EWCE 333 — SB

Rough / CT-2 27/12

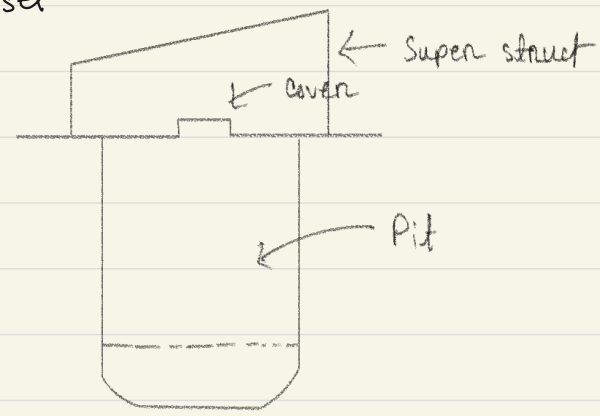
Low-cost sanitation technologies

- Pit-latrine → Liquids soaks into ground; solids retained and decomposed in the pit
- Pour-flush latrines

Pit-latrines

Techs

- Simple Pit
- Ventilated Improved Pit (VIP)
- Reed odorless Earth Closet



Types

- Direct pit
- Offset pit
- Partly offset pit

Design considerations (essentially 6)

1. Pit width $\leq$ 1.5 m (commonly 1 – 1.5 m)
2. Soil permeability $\geq$ 2.5 mm/hr
3. At least 10m away from nearest source of drinking water
4. " " 2m above GWT
5. Door w/ openings on spinal wall w/ no doors (ventilation)
6. Depth depending on GWT & soil cond. (commonly 5 ring, 1' per ring)

Design of Pit Latrine

Demand volume, $V_d = CPN$;

- N = no. of person
- P = design period (yr)
- C = rate of solid accumulation → m^3/person/year
  - 0.04 for wet pit
  - 0.06 for dry pit

Structure volume, $V_s = \frac{\pi d^2}{4} h$;

$d_{max} = 1.5\ m$

$V_s = V_d$ → solve for d & h — 5'-6' (human ht + hand)

actual struct ht, $H = h + 0.5\ m$

Advantages

- Low cost
- No expert input needed
- Design readily available, local materials can be used
- Easy maintenance
- Better than open defecation
- no water for flushing
- one unit can serve multiple home

Disadvantages

- risk of odor & flies in simple pit
- cannot be located inside house — risk during night
- requires digging of new pit on cleaning of existing ones every few years
- cannot be situated at crowded areas, on flood prone area or where GWT is high on rocky soil.

Prob – 1

Given $d = 1m$ $C = 0.06\ m^3/person/yr$ [dry pit]

ring depth $= 0.3m$

$P = 7$

GWT is 5m below

$N = 4yr$

Now, $V_{demand} = CPN$

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

$= 1.68\ m^3$

$V_{struct} = \frac{\pi d^2}{4} h = V_{demand}$

$\Rightarrow \frac{\pi \times 1}{4} h = 1.68$

$\Rightarrow h = 2.14\ m$

$\therefore H = 2.14 + 0.5 = 2.64\ m$

No. of ring $= \frac{2.64}{0.3} = 8.8 \simeq 9$

However, ring should be 5–6. Retry with design year, $N = 3yr$

$V_{demand} = V_{structure}$

$\Rightarrow CNP = \frac{\pi d^2}{4} h$

$\Rightarrow 0.06 \times 3 \times 7 = \frac{\pi}{4} h$

$\Rightarrow h = \frac{1.26 \times 4}{\pi} = 1.6\ m$

$\therefore H = 2.1\ m$

No of ring $= \frac{2.1}{0.3} = 7 > 6$ [not okay]

Again with $N = 2yn$

$V_{struct} = V_{demand}$

$\Rightarrow \frac{\pi d^2}{4} h = CPN$

$\Rightarrow \frac{\pi}{4} h = 0.06 \times 7 \times 2$

$\Rightarrow h = \frac{0.84 \times 4}{\pi} = 1.07 \text{ m}$

$\therefore H = 1.07 + 0.5 = 1.57 \text{ m}$

$\therefore$ No. of ring $= \frac{1.57}{0.3} = 523 \simeq 6$ ring

Check:

actual depth: $6 \times 0.3 \text{ m} = 1.8 \text{ m} < 5 - 2 = 3 \text{ m}$ [OK]

Prob – 2

Given, $d = 1\ m$ $\quad C = 0.06\ m^3/person/yr$ [dry pit]

ring depth $= 0.3\ m$

$P = 2 \times 7 = 14$

GWT $\rightarrow$ 4m below surface

$N = 2\ yr$ (or more)

$H_{max} = 4 - 2 = 2\ m$

Now, $V_{demand} = V_{struct.}$

$\Rightarrow CPN = \frac{\pi d^2}{4} h$

$\Rightarrow 0.06 \times 14 \times 2 = \frac{\pi}{4} h$

$\Rightarrow h = \frac{1.68 \times 4}{\pi} = 2.14\ m$

$\therefore H = 2.64\ m > 2\ m$ [not ok]

Two pit to be constructed

- - -

Prob 3

Given, $C = 0.06$

$P = 6$

$N = ?$

Now, $V_{demand} = V_{struct.}$

$\Rightarrow CPN = wLh$

$\Rightarrow 0.06 \times 6 \times N = 1.5 \times 2 \times (2.5 - 0.5)$

$\Rightarrow N = 16\,y$

Lec 5

Pour-flush tech

- improvement to pit latrine → water seal
- three components → super-struct
  latrine pan with water seal
  single or alternating twin leach pits
- U-pipe prevents passage of odor & flies
- Flushed by hand, 1.5-2 ltr of water
- water seal 15-25 mm deep
- Latrine can be located inside with offset pit

Basic difference

1. Mechanism:
   Pit latrine: Excreta falls directly into pit; no water
   Pour-flush: It has a water seal (U-shape pipe) below the pan that holds water. water is used to push the waste into the pit

2. odor & flies:
   Pit latrine: no water-seal; odor & flies can come out of the pit
   Pour-flush: water-seal prevents the passage of bad smell & flies

3. Location:

Pit latrine: Located outside of house due to smell and flies.

Pour-flush: Latrine can be located inside

4. Water usage:

Pit latrine: no water

Pour-flush: 1.5 to 2 L of water needed for flush

Types

1. Direct pit pour-flush →

Simple pit latrine with 25mm water seal above to pit

2. Offset pit pour-flush →

Latrine inside

Pit is outside, connected by a 100 mm dia pipe

Two types →

a. Single pit

b. Alternating twin pit

Alternating twin pit:

Components → Squatting pan

Y-junction

Pits are used alternatingly as one gets full and is left for solid decomposition (18-24 months)

Functions:

- Manual flush after each use with 2-3 L of water
- water seal provides a barrier for odor & flies.
- Around 10-20 lpcd water enters into the pit
- Sufficient vol to be provided for solids
- sufficient area for infiltration
- Soil's long-term infiltrative capacity or remove liquid by other means.

Suitability

- Can be used in both urban & residential settings given sufficient water is available for flushing & water seal
- Single pit can be used if mechanical vaccum tanker is available for desludging as contents are not pathogen-free.
- Twin pits can be used if desludging to be done manually as resting period makes the content substantially pathogen free

Design

For liquid: Side wall, $A = \frac{Q}{I}$ → demand

(Q: L/d; I: $\frac{L}{m^2\text{-day}}$)

$$A_{\text{structure}} = \pi d h \rightarrow h = \frac{A}{\pi d}$$

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

$$= \frac{\pi d^2}{4} \frac{A}{\pi d}$$

$$= \frac{\pi d^{\not 2}}{4} \frac{Q}{I \not{\pi} d}$$

$$= \frac{Qd}{4I} \rightarrow V_i = \frac{QD}{4I}$$

For solids → $V_s = CPN$

$$V = V_s + V_i$$

For single pit, design with $V = V_s + V_i$

twin pit, " " $V = \max(V_s, V_i)$

P21/ P: 7

N: 2.5 y

Q: 12 lpcd × 7p = 84 L/d

I: 20 L/m²-day

Cross-section of the pit ⟶ sqr

$A_{i,demand} = \frac{Q}{I} = \frac{84}{20} = 4.2\ m$

$A_{i,struct} = 4Dxh = 4 \times 1.2 \times h = 4.8h$

Now, $4.2 = 4.8h \Rightarrow h = 0.875\ m$

$\therefore V_i = D^2 h = 1.2^2 \times 0.875 = 1.26\ m^3$

Again, $V_s = CPN = 0.04 \times 7 \times 25 = 0.7\ m^3$

a) Single pit: $V = V_i + V_s = 1.26 + 1.7 = 1.96\ m^3$

Again, $V = D^2 h = 1.96$

$\Rightarrow 1.2^2 \times h = 1.96 \Rightarrow h = 1.36\ m$

$\therefore H = 1.36 + 0.5 = 1.86\ m \simeq 2m$

b) Twin pit: $V = \max(V_i, V_s) = 1.26\ m^3$

Again, $V = D^2 h = 1.26$

$\Rightarrow 1.2^2 \times h = 1.26$

$\Rightarrow h = 0.875 m$

$\therefore H = 1.38 \simeq 1.5 m$

Advantages

- Less expensive compared to conventional sys
- Hygienic soln for excreta disposal
- Less water req (2-3 L)
- Can be upgraded to connect to sewerage sys on septic tank
- No odor and flies
- Sludge can be used as soil conditioner
- Can be built permanently as alternatingly used
- Can be located inside house

Disadvantage

- Separate sullage disposal facilities
- At least 4 lpcd water must be present throughout the year.
- water seal may get clogged easily if garbage is thrown
- Construction difficult in areas with high GWT and rocky soil.
- Risk of polluting GW

Rough / midterm 07/01

Septic tank

Processes:

1) Separation of solids → sludge at btm,
   scum at top,
   relatively clear layer in middle
2) Digestion of sludge & scum → Anaerobic bacteria degrade organic matter & for volatile acids at first. They are then converted to H_2O, CO_2, CH_4, etc
3) Stabilization of liquid → organic matters in liquid are stabilized by anerobic bacteria
4) Growth of microorganism → large varieties of them grow, reproduce, and die.

Factor affecting septic tank perf

1) Retention time
2) Ambient temp
3) Content of wastewater
4) position of inlet & outlets

P35 $P = 3 \times 6 = 18$ person

$q = 85$ lpcd

$N = 2$ yr ; $C = 0.06$

$t_{h,min} = 0.8$ d

$A_{max} = 35\ m^2$

Sedimentation zone:

$$t_h = 1.5 - 0.3 \log(Pq) = 1.5 - 0.3 \log(18 \times 85) \geq 0.8 \text{ d}$$
$$= 0.54 \geq 0.8 \text{ d}$$
$$= 0.8 \text{ d}$$
$$\therefore V_h = 10^{-3} P q t_h = 10^{-3} \times 18 \times 85 \times 0.8 = 1.224\ m^3$$
$$d_h = 1.224/35 = 0.35\ m$$

Digestion:

$$t_d = 30(1.035)^{35-T} = 30(1.035)^{35-25^\circ}$$
$$= 42.32 \text{ d}$$
$$\therefore V_d = 10^{-3} P t_d \times 0.5 = 0.5 \times 10^{-3} \times 18 \times 42.32$$
$$= 0.38\ m^3$$
$$d_d = 0.11\ m$$

Sludge storage:

$$V_{sl} = CPN = 0.06 \times 18 \times 2 = 2.16\ m^3$$
$$d_{sl} = 0.62\ m$$

Scum storage

$$V_{sc} = 2.16 \times 0.4 = 0.864\ m^3 ; \quad d = 0.25\ m$$

$\therefore V = 1.224 + 0.38 + 2.16 + 0.864 = 4.628\ m^3$

Clear spacing,

Scum clear depth = 0.075 m

Sludge " " $= 0.82 - 0.26A \geq 0.3\ m$

$= 0.82 - 0.26 \times 3.5 \geq 0.3\ m$

$= -0.09 \geq 0.3\ m$

$= 0.3\ m$

$\therefore$ Total clear spacing = 0.375 m $> (d_h = 0.35 m)$

$\therefore d_{h,revised} = 0.375\ m$

Total eff. depth = $0.375 + 0.11 + 0.62 + 0.25$ m

$= 1.36\ m \simeq 1.5\ m$

Now, $A = WL = 3.5\ m^2$

$\Rightarrow (W = 1m) \times (L = 3.5m) = 3.5\ m^2$

1m X 3.5m X 1.5m

1st comp = $2/3 \times 3.5 = 2.33$ m

2nd " = --- = 1.17 m

Soak pit: $A_{demand} = Q/I = \frac{18 \times 85}{40} = 38.25\ m^2$

$A_{struct} = \pi dh = \pi \times 1.25 \times h$

$\Rightarrow 38.25 = 1.25\pi h$

$\Rightarrow h = 9.7\ m$

(1) Sedimentation → $t_h = 1.5 - 0.3 \log(pq)$

$V_h = 10^{-3} pq t_h \rightarrow d_h$

(2) Digestion → $t_d = 30(1.035)^{35-T}$

$V_d = 10^{-3} \times 0.5 \times p t_d \rightarrow d_d$

(3) Sludge → $V_{sl} = CPN \rightarrow d_{sl}$

(4) Scum → $V_{sc} = 0.4 V_{sl} \rightarrow d_{sc}$

Clear spacing! $a = 0.075\ m$

$b = 0.82 - 0.26A \geq 0.3\ m$

Soak pit: $A_{dem} = Q/I$ → 1.25 m

$A_{str} = \pi D h$

Disposal of tank effluents:

(1) Absorption trenches: Effluents flow by gravity from septic tank and distribution boxes into perforated pipes in trenches.
(2) Soakage pit: Deep excavated pits that acts as a settling chamber and wastewater is flushed into. waste is retained for around 24 hrs for settlement & digestion then they pass out of the tank into subsoil drainage sys.
(3) Small Bore Solid free sewer: Liquid effluents is carried from septic tank to a communal treatment plant by a system of small pipes.

SBS vs conventional

(1) Reduced sewer size due to attenuation of flow by septic tank
(2) Minimal solid, self cleansing not necessary, reduced grad
(3) Minimal blockages
(4) Reduced excavation
(5) Fast construction
(6) Solid handling at secondary treatment site is minimal

Rough / CT-3 17/02

Background:

Preliminary + primary treatment → Removes floating matters and settleable suspended solids

Secondary treatment → Removes organic matters
↳ AKA Biological treatment

Biological treatment processes:

Suspended growth process vs attached growth process:

→ Both biological treatment process. Differs on where bacteria live.

→ For the former, micro-organisms are kept suspended as single cells or cluster of cells called flocs. They move freely through the waste water which contains their foods. Ex., Activated Sludge Process.

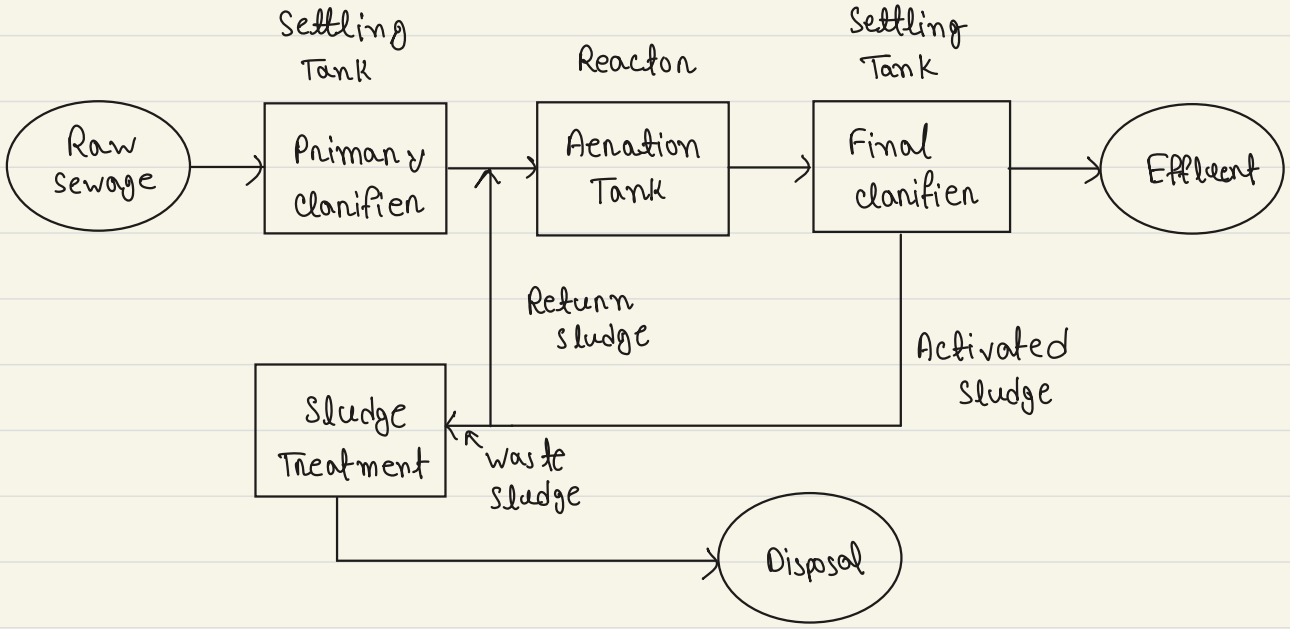
→ For the latter, micro-organisms are attached to a fixed inert surface forming a layer of microbial film. wastewater passes over this layer. Ex, Trickling filter process.

Activated Sludge process:

suspended growth

Defⁿ → An biological treatment process that utilizes aeration tank and a mixture of micro-organisms (activated sludge) to metabolize and remove organic matters.

Mechanisms →



Schematic diagram

1. Raw sewage is brought into the aeration tank
2. Air is bubbled into the wastewater mixture and aerobic bacteria metabolize the dissolved and suspended organic matter.
3. The effluent is then moved to a secondary settling tank.
4. Part of the settled masses are returned to the aeration tank while rest is disposed to maintain a viable biomass concentration.

5. The portion of the biomass, that is recirculated, containing living and active micro-organism, is called activated sludge.
6. The activated sludge increases the amount of available biomass and speeds up reaction.

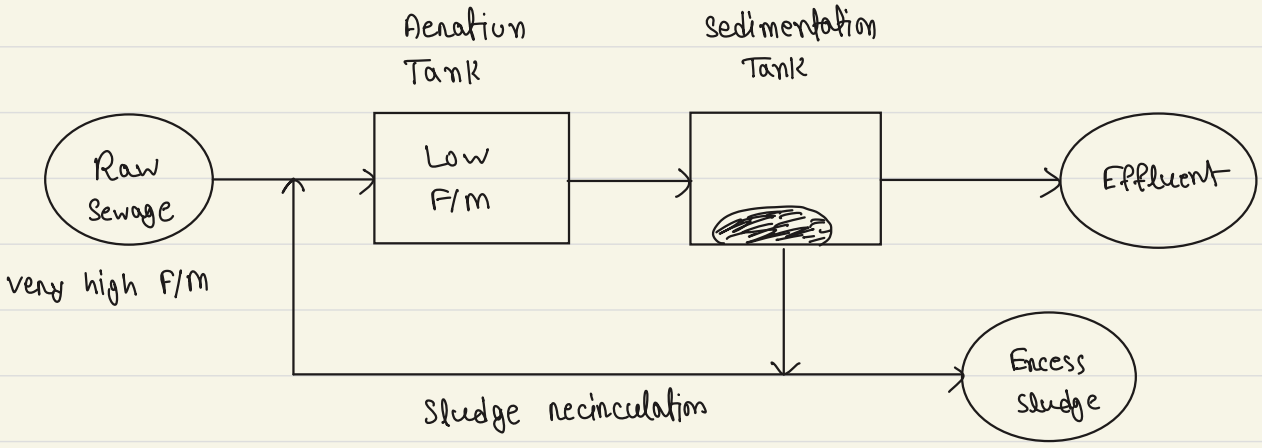
Process design considerations:

1. Mixture of the activated sludge with wastewater to be treated (mixed liquor).
2. Aeration and agitation of the mixed liquor for required duration.
3. Seperation of activated sludge from mixed liquor in the final clarifier.
4. Return of the activated sludge into aeration tank in proper amount.
5. Disposal of the excess activated sludge.

Significance of F/M on Activated Sludge Process

High F/M →

1. Micro-organisms are in exponential growth rate. Characterised by excess food and high bacteria conc.
2. Although high metabolism rate is present, micro-organisms stay very active and dispensed, making floc formation not possible.
3. As a result, secondary sedimentation tank become ineffective in separating activated sludge to be recirculated.
4. Also, there's excess organic matter that passes through the system w/o being eaten and cannot be removed by sedimentation.
5. It results in poor BOD removal.



Low F/M →

1. Overall endogenous stage
2. Although rapid growth initially when organic matter inflow and return micro-organisms are mixed, organic matters become scanced and micro-organisms results in near-starvation situation.
3. At this stage, aeration results in auto-oxidation through autolysis and re-synthesis.
4. Although low metabolism rate, organic matter metabolism nearly complete and micro-organisms naturally flocculate to save energy and settle out by gravity.
5. Desirable when BOD removal efficiency is desired.

Design criteria for Activated Sludge Process

1. Mixed liquor suspended solids concentration 1500 - 3000 mg/L
2. Hydraulic detention time 6 — 24 hrs
3. Solids residence time 3 — 20 days.

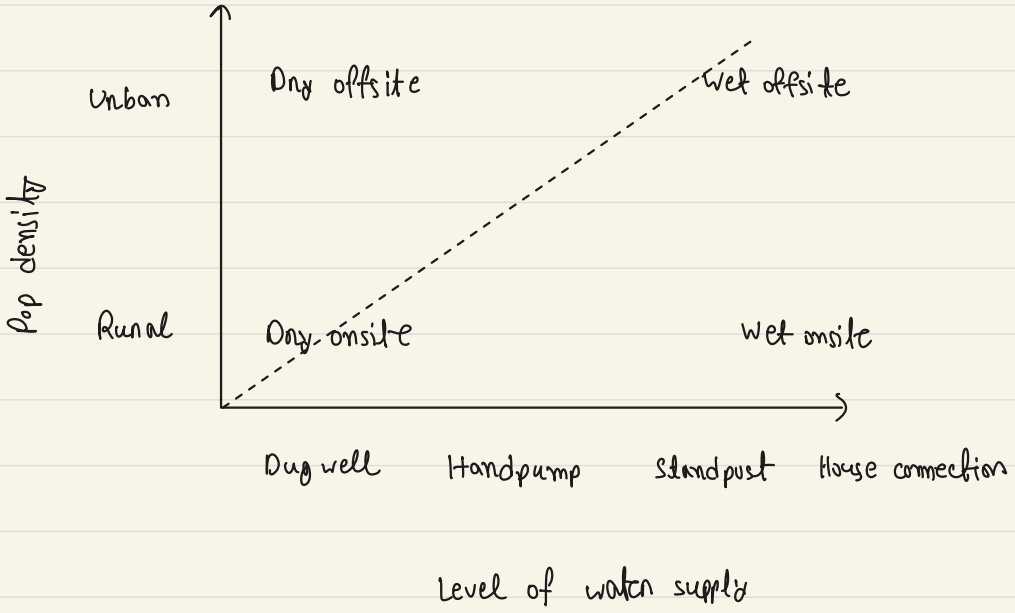
Rough / Final 11/05

General criteria for good sanitation system:

1. Should be simple & cheap to construct
2. Shouldn't contaminate Gw, surface water
3. Free of acess from flies, animals
4. Free from odor & unsightly conditions
5. Require little to no supervision & maintenance
6. Use as little water as possible
7. Less mechanical equips
8. Handle all types of waste & waste water

Appropriatenss of sanitation system

Depends on level of water supply and population density



Design of pit (pour-flush latrine):

Demand:

Liquid: $A_i = \frac{Q}{I}$ (Q ← l/d, I ← l/m²-d)

$A = \pi D h = \frac{Q}{I} \rightarrow h = \dots$

$V_i = \frac{\pi D^2}{4} h$

alt: $V_i = \frac{QD}{4I}$

Solid: $V_s = CPN$

$V = V_i + V_s$ for single pit

$V = \max(V_i; V_s)$ for twin pit

$D = 1.2\,m$ if not specified

LO5-P22/ $P = 7$

$N = 2.5\ y$

x-section is square

$q = 12\ lpcd$

$I = 20\ l/m^2\text{-}d$

1. V_i: $Q = 12 \times 7 = 84\ l/d$

$\therefore A_i = \frac{Q}{I} = \frac{84}{20} = 4.2\ m^2$

or, $4bh = 4.2 \Rightarrow h = 0.875\ m$ $b = 1.2m$

$\therefore V_i = b^2 h = 1.2^2 \times 0.875 = 1.26\ m^3$

2. V_s: $V_s = CPN = 0.04 \times 7 \times 2.5 = 0.7\ m^3$

Single pit: $V = V_s + V_i = 1.96\ m^3$

or, $b^2 h = 1.96 \Rightarrow h = 1.36\ m$

$\therefore H = 1.36 + 0.5 = 1.86\ m \approx 2m$

Twin-pit: $V = \max(V_i, V_s) = 1.26\ m^3$

$\Rightarrow b^2 h = 1.26 \Rightarrow h = 0.875\ m$

$\therefore H = 1.375\ m \approx 1.5\ m$

Ex. 04 (P149) :

P = 8

q = 12 lpcd

I = 20 l/m²-d

1. $V_i = \frac{QD}{4I} = \frac{(12 \times 8) \times 1.2}{4 \times 20} = 1.44\ m^3$

2 $V_s = CPN = 0.04 \times 8 \times 2 = 0.64\ m^3$ [N assumed 2d]

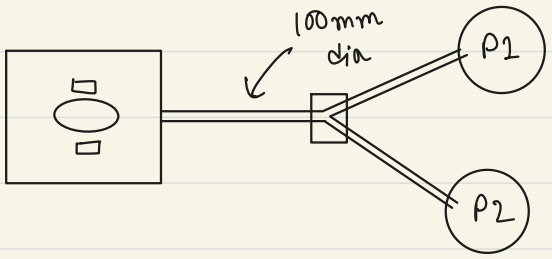
Single pit: $V = 1.44 + 0.64 = 2.08\ m^3$

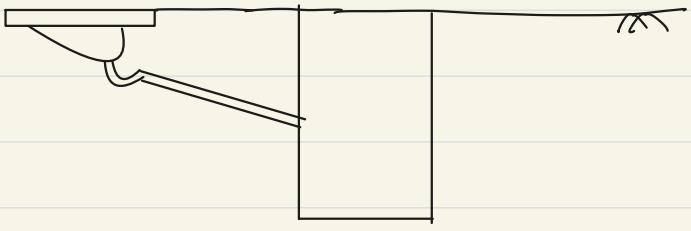
$\Rightarrow \frac{\pi D^2}{4} \times h = 2.08 \Rightarrow h = 1.8\ m \approx 2m \rightarrow 2.5\ m$

Twin pit: $V = 1.44\ m^3$

$\Rightarrow \frac{\pi \times 1.2^2}{4} h = 1.44 \Rightarrow h = 1.27\ m \approx 1.5m \rightarrow 2m$

Sketch





Design of septic tank:

4 zones:

i) Sedimentation: $t_h = 1.5 - 0.3 \log(Pq)$ (day)

$V = Pq t \times 10^{-3}$ (m^3)

$d_h \rightarrow$

ii) Digestion storage: $t_d = 30(1.035)^{35-T}$ (day)

$V = P \times 0.5 t_d \times 10^{-3}$ (m^3)

$d_d \rightarrow$

iii) Sludge storage: $V_{sl} = CPN$; $C = 0.04$ when $N > 5$

$d \rightarrow$ 0.06 $N < 5$

iv) Scum storage: $V_{sc} = 0.4 V_{sl}$

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

Check d:

$a = 0.075$ m

$b = 0.82 - 0.26A \geq 0.3$

$d_h = a + b \geq d_h$

Compartment: $L \times w = A$ [maximize L]

1st comp. $= 2/3\ L$

2nd comp $= 1/3\ L$

Soak pit: $A_{req} = Q/I$

$\pi D h = A_{req} \rightarrow h$

$V = \frac{\pi D^2}{4} h$

LOG1 P35)

$P = 3 \times 6 = 18$

$q = 85$ lpcd

$N = 2y$

$t_{h,min} = 0.8\,d$

$A_{max} = 3.5\ m^2$

1. Sedimentation:

$t_h = 1.5 - 0.3 \log(Pq) \geq 0.8$

$= 1.5 - 0.3 \log(18 \times 85) \geq 0.8 = 0.8\ d$

$V_h = Pq\, t_h \times 10^{-3} = 1.224\ m^3$

$\therefore d_h = \frac{1.224}{3.5} = 0.35\ m$

2. Digestion:

$t_d = 30(1.035)^{35-T}$ [Let $T = 25^\circ C$]

$= 30(1.035)^{10} = 42.3\ d$

$\therefore V_d = 0.5 \times P t_d \times 10^{-3}$

$= 0.5 \times 18 \times 42.3 = 0.381\ m^3$

$\therefore d_d = \frac{0.381}{3.5} = 0.11\ m$

3. Sludge:

$V_{sl} = CPN$

$= 0.06 \times 18 \times 2 = 2.16\ m^3$

$\therefore d_{sl} = \frac{2.16}{3.5} = 0.62\ m$

4. Scum:

$V_{sc} = 0.4\, V_{sl} = 0.864\ m^3$

$d_{sl} = 0.25\ m$

d-check:

$a = 0.075\ m$

$b = 0.82 - 0.26A \geq 0.3$

$= 0.3$

$\therefore d_a = 0.3 + 0.075 = 0.375\ m$

$\therefore d_h = 0.375\ m$

$\therefore d = 0.375 + 0.11 + 0.62 + 0.25 + 0.36 \approx 1.5\ m$

Compartment: $B \times L = 3.5$

$\Rightarrow 1 \times 3.5 = 3.5$

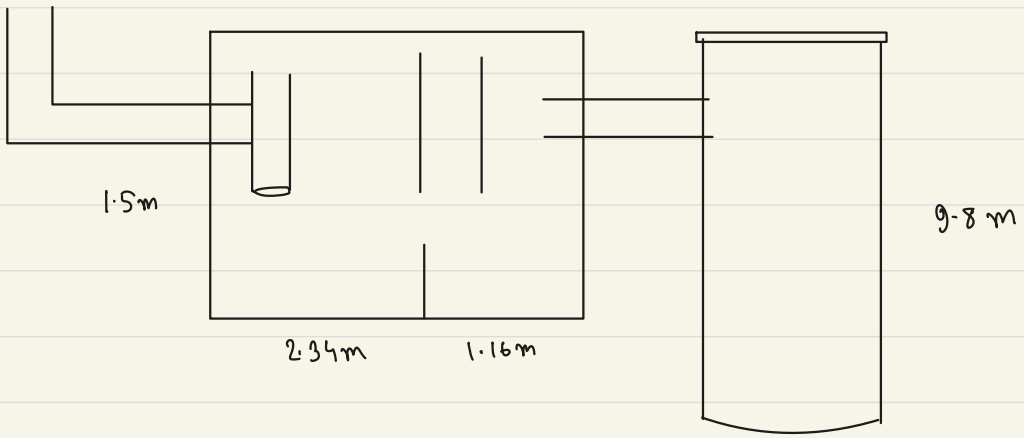
1st: $\frac{2}{3} \times 3.5 = 2.34$ m

2nd: $3.5 - 2.34 = 1.16$ m

Soakage pit: $\text{Area} = \frac{Q}{I} = \frac{85 \times 18}{40} = 38.25\ m^2$

$\pi D h = 38.25$; $D = 1.25$m

$\Rightarrow h = 9.74$ m



Tank effluent disposal:

1. Absorption trenches: Liquid from septic tank flows by gravity through perforated pipes buried in trenches filled with gravel/ crushed stones.

   As soil passes from pipe into soil, bacteria acts as tiny purifiers

   Requires large open area.

2. Absorption pits: Partially treated liquid from septic tank flows into soakage pits.
   The pits are dug of around 3-6m and 2-3.5m diameter.

   Effluents flows into soil through brick wall openings

   Used when trenches not possible.

3. Disposal to nearby sewer: Connects to communal treatment plant by a system of small dia sewers

Basic diff: SBS vs conventional

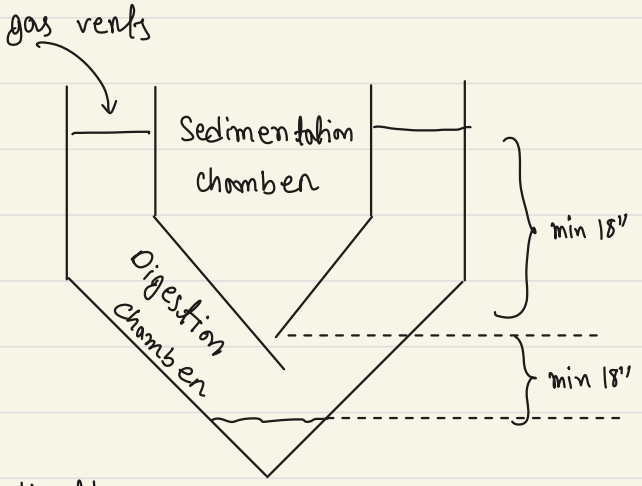
1. Incorporation of septic tank
2. Liquid sewage flows from septic tank into system of small bore pipe then into communal treatment plant
3. Houses w/ existing septic tank can directly connect to SBS network; while new conn. reqs septic tank for connectn

Technical adv. over conventional:

1. Reduced sewer size due to attenuation of flow at tank
2. No self cleansing vel as less solids; hence lower grade can be provided
3. Less chance of blockage as low solid
4. Less area to be excavated
5. Rapid construction
6. Solid handling at secondary trtmnt plant is minimal.

Imhoff tank:

Mechanism of solid removal:



1. Water flows at a lower velocity. As a result, gravity action kicks in and sedimentation occurs.
2. The bottom of the sedimentation chamber has 5V:4H slope, thus settled materials passes into the digestion chamber through this overlapping slots.
3. The slots are overlapped in such way allowing one-way exit only (no vertical clear path into sedimentation chamber from bottom.
   As a result, gases generated there cannot mix back into the effluent of sedimentation chamber which remains clear.

Basic diff in operating principle vs septic tank

1. Incoming sewage is not allowed to get mixed with generated sludge.
2. Effluent is not allowed to carry w/ it large amount of sludge.
3. Effluent remains not septic
5. Bubbling of gases don't get mixed w/ effluent

Mechanism of Dissolved Air flotation (DAF)

1. wastewater & air are pressurized up to 3-5 atm in a chamber.
2. They are then released into a tank that is open to atm.
3. This release in pressure forms micro bubbles which start floating upward.
4. The bubbles are entangled w/ oil and other small solid causing them to form a layer at the top
5. A skimmer collects this layer.

Advantages of DAF over simple aeration

1. More efficient
2. Less hydraulic retention time
3. Higher quality fat recovered
4. Less odor problem
5. Not affected by thermal conditions
6. Higher solid conc. in sludge

Phase of bacterial growth most desirable:

Most desirable is declining growth phase; even though in log phase bacteria eat the fastest!

1. In log phase, bacteria requires ample of food supply, however we want low conc. waste
   In declining growth phase, bacteria has to fight w/ each other and consume the last source of food (waste)

2. In log growth phase, bacteria has high energy preventing their flocculation, however, in declining phase, they tend to stay stable and accumulate forming a slime scum layer at top

F/M	Phase	Waste removal	Biomass settling
V. high	Log growth	V. good	Poor
moderate	Declining	Good	Good
Low	Stationary	moderate	v good
V. Low	Death phase	Negative	Autolysis

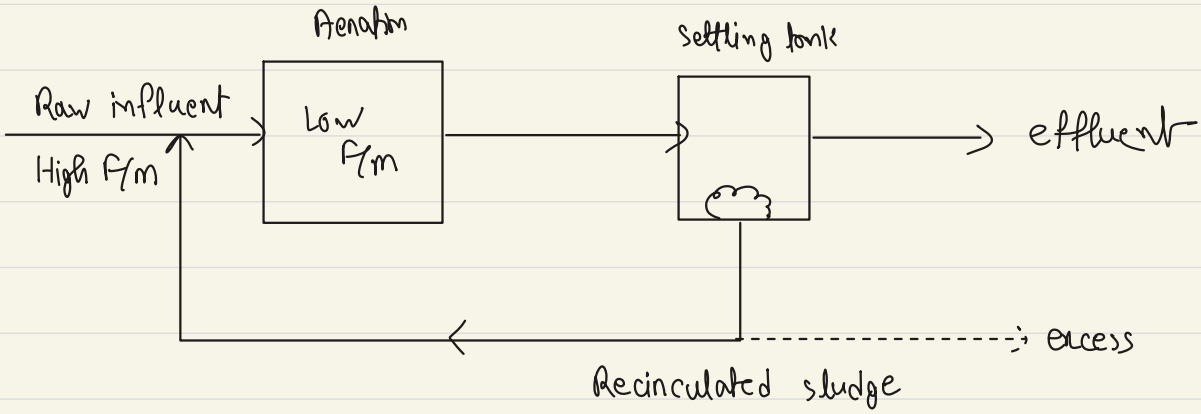
Significance of F/m on activated sludge process

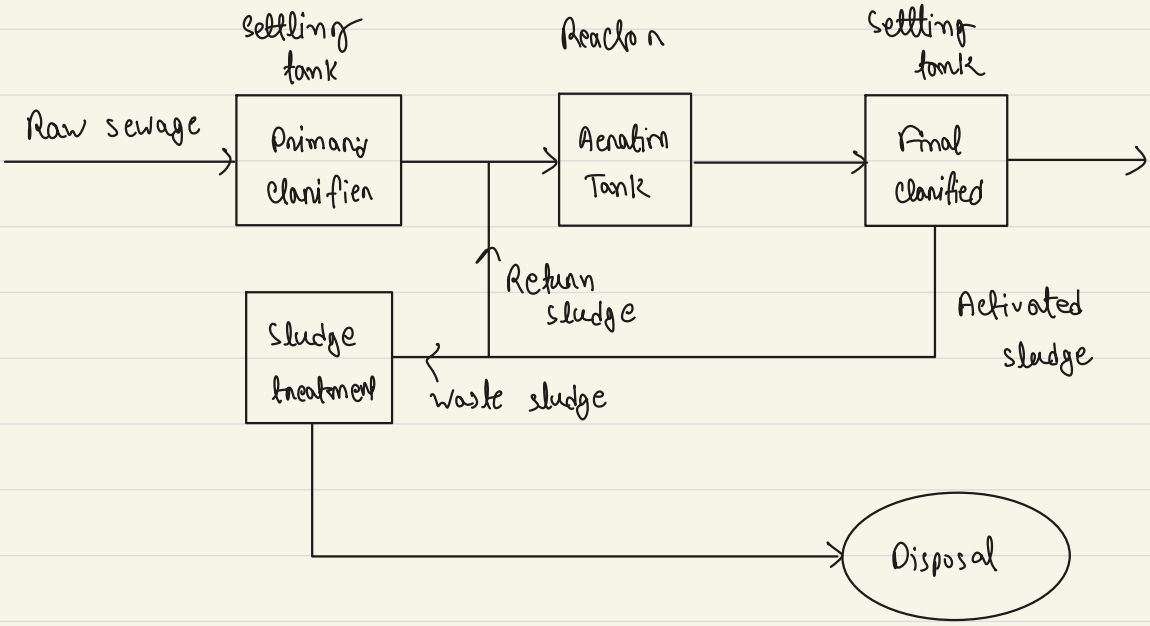
At high F/m ratio:

1. Exponential growth phase ← excess food
2. Although high metabolism rate (and high oxidization of organic matter), bacteria are in dispersed state and refuse to settle out by gravity.
3. As a result, effluent remain in high concentration of micro-org which cannot be separated in the settling tank for re-circulation back into primary clarifier
4. Produces low BOD removal eff.

At low F/m ratio:

1. Overall, a decaying / declining growth phase.
2. Although F/m gets high initially when influent and micro-org. are mixed, they are reduced and result in a near starvation situation.
3. If aeration continues, then they auto-oxidizes through auto-lysis or re-synthesis.
4. Bacteria starts to save energy by reducing movement and resulting in a floc which gets settled by gravity. This stage happens after metabolism nearly completes
5. Results in high BOD removal eff.





Schematic diagram of Activated sludge Process

Trickling filter:

P310/ $C_i = 150$ mg/L

Soluble BOD_5:

Influent = 0.65×150
= 97.5 mg/L

Effluent: $97.5(1-0.9)$
= 9.75 mg/L

Suspended solids:

$\frac{BOD_5}{TSS} = 0.5 \rightarrow BOD_5 = 0.5 \times 30$
$= 15$ mg/L

∴ Total eff. BOD = 15 + 9.75 = 24.75 mg/L

Efficiency = $\frac{150 - 24.75}{150} = 83.5\%$

Estimation of effluent BOD by velz formula:

$$C_e = \left(\frac{C_i + nC_e}{1+n}\right) e^{-KD} \quad ; \quad K = 0.175\ ft^{-1} \quad \text{low rate fil}$$

$$0.1505\ ft^{-1} \quad \text{high} \longrightarrow$$

$$D \rightarrow ft$$

P813/ $D = 2m = 6.56\ ft$

$n = 1.25$

$C_i = 170\ mg/L$

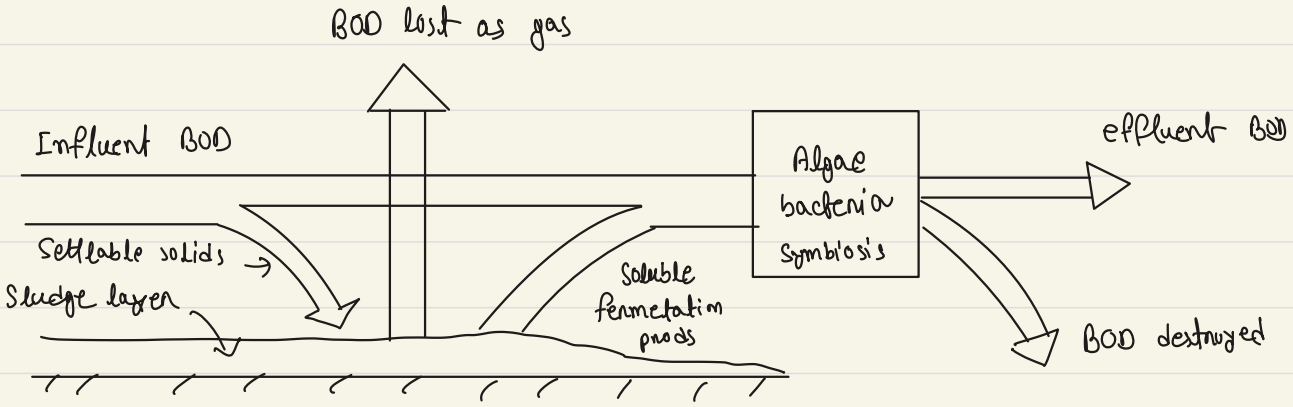
$$\therefore C_e = \left(\frac{C_i + nC_e}{1+n}\right) e^{-KD}$$

$$= \left(\frac{170 + 1.25 \times C_e}{1+1.25}\right) e^{-0.175 \times 6.56}$$

$$\Rightarrow C_e = 29.1\ mg/L$$

$$Eff = 82.9\ \%$$

Principal pathways of BOD removal in facultative pond:



2. Sedimentation: Solid organic matters sink to the bottom and thereby BOD is lost
2. Symbiosis: Algae receives light from sun and performs photosynthesis; producing O_2, which is used by aerobic bacteria for oxidation. Aerobic bacteria produces CO_2 which is used by algae
3. Fermentation: Anaerobic bacteria towards the bottom of pond digests organic matters & produces gas which escapes resulting in BOD removal

Optimium retention period in anerobic pond:

Five days. why:

i) At 5-day, 70% BOD removal is possible (while 2-day → 50%)
ii) If of 5-day, chance of acting as facultative pond
iii) If lt 5-day,

a. Odon release possibility
b. Frequent desludging interval
c. Poor bacterial quality of end product
d. Below 70% BOD removal

Criteria: i) max BOD removal
ii) Prevent biological transition into facultative
iii) Odon control
iv) Less freq desludging

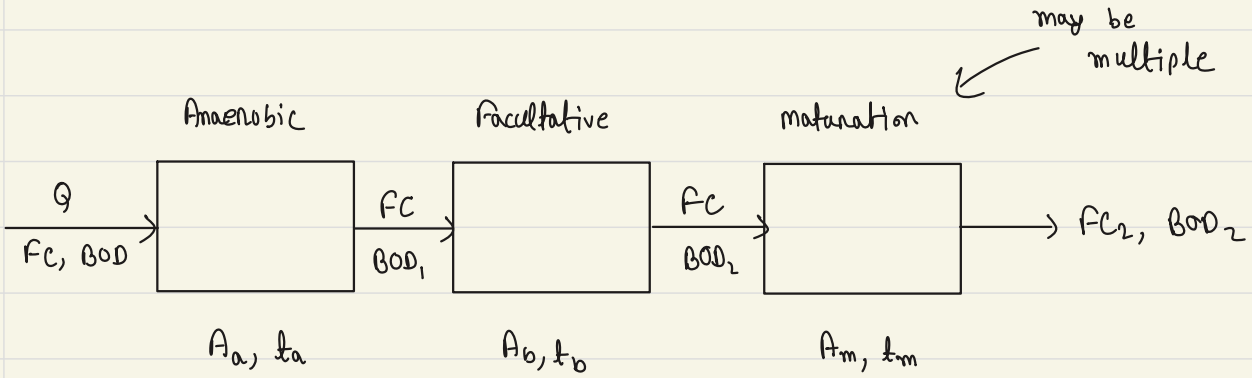
Sources of odon:

1. High volumetric loading rat ($\lambda_v > 400\ g/m^3$)
2. Influent w/ industrial waste; specially if contains sulphate.

Control of odon:

1. Raise pH to about 8; odorous sulphide converts to odorless bi-sulphide ion.
2. Recirculate effluent from facultative or maturation pond in 1:6 (eff. : raw sewage) ratio.

Design of stabilization pond:



Design of anaerobic pond:

$L_i \rightarrow mg/L$; $Q \rightarrow m^3/s$; $V \rightarrow m^3$

$A \rightarrow m^2$

$$\lambda_v = \frac{L_i Q}{V} \rightarrow V = \dots$$

$A = \dots$ [Assume $D = 2-4\ m$]

$t = Q/V$ [from chart]

BOD remaining = $\dots$

Design of facultative pond:

$$\lambda_s = \frac{10 L_i Q}{A} \rightarrow A = \dots$$

$t = \frac{AD}{Q}$ [Assume $D = 1-1.5\ m$]

BOD remaining = $\frac{L_i}{1 + Kt}$

Design of maturation pond:

Assume load per pond = → 75% $[\lambda_s = 0.75\,\lambda_s]$

$$t_m = \frac{10\,L_i\,D}{\lambda_s}$$ [Assume $D = 1-1.5\,m$]

$$N_e = \frac{N_i}{(1+k_b t_a)(1+k_b t_p)(1+k_b t_{mi})^n}$$

→ find t_{mi} for $n \in N$ until $t_{mi} \leq t_m$

$t = \frac{AD}{Q}$ → $A = \dots$

P362/ $Q = 2000\ m^3/d$ FC < 1000/100 ml

$BOD_i = 400\ mg/l$ $k = 0.3\ d^{-1}$

$t = 20°C,\ 25°C$ $K_b = 2.6\ d^{-1}$

$N_i = 10^8 / 100\ ml$

Anaerobic pond: 20°C

$\lambda_v = 300\ g/m^3\text{-}d$

$\Rightarrow 300 = \frac{L_i Q}{V}$

$\Rightarrow 300 = \frac{400 \times 2000}{V} \Rightarrow V = 2667\ m^3$

$\Rightarrow A = \frac{V}{D}$

$\therefore A = \frac{2667}{3} = 889\ m^2$

$t_a = \frac{V}{Q} = \frac{2667}{2000} = 1.3$ days

$BOD = 400(1 - 0.6) = 160\ mg/L$

Facultative: (20°C)

$\lambda_s = \frac{10 L_i Q}{A} \Rightarrow 259 = \frac{10 \times 160 \times 2000}{A}$

$\Rightarrow A = 12648\ m^2$

$t_f = \frac{V}{Q} = \frac{12648 \times 1.5}{2000} = 9.5$ days

$BOD = \frac{L_i}{1 + kt} = \frac{160}{1 + 0.3 \times 9.5} = 41.6\ mg/L$

maturation pond: (25°C)

$$t_m = \frac{10 L_i D}{\lambda_s}$$

$$= \frac{10 \times 0.5 (1.06) \times 1}{0.75 \times 350} = 3.05 \text{ days}$$

[For the purpose of following, take 50%]

$$N_e = \frac{N_i}{(1 + K_b t_a) + (1 + K_b t_f)(1 + K_b t_m)^n} \quad ; \quad N_e = 1000 \text{ mg/l}$$

$K_b = 2.6 \times 1.19^{25-20}$

$= 6.2$

For $n = 1$, $t_m = 30$ d

$n = 2$, $t_m = 2.02$ d

∴ 2 tanks

$t_{m_1} = 3$ d → $A_{m_1} = 6000$ m²

$t_{m_2} = 3.05$ d → $A_{m_2} = 6100$ m²

Coliform check: $N_e = \frac{N_i}{(\text{---})} = 480 < 1000$ (OK)

Anaerobic & aerobic process for sludge digestion:

Anaerobic:

Happens in close, airtight containers called sludge digester (anaerobically)
Process is split into two stage:

i) Acid former: Facultative bacteria turns complex organics (e.g., fats) into simpler compounds or organic acid

ii) Gas former: Obligate anaerobics takes those organic acid and turns into CH_4 & CO_2.

Preferrable because:

i) volume reduction: turns solid into liquid & gas,

Volatile mats into 65% – 85%
TSS reduction 45% – 55%

ii) Biogass: Generated CH_4 may be used for fuel while solid work as soil conditioner

iii) Upto 99% pathogen reduction when 35°C over 30d

Aerobic: Happens in open space in presence of O_2.

Chars: (i) Higher volatile mats reduction than anaerobic

(ii) Simpler; low operational hassles, low capital cost, easy to construct

(iii) Lower BOD at top layer (supernatant water)

Metabolic pathways:

