several long constant-velocity grit channels.

- The most common type is a settling tank of sufficiently short retention time to allow the grit, but not the organic solids, to settle out.

- One of the simplest grit trap is the Jones & Attwood ‘Pista’ grit trap, where no moving parts come in contact with the grit and that the grit is automatically cleaned before discharge.

Grit Removal Plants - Propriety Trap



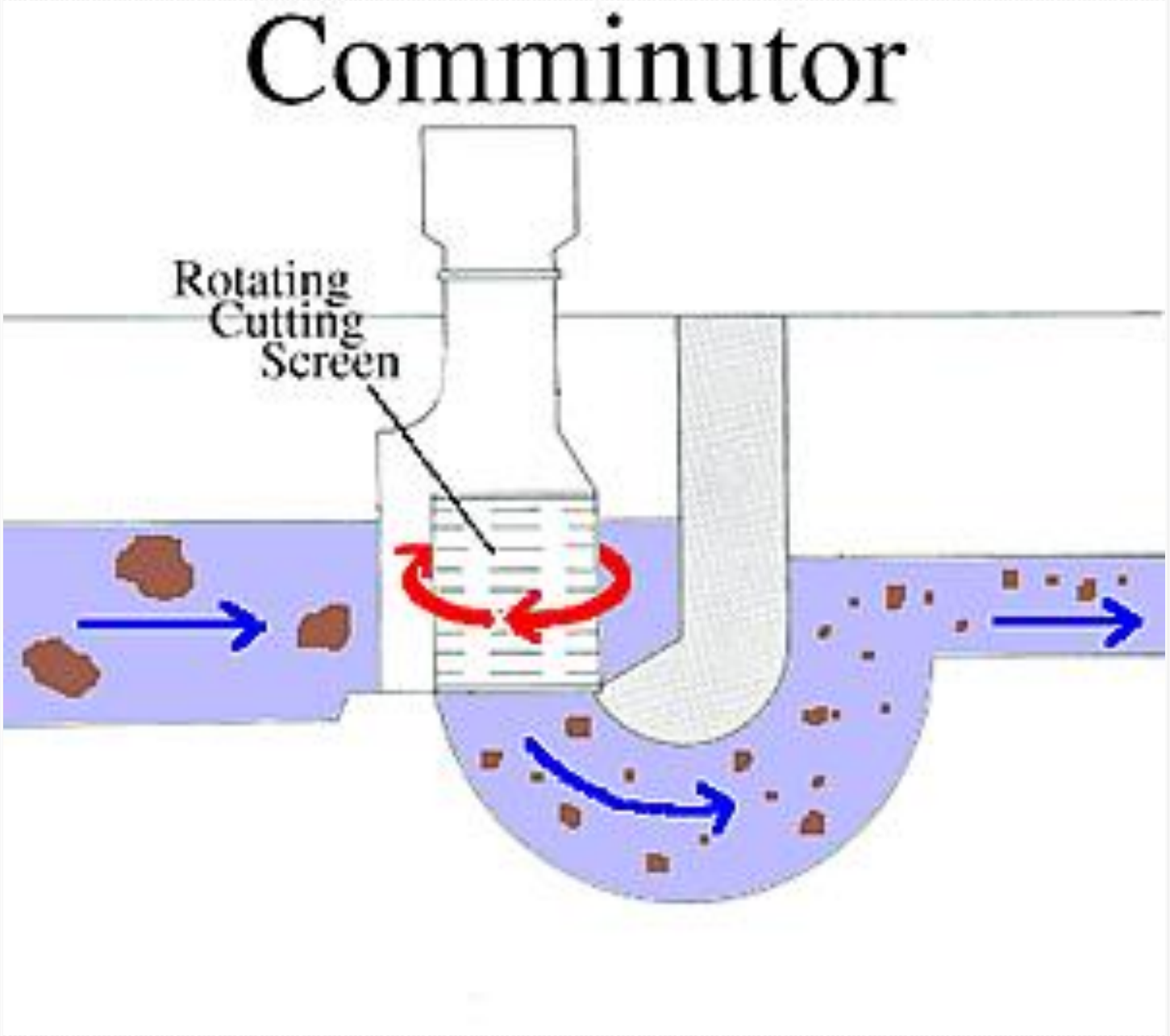
Grit Disposal

- The quantity of grit collected may be as high as 0.17 m^3 / l000 m^3 of sewage, although the average figure is 0.05-0.10 m^3/1000 m^3.
- The grit is either used for landfill or disposed of by burial.

Cutting Screen/ Comminutors

- A comminutor is a self-cleansing shredding machine.
- Instead of removing large suspended solids, comminutors reduce them in such size so that they will not interfere with other treatment processes.
- The comminutor consist of a hollow cast-iron drum, which is a screen with 6-8 mm horizontal slots on which cutter bars and a large number of projecting cutting teeth are fixed. The bars and teeth engage with stationary steel combs.

Comminutor



Cutting Screen/ Comminutors

- Comminutors avoid the problems associated with the handling and disposal of screenings and for this reason they are popular with plant operators.

- Grit can damage the cutting teeth and to avoid this occurring comminutors should be located downstream of grit channels or traps.

Skimming Tank

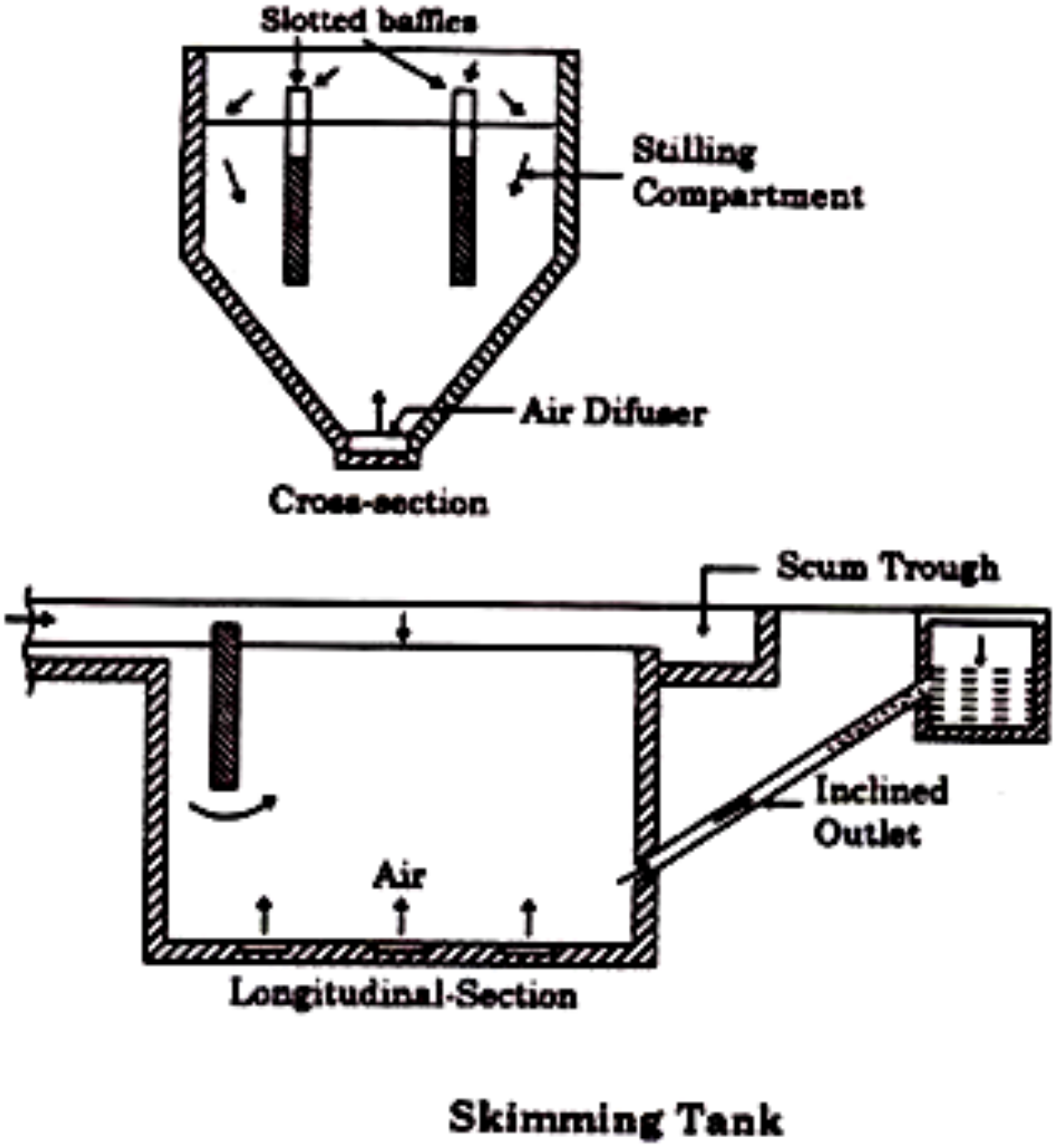
Principle:

- Floating efficiency can be promoted by introducing finely divided air bubbles at the bottom of the tank through skimming device.

- A skimming tank generally includes an aerating device which blows air through the sewage at a 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.

Aerated Skimming Tank



Skimming Tank

Skimming Tank

Design Criteria:

- Plain skimming tanks are commonly designed on the basis of overflow rate **(Q/A)** with the surface area as the desire factor.

- To avoid turbulence and bottom scour, these tanks are designed as long narrow trough shaped structure with a high velocity of horizontal flow.

- The depth is commonly between 1- 2 m.

Skimming Tank

Design Criteria:

- Short detention period of 300 to 500 sec and high velocity of horizontal flow are commonly preferred to avoid solid deposition at tank bottom and flocculation (when necessary) is promoted by the addition of chemicals such as iron and aluminum salts.

- In case settling cannot be prevented entirely, removal of detritus must be incorporated in the flotation process by equipping the unit with sludge removal facilities.

Skimming Tank

Design Criteria:

- An aerated skimming tank is shown in the above figure, where vertical baffles separate the tank into a central aerated channel and two lateral stilling chambers in which oil and greases gather at the surface.

- Settleable matter slides back into the central channel where it is re-suspended and moved forward till it ultimately reaches the inclined outlet from the tank.

Pre-aeration

- Aeration will strip volatile compounds
- Increase dissolved oxygen content

Preaeration of sewage prior to primary treatment may often provide a number of advantages as follows:

✓ Grease removal may be modestly improved

✓ A degree of flocculation may occur.

✓ Solids will remain in uniform suspension.

✓ BOD will be reduced.

✓ Odor from septic sewage will be reduced.

Flow Equalization

- Reduce the fluctuations in wastewater flow.
- Delivering the flow to treatment processes at a constant rate, which would make the system more efficient

Applications of Preliminary Treatment Methods

- All treatment processes, with the exception of septic tanks and household systems, require some sort of preliminary or screening process to remove large and floatable objects.
- For mechanically intensive wastewater treatment systems, screening and grit removal are strongly recommended.

Applications of Preliminary Treatment Methods

- Grit removal is not necessary in most natural systems, but should be considered in highly mechanized wastewater treatment systems to prolong equipment life.
- The presence of a significant amount of grit in wastewater quickly wears down pumps and other mechanical equipment.

EWC 333
Wastewater Engineering and Sanitation

Lecture 10

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Lecture Outline

Topics	Reference
• Primary treatment methods – ✓ Sedimentation/ settling tank ✓ Septic tank (covered earlier) ✓ Imhoff tank ✓ Dissolved air flotation	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Purpose of Primary Treatment

- To produce high degree of clarification.

Clarification is the removal of solids from the liquid phase.
A high degree of clarification is required to reduce the load on the secondary (biological) treatment plant.

- To acquire high degree of thickening.

Thickening means the removal of liquid from the solid or sludge phase.
A high degree of thickening is desirable so that sludge handling and treatment is minimized.

Primary Treatment Methods

Primary treatment is performed by-

(a) Sedimentation tank

(b) Septic tank

(c) Imholf tank

(d) Dissolved Air Floatation (DAF)

Sedimentation

Sedimentation of sewage is the removal of solid settleable suspended particles present in sewage through settling by gravity.

Types of Sedimentation:

Depending on the addition of chemical additives –

(1) Plain sedimentation

(2) Chemical sedimentation or sedimentation with coagulation.

Types of Sedimentation

Plain sedimentation

- Settling occurs by natural forces, by gravitation and by natural aggregation of suspended particles

- Sedimentation is not aided by chemicals (coagulants)

- The sludge (mixture of sewage solids and water) is not retained for digestion.

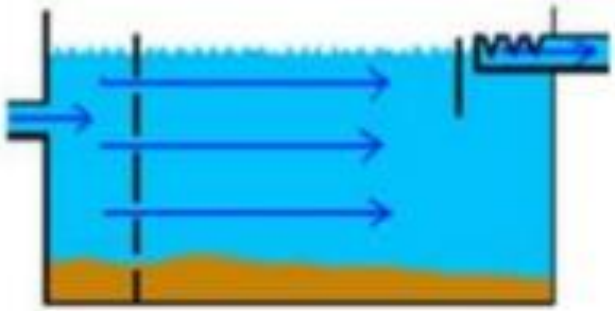
Types of Sedimentation

Chemical sedimentation

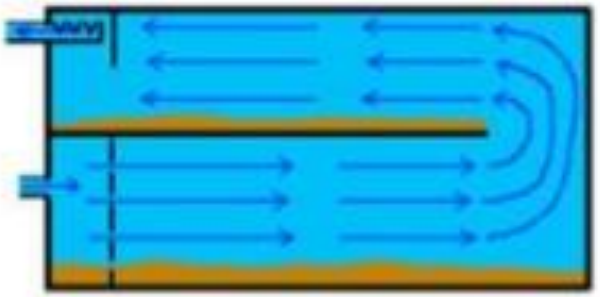
- Chemical sedimentation is accomplished by adding chemicals to sewage.

- Added chemicals form a flocculent precipitate with the waste material and thus hasten the removal of suspended solids.

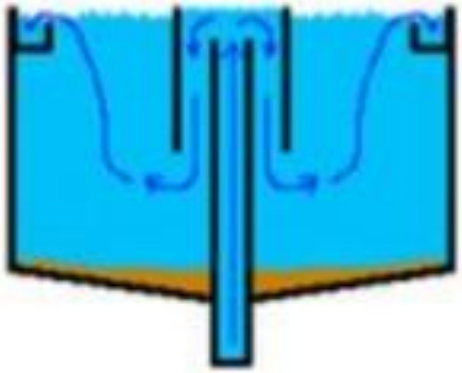
Types of sedimentation basins



Rectangular basins

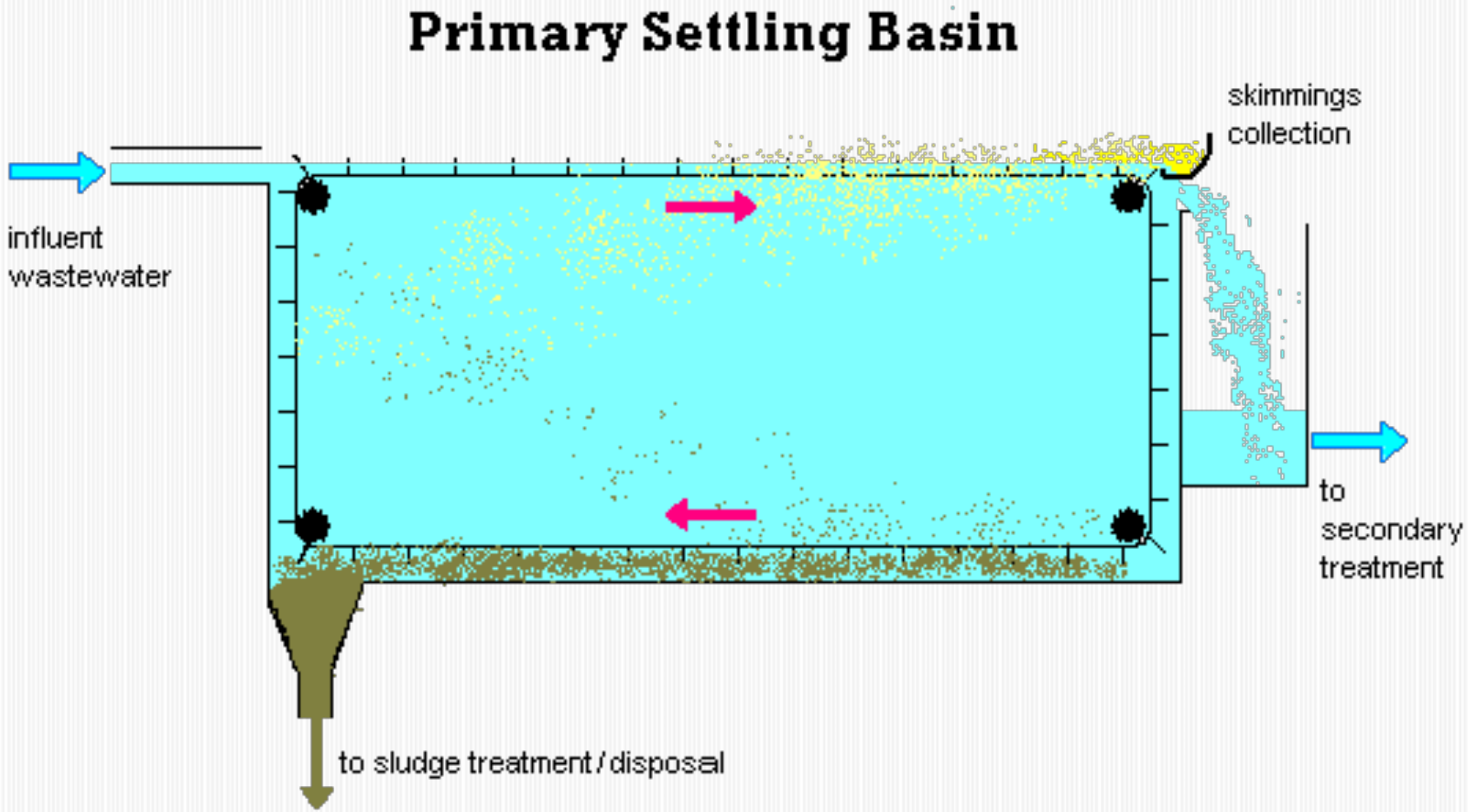


Double-deck rectangular basins

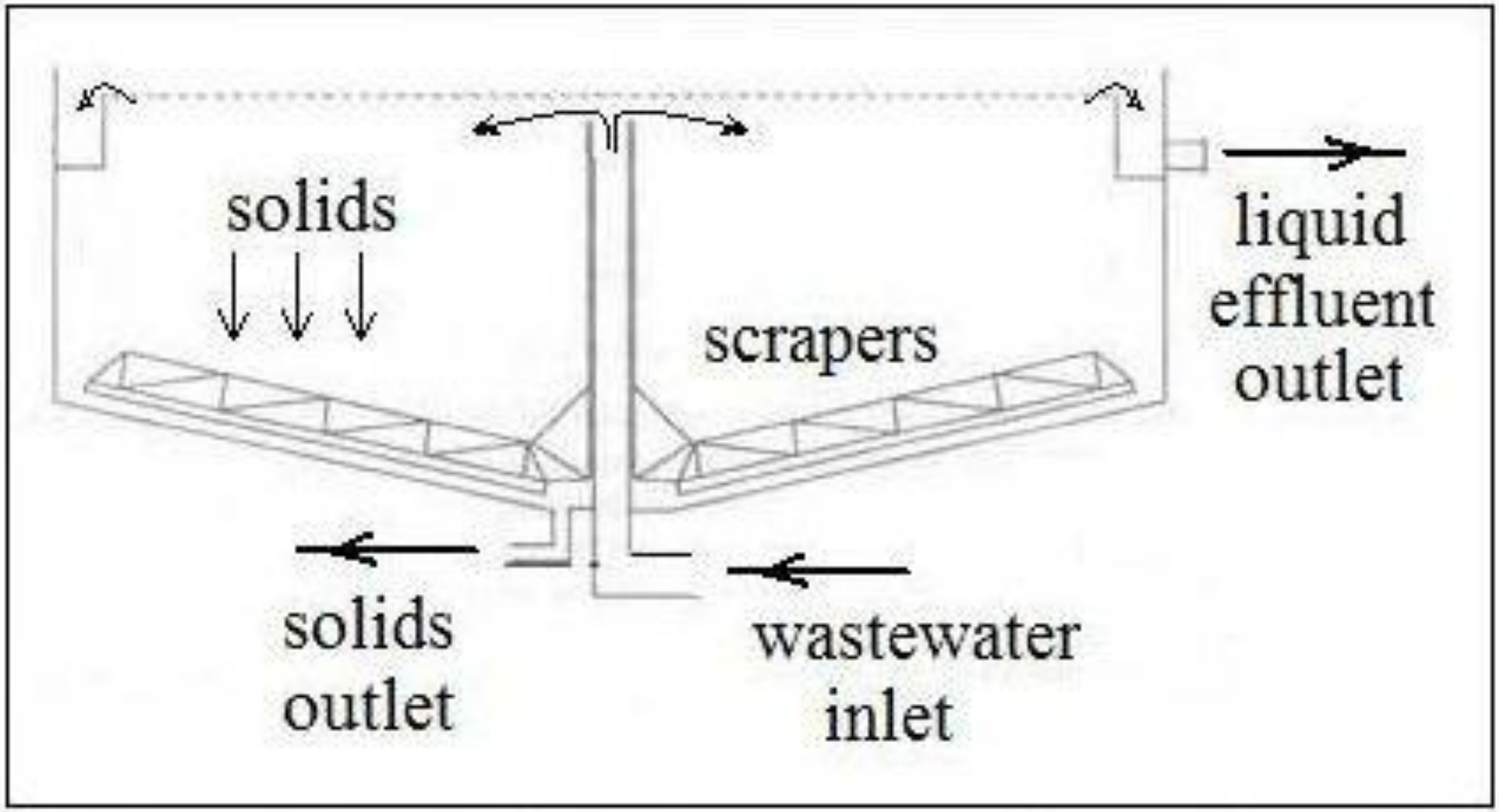


Square or circular sedimentation basins

Rectangular Sedimentation Tank



Circular Sedimentation Tank



Sedimentation Tank

Design Principle:

The settling velocity of a particle is given by stokes law:

$$U_s = g\,(\rho_s - \rho)\,d^2/18\mu \quad \ldots\ldots(1)$$

where,

U_s = settling velocity, m/s

g = acceleration due to gravity, m^2/sec

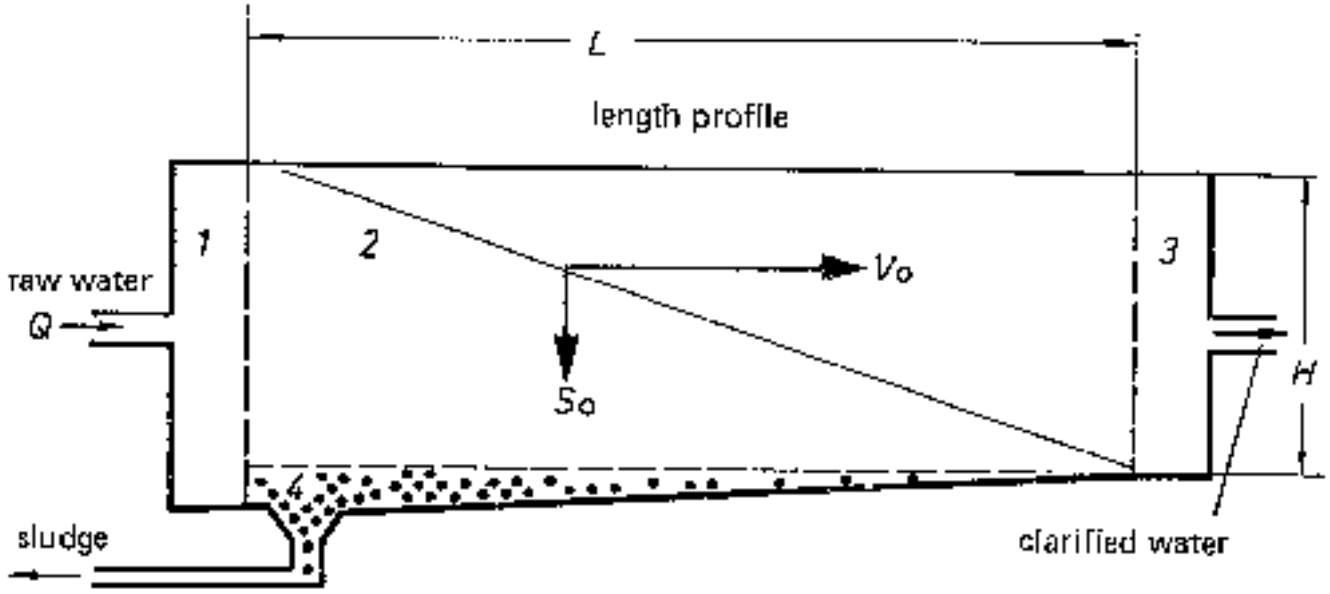
ρ = density of particles, kg/m^3

ρ_s = density of suspending fluid, kg/m^3

d = characteristic linear dimension of the particle, m

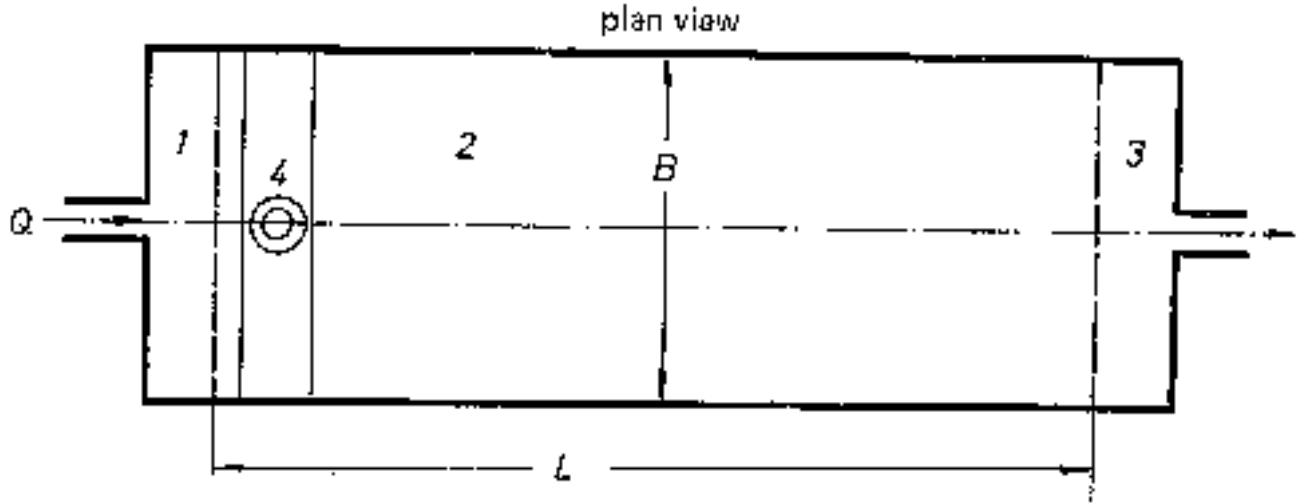
μ = molecular viscosity of suspending fluid, Ns/m^2

Sedimentation Tank



L = length
B = width
H = depth

1 inlet zone
2 settling zone
3 outlet zone
4 sludge zone



Sedimentation Tank

Equation 1 is valid only for particle's Reynolds number, $R_e < 0.2$, although little error is introduced for up to $R_e = 5$.

R_e is defined as:

$$R_e = \rho U_s d / \mu \quad \ldots\ldots (2)$$

R_e = Inertia force / Viscous force

A particle can be assumed to be retained in a continuous flow in sedimentation tank, if its settling velocity is high enough to permit it to settle through the full tank depth within one retention time.

Under this condition, the limiting minimum settling velocity is:

$$U_s = D / t \quad \ldots\ldots (3)$$

where,

D= tank depth, m

t= mean hydraulic retention time, sec

Sedimentation Tank

The retention time in a continuous flow tank is given by:

$$\mathbf{t = AD/Q} \quad \ldots\ldots (4)$$

where,

A = surface area of the tank, m^2

AD = tank volume, m^3

Q = flow through tank, m^3/s

Therefore, $\mathbf{U_s = Q/A}$ (m/s) (from eqn 3 and 4)

The ratio **Q/A** is the flow per unit surface area and is termed as the overflow rate.

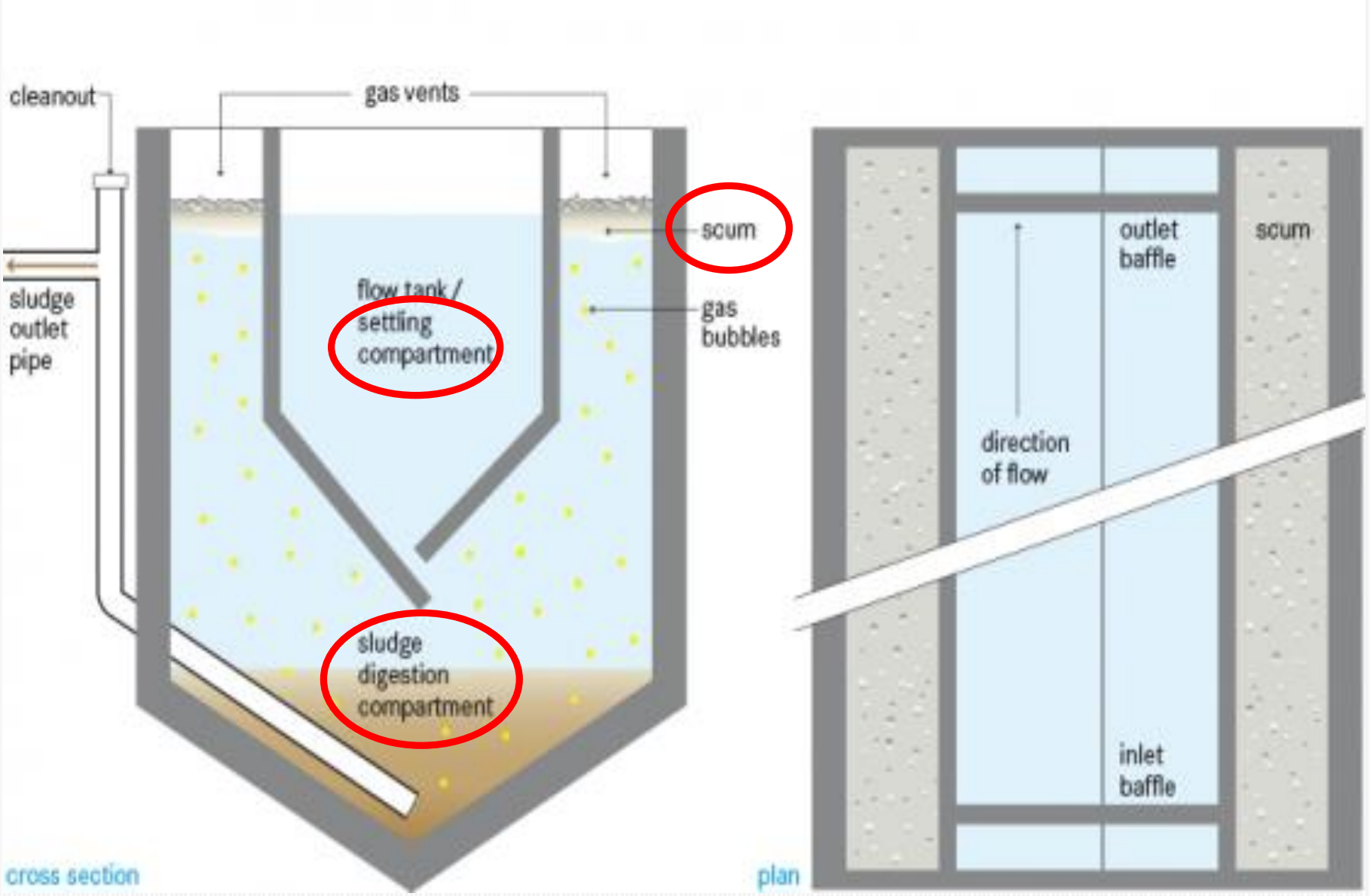
Imhoff Tank

Pronounced Impact

- It is an improved septic tank in which the incoming sewage or influent is not allowed to get mixed up will the sludge produced, and

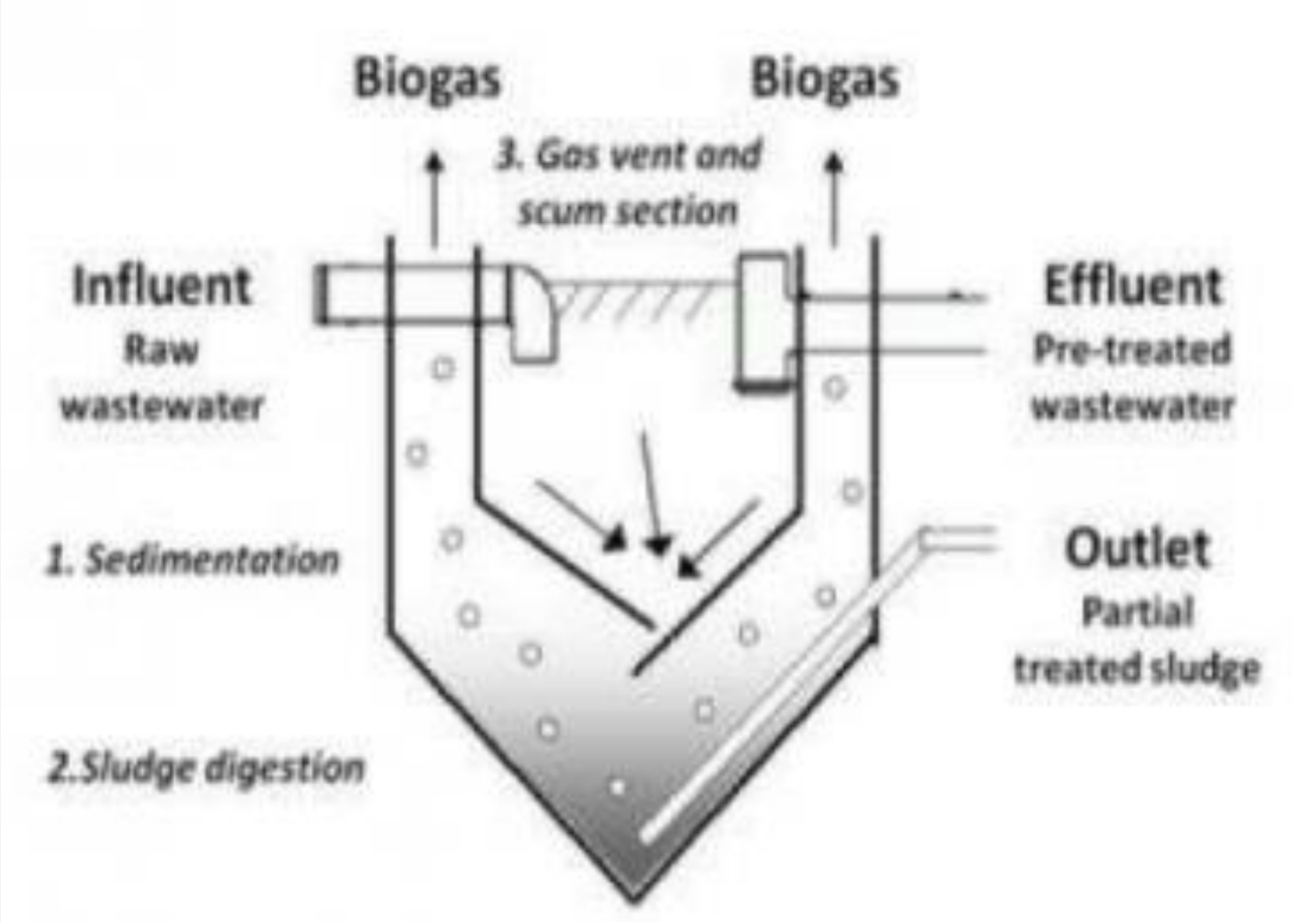
- the outgoing sewage or effluent is not allowed to carry with it large amount of the suspended matter as in the case of a septic tank.

Imhoff Tank


cleanout
gas vents
scum
sludge outlet pipe
flow tank / settling compartment
gas bubbles
sludge digestion compartment
cross section
outlet baffle
scum
direction of flow
inlet baffle
plan

Components of Imhoff Tank

1. Upper compartment for sedimentation
2. Lower section for sludge digestion
3. Gas vent and scum section



Components of Imhoff Tank

Sedimentation or Flowing Through Chamber

- The upper level of the tank is called the sedimentation or flowing trough chamber.

- This chamber is used for clarifying the water.

- Sewage flows at a very low velocity in this level.

Components of Imhoff Tank

Digestion Chamber

- The lower level of the tank is called the digestion chamber.

- This chamber is used for digestion of the sludge.

- Anaerobic or septic decomposition occurs in this chamber.

- The digestion chamber is made up of two or three inverted cones called **hoppers** with sides sloping (1:1) as to concentrate the sludge at the bottom of the hopper.

Imhoff Tank

Mechanism of Solids Removal

- The solids of the sewage settling to the bottom of the sedimentation chamber through the sloping bottom walls (slope V:H = 5:4) are made to fall in the digestion chamber through an entrance slot at the lowest point of the sedimentation chamber.

- The slot is trapped or overlapped in such a way that the gases generated in the digestion chamber cannot enter the sedimentation chamber.

Components of Imhoff Tank

- A gas vent is provided with the digestion chamber to take care of the gases escaping to the surface.
- In order to prevent particles of sludge or scum from penetrating into the sedimentation chamber, the sludge and scum must be maintained at a distance of at least 18 inch below and above the slots respectively.
- This free clear zone is called neutral zone.

Advantages of Imhoff Tank

- Solid-liquid separation and sludge stabilization are combined in one single unit
- Resistant against organic shock loads
- Small space requirements
- The effluent remains fresh (i.e., not septic)

Advantages of Imhoff Tank

- Low operating costs
- Suitable for small settlements and house clusters
- Standardized designs are available
- Simple operation and maintenance

Disadvantages of Imhoff Tank

- Very deep/high infrastructure, depth may be a problem in case of high groundwater table
- Requires expert design and construction
- Low reduction of pathogens
- Requires desludging

Disadvantages of Imhoff Tank

- Inefficient treatment option if not regularly desludged
- Odor occurs from escaping gases
- Effluent, sludge and scum require further treatment
- Less simple than septic tank

Application of Imhoff Tank

- Imhoff tanks are recommended for domestic or mixed wastewater flows between 50 and 20,000 population.
- Normally, Imhoff tanks are used by small communities with raw wastewater flows on the order of 950 m^3/day (population about 8000 people or 1300 households)
- Imhoff tanks can be used in warm and cold climates

Application of Imhoff Tank

- As the tank is very high/deep, it can be built underground if the groundwater table is low and the location is not flood prone.
- If constructed underground, land use is very limited and Imhoff tanks can be constructed in both, rural or urban areas.
- Investment costs are low and operation and maintenance simple.

Improvement of Sedimentation Efficiency

- Precipitation with chemicals (Lime, Alum, Ferric Chloride), though it causes additional sludge production
- Flocculation
- Tube settlers
- Lamella Plate Settlers
- Pre-equalization Basins – reduces flow variation
- Septicity Control

Dissolved Air Flotation (DAF)

- A type of primary treatment process commonly used for industrial wastewater.
- A DAF process removes oil and grease in less space than by primary sedimentation.
- Wastewater and air are pressurized to 3 to 5 atmospheres and released in a tank open to the atmosphere.
- This releases small bubbles from the solution, which float to the top.

Dissolved Air Flotation (DAF)

- The bubbles become enmeshed (← entangled) in the light solids and oils and bring them to the surface.
- A skimmer then collects solids on the water surface, and the clarified liquid continues to downstream processes.
- Other types of oil-water separating processes are also widely used in the petroleum industry.

Advantages of DAF over Simple Aeration

- More efficient
- Lower hydraulic retention time (HRT)
- Higher solids content in sludge
- Higher quality fat recovered
- Not affected by thermal effects
- Reduced odor problems

Disadvantages of DAF

- Higher operating and maintenance costs
- Operational problems e.g. blockage in recycle line

Application of DAF

- DAF is used mostly for industrial sewage that contains oil, grease, and other easily floatable solids.

- Oil refineries, meat packing factories, and dairy processing plants commonly use DAF for primary treatment.

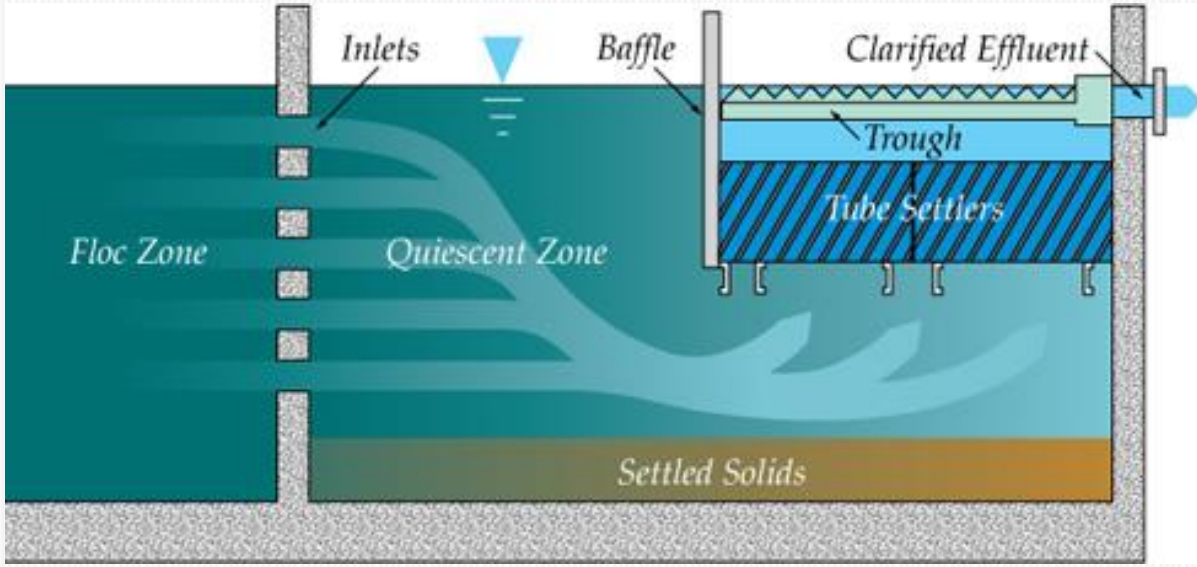
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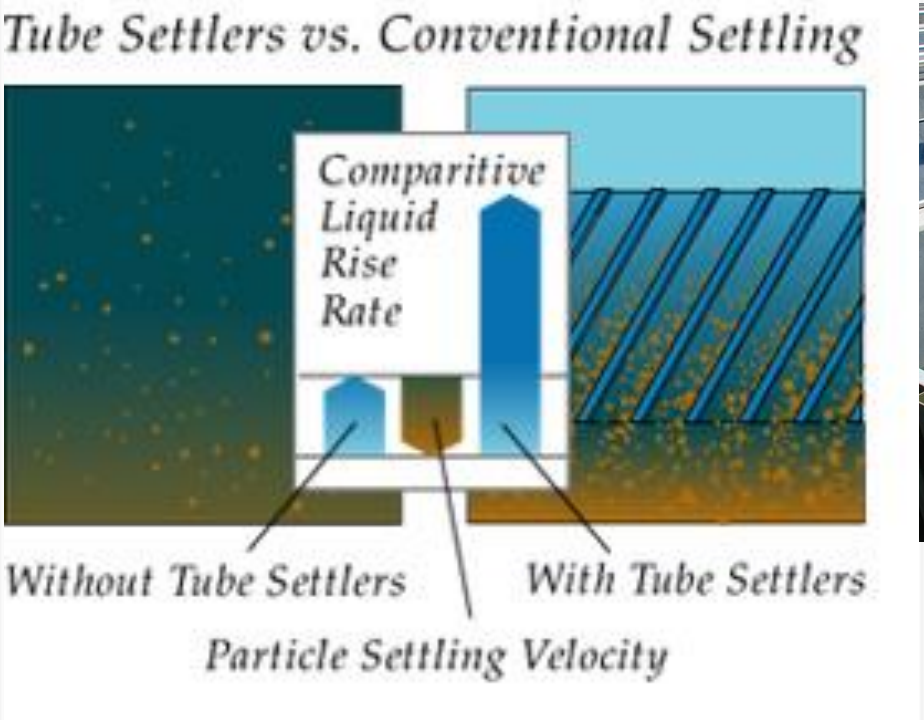
Reynolds Number

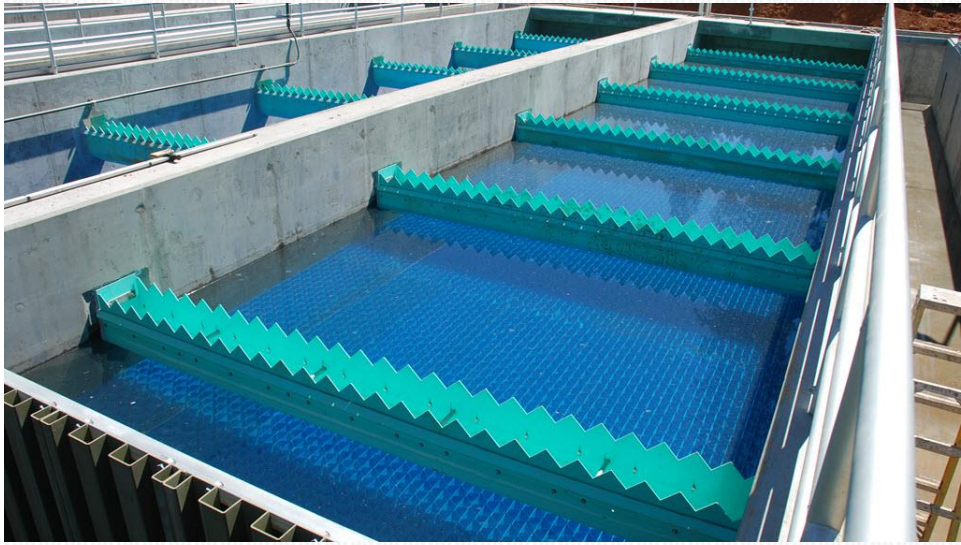
- dimensionless quantity that is used to help predict similar flow patterns in different fluid flow situations

- The Reynolds number is defined as the ratio of momentum forces to viscous forces and consequently quantifies the relative importance of these two types of forces for given flow conditions

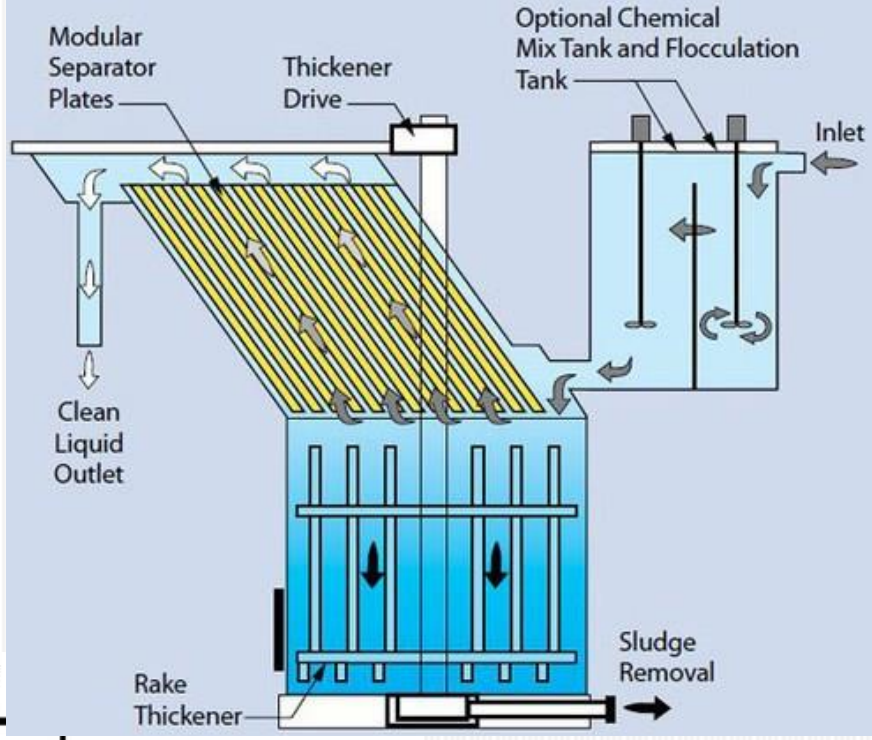
Tube Settlers

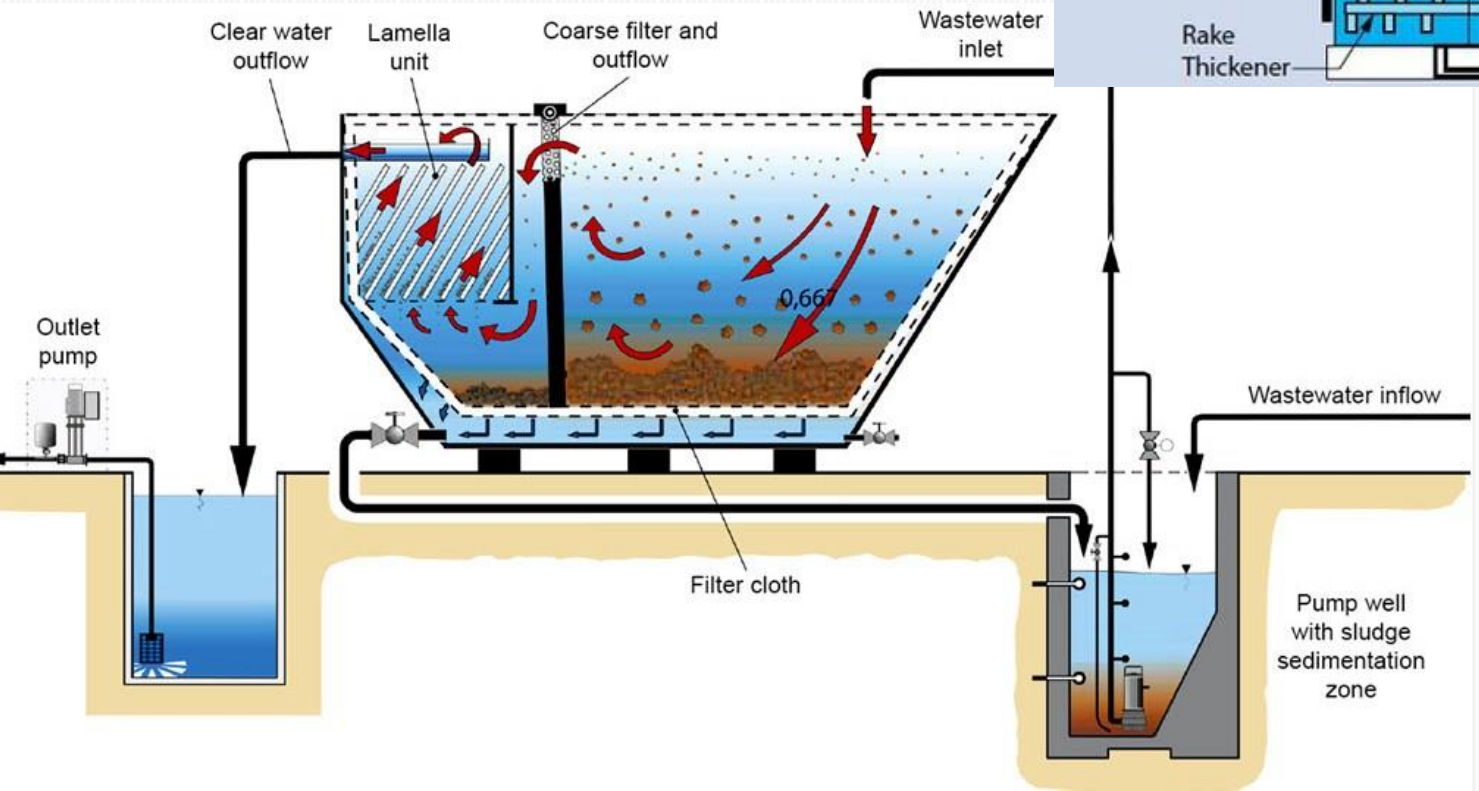




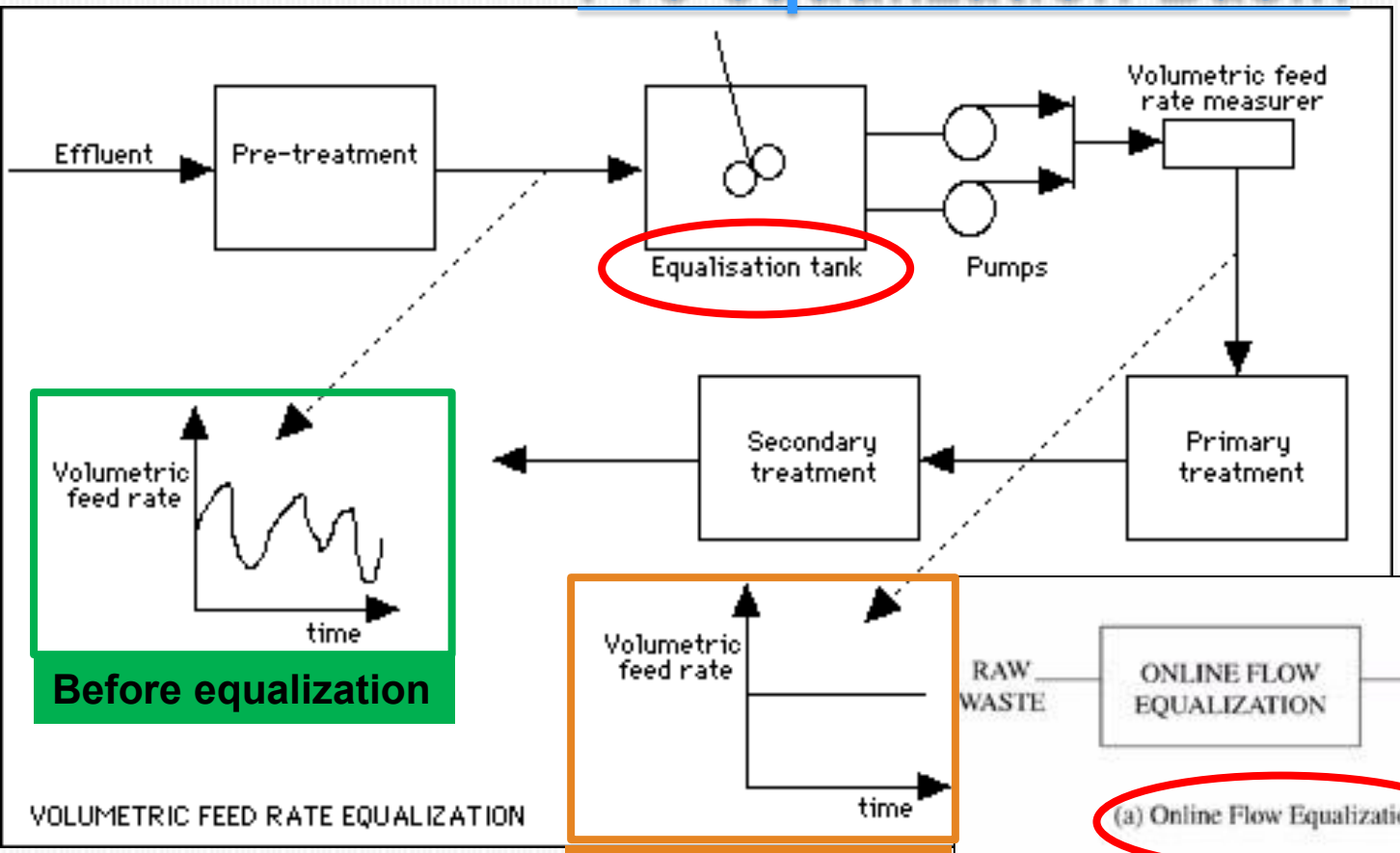


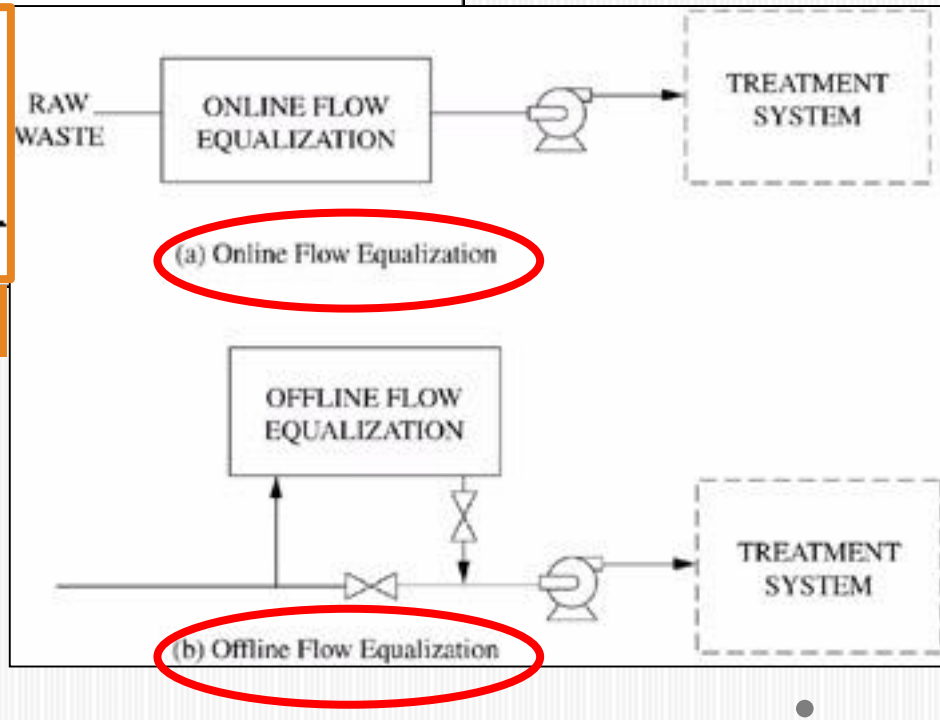
Lamella Plate Settlers





Pre-equalization Basin





EWC 333
Wastewater Engineering and Sanitation

Lecture 11

Instructor

Lt Col Kazi Shamima Akter, Ph.D., Engrs

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Lecture Outline

Topics	Reference
• Secondary treatment – purpose, biological treatment mechanism • Important organisms involved in biological treatment	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Purpose of Secondary Treatment

- The effluent from primary treatment still contains 40 to 50 percent of the original suspended solids and virtually all of the dissolved organic and inorganic matters. To remove these, further treatment is required.

- Organic matters are removed through secondary treatment processes.

Biological Treatment Mechanism

- In biological treatment, microorganisms use the organics in wastewater as a food supply and convert them into biological cells or *biomass*.

- Because wastewater contains a wide variety of organics, a wide variety of organisms, or a mixed culture, is required for complete treatment.

Biological Treatment Mechanism

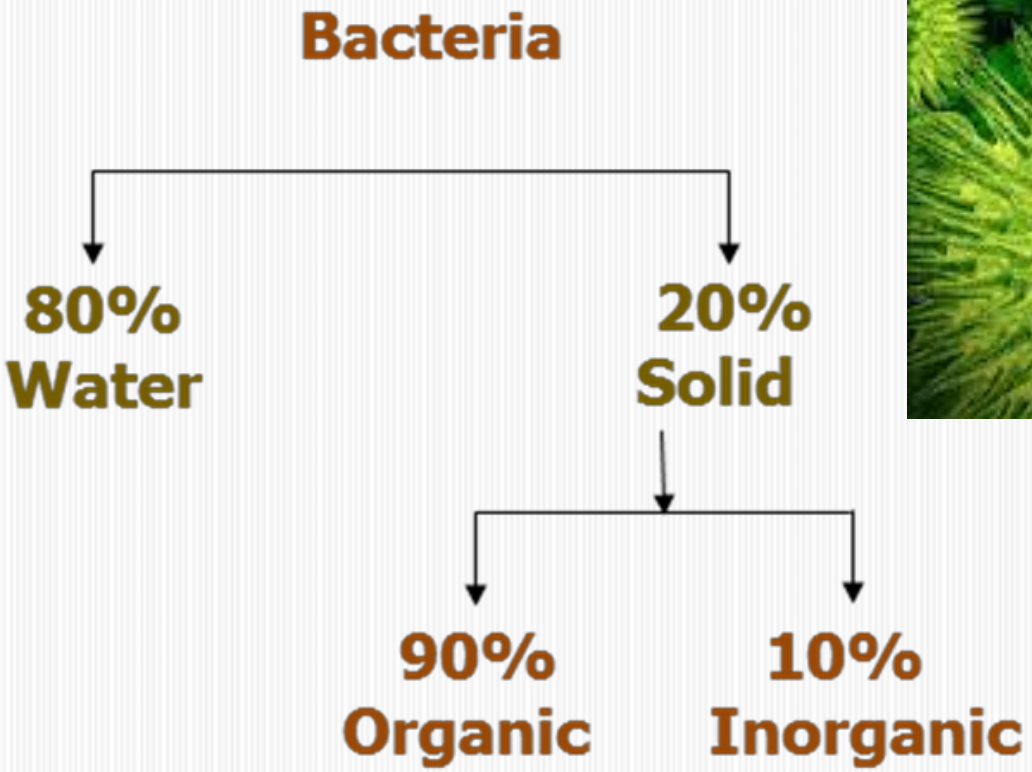
- Each type of organism in the mixed culture utilizes the food source suitable to its metabolism.
- Most mixed cultures will also contain grazers, or organisms that prey on other species.
- The newly created biomass must be removed from the wastewater to complete the treatment process

Important Organisms - Bacteria

- Single cell protists.
- They use soluble food and in general will found whenever moisture and a food source are available.
- Their usual mode of reproduction is by binary fission.
- Bacteria are capable of storing food particles outside the cell by means of extracellular enzymes and hence can remove soluble, colloidal and solid organic matter from waste water.

Important Organisms - Bacteria





Composition of bacteria



Important Organisms - Bacteria

- Each type of bacteria lives and multiplies under specific environmental conditions. Of the various environmental conditions, light, air, water, food, temperature, pH and dissolved oxygen play a very important part.

- Temperature and pH play a vital role in the life and death of bacteria.

- Rate of reaction will be doubled with about every 10° C of rise in temperature.

Important Organisms - Bacteria

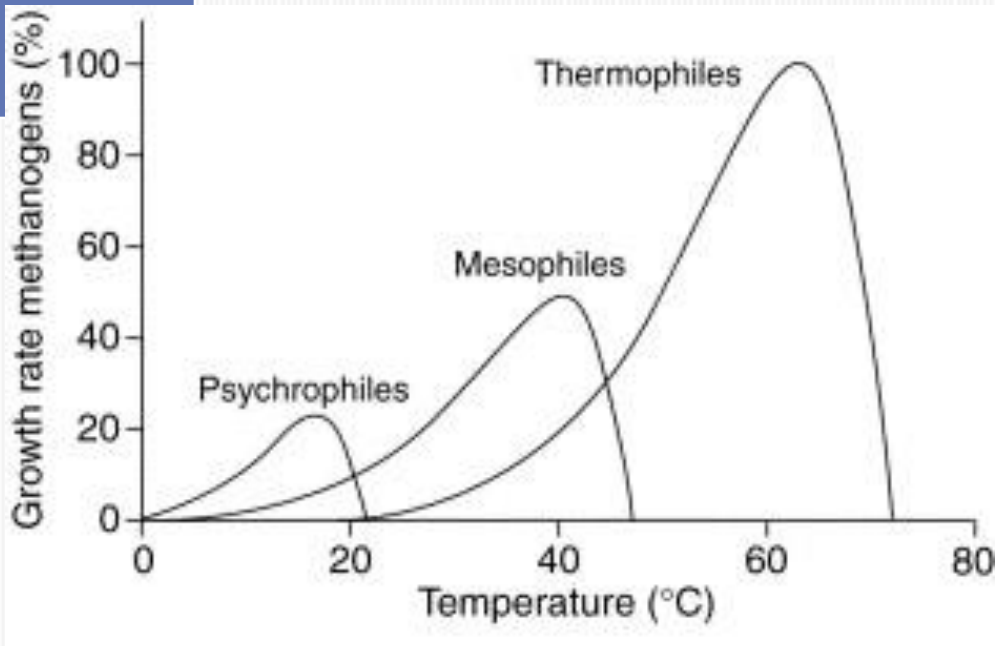
- Few bacteria can tolerate acid or alkaline conditions and most organisms (bacteria) cannot tolerate pH levels above 9.5 or below 4.0.

- Generally the optimum pH for growth lies between 6.5 and 7.5.

Types of Bacteria

1. Depending on temperature -

Type	Temperature (ºC)	
	Range	Optimum
Psychrophilic	-2 to 30	12 to 18
Mesophilic	20 to 45	25 to 40
Thermophilic	45 to 75	55 to 65



Types of Bacteria

2. Depending on need for oxygen –

- Aerobic – Oxygen is essential for oxidizing organic matter

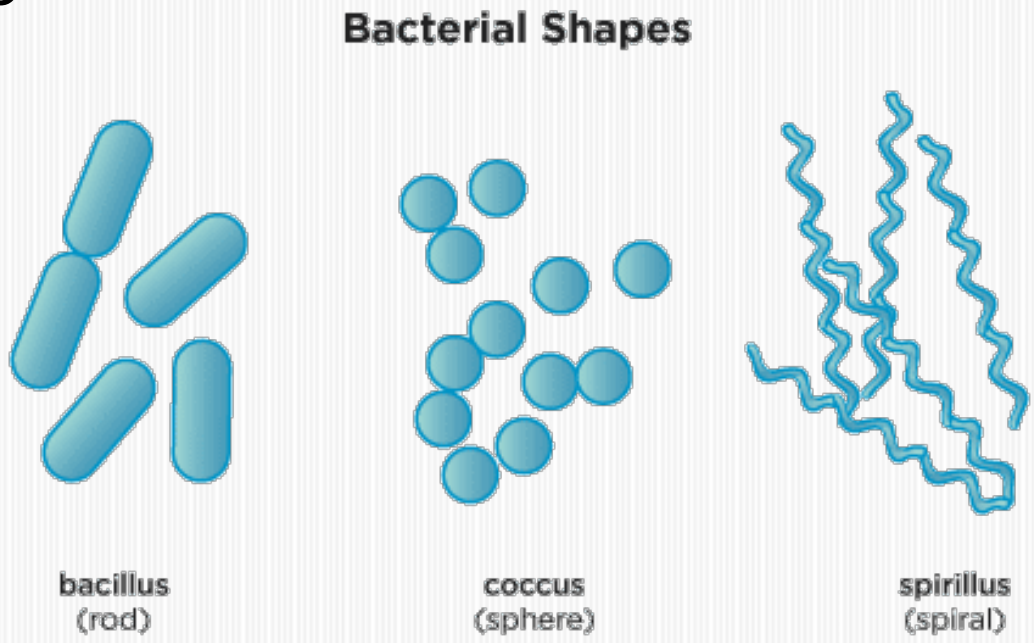
- Anaerobic – Oxidation of organic matter occur in absence of oxygen

- Facultative – Can grow aerobically in presence of air as well as anaerobically in absence of air.

Types of Bacteria

3. Depending on shape –

- Rod shaped – width 0.5 μ to 1.0 μ and length 1 μ to 3 μ
- Spherical – diameter 0.5 μ to 1.0 μ
- Spiral – width 0.5 μ to 5 μ and length 6 μ to 15 μ



Types of Bacteria

5. Depending on metabolism -

- According to metabolism (i.e. bacteria's ability to grow in any environment), bacteria are divided into two distinct groups, (a) Autotrophic and (b) Heterotrophic.

Type of Bacteria		Source of carbon	Source of energy
Autotrophic	Photosynthetic	CO_2	Sunlight
	Chemosynthetic	CO_2	Inorganic matter
Heterotrophic		Organic matter	Organic matter

Heterotropic organisms are important, 'cause their source of energy is organic matter, thus reduce load of OM.

Favored: Mesophilic — 25° – 40°C
Facultative — both aerobic, anaerobic
Rod shaped — easy to remove
Hatenophilic — OM as source of energy

Metabolism of Bacteria

Bacterial metabolism has two component parts:

Catabolism for energy

Anabolism for synthesis.

(1) Catabolism

$$C_XH_YO_ZN + O_2 \xrightarrow{\text{bacteria}} CO_2 + H_2O + NH_3 + \text{energy}$$

(organic matter)

(2) Anabolism

$$C_XH_YO_ZN + \text{energy} \xrightarrow{\text{bacteria}} C_5H_7NO_2$$

(organic matter) (bacteria cell)

(3) Autolysis

$$C_5H_7NO_2 + 5O_2 \xrightarrow{\text{bacteria}} 5CO_2 + NH_3 + 2H_2O + \text{energy}$$

(bacteria cell)

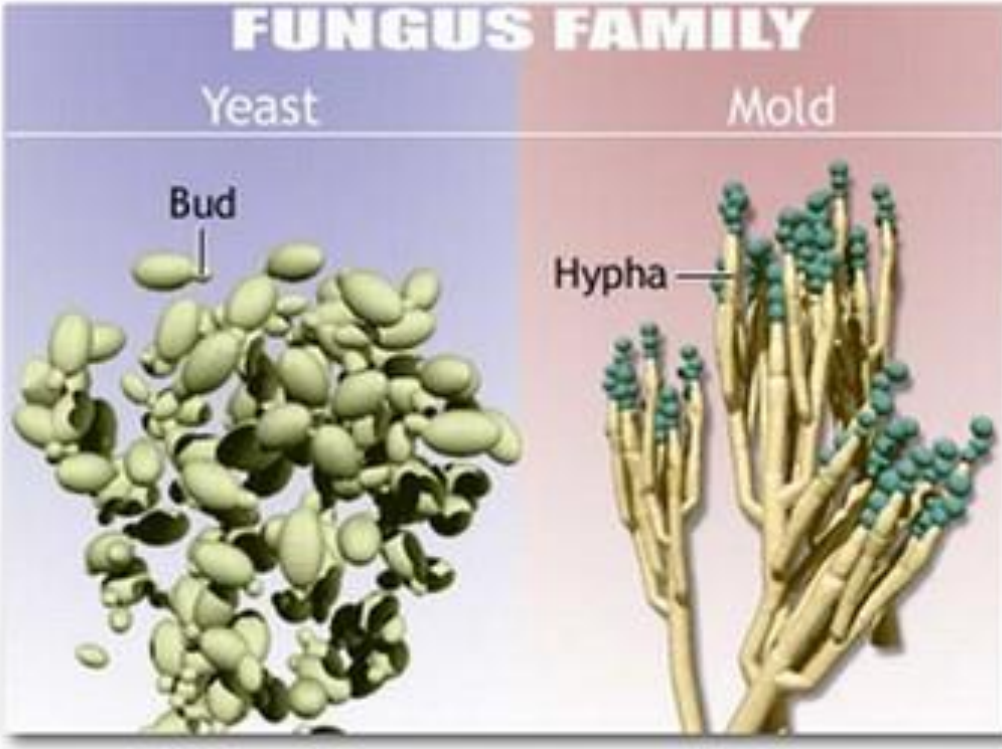
Metabolism of Bacteria

- As a general guide one-third of the available BOD is used in catabolic reactions and two-thirds in anabolic reactions.

- The process for autolysis does not proceed to completion since approximately 20-25 % of the cell mass is resistant to aerobic degradation.

Important Organisms - Fungi

- Multicellular, nonphotosynthetic, heterotrophic protists.
- Most fungi are strict aerobes.
- Ability to grow under low moisture condition.



Important Organisms - Fungi

- Can tolerate a relatively low pH range of 2 to 9, optimum is 5 to 6.
- Survive in nitrogen limiting condition.
- Important in biological treatment of some industrial waste.
- Being relatively large and filamentous shape, fungi tends to settle poorly and undesirable in biological treatment process.

Important Organisms - Algae

- Algae are unicellular or multicellular, autotrophic photosyntehtic protists.

- Undesirable in water supply for bad taste, odour and shorten filter run.



red alga



brown alga



green alga

Important Organisms - Algae

- Aesthetically objectionable.

- In waste stabilization ponds, algae are valuable to produce oxygen.





Important Organisms - Algae

Reaction:

(1) Photosynthesis

$$CO_2 + 2H_2O \xrightarrow{\text{light}} \underset{\text{(new algae cell)}}{\mathbf{CH_2O}} + O_2 + H_2O$$

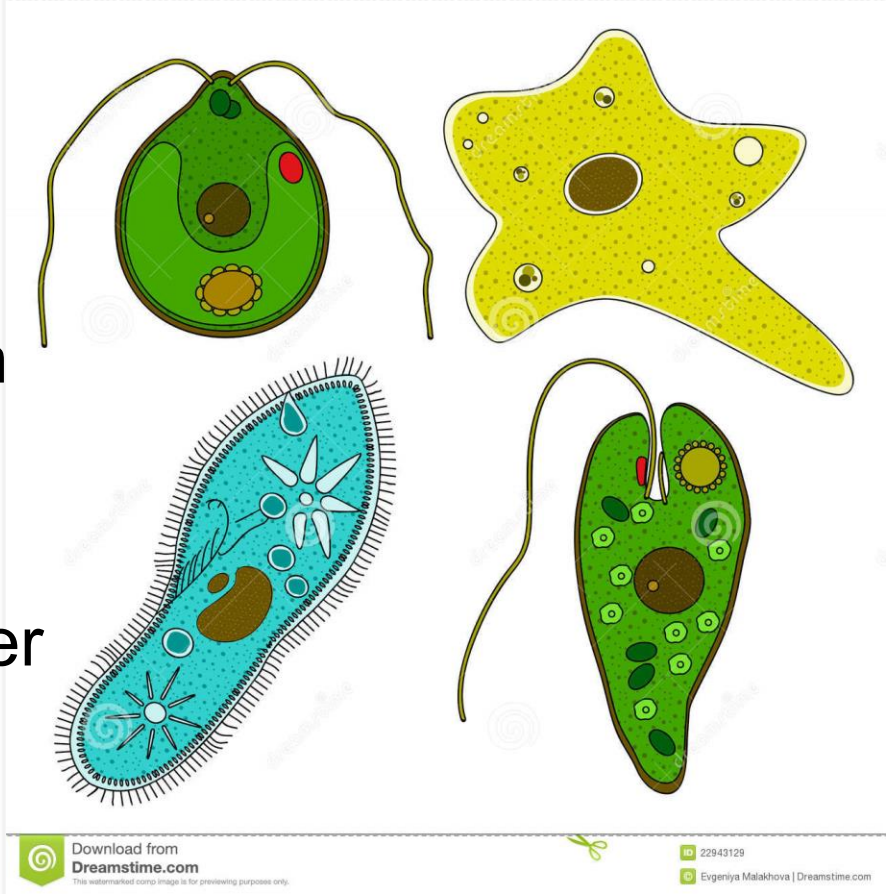
(2) Respiration

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

- Because algae use CO_2 in photosynthetic activity, high pH conditional can result.

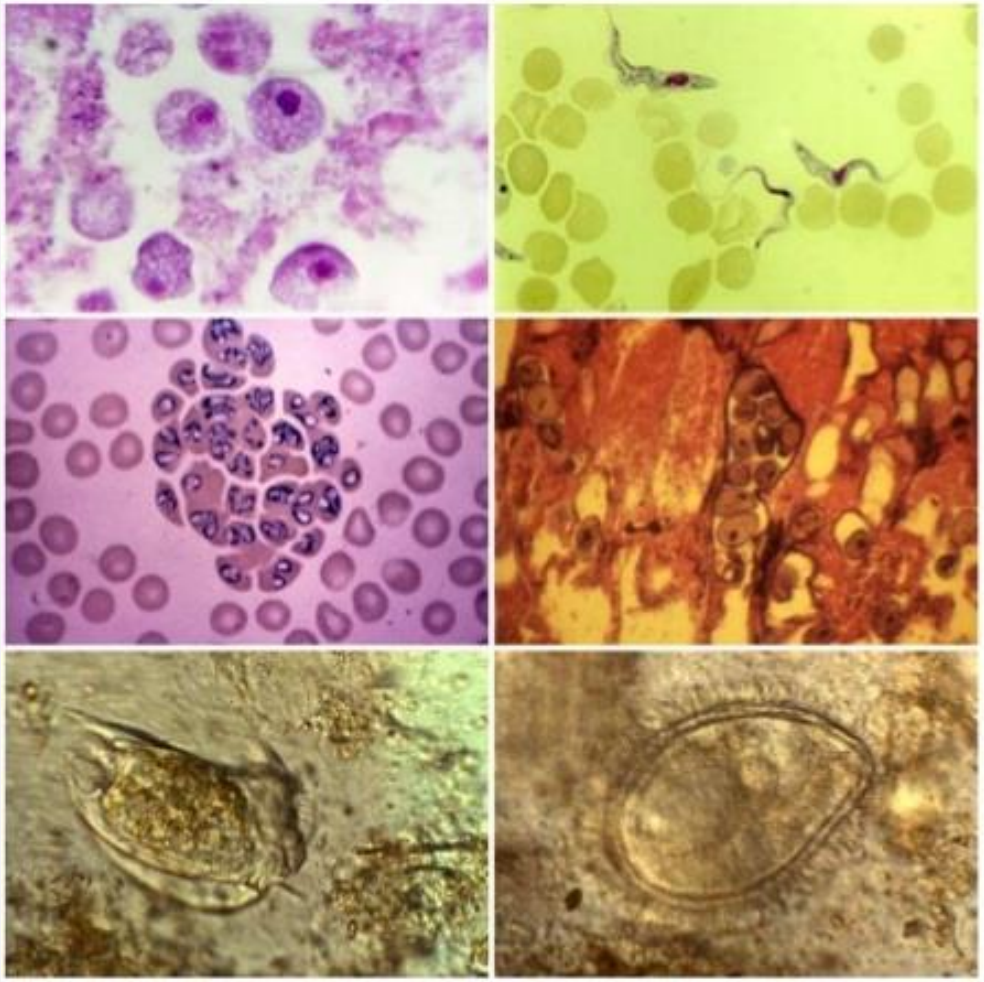
Important Organisms - Protozoa

- Protozoa are motile, microscopic protists that are usually single cells.
- The majority of protozoa are aerobic heterotrophs, although a few are anaerobic.
- Protozoa are generally an order of magnitude larger than bacteria and often consume bacteria as an energy source.



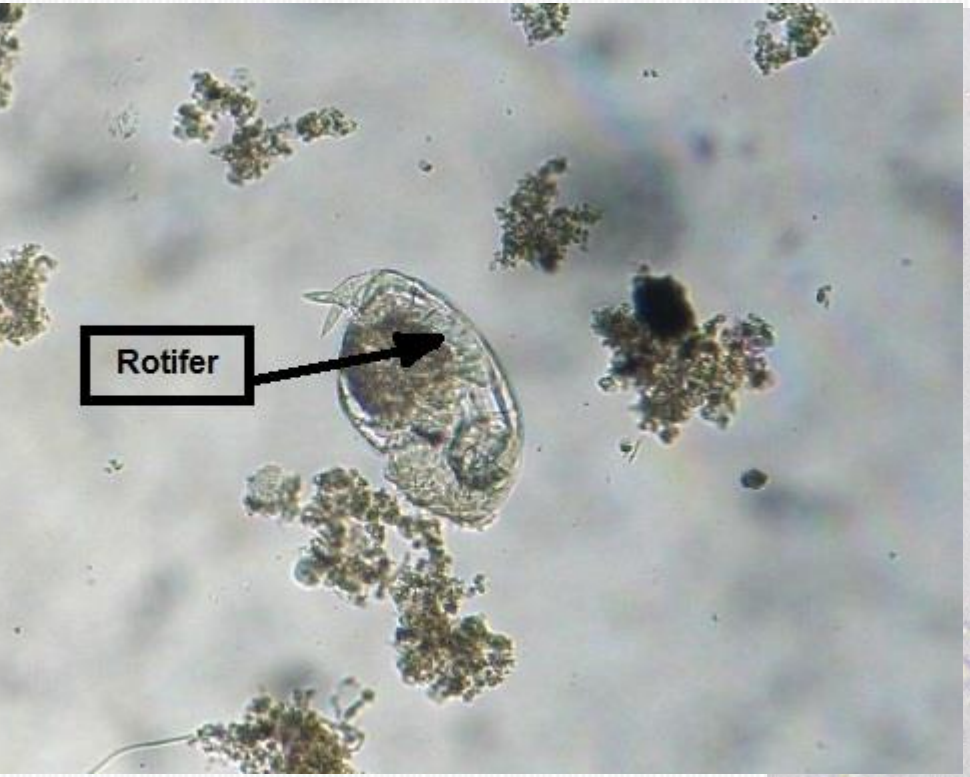
Important Organisms - Protozoa

- The protozoa act as polishers of the effluents from biological waste-treatment processes by consuming bacteria and particulate organic matter.
- The reproduce by binary fission.



Important Organisms - Rotifers

- Rotifers are aerobic, heterotrophic and multicellular animal.
- Rotifers are very effective in consuming dispersed and flocculated bacteria, protozoa and small particles of organic matter.

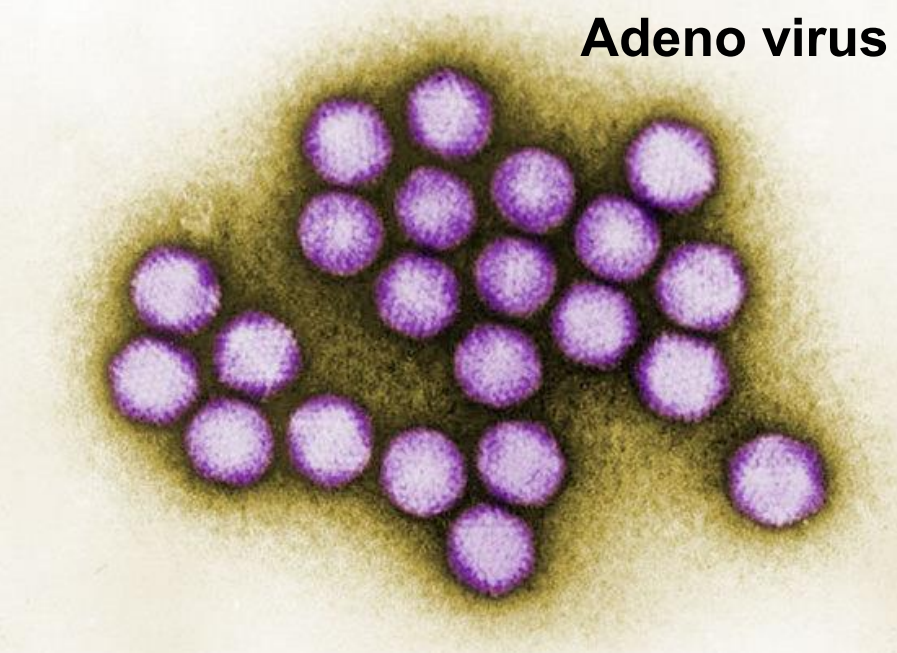




Important Organisms - Viruses

- Obligate parasites and requires a host to live in.
- Causes various diseases.
- During wastewater treatment, these are controlled by chlorination and proper disposal of the plant effluent.





EWC 333
Wastewater Engineering and Sanitation

Lecture 12

Instructor

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Lecture Outline

Topics	Reference
• Role of bacteria in sewage treatment • Bacterial growth pattern in biological treatment • Relation between Food/Microorganism (F/M) ratio and biomass settling characteristics	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Role of Bacteria in Sewage Treatment

- Bacteria are capable of solubilizing food particles outside their cell wall by means of extracellular enzymes, and hence can remove soluble, colloidal and solid organic matter from wastewater.

- The bacteria important in the aerobic treatment of sewage are rod-shaped, facultative and mesophilic.

- They are excellent oxidizers of dead organic matter and grow extremely well in sewage.

Role of Bacteria in Sewage Treatment

- They are all capable of exuding a slimy flocculant layer which in some treatment units (e.g. activated sludge) in an important mechanism in the treatment process.

- Coliforms and other intestinal bacteria do not play any significant role in the sewage treatment processes. They are merely passengers in the system.

Role of Bacteria in Sewage Treatment

- Aerobic bacteria utilize free oxygen as an electron acceptor. The end products of aerobic activity are CO_2, H_2O, SO_4^{-2}, NO_3^-, NH_3 and more bacteria.

- The bulk of the available energy is converted into either cell mass or heat, yielding a stable effluent, which will not undergo further decomposition. And this indicates the completion of treatment.

Favorable Environment for Bacterial Growth

Bacteria can grow in an environment only if –

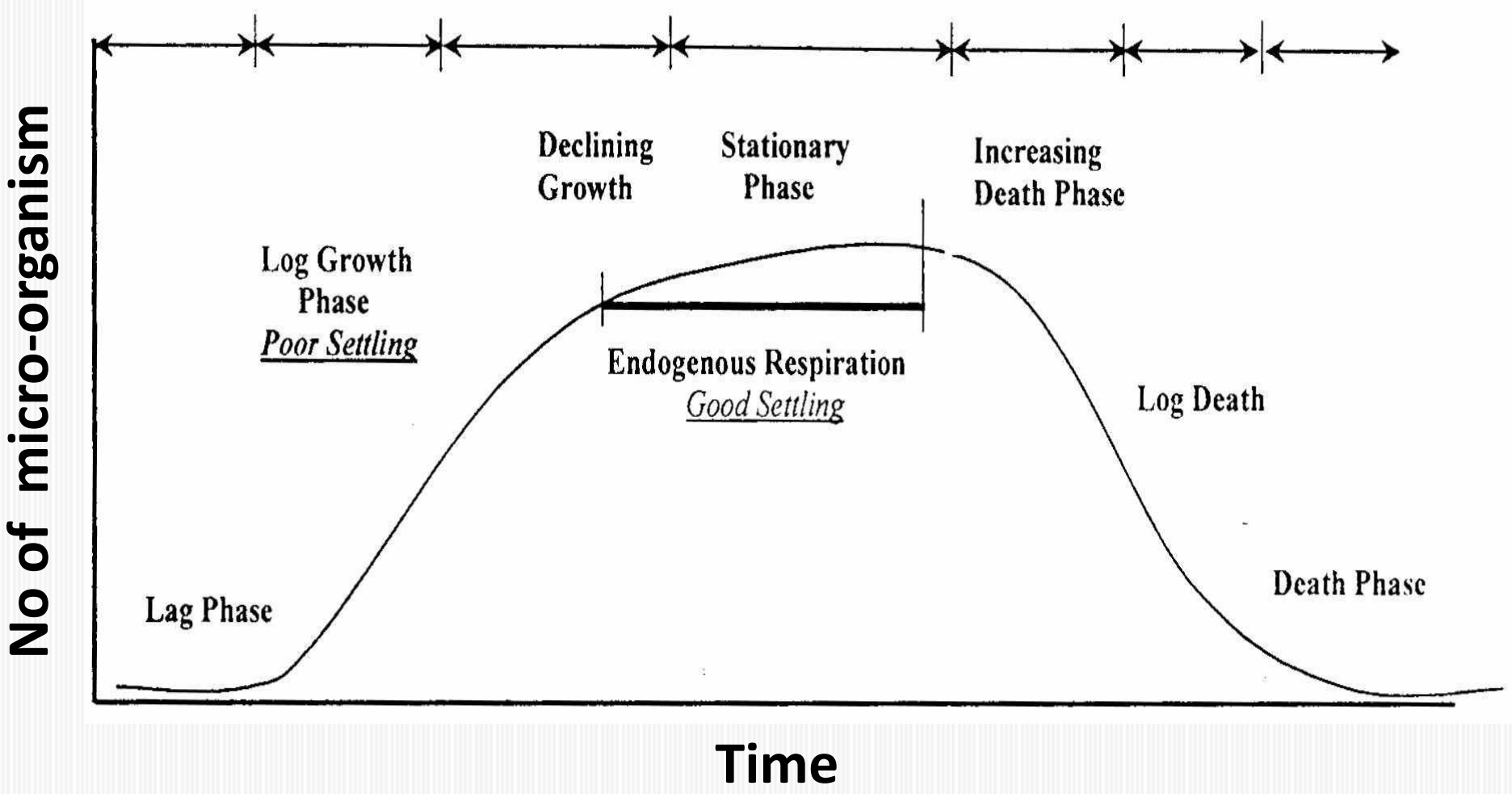
- There are sufficient nutrients available. Bacteria require relatively large amounts of carbon, nitrogen, hydrogen and oxygen; smaller amounts of phosphorus, sulphur, potassium, calcium, iron and magnesium; and trace quantities of several other elements (e.g. zinc, molybdenum).
- There is an absence of toxic compounds (Chlorine compounds, Cr, Pb, Hg, Ag etc)

Favorable Environment for Bacterial Growth

- The environment itself is suitable, having the following conditions-

  - ✓ Neutral pH (about 6.5-8.5 units)
  - ✓ Correct concentration of dissolved oxygen (zero for anaerobes; a minimum of 1-2 mg/l for aerobic growth)
  - ✓ Temperature around 35ºC.

Bacterial Growth Pattern



Bacterial Growth Pattern

(i) ***Lag Phase***

- Cell numbers do not increase;
- The bacteria are however internally active, manufacturing if necessary any extra-cellular catalysts (enzymes) that they may require in order to be able to oxidize the waste.

Bacterial Growth Pattern

(ii) *Exponential or Log Phase*

- Logarithmic growth occurs during this phase
- The bacteria lay down food reserves within their cells which they may use when there is little or no food left in their environment.
- The bacteria arc now growing as fast as they are able to in the waste.
- Although the log growth phase coincides with the maximum rate of substrate (waste) removal, this is not the optimum zone of operation for waste treatment systems.

Bacterial Growth Pattern

(ii) *Exponential or Log Phase*

- In order to maintain log growth, the food must be in ample supply, but a low concentration is desired in the treated waste.

- Further, the maximum rate of utilization requires that other growth factors, such as oxygen, be supplied at a maximum rate and this may be difficult to do.

Bacterial Growth Pattern

(ii) ***Exponential or Log Phase***

- Finally, bacteria in the log growth phase of development have a great deal of energy available, have limited accumulation of waste products, and hence are likely to be motile, dispersed, and difficult to remove by sedimentation.

Bacterial Growth Pattern

(iii) ***Declining Growth Phase***

- Available food supply has been largely depicted and. food becomes the limiting factor in further growth.

- The declining growth phase is generally used for biological treatment systems.

Good as both waste removal & biological settling happens

Bacterial Growth Pattern

(iv) *Stationary Phase*

- The number of new cells is approximately balanced by those that die, so that the population cell density does not change.

(v) *Death Phase*

- As the death rate exceeds the growth rate, the culture enters the dead phase.
- The population density steadily declines.

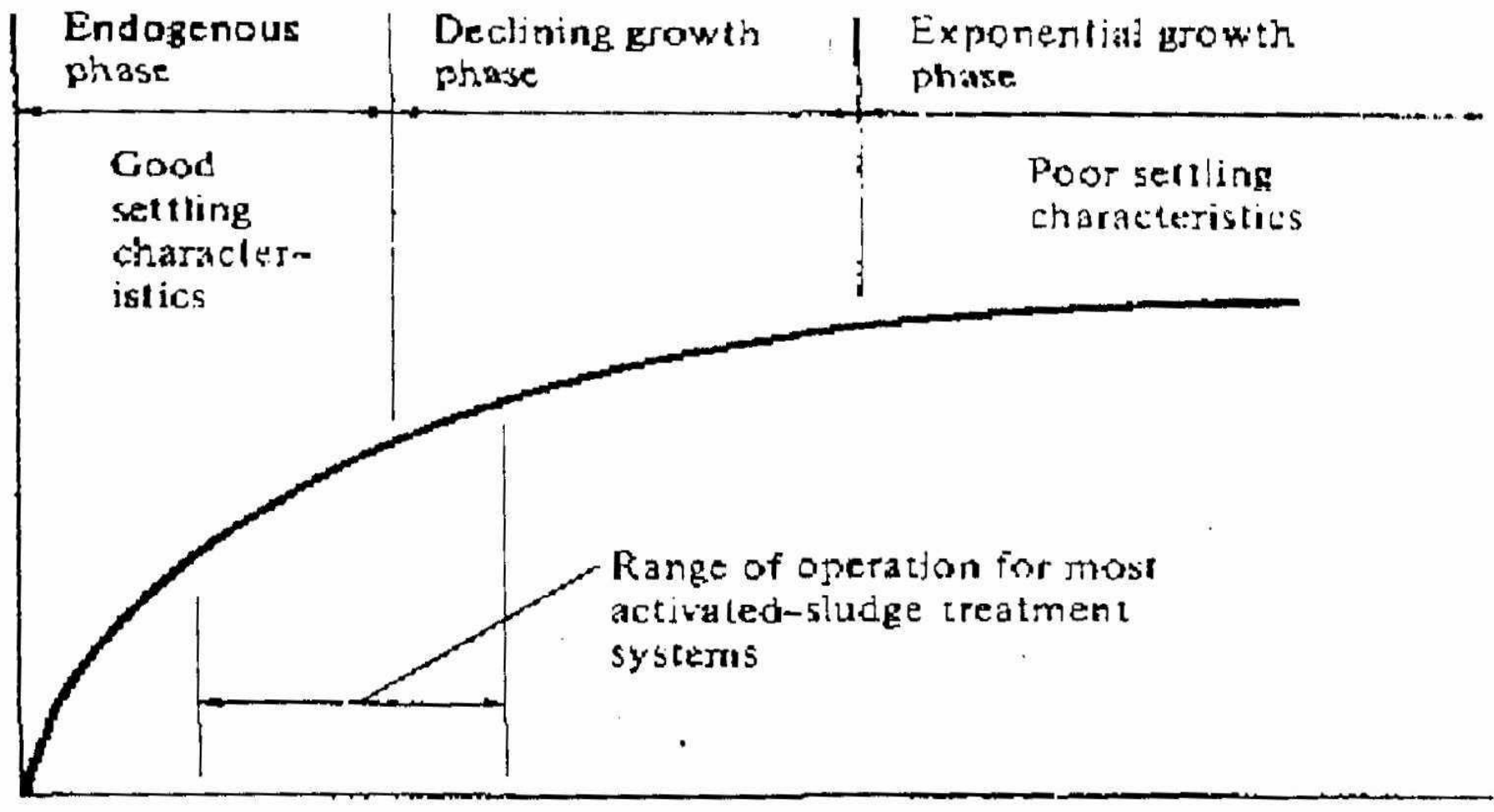
Bacterial Growth Pattern

- During both the *stationary* and *death phases* there are a substantial proportion of cells which neither die nor subdivide.
- They exist by utilizing the intracellular food reserves laid down during exponential growth; this process is known as *endogenous respiration.*
- When a cell has depleted its food reserves, it starts to oxidize itself, this process is known as autolysis (self-destruction), leads of course to *death.*

Relation between F/M ratio and Bio-mass Settling

Food : Micro-organisms (F/M)	Growth phase	Waste removal rate	Bio-mass settling characteristics
Very High	Log Phase	Maximum	**Dispersed, Poor**
Moderate	Declining Growth	Good	**Good**
Low	Stationary Phase	Moderate	**Very good**
Very low	**Death Phase**	**Negative**	**Autolysis**

Relation between F/M ratio and Bio-mass Settling



EWCE 333
Wastewater Engineering and Sanitation

Lecture 13

Instructor
Lt Col Kazi Shamima Akter, Ph.D., Engrs
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Department of EWCE, MIST

Lecture Outline

Topics	Reference
• Types of biological treatment process • Activated sludge process • Significance of F/M ratio in activated sludge process	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Biological Treatment Processes

Suspended Growth Processes

- In suspended cultures, the microorganisms are suspended in the wastewater either as single cells or as clusters of cells called flocs.
- The microorganisms are surrounded by the wastewater which contains their food and other essential elements.
- Examples: Activated Sludge process, Waste Stabilization Ponds, Oxidation Ditches etc

Biological Treatment Processes

Attached Growth Processes

- Attached culture consists of masses of organisms adhered to inert surfaces with wastewater passing over the microbial film.

- Example: Trickling Filter process, Bio-Towers, Rotating Biological Contractors (RBC), Submerged Anaerobic Filters, Fluidized Beds etc.

Activated Sludge Process

- In the activated sludge process, raw sewage or primary effluent is brought into an aeration basin (reactor).
- In the aeration tank, air is bubbled into the wastewater mixture (mixed liquor) and aerobic bacteria metabolise the dissolved and suspended organic material.
- From the aeration basin, the effluent flows into a secondary sedimentation tank, where the cell mass are settled out.

Activated Sludge Process

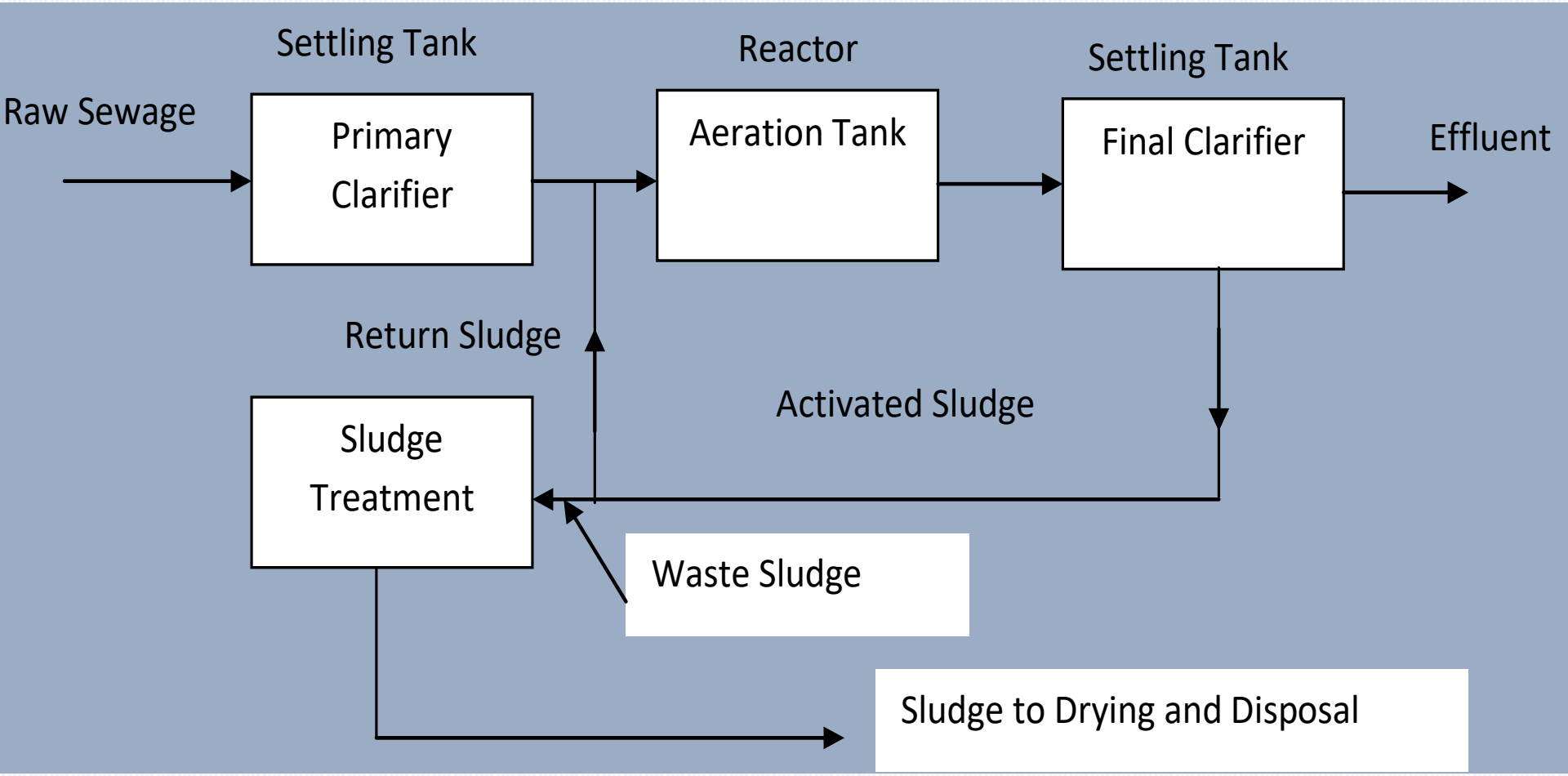


Figure: Schematic Diagram of the Activated Sludge Process

Activated Sludge Process

- Part of the settled biomass is wasted, and some of it is returned into the aeration basin to maintain a viable biomass concentration.

- The setteled sludge, containing living or active microorganism, which is returned to the aeration tank, is called activated sludge.

- This activated sludge increases the amount of available biomass and speed up the reaction.

Activated Sludge Process

Process Design Consideration

1. Mixing the activated sludge with the wastewater to be treated (mixed liquor).

2. Aeration and agitation of this mixed liquor for the required length of time.

3. Separation of the activated sludge from the mixed liquor, in the final clarification process.

4. Return the proper amount of activated sludge for mixture with the wastewater.

5. Disposal of the excess activated sludge.

Significance of F/M on Activated Sludge Process

At a high F/M ratio –

- Microorganisms are in the exponential growth phase, characterized by excess food and maximum rate of metabolism.

- Although the exponential growth phase is desirable for maximum rate of organic matter removal. The microorganisms are in dispersed growth such that they do not settle out of solution by gravity.

Significance of F/M on Activated Sludge Process

- Consequently, the settling tank is not effective in separating microorganisms from the effluent for return to the aeration lank.
- Again, there is excess unused organic matter in solution which cannot be removed by sedimentation and passes out in the effluent.
- Operation at a high F/M ratio results in poor BOD removal efficiency.

Significance of F/M on Activated Sludge Process

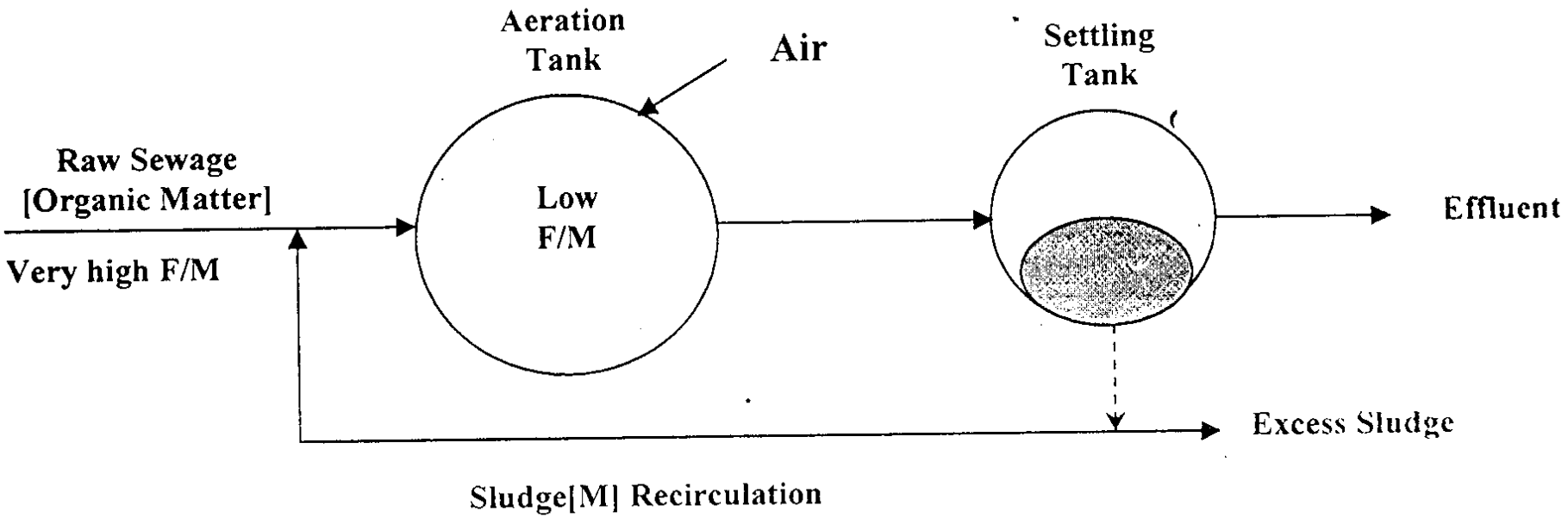


Figure: Food/Microorganism ratio in Activated Sludge Process

Significance of F/M on Activated Sludge Process

At a low F/M ratio –

- Overall metabolic activity in the aeration tank may be considered endogenous.

- Although initially there is rapid growth when the influent food and return microorganisms are mixed, competition, for the small amount of food made available to the large mass of microorganisms results in near-starvation conditions for the majority of microorganisms within a short period of time.

Significance of F/M on Activated Sludge Process

- Under these conditions, continued aeration results in auto-oxidation of the microbial mass through autolysis and re-synthesis.
- Although the rate of metabolism is relatively low in the endogenous phase, metabolism of the organics nearly complete and the microorganisms flocculate rapidly and settle out of solution by gravity.
- The good settling characteristics exhibited by activated sludge in the endogenous phase make operation in this growth period desirable where a high BOD removal efficiency is desired.

Activated Sludge Process

Design Criteria

- The mixed liquor suspended solids concentration (MLSS) ranges from 1,500 to 3,000 mg/L.
- The hydraulic detention time is from 6 to 24 hours.
- The solids residence time is from 3 to 20 days.

EWCE 333
Wastewater Engineering and Sanitation

Lecture 14

Instructor

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Lecture Outline

Topics	Reference
• Trickling Filter process – mechanisms and biological processes • Advantages, disadvantages, influencing factors in trickling filter process • Design of trickling filter	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Trickling Filter Process

- Trickling filters are fixed-growth biological beds where wastewater is spread on the surface of media supporting microbial growths.
- The media placed in a tank under the wastewater distributor can be crushed rock, plastic-sheet packing formed into modules, or random plastic packing of various shapes.
- Bacteria, fungi, and algae grow on the rock surface.

Trickling Filter Process

- As wastewater flows between the rocks, aerobic bacteria metabolize the organic material in the wastewater.
- As the biomass grows, the influent wastewater flow sloughs off the excess, which settles out in a secondary sedimentation tank.
- There is no recycling of sludge for a trickling filter, but there is usually a high effluent recycle ratio 300 to 500 percent of the influent flow is recycled from after the filter or sedimentation tank back to the filter.

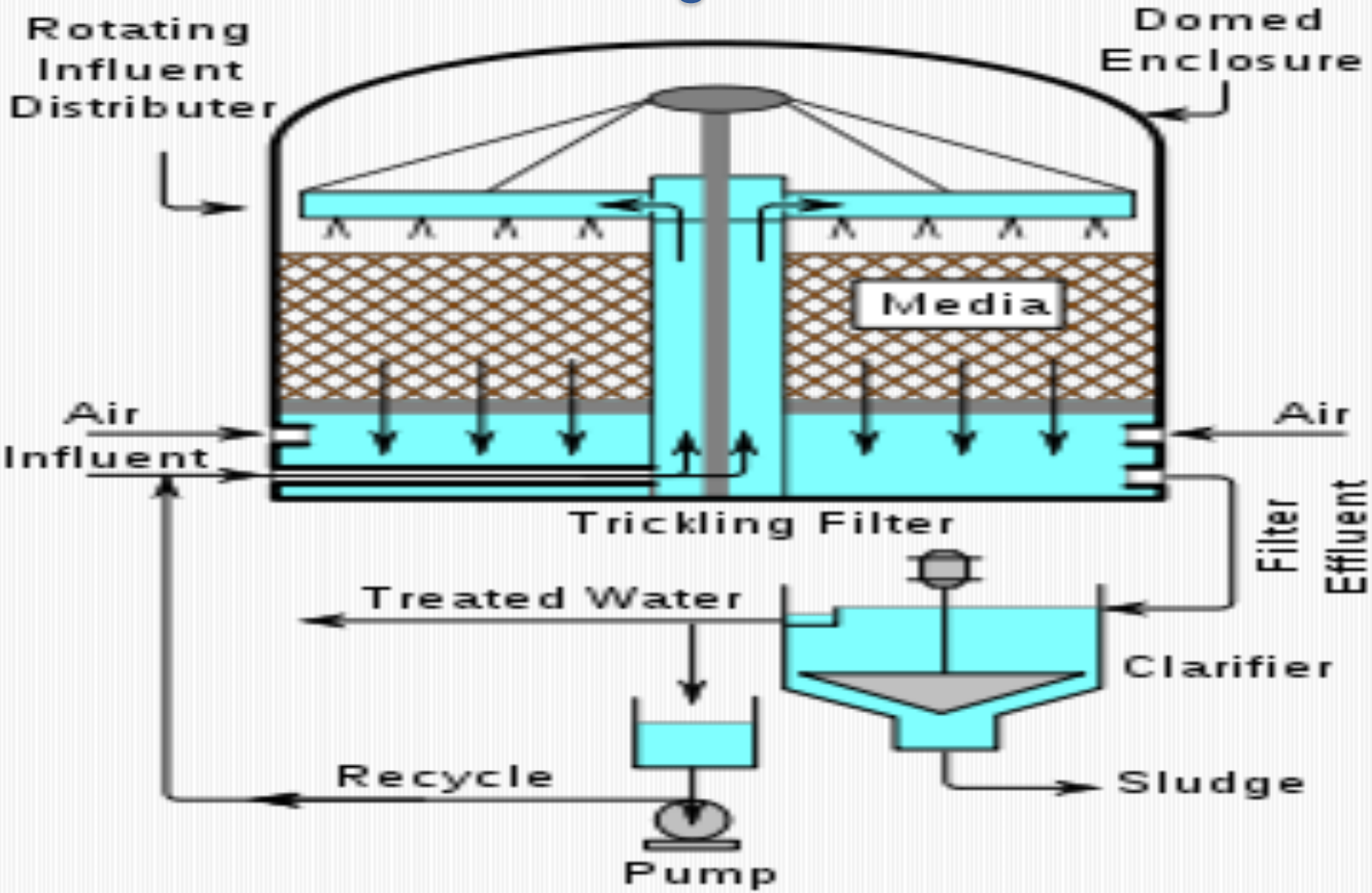
Components of Trickling Filter Media

(a) The Sewage Distributor

- It spreads the wastewater at a uniform hydraulic load per unit area on the surface of the bed.

- The arms are driven by the reaction of wastewater flowing out of the distributor nozzles, which usually requires a pressure head of 24 in. measured at the center column that supports the arms.

Trickling Filter



- Figure: Components of a typical Trickling Filter Media

Components of Trickling Filter Media

(b) The underdrain system

- The underdrain system may be composed of vitrified clay blocks with entrance holes to drainage channels
- It carries away the effluent and permits circulation through the bed.
- The need for free passage of air controls the size of openings in the underdrain.
- The filter media provide a surface for biological growth and voids for passage of air and water.

Components of Trickling Filter Media

(c) Filter media

- Traditionally, the common filter media have been crushed rock, slag, or field stone, since these are durable, insoluble, resistant to spalling, and often locally available.

- Stones, however, have the disadvantage of occupying the majority of the volume in a filter bed, thus reducing the void spaces for passage of air and limiting the surface area per unit volume for biological growth.

Components of Trickling Filter Media

- Several forms of chemical-resistant plastic media are available that have much greater surface area per unit volume and a large percentage of free space.

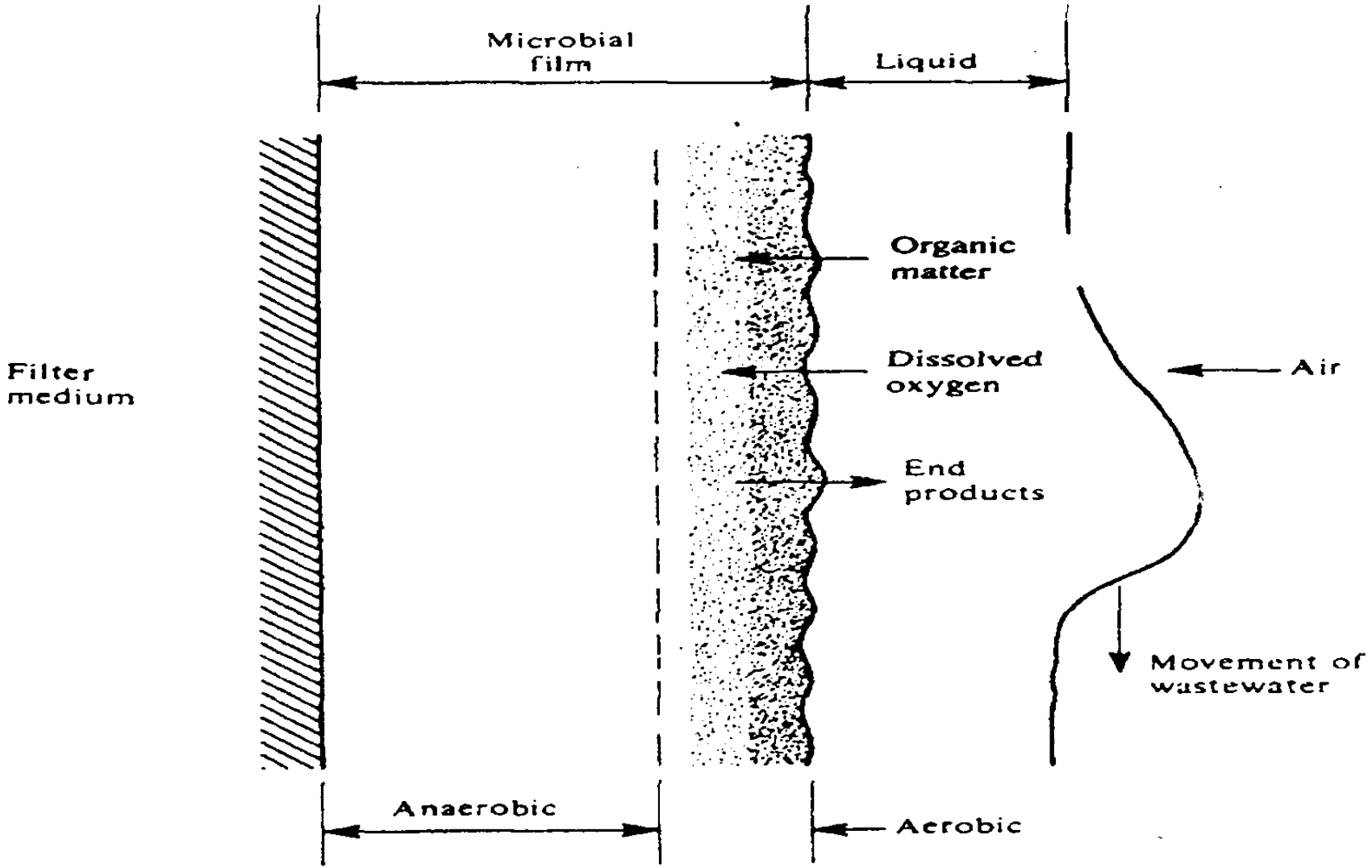
- For shallow filters, the common types are random packing and high density cross-flow media manufactured in comfortable modules that can be cut and fitted.

Biological Process in Trickling Filtration

(a) Formation of Biological Slime layers

- Filter media is aerobic to a depth of only 0.1-0.2 mm.
- The zone adjacent to the medium is anaerobic.
- The slime layers consist of bacteria, protozoa, and fungi. Frequently, noticeable populations of larger organisms such as sludge worms and rotifers are present.

Biological Process in Trickling Filtration



Schematic diagram showing the form of the biological process in a trickling filter.

Biological Process in Trickling Filtration

- The top surface of a bed exposed to sunlight is coated with algae, and lower portion of a deep filter can support nitrifying bacteria.

- Microorganisms near the surface of the bed where the food concentration is high are in a rapid growth phase, while the microorganisms near the bottom are in a state of starvation.

Biological Process in Trickling Filtration

(b) Biological Metabolic Action

- As the wastewater flows over the microbial film, the soluble organic matter is metabolized and the colloidal organic matter is adsorbed on the film.

(c) Supply of O_2

- Dissolved oxygen taken up in the liquid layer is replenished by re-oxygenation from the surrounding air.

- Continuous passage of air through the bed is essential to prevent undesirable anerobic conditions.

Physical Factors influencing Trickling Filtration

- **Media configuration** - Several forms of manufactured media provide a high specific surface area with a corresponding large percentage of void volume. This permits substantial biological growth without inhibiting passage of air through the bed.

- **Bed depth** - A uniform medium also allows even loading distribution, and light weight packing permits the construction of deep beds.

- **Hydraulic loading**

Advantages of Trickling Filter

- Simplicity
- Low operating cost
- Production of a waste sludge that is easy to process.

Disadvantages of Trickling Filter

- Poor effluent quality and emission of offensive odors, both associated with organic loading, industrial wastes, and cold-weather operation.

- The anaerobic zone of the film adjacent to the medium surface can produce odorous metabolic end products. If they are not oxidized while moving through the aerobic zone, they can be released and carried out in the airflow through the bed.

- Some industrial wastes have characteristic odors that are not easily oxidized by the microbial film.

Disadvantages of Trickling Filter

- Ponding results from sloughings due to excessive organism growth.

- Filter Flies

- Degradation of final effluent due to excessive loading from sloughings on final sedimentation tanks.

Effluent BOD from Trickling Filter

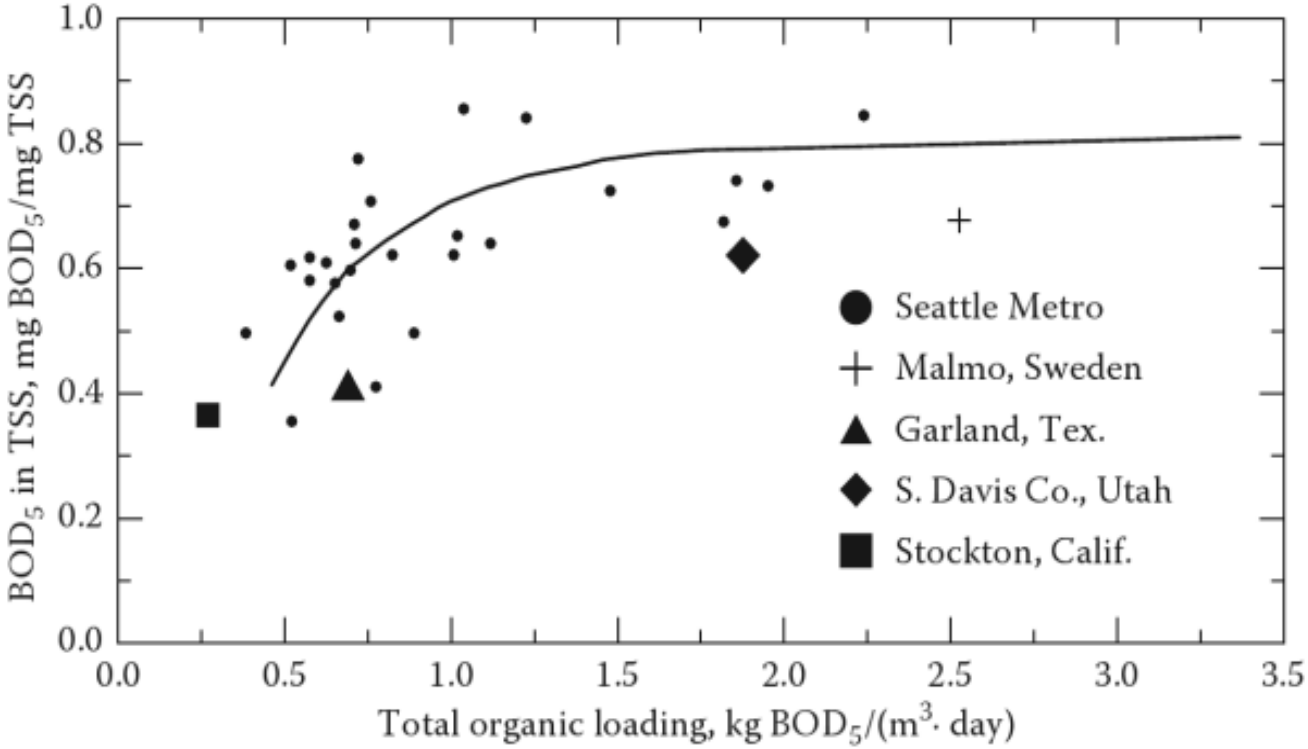


FIGURE 19.9 Effect of total organic loading (TOL) on the BOD_5 of suspended solids leaving a trickling filter. (From Water Environment Federation, *Design of Municipal Wastewater Treatment Plants*, Manual of Practice No. 8, Water Environment Federation, Alexandria, Virginia, 1992. Copyright © Water Environment Federation, Alexandria, Virginia. Reprinted with permission.)

Ref: Biological Wastewater Treatment (3rd ed.)–
By C. P. Leslie Grady, Jr., Glen T. Daigger, Nancy G. Love, Carlos D. M. Filipe

Estimation of Effluent BOD from Trickling Filter

Example 19.2.9.1

A trickling filter receiving a wastewater with a total BOD_5 of 150 mg/L achieves 90% removal of soluble BOD_5 by being operated at a TOL of 0.75 kg $BOD_5/(m^3 \cdot day)$. What will be the BOD_5 of the clarified effluent if it contains 30 mg/L of suspended solids? Assume that the soluble BOD_5 concentration of the influent wastewater is 65% of the total BOD_5.

a. First calculate the soluble BOD_5 in the effluent.
   The soluble BOD_5 in the influent wastewater is $(0.65)(150) = 97.5$ mg/L. Since 90% of it is removed, the soluble BOD_5 concentration in the trickling filter effluent is 9.75 mg/L.
b. Next estimate the BOD_5 due to particulate matter in the effluent.
   Entering Figure 19.9 with a TOL of 0.75 kg $BOD_5/(m^3 \cdot day)$, it can be seen that the BOD_5/TSS ratio is 0.5. Since the suspended solids concentration in the effluent is 30 mg/L, the particulate BOD_5 is $(0.5)(30) = 15$ mg/L.
c. The total BOD_5 is just the sum of the soluble and particulate BOD_5 values.
   Total $BOD_5 = 9.75 + 15 = 24.75$ mg/L.

Estimation of Effluent BOD from Trickling Filter

Velz formula:

$$C_e = \left(\frac{C_i + rC_e}{1 + r} \right) e^{-kD}$$

where,

C_e = Effluent BOD, mg/L

C_i = Influent BOD, mg/L

r = Ratio of recirculated flow to wastewater

D = Depth of filter, ft

K = Velz decay rate,

= 0.175 ft^{-1} for low rate filters and

= 0.1505 ft^{-1} for high rate filters (operated at 20°C)

Temperature correction for, K

$$\mathbf{K_T = K_{20°C}\ (1.047)^{T-20°C}}$$

Estimation of Effluent BOD from Trickling Filter

Velz formula

- Gave the first semi-theoretical analysis of trickling filter performance vs depth of filter media.

- Useful in predicting BOD removal fraction for any generic trickling filter, especially with synthetic media.

Estimation of Effluent BOD from Trickling Filter

Problem

Calculate the effluent BOD from a trickling filter having a depth of 2 m and a re-circulated rate of 125 percent of the flow. The influent BOD is 170 mg/L following primary treatment.

EWCE 333
Wastewater Engineering and Sanitation

Lecture 15

Instructor

Lt Col Kazi Shamima Akter, Ph.D., Engrs

Associate Professor

Department of EWCE, MIST

Lecture Outline

Topics	Reference
• Waste stabilization ponds – process involved, advantages, disadvantages • Types of stabilization ponds	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Waste Stabilization Ponds

- Large shallow rectangular basins enclosed by earthen embankments.
- Open to atmosphere.
- Treatment by natural processes involving both algae and bacteria.
- As unaided by man, the rate of oxidation is rather slow.
- Longer hydraulic retention time: 30-50 days not being uncommon.

Process involved in Waste Stabilization Ponds

- Sedimentation
- Oxidation
- Digestion
- Synthesis
- Photosynthesis
- Endogenous Gas Respiration
- Gas Exchange
- Aeration
- Evaporation
- Thermal Currents
- Seepage

Advantages of Waste Stabilization Ponds

- Cheapest and simplest of all treatment technologies.
- Produce high quality effluent.
- Reduce the level of pathogens much lower than other methods
- Absorb variable organic and hydraulic loading with less adverse effect on the effluent quality

Advantages of Waste Stabilization Ponds

- No mechanical or external energy (except atmosphere) input
- Minimum control
- Skilled operators are not required
- Lower capital, operation and maintenance cost

Disadvantages of Waste Stabilization Ponds

- Large land area is required
- Odor problem in anaerobic condition
- Excessive accumulation of algae and bacteria cells may overload the receiving water bodies

Types of Waste Stabilization Ponds

(a) Anaerobic Ponds

- A digester requiring no oxygen supply
- Anaerobic bacteria break down the complex organic wastes

(b) Facultative Ponds

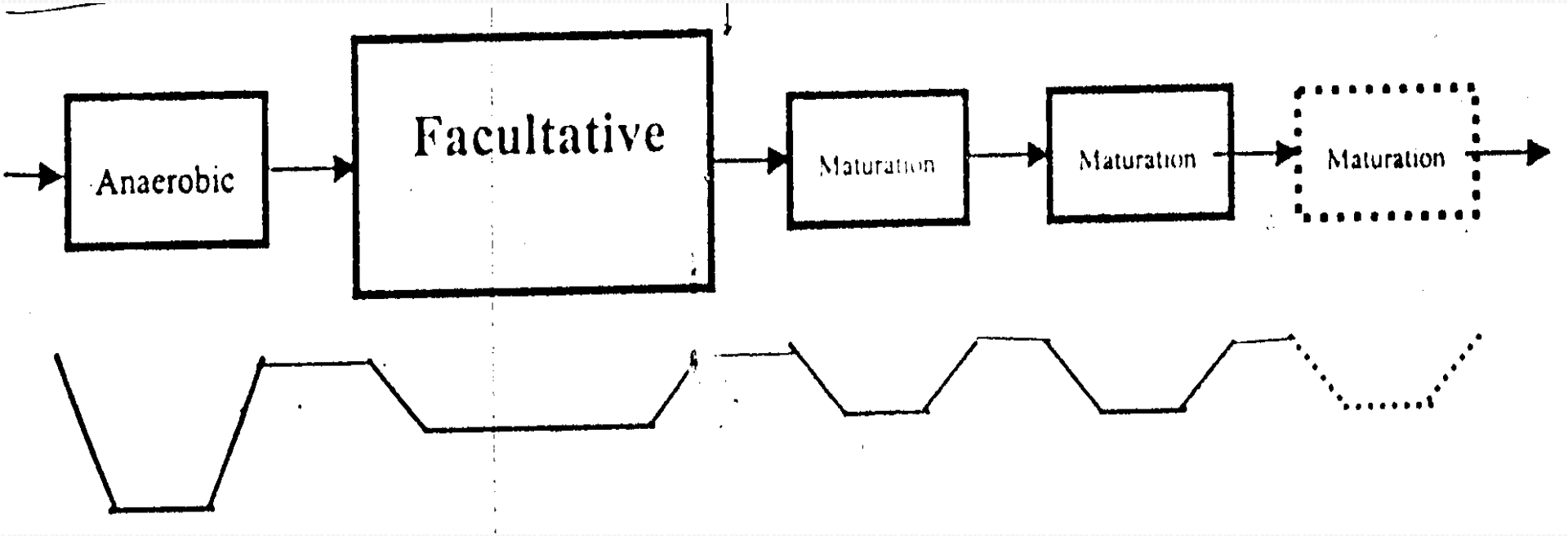
- Upper aerobic zone is maintained by algae
- Lower anaerobic zone
- Aerobic, facultative and anaerobic organisms act in these ponds

Types of Waste Stabilization Ponds

(c) Aerobic / Maturation Ponds

- Aerobic bacteria break down the wastes

- Algae provide oxygen through photosynthesis to maintain aerobic condition



Anaerobic Pretreatment Ponds

- Receive a high organic loading and become completely devoid of dissolved oxygen.
- Used to pre-treat strong wastes having a high solids content.
- The solids settle to the bottom and digested anaerobically.

Anaerobic Pretreatment Ponds

- Partially clarified supernatant liquor is discharged into a facultative pond for further treatment.

- The successful operation of anaerobic ponds depends on the delicate balance between the acid-forming bacteria and the methanogenic bacteria.

Anaerobic Pretreatment Ponds

Favorable Conditions in Anaerobic Ponds:

- Temperature > 15 °C
- pH > 6

Under the above conditions -

- Sludge accumulation is minimum
- Desludging is required only at every 3-5 years

Facultative Ponds

- Receive raw sewage or that which has received only preliminary treatment
- Treat the settled effluent from septic tanks and anaerobic pretreatment ponds.
- Aerobic condition is maintained in upper layers while anaerobic conditions exist towards the bottom.

Facultative Ponds

- Oxygen in the upper aerobic layer comes from re-aeration from surface, but major portion of O_2 is supplied by photosynthesis of algae.

- Bacteria use the algal O_2 to oxidize organic waste, whereas algae use CO_2, which is the end product of bacterial metabolism. This association is called symbiosis between bacteria and algae.

- The pH of the pond contents also follows a daily cycle increasing with photosynthesis to a maximum which may be as high as 10.

Facultative Ponds

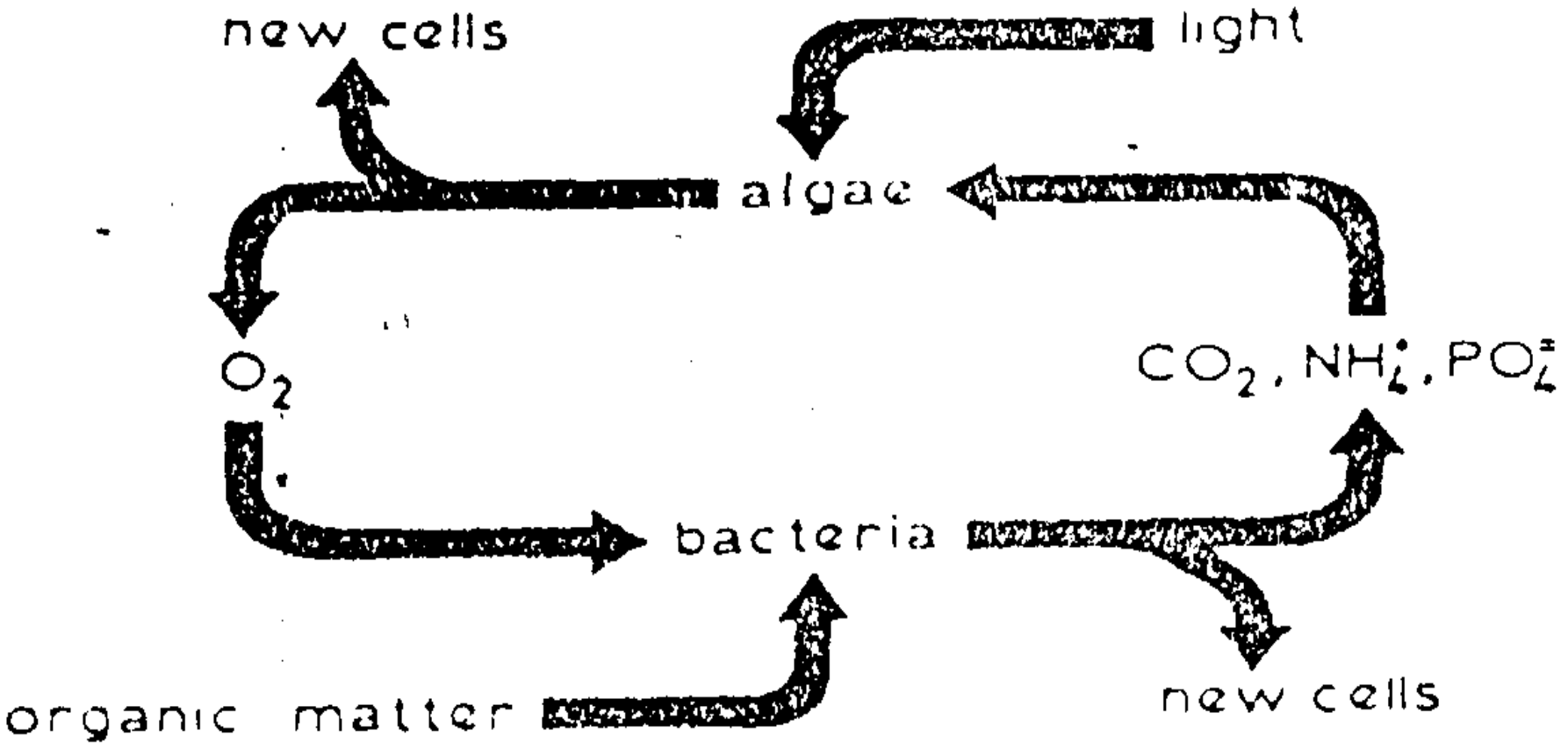


Figure: Symbiosis of algae and bacteria

Facultative Ponds

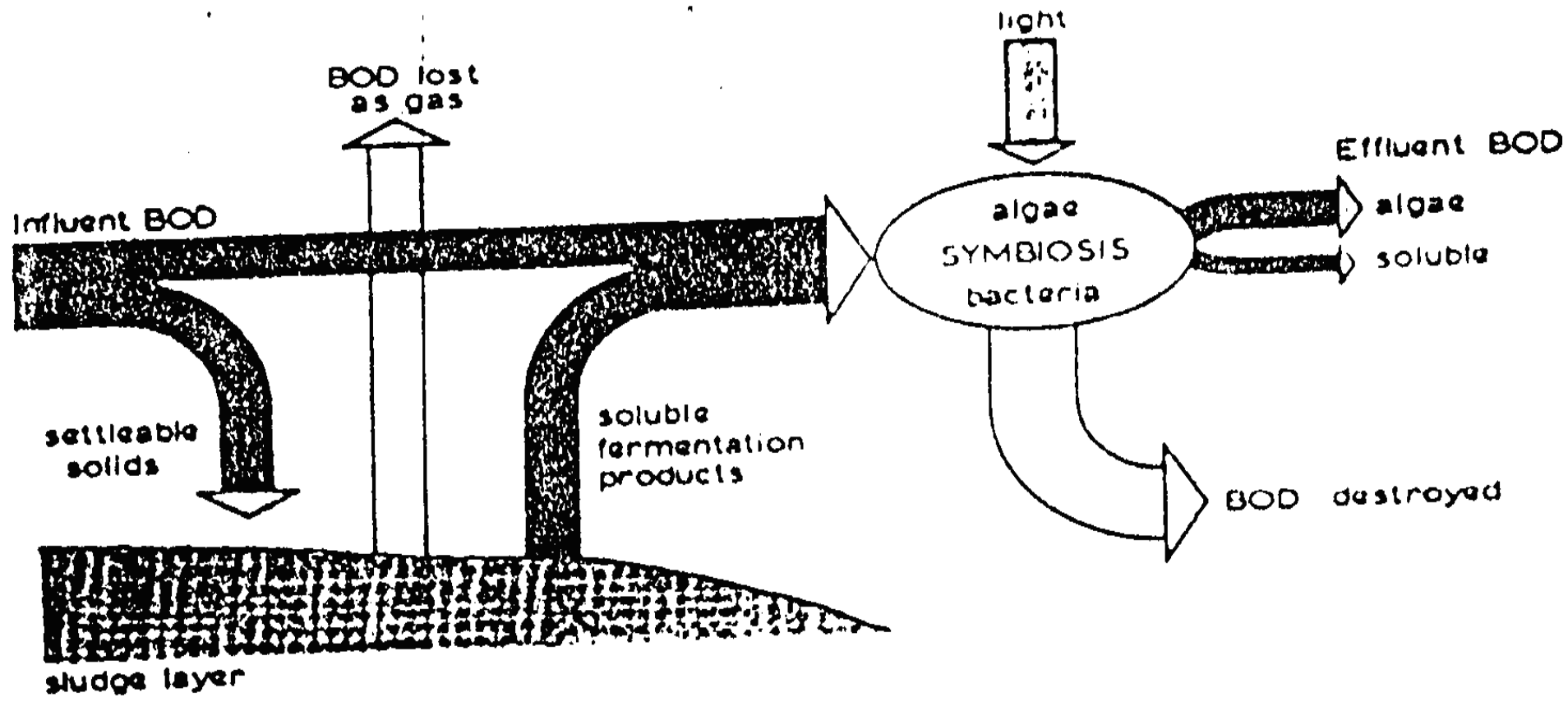


Figure: Principal pathways of BOD removal in facultative ponds

Maturation Ponds

- Used as a second stage to facultative ponds.
- Main function is the destruction of pathogen.
- Completely aerobic and able to maintain aerobic conditions at depths of up to 3 m.
- Usually, the depth of a maturation lagoon is 1-1.5 m.

Maturation Ponds

- BOD removal is small.
- Two maturation ponds in a series, each with a retention period of 7 days, are required to reduce BOD from about 50-70 mg/L to 25 mg/L (about 50%).
- Effectiveness in removing pathogens is assessed by the removal of faecal coliforms.
- More than 99% removal of pathogens is possible by proper design.
- Effluent standard of < 5000 FC / 100 ml can be maintained with proper design of maturation ponds.

Design Preliminaries of Stabilization Ponds

Depth

Most commonly used depth:

Anaerobic ponds	: 2 - 4 m
Facultative ponds	: 1-1.5 m
Maturation ponds	: 1-1.5 m

Design Preliminaries of Stabilization Ponds

Area

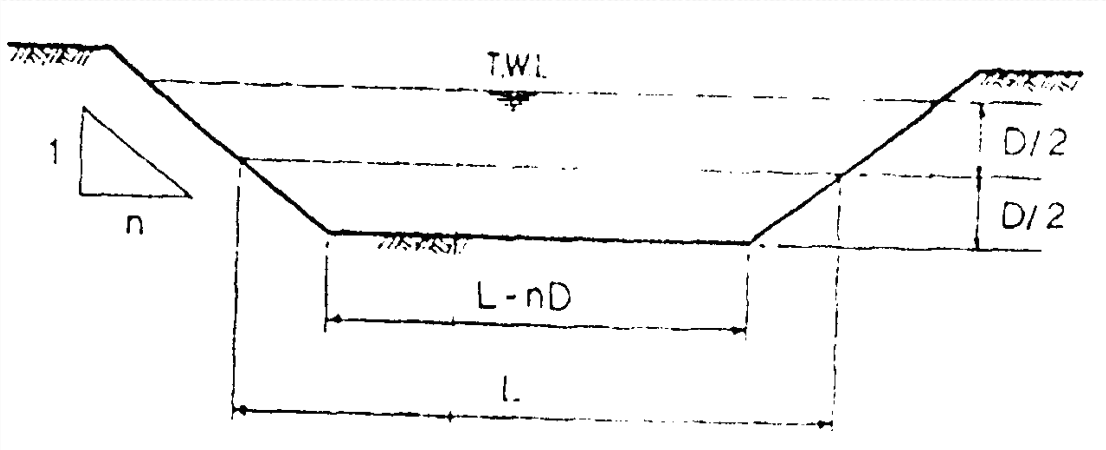
- Length / Width ratio is generally 2-3 to 1. The length and breadth are obtained from the mid-depth area, shown in the following figure.
- The mid-depth area (which is what the surface and base areas would be if the pond had vertical sides) is given by:

$$A = Q*t / D$$

where, Q = Volumetric flow rate (m^3/day)

t = Retention time (day)

D = Pond depth (m)



Design Preliminaries of Stabilization Ponds

Surface BOD_5 Loading

- The areal or surface BOD_5 loading (λ_s) is the weight of BOD_5 applied per unit area per day.
- The weight (g) of BOD_5 applied to the pond (A, m^2) each day is L_iQ.
- Therefore, expressing λ_s in its usual units of kg/ha-d:

$$\lambda_s = (10^{-3} L_i Q) / (10^{-4} A)$$
$$= 10 L_i Q / A$$

Design Preliminaries of Stabilization Ponds

Volumetric Loading

- Used particularly with anaerobic ponds.
- Volumetric loading λ_v is the weight of BOD_5 applied per unit volume per day.
- Expressing λ_v in $g/m^3\ d$:

$$\boldsymbol{\lambda_v = L_i\ Q\ /\ AD}$$

Since, AD / Q = retention period, t

Therefore, $\boldsymbol{\lambda_v = L_i\ /\ t}$

- In anaerobic ponds, $\lambda_v > 100\ g/m^3\ d$, which is a criterion for odour development.
- In facultative ponds, λ_v ranges from 15 to 30 $g/m^3\ d$.

Design of Anaerobic Ponds

- **Volumetric Loading Rate**:

The volumetric loading rate, λ_v can be expressed as

$$\lambda_v = L_i Q / V_a$$

where, L_i = BOD of the raw wastewater (mg/L)

Q = Wastewater flow rate (m^3 /d)

V_a = Anaerobic pond volume (m^3)

Design of Anaerobic Ponds

- **Temperature:**

  At pH > 6, BOD reduction in anaerobic pond = f (temperature)

  BOD reduction increases with increasing temperatures > 15°C

Design of Anaerobic Ponds

Table: Design values of λ_v and BOD removal rate at various temperatures

Temperature (° C)	Volumetric Loading Rate, λ_v (g/m^3 d)	BOD removal (%)
<10	100	40
11	120	42
12	140	44
13	160	46
14	180	48
15	200	50
16	220	52
17	240	54
18	260	56
19	280	58
20	300	60
21	300	62
22	300	64
23	300	66
24	300	68

Design of Anaerobic Ponds

- **Retention Period**:

Table: Design values of BOD reduction for varying retention period

Retention Period (d)	BOD reduction (%)
1	50
2 - < 5	60
5	70

- Optimum retention period is 5 days.
  - ✓Ponds operated with retention period > 5 days, act as facultative rather than anaerobic.
  - ✓Retention periods < 5 d are not recommended, because
  - – The risk of odor release is greater.
  - – The interval between successive desludging operations is shorter.
  - – The bacterial quality of the final effluent is poorer.
  - – The BOD removal is smaller.

Design of Anaerobic Ponds

Desludging Frequency:

- Rate of sludge accumulation is approx. 0.03-0.04 m^3/hd year. For design, 0.04 m^3/hd year can be considered.

- Desludging is required when the pond is half-full of sludge.

- Desludging frequency is given by, **N = V/CP**

Where, V = Pond volume (m^3)

C = Sludge accumulation rate (m^3/hd year)

P = No of population

Design of Anaerobic Ponds

Odor Release and Control:

- Sources of odor release –
  - ✓ Volumetric Loading Rate, $\lambda_v > 400$ g/m^3 d
  - ✓ Presence of industrial or organic wastes, particularly those with high concentration of sulphate.
- Control of odor –

✓ Raising of pH to about 8, to convert odorous sulphide (formed by bacterial reduction bacteria) to odorless bisulphide ion.

✓ Recirculating the effluent from the facultative or maturation ponds to the anaerobic pond in the ratio of 1:6 (Effluent : Raw sewage)

Design of Facultative Ponds

- ***Surface Loading rate:***

Surface Loading Rate, λ_s (kg/ha-d) can be expressed as:

$$\lambda_s = (10^{-3} L_i Q) /(10^{-4} A)$$

$$= 10 L_i Q / A$$

Design of Facultative Ponds

Table: Design values for surface BOD loading rates for facultative ponds at various temperatures

Temperature (ºC)	Surface loading rate, λ_s (kg/ha d)	Temperature (ºC)	Surface loading rate, λ_s (kg/ha d)
10	100	20	**253**
11	112	21	**272**
12	124	22	**292**
13	137	23	**311**
14	152	24	**331**
15	167	25	**350**
16	183	26	**369**
17	199	27	**389**
18	217	28	**406**
19	**235**	**29**	**424**

Design of Facultative Ponds

BOD removal kinetics:

If L_0 = Ultimate CBOD

L_t = amount of oxygen demand after time t

Then, assuming first order reaction, $\frac{dL_t}{dt} = -kL_t$

here, k = BOD rate constant

= f(nature of waste, ability of bacteria, temperature)

$$\int_{L_0}^{L_t} \frac{dL_t}{L_t} = -k\int_0^t dt \qquad \therefore L_t = L_0 e^{-kt}$$

Now, $L_0 = BOD_t + L_t$

$$\therefore \; BOD_t = L_0\left(1 - e^{-kt}\right)$$ ……. BOD rate equation

Design of Anaerobic Ponds

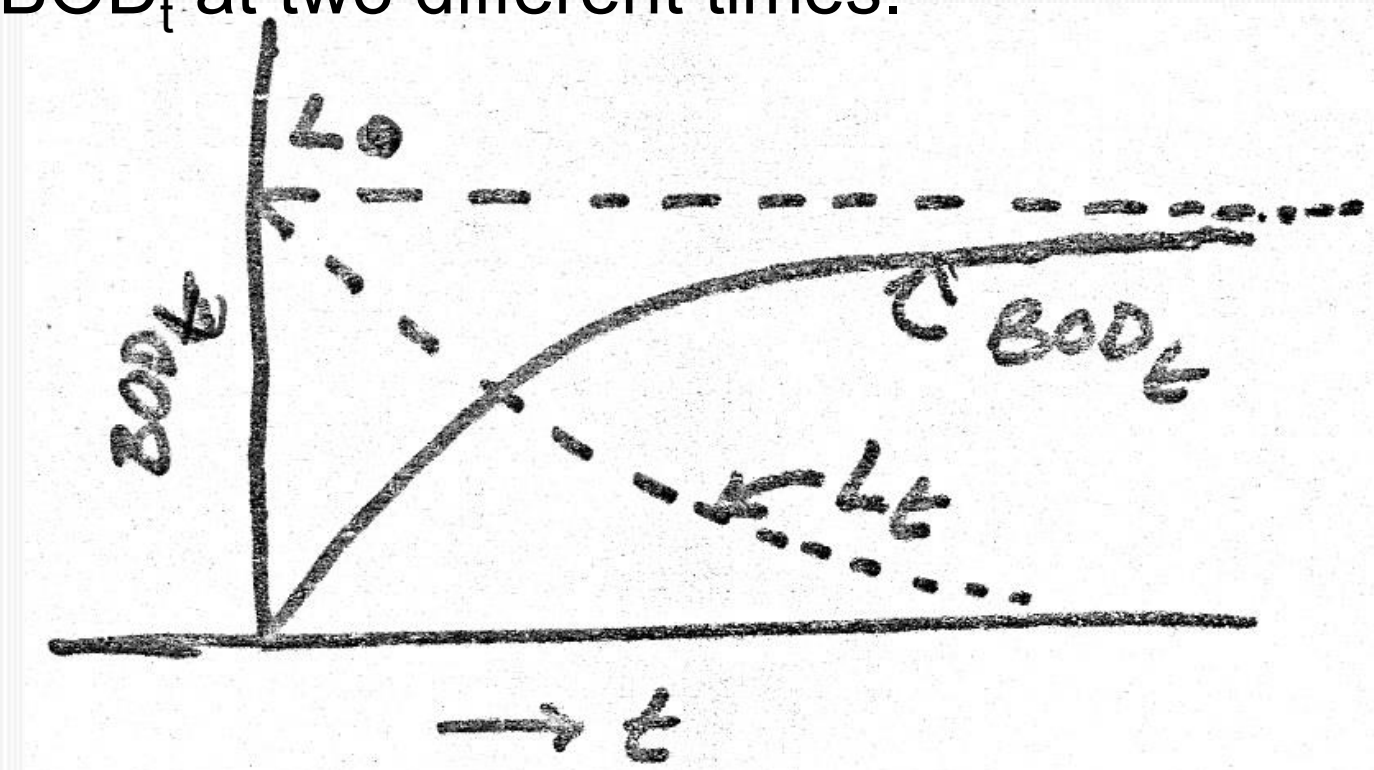
Typical k values:

Raw sewage: 0.35 – 0.70 /day

Treated sewage: 0.10 – 0.25/day

Higher k for sugar, lower for cellulose

k can be determined in laboratory along with L_0 by measuring BOD_t at two different times.



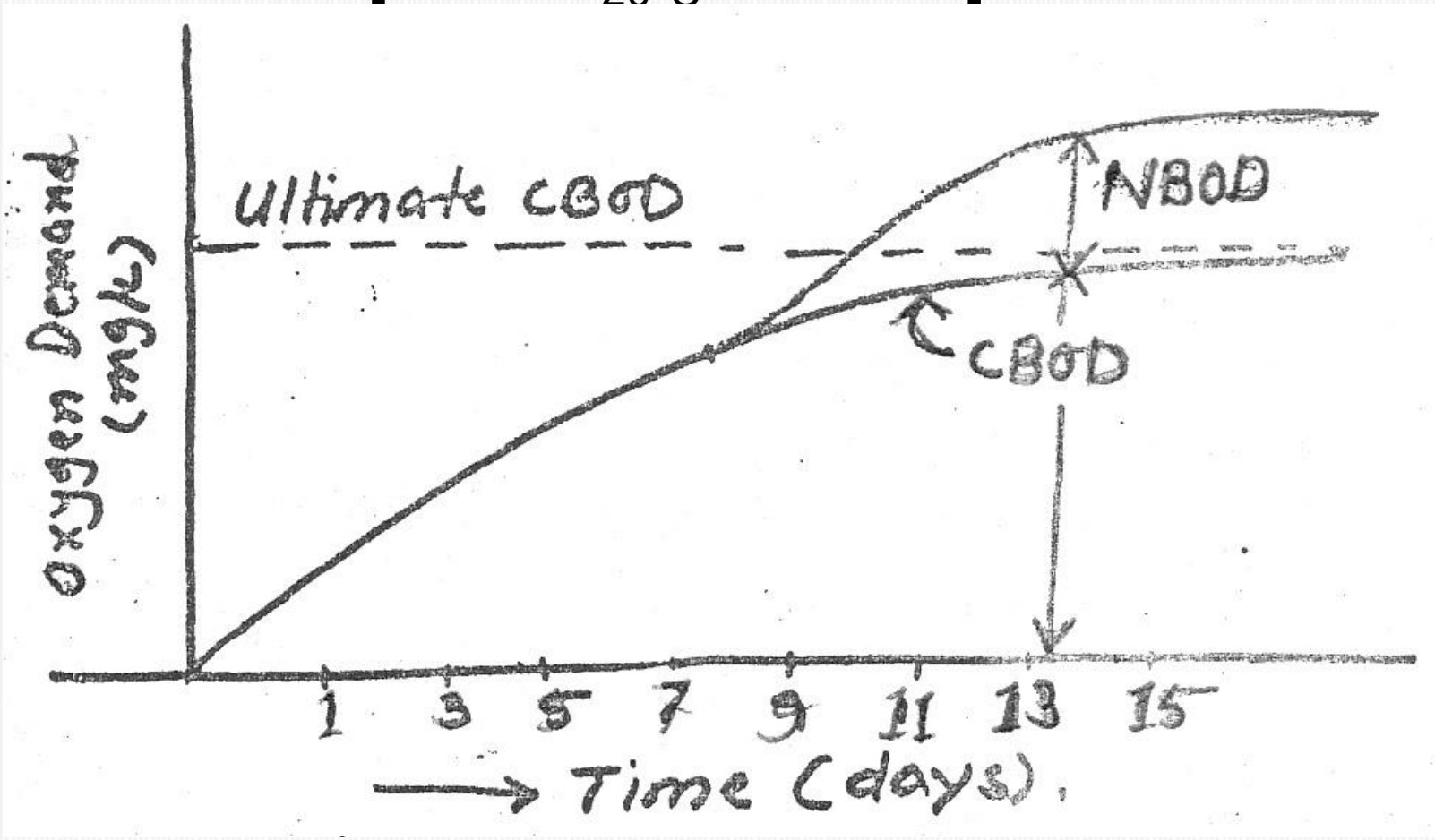
Design of Anaerobic Ponds

Effect of temperature on k values

Commonly used expression:

$$k_{T°C} = k_{20°C}\,\theta^{(T-20)},\quad \theta = 1.047$$

[here, $K_{20°C} = 0.3\ d^{-1}$]



Mathematical Problems on BOD Kinetics

Problem:

For a BOD test: initial DO = 8.5 mg/L. After 5 days, DO = 4.5 mg/L. If dilution factor P = 50 and k = 0.20/d, calculate: (i) BOD_5 (ii) ultimate CBOD, (iii) BOD remaining after 5-days.

Solution:

(i) $BOD_5 = (DO_0 – DO_5) \times$ dilution factor = (8.5 – 4.5) × 50 = 200 mg/L

(ii) $BOD_t = L_0 (1- e^{-kt})$

Therefore, ultimate CBOD,

$L_0 = BOD_5 / (1- e^{-0.20\times5}) = 200/ (1- e^{-0.20\times5}) = 316.4$ mg/L

Mathematical Problems on BOD Kinetics

(iii) BOD remaining after 5 days

$L_5 = L_0 - BOD_5$

$= 316.4 - 200$

$= 116.4$ mg/L

Mathematical Problems on BOD Kinetics

Problem on effect of temperature on BOD:

For a wastewater ultimate BOD= 350 mg/L. BOD_5 = 200 mg/L (determined at 20°C) and k = 0.22/day (also at 20°C). What would be BOD_5 at 25°C?

Solution:

$k_T = k_{20}\, \theta^{(T-20)}$

$k_{25} = 0.22\ (1.047)^5 = 0.277/day$

Now, BOD_5 (25°C) $= L_0\ (1- e^{-kt})$

$= 350\ (1- e^{-0.277\times5})$

$= 262$ mg/L

BOD Kinetics in Facultative Ponds

- In completely mixed reactors, BOD removal follows the first order kinetics, as follows:

$$\frac{L_e}{L_i} = \frac{1}{1 + k_1 t}$$

$$t = \left(\frac{L_i}{L_e} - 1 \right) \frac{1}{k_1}$$

$$A = \frac{Q}{D k_1} \left(\frac{L_i}{L_e} - 1 \right)$$

- To maintain the pond contents predominately aerobic, L_e should be in the range of 50-70 mg/L for pond depths of 1-1.5 m.

BOD Kinetics in Facultative Ponds

- The value of k_1 is about 0.3 d^{-1} at 20 ºC. The variation of k_1 is given by –

$$k_{1(T)} = 0.3(1.05)^{T-20}$$

- Substitution of this equation into above equation and selection of L_e as 60 mg/L gives the following design equation for A:

$$A = \frac{Q(L_i - 60)}{18D(1.05)^{T-20}}$$

BOD Kinetics in Facultative Ponds

- Maximum BOD_5 surface loading that can be applied to a facultative pond before it failed (i.e. become completely anaerobic) is related to the monthly ambient air temperature, T (ºC)

$$\lambda_S = 20T - 120$$

- The Design equation for A is then simply obtained from equation:

$$A = \frac{L_i Q}{2T - 12}$$

Design of Maturation Ponds

- ***Retention Period:***

To produce an effluent with BOD_5 < 25 mg/l –
7 days (each) for two ponds in series
5 days (each) for three ponds in series

- ***Bacterial Reduction:***

The primary objective of maturation pond design is to remove faecal coliform bacteria.

Design of Maturation Ponds

- Reduction of faecal bacteria in a pond (anaerobic, facultative or maturation) follows first order kinetics.

$$N_e = \frac{N_i}{1 + k_b t}$$

where, N_e = Number of FC/100 ml of effluent
N_i = Number of FC/100 ml of influent
K_b = First order rate constant for FC removal (d^{-1})

- For n ponds in series, the equation becomes:

$$N_e = \frac{N_i}{(1 + k_b t_1)(1 + k_b t_2)\ldots.(1 + k_b t_n)}$$

where, t_n = retention time in the n^{th} pond

Design of Maturation Ponds

- The value of k_b is extremely temperature sensitive, which is given by the following equation:

$$k_{b(T)} = 2.6(1.19)^{T-20}$$

where, $k_{b(T)}$ = the value of k_b at T °C

- A reasonable value of N_i is 4×10^7 FC/100 ml, which is slightly higher than average values found in practice.

Design of Stabilization Ponds

Problem:

Design a waste stabilization pond system to treat 2000 m^3/d of domestic sewage with a BOD contribution of 400 mg/l. The mean temperature of the coolest month is 20°C and during irrigation season, 25°C. It is desired that the final effluent be used for crop irrigation. Assume fecal coliform concentration in raw waste water to be 1×10^8 per 100 ml. The required effluent standards are FC < 1000 per 100 ml. Assume k and k_b as 0.3 d^{-1} and 2.6 d^{-1} respectively at 20 °C.

$$k_{b(T°C)} = k_{b(20°C)} X (1.19)^{T-20}$$

$$k_{(T°C)} = k_{(20°C)} X (1.05)^{T-20}$$

Design of Stabilization Ponds

Solution:

$Q = 2000\ m^3/d$

$L_i = 400\ mg/l$

$N_i = 1 \times 10^8\ FC/100\ ml$

$k_{(25°C)} = 0.3\ X\ (1.05)^{25-20} = 0.38\ d^{-1}$

<u>Anaerobic pond design:</u>

The volumetric loading rate at 20°C, $\lambda_v = 300\ g/m^3\ d$ (from table)

Now, $V_a = L_i\ Q/\ \lambda_v = 400 \times 2000\ /300 = 2667\ m^3$

Assuming a depth of 3 m, $A_a = 2667/\ 3 = 889\ m^2$

Design of Stabilization Ponds

The BOD removal in the anaerobic pond is 60% (from table)

So, the BOD of the anaerobic pond effluent =400×0.40=160 mg/L

Now, the retention time, $t_a = V_a / Q = 2667 / 2000$ =1.33 days

Facaltative pond design:

The BOD surface loading rate at 20°C, $\lambda_s = 253$ kg/ha d (from table)

The pond area is given by,

$A_f = 10\ L_i\ Q / \lambda_s$

$= 10 \times 160 \times 2000 / 253 = 12648\ m^2$

Design of Stabilization Ponds

Retention time, $t_f = A_f D_f / Q$

Assuming a depth of 1.5 m,

$$t_f = 12648 \times 1.5 / 2000$$

$$= 9.5 \text{ days}$$

Maturation pond design:

The FC removal rate at 25°C,

$$k_{(25°C)} = 2.6 \text{ X } (1.19)^{25-20} = 6.2 \text{ d}^{-1}$$

Assuming a maturation pond depth of 1.0 m, 50% BOD removal in facultative pond and 75% loading in the first maturation pond, the retention time in the first maturation pond is

$$t_{m1} = 10 L_i D_m / 0.75 \lambda_s$$

$$= (10 \times 0.5 \times 160 \times 1.0) / (0.75 \times 350) = 3.05 \text{ days}$$

Design of Stabilization Ponds

Now, using

$t_m = \{[N_i / N_e (1+k_b t_a) (1+k_b t_f)]^{1/n} - 1\} / k_b$

$= \{[1\times10^8 / 1000 (1+ 6.2\times 1.33) (1 + 6.2 \times 9.5)]^{1/n} - 1\} / 6.2$

when, n = 1,

t_m = 28.96 days (ignore as > t_f)

when, n = 2,

t_m = 2.00 days (ignore as < 3 days)

So, two maturation ponds with retention times t_{m1} = 3.05 days and t_{m2} = 3.0 days may be selected.

Design of Stabilization Ponds

Check for coliform concentration:

$N_e = N_i / (1+ k_b\, t_a)\,(1+ k_b\, t_f)\,(1+ k_b\, t_{m1})\,(1+ k_b\, t_{m2})$

$= 10^8 / (1+ 6.2\times1.33)\,(1+ 6.2\times9.5)\,(1+ 6.2\times3.05)\,(1+ 6.2\times3.0)$

$= 465$ per 100 ml, which is satisfactory

Now the corresponding areas for maturation pond 1 and 2 are

$A_{m1} = 2000 \times 3.05 / 1.0 = 6100\ m^2$

$A_{m2} = 2000 \times 3.00 / 1.0 = 6000\ m^2$

Design of Stabilization Ponds

A complete stabilization pond system would be:

Anaerobic pond: $A_a = 889\ m^2$, $t_a = 1.33$ days

Facultative pond: $A_f = 12648\ m^2$, $t_f = 9.50$ days

1st maturation pond: $A_{m1} = 6100\ m^2$, $t_{m1} = 3.05$ days

2nd maturation pond: $A_{m2} = 6000\ m^2$, $t_{m2} = 3.00$ days

EWCE 333
Wastewater Engineering and Sanitation

Lecture 16

Instructor

Associate Professor

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Department of EWCE, MIST

Lecture Outline

Topics	Reference
• Sewage Effluent Disposal Methods • Sludge Treatment and Disposal Methods	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Sewage Effluent Disposal

Sewage and sewage effluent is disposed of by two methods:

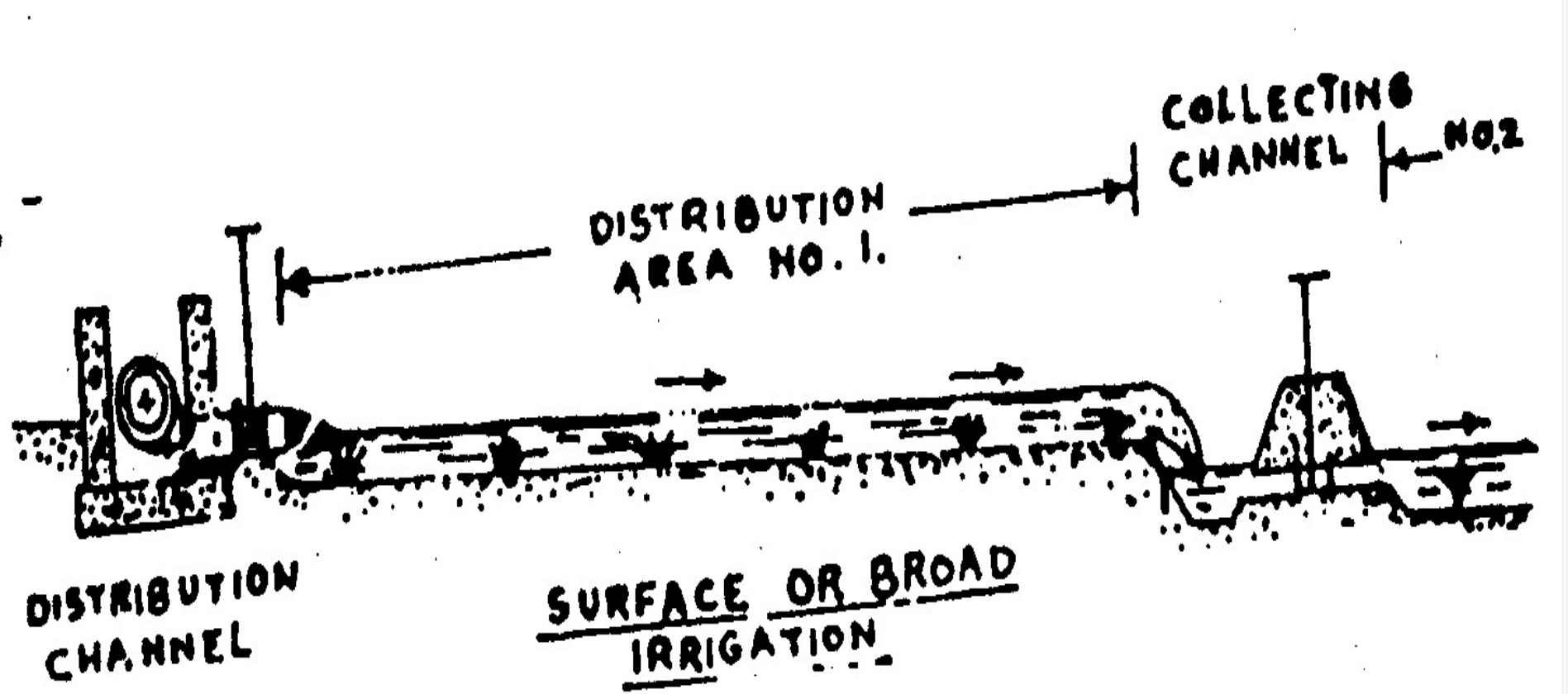
1. Disposal on Land by Irrigation
2. Disposal by Dilution in Water Bodies

1. ***DISPOSAL BY IRRIGATION***
   a. Surface or Board Irrigation
   b. Sub-Irrigation or inundation or Flooding
   c. Ridge and Furrow Method
   d. Sub-surface Irrigation

Sewage Effluent Disposal

DISPOSAL BY IRRIGATION

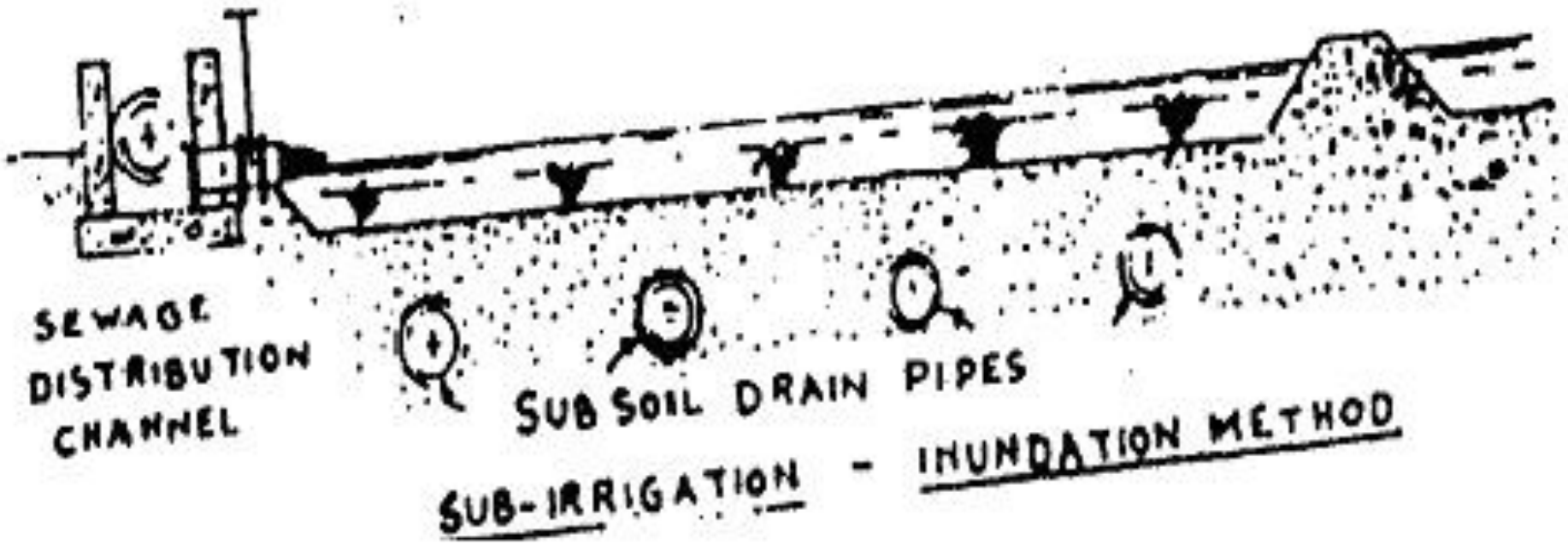
Surface or Board Irrigation



Sewage Effluent Disposal

DISPOSAL BY IRRIGATION

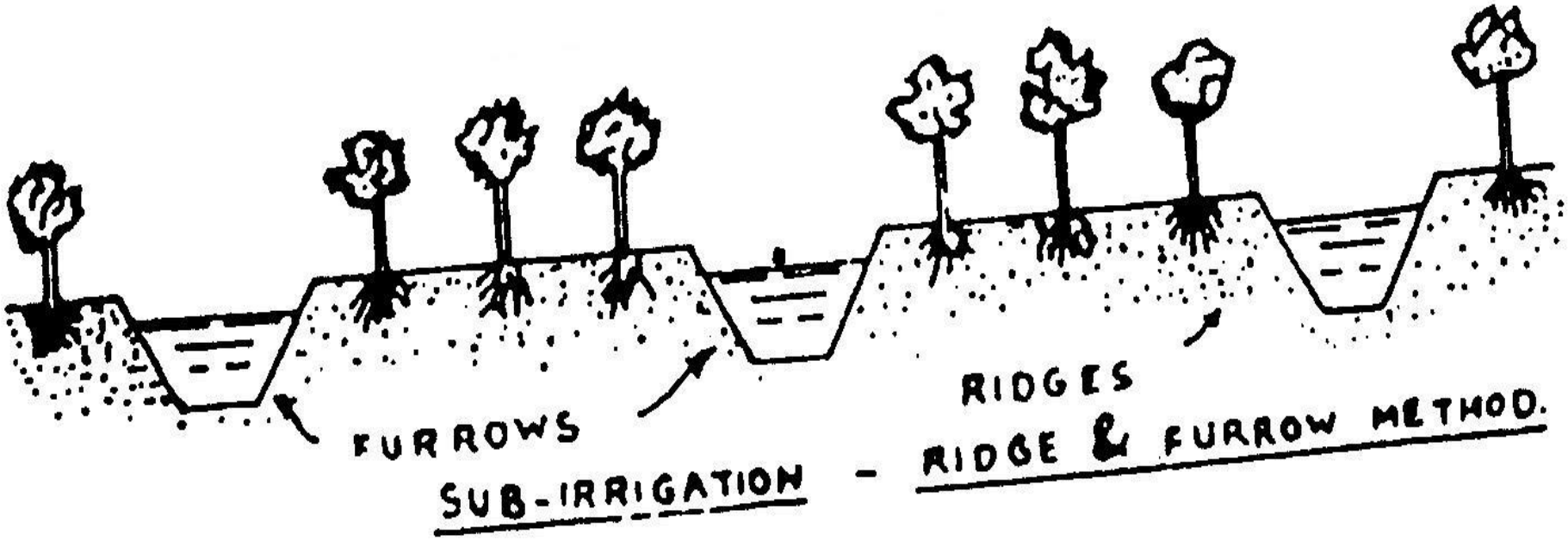
Sub-Irrigation or inundation or Flooding



Sewage Effluent Disposal

DISPOSAL BY IRRIGATION

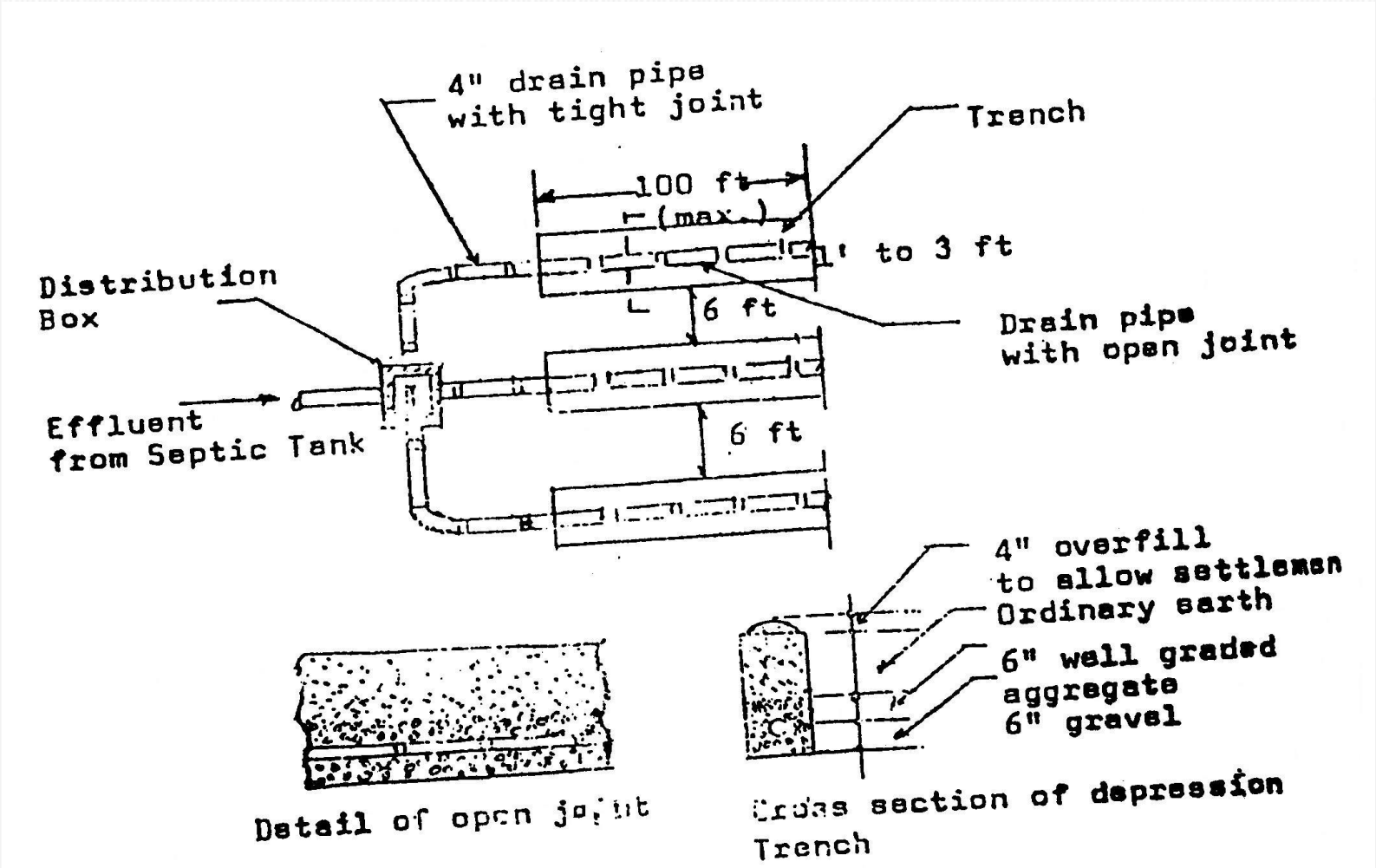
Ridge and Furrow Method



Sewage Effluent Disposal

DISPOSAL BY IRRIGATION

Sub-surface Irrigation



Sewage Effluent Disposal by Irrigation

Advantages

- Provide disposal option in the absence of big water bodies
- Disposal is accompanied by natural treatment
- Fertilizing value of sewage/effluent is returned to the land
- Does not require installation of costly machinery or skilled operator
- No surface water pollution

Sewage Effluent Disposal by Irrigation

Disadvantages

- Large area of land is required
- Not suitable in rainy season or wet climate
- The method is not efficient in case of clayey soils
- Possibility of spreading diseases through crops grown in sewage irrigated lands
- If not properly supervised, the land may become sewage sick

Sewage Effluent Disposal

2. ***DISPOSAL BY DILUTION***

- Disposal of sewage into a body of water or watercourse is known as disposal by dilution.
- In this method the advantage of self- purification capacity of receiving water body is utilized.

Sludge Treatment and Disposal

Sludge:

- Sludge is defined as the solid matter separated from the domestic and the industrial wastes in the process of biological treatment.

- It is an important by-product of waste treatment.

Depending on the degrees and method of treatment sludge can more specifically be termed as:

1) Raw or Primary Sludge
2) Secondary Sludge
3) Activated Sludge and
4) Digested Sludge

Importance of Sludge Management

- Sewage is the waste product of the community.
- Sludge is derived as a by-product from sewage in the process of treatment.
- Safe and proper treatment and disposal of sludge is important for maintaining the health of community and that of the overall environment.

Importance of Sludge Management

- Sludge treatment and disposal is important in view of the following considerations:

1) Sewage contains a large volume of suspended solids. This solid part derived out of biological treatment is objectionable and detrimental to health. So it needs to be handled at some point as a part of the overall sewage treatment processes.

Importance of Sludge Management

2) The sludge from domestic sewage, may contain pathogenic organisms may transmit diseases as well as organic and inorganic contaminants.

3) The sludge may sometimes become hazardous or toxic to human or have detrimental effect on the environment.

Collection of Sludge

Sludge is collected from -

- Primary clarifier
- Intermediate clarifier
- Secondary clarifier
- Sedimentation tanks of trickling filters
- Activated sludge unit
- Oxidation pond

Characteristics of Sludge

1) Sewage sludge contains both organic and inorganic solids as in the raw sewage.
2) Raw sludge is odorous and highly putrescible. It turns into objectionable mass if not properly treated and disposed of.
3) Sludge contains moisture in it. The amount of moisture depends on the processes involved in the treatment.

- Trickling filter plus primary sludge may range from 5 to 10% solids.
- Activated sludge plus primary sludge forms 2 to 5% solids.
- Activated sludge by itself contains less than 1% solids.

Methods of Sludge Treatment and Disposal

- The common methods of sludge treatment and disposal are:

✓ Digestion in a heated tank with subsequent dewatering by air drying or sand bed or by vacuum filtration.

✓ Centrifugation
✓ Wet oxidation
✓ Incineration
✓ Composting
✓ Sanitary landfill
✓ Water disposal

Sludge Digestion

Sludge digestion may be accomplished in both anaerobic and aerobic conditions of which the former is widely used.

Anaerobic Digestion of Sludge:-

- It is the sludge digestion in anaerobic condition.
- This is usually done in closed tank known as *Sludge Digester*.
- It is the process which liquefies sludge, produces gases and stabilizes the organic matters.

Anaerobic Sludge Digestion

Sludge digestion is adopted, because

1) It breaks down the complex organic matters of sludge into simple compounds.

2) It transforms a portion of solid content into liquid and gases. It thus reduces the volume of sludge.

- The volatile matter of sludge reduces to 65 to 85% in dry weight.
- The total reduction of the suspended solids ranges from 45 to 55%.

Anaerobic Sludge Digestion

3) Digested sludge may be used as a fertilizer or soil conditioner. Gases produced in digestion are used as fuel.

4) Coliforms are reduced by 99.9 percent by digestion for a period of 30 days at a temperature of 95 to 100º F.

Anaerobic Sludge Digestion

Process of Anaerobic Sludge Digestion:-

Anaerobic digestion is a two-stage process where -

- the complex organics in the waste solids are first broken down to simpler compounds specially the short chain fatty acids by the action of facultative microorganisms.

- These intermediates are then further reduced by a separate group of bacteria to methane and carbon dioxide.

Anaerobic Sludge Digestion

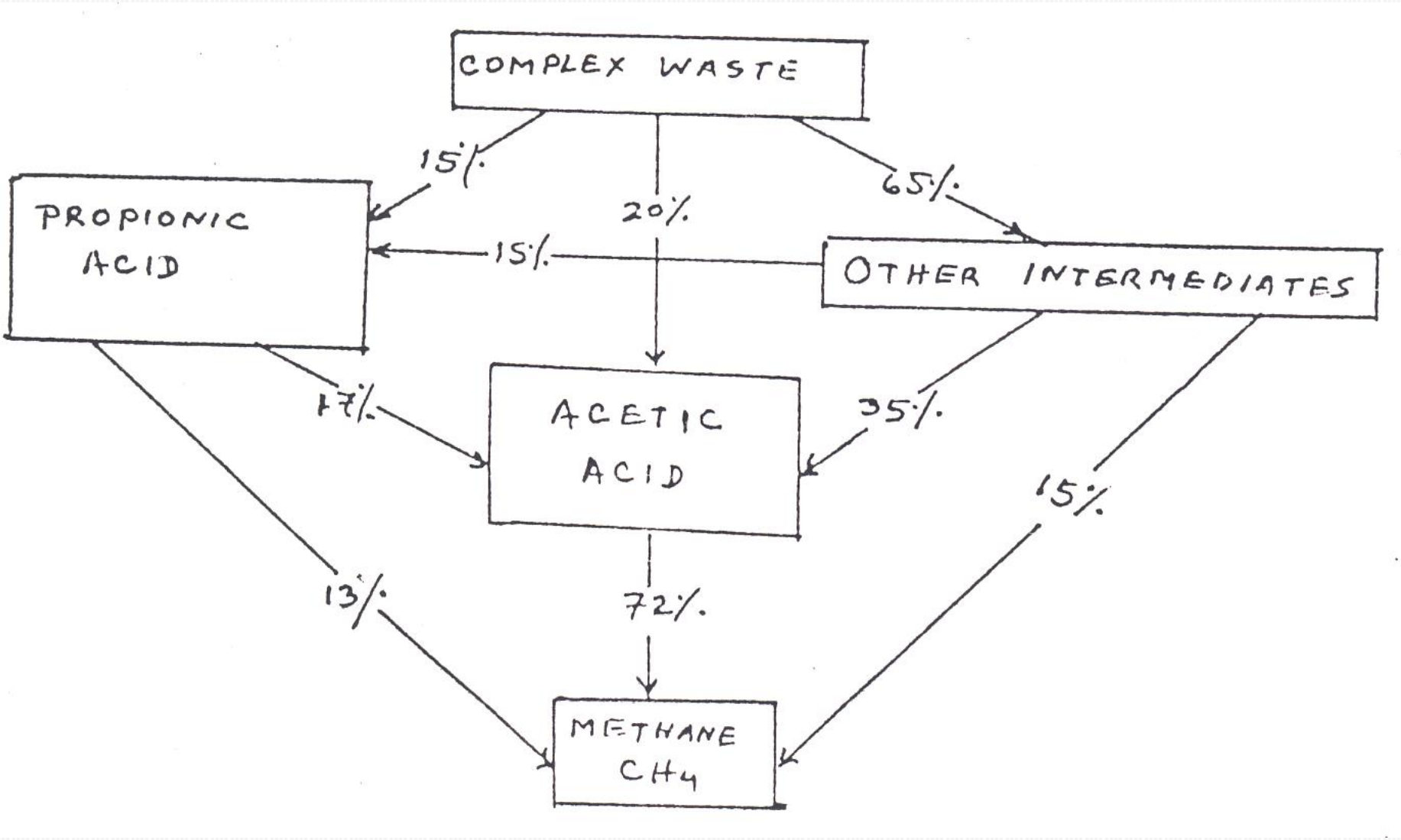


Figure: Metabolic Pathways in Anaerobic Digestion

Anaerobic Sludge Digestion

1st stage:

- Intermediate organic acids can lead to toxicity problem due to either pH or the cations associated with the acid.

- Heavy metals may exhibit toxic effect in anaerobic systems, being solubilized under the chemically reduced conditions therein.

- The metals may be precipitated as sulphides by chemical addition if they are present.

Anaerobic Sludge Digestion

2nd stage:

- The obligate anaerobes convert organic acids to methane and carbon dioxide.
- The microorganisms are more sensitive to the surrounding environment than are the facultative organisms which affect the first step.
- Toxic constituents will affect them first and cessation or slowing of their activity can lead to pickling of the digester.

Anaerobic Sludge Digestion

- Methane gas produced in anaerobic digestion is mostly used to heat the digester.
- Sometimes it is used to provide mechanical power for other plant process.
- Heat needed depends upon climate, construction of digester walls and retention time.
- The digested solids from anaerobic processes may be dewatered without further treatment upon open or covered drying beds.
- It may be necessary to add chemicals for satisfactory mechanical dewatering.

Anaerobic Sludge Digestion

Control of Digestion:-

To have control over the digestion process it is necessary to have control over some conditions in the operation of digestion tanks. These are:

- ✓ Control of temperature
- ✓ Control of alkaline range of pH of sludge
- ✓ Control of seeding of digested sludge.

Anaerobic Sludge Digestion

Control of Temperature:-

Digestion process is accelerated at high temperatures.

a) **Zone of thermophilic digestion**:

- Temperature range - 100° to 131°F (38 to 55ºC).
- Not used because of odor and other operating difficulties.

b) **Zone of mesophilic digestion**:

- Optimum temperature - about 85°F(29°C) with a digestion period of 4 weeks.
- Further heating to 120°F (49°C) or so would reduce the digestion period to 15-18 days

Anaerobic Sludge Digestion

Control of Alkaline Range:-

- pH value should be maintained at 7.2 to 7.4, if raw sludge is added.

- To maintain optimum pH value, added raw sludge ≤ 3 to 5% by weight of the digested sludge.

Control of Seeding:-

- Seeding is the addition of fresh sludge with the previously well digested sludge under controlled condition of temperature.

- Seeding is also important for successful operation of the digestion tanks.

Aerobic Sludge Digestion

- Sludge digestion may also occur at aerobic condition.
- Under such situation different organisms oxidize complex organics using different biological pathways.
- They are not readily affected by toxic substances.

Aerobic Sludge Digestion

Aerobic digestion has got the following characteristics :—

- volatile solids reduction is much more than in anaerobic digestion
- has lower BOD in the supernatant
- has less operational problems
- involves lower capital cost requirement

Sludge Treatment

Centrifugation

- It is the process of dewatering moist sludge by continuous centrifugation where solids get separated from the liquid in the treatment plant.

- A solid bowl horizontal centrifuge is generally used. The screw conveyor or scroll rotates at speed slightly more than that of the bowl and thus carries the solids through the device and up the ramp to sludge cake outlet.

Sludge Treatment

Centrifugation

The variables which are involved in the process are –

the bowl diameter
the ram slope and length
the scroll speed and pitch
the feed point of sludge and chemicals
the retention time
the sludge conditioning

- This method is satisfactorily used in dewatering paper mill waste, packing house waste, foundry sludge, refinery wastes and also sewage sludge.

Sludge Treatment

Wet Oxidation

- In this process, sludge is treated by incineration i.e., heating at high temperature that uses the principle of wet combustion to degrade the organic matter in sludges.

- To support the combustion process, oxygen is supplied by injection of air into the system.

- The combustion temperatures in wet oxidation are considerably lower than the temperatures in normal dry combustion.

- This process may be used in disposal of organic waste sludge.

Sludge Treatment

Incineration

- It is the process of burning sludges at high temperatures.
- Clinical and hospital wastes are generally considered too difficult to handle in a landfill site.
- To dispose of these wastes safely they are burnt.
- Sludge from some difficult wastes as dioxines should only be disposed of by burning at high temperatures.
- Incinerators are very high capital projects though they have less operational problems.

Sludge Treatment

Composting

- Composting is a biological process of decomposition of organic solid wastes to a relatively stable end product.

- The sludge that has been composted properly is sanitary nuisance-free, humus like material.

- Approximately, 20 to 30% of the volatile solids are converted to carbon dioxide and water.

- In addition, as the sludge is usually processed in the thermophilic temperature range, the product sludge is essentially pasteurized.

Sludge Treatment

Composting

- The composted sludge may be used as a soil conditioner.

- Most composting operations consists of three basic steps:-

  Preparation of wastes to be composted

  Decomposition of the prepared wastes

  Preparation and marketing of the product

Sludge Dewatering Methods

Sludge Drying Bed

- Beds are 6 to 10 m wide and upto 40 m long.
- At least two beds are necessary even for a small plant.
- Dewatering occurs as a result of drainage and evaporation and is heavily dependent on climate.

Sludge Dewatering Methods

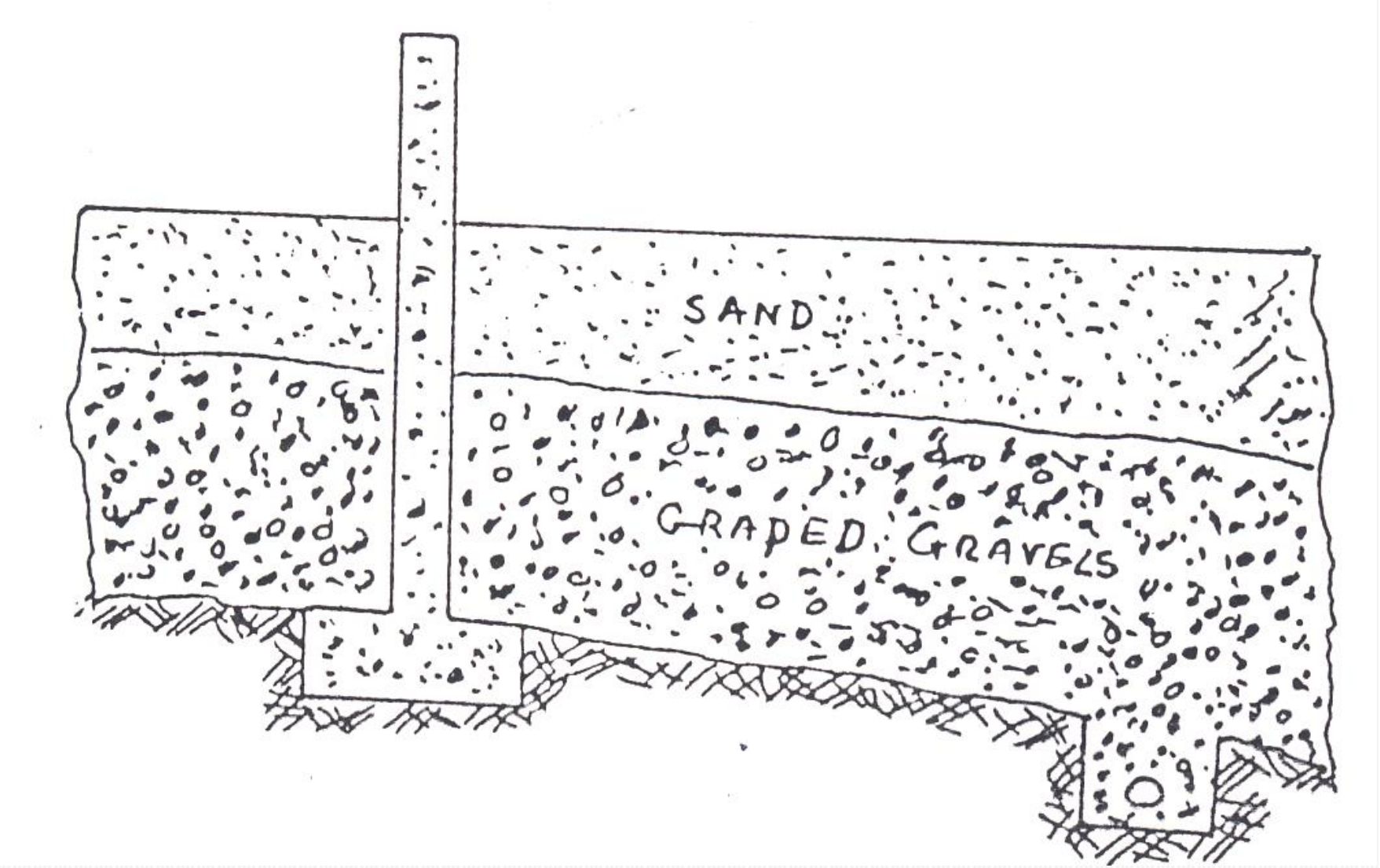


Figure: Section of Sludge Drying Bed

Sludge Dewatering Methods

Sludge Drying Bed

- In wet climate it is convenient to cover beds by glass or translucent plastic.
- Beds are operated by filling them with digested sludge to a depth of 200 to 300 mm.
- After dewatering, the volume will be reduced to 60%. The cake may be removed with appropriate mechanical device.

Sludge Dewatering Methods

Vacuum Filtration

- Vacuum filters are also used for dewatering digested sludge.
- This is done by means of drum set horizontally and covered with the filter media.
- The drum is rotated in the tank about one quarter of drum submerged in the wet digested sludge.
- Valves and pipings are arranged in such a way that as the drum rotates, a vacuum applied on the inner side of the filter media draws water from the sludge and holds a layer of sludge to the drum.

Sludge Dewatering Methods

Vacuum Filtration

- The application of vacuum is continued as the drum rotates out of the sludge into the atmosphere. This pulls additional water away from the sludge mat leaving a moist cake of sludge on the outer surface.

- The sludge mat is scraped blown or lifted away from the drum just before it enters the sludge tank again.

Sludge Disposal Methods

Landfill

- It is the method of disposal of sewage sludge and solid wastes on land without creating nuisance or hazards.
- If a suitable site is found, a sanitary landfill can be used for disposal of sludge, grease, grit and other solids whether it is stabilized or not.

Sludge Disposal Methods

Landfill

- In a true sanitary landfill, the wastes are deposited in a designated area, compacted in a place with a tractor or roller and covered with a 30 cm layer of clean soil.

- This prevents creation of nuisance conditions such as odors and flies. But in this process drainage from the site (known as leachate) would cause pollution of ground water supplies or surface streams should be guarded against.

Sludge Disposal Methods

Disposal to Water Bodies

- Sewage sludges are sometimes disposed of at the sea from coastal cities and towns.
- But the outfall should be at a greater depth so that the sludge does not rise to the water surface.