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

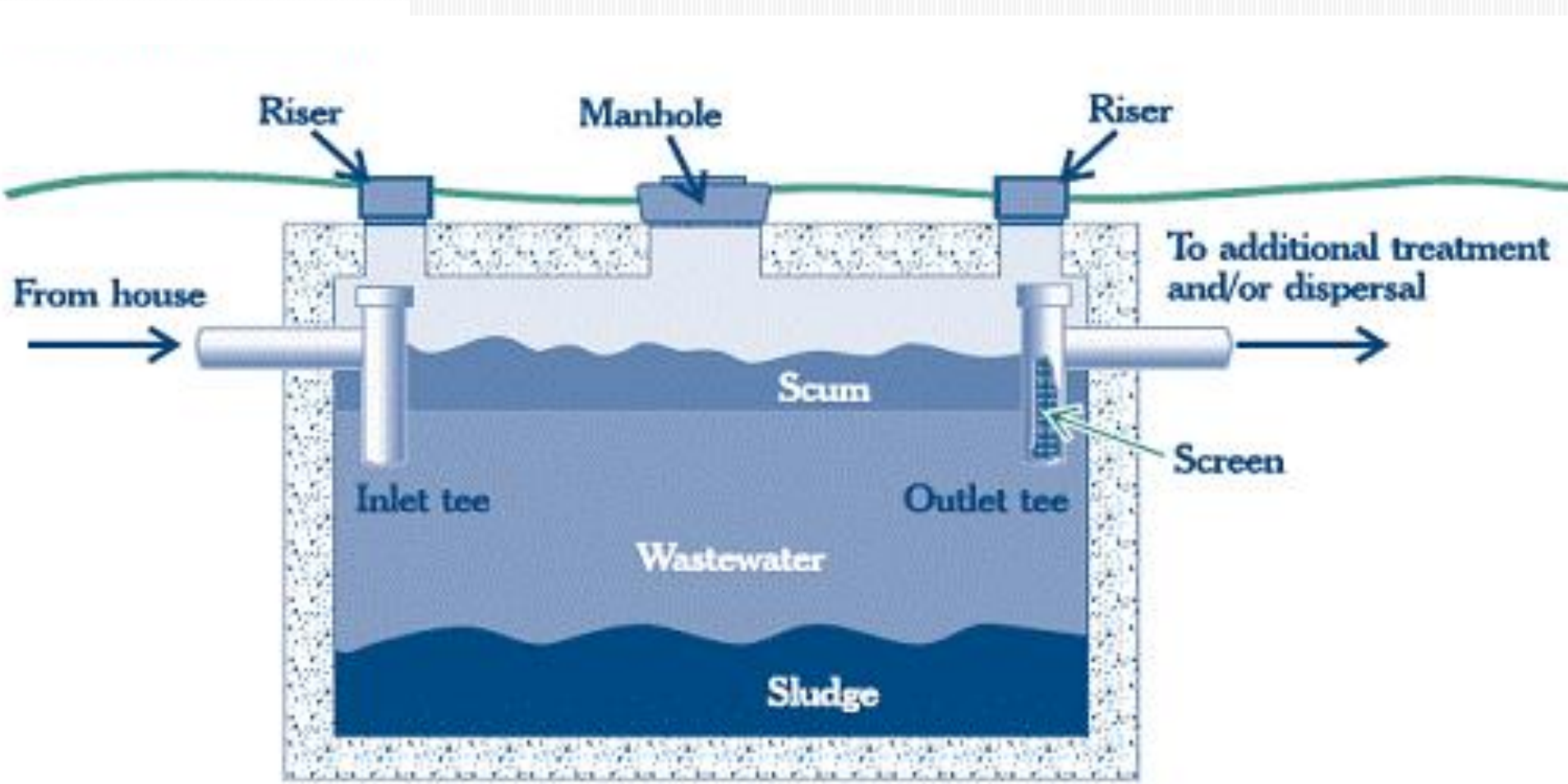
- Scope of use: Wherever the conventional sewerage system has not been feasible due to technical or economic reasons.

- 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

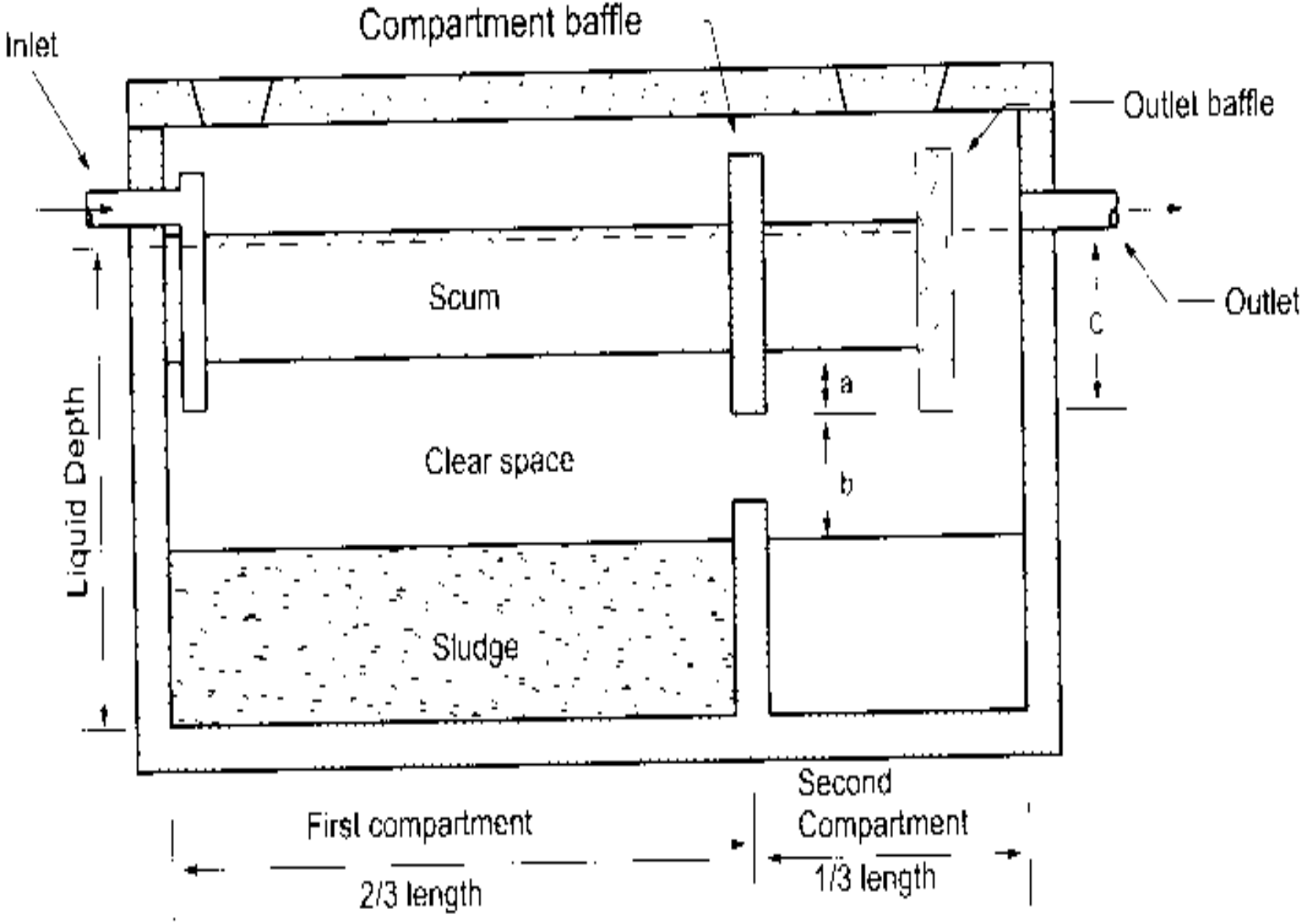
- Settleable solids and partially decomposed sludge settle to the bottom of the tank and gradually build up.
- A scum of light-weight material including fats and greases rises to the top.
- The partially treated effluent is allowed to flow through an outlet structure just below the floating scum layer.
- 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.. $\mathbf{V_{sc} = 0.4\ V_{sl}}$ **..... (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:

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

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:

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

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

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

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

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

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

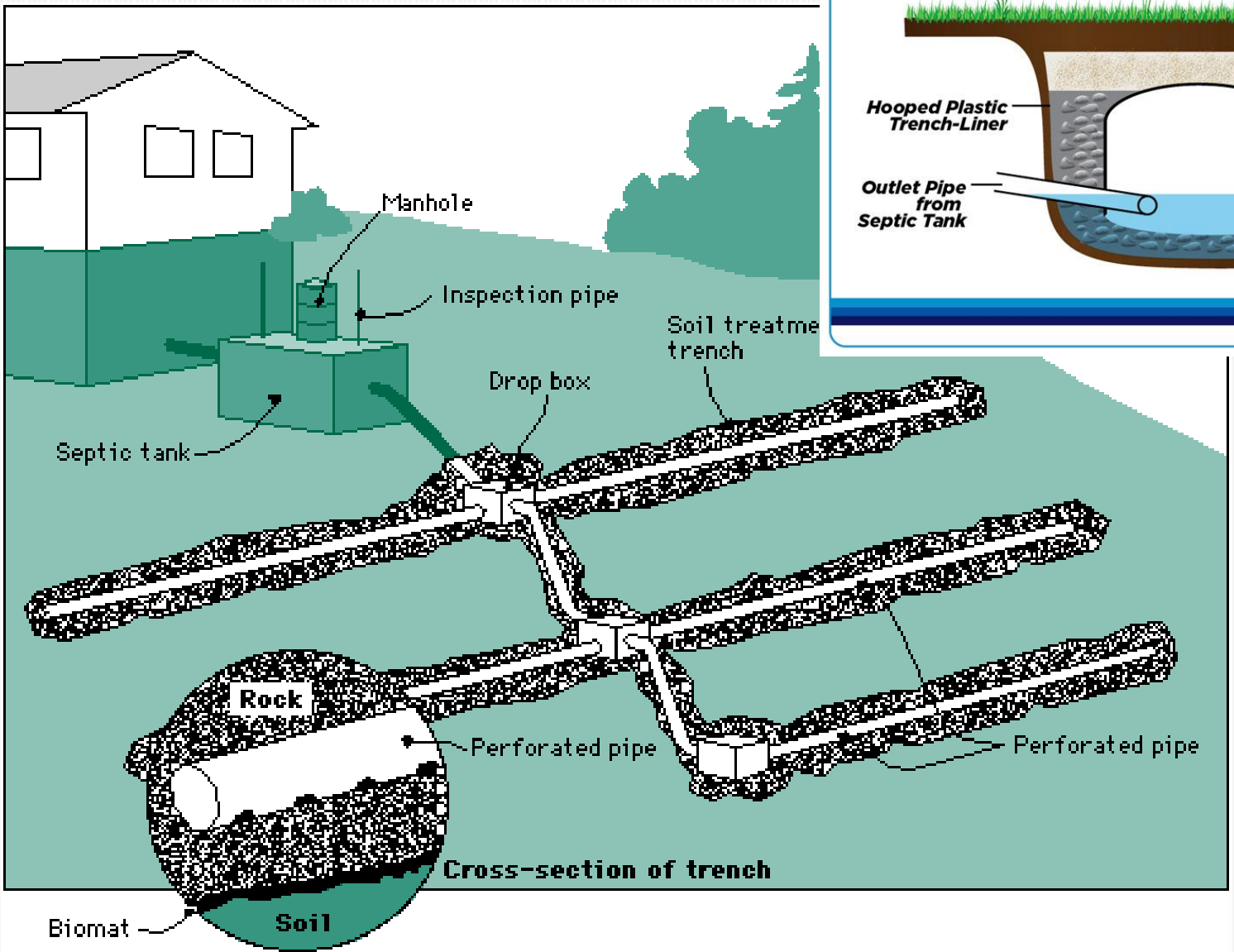
(a) Absorption trenches

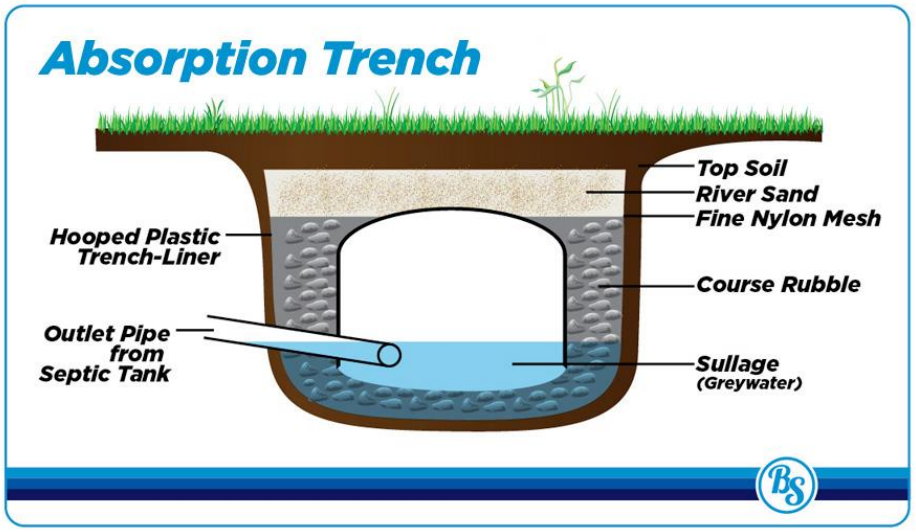
- Effluent flows by gravity from septic tank through a closed pipe and distribution box into perforated pipes in trenches.

- Bacteria in the soil help to purify the effluent.

Disposal of Tank Effluent

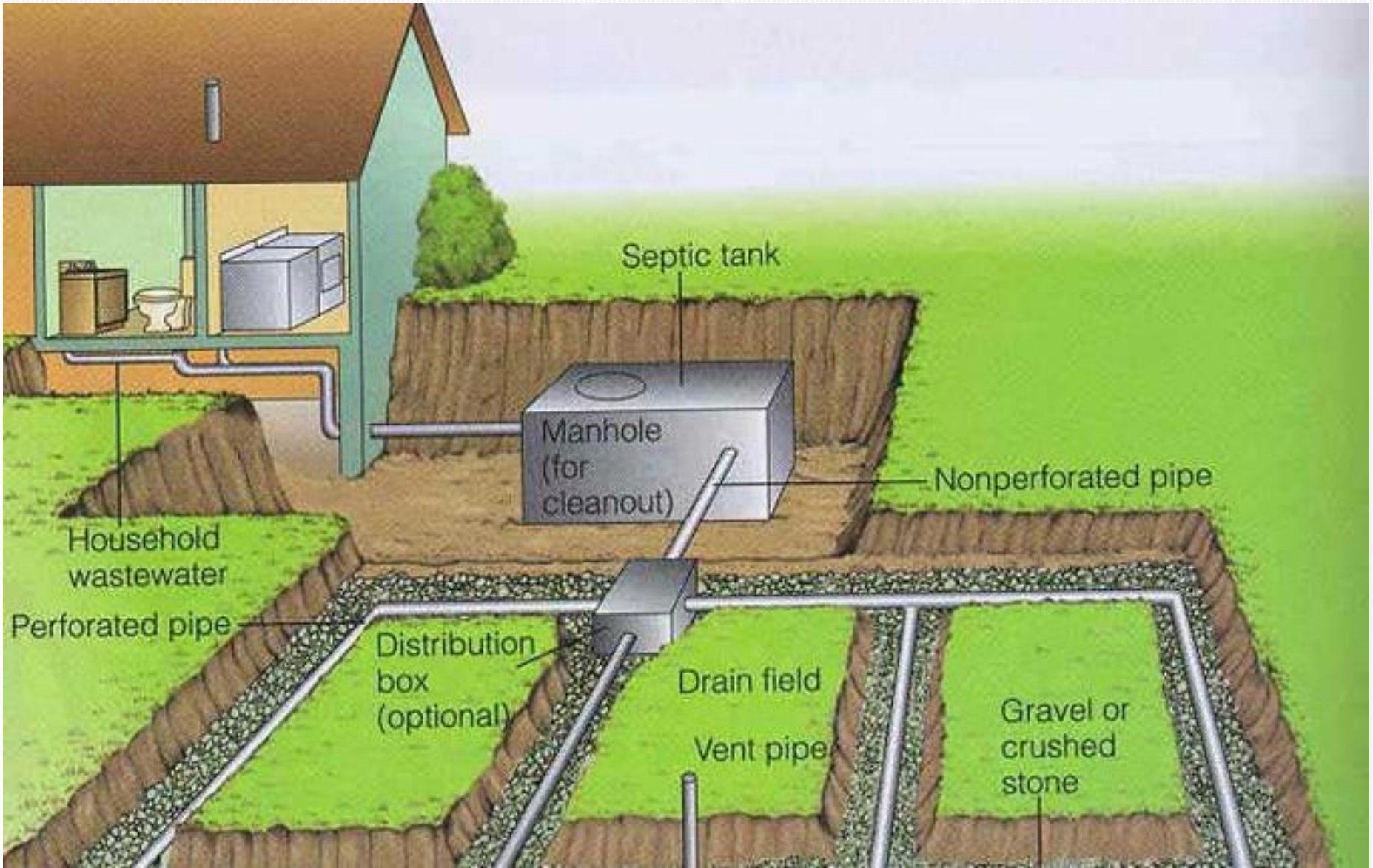
(a) Absorption trenches





Disposal of Tank Effluent

(a) Absorption trenches



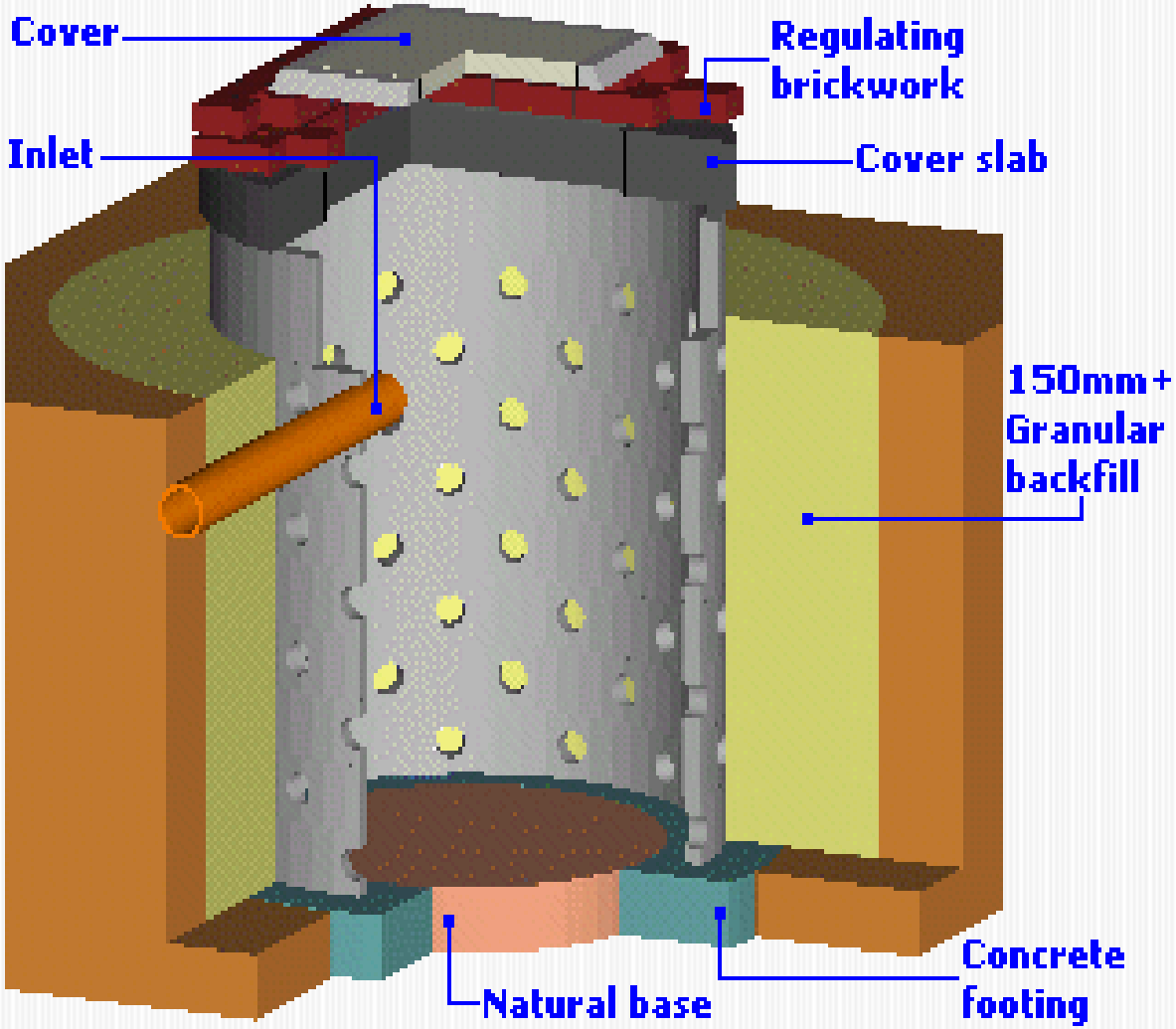
Disposal of Tank Effluent

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

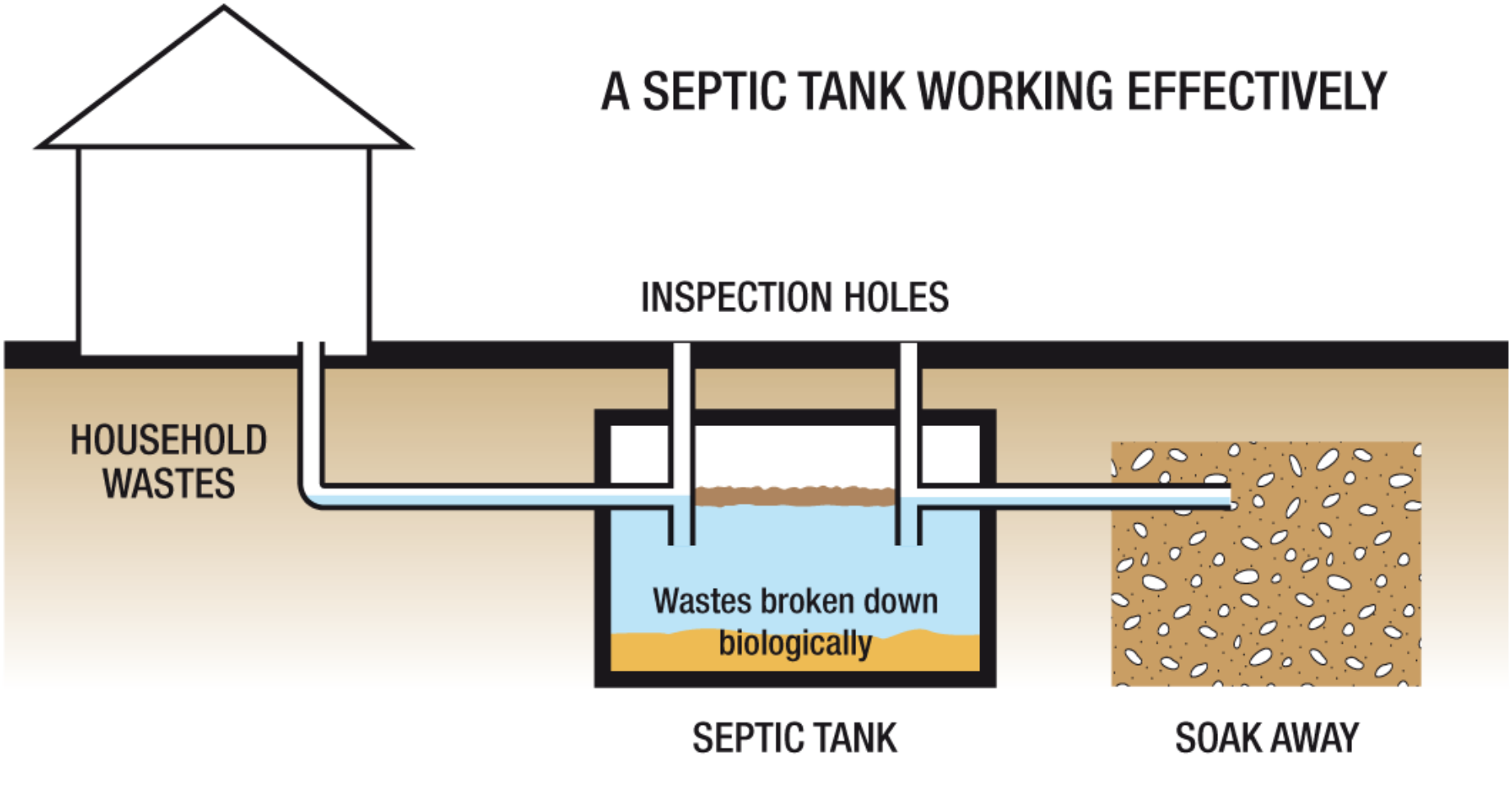
b) Absorption pits or soakage pits (Soakways)





Disposal of Tank Effluent

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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.

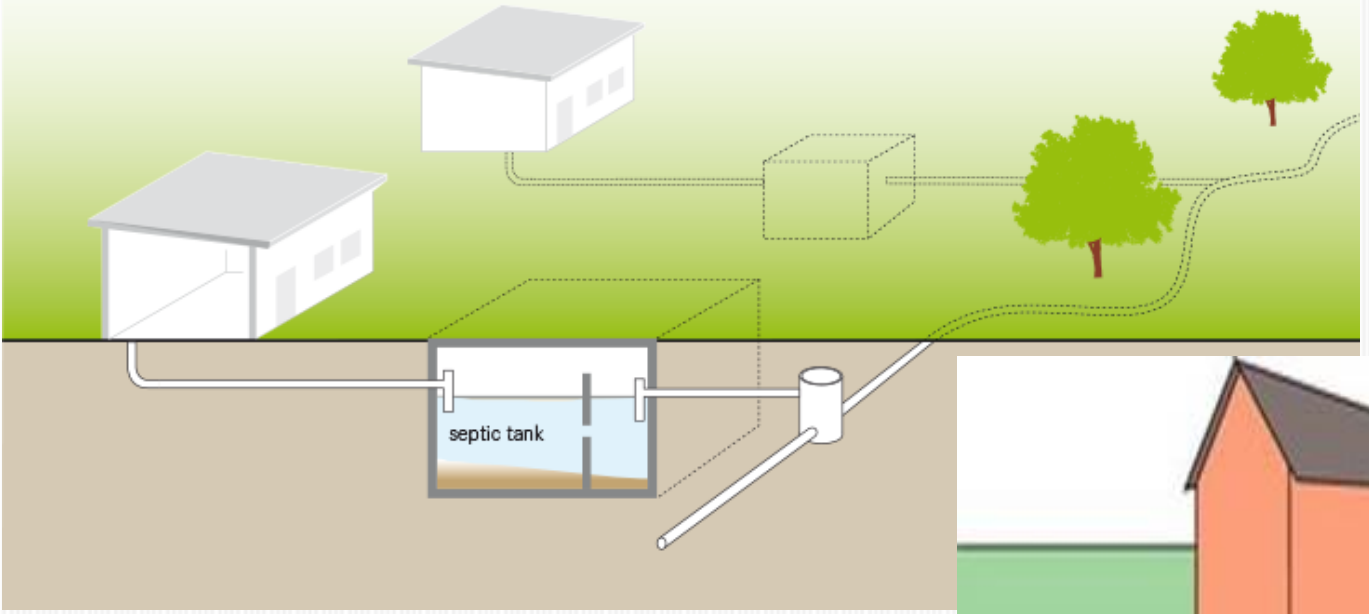
Disposal of Tank Effluent

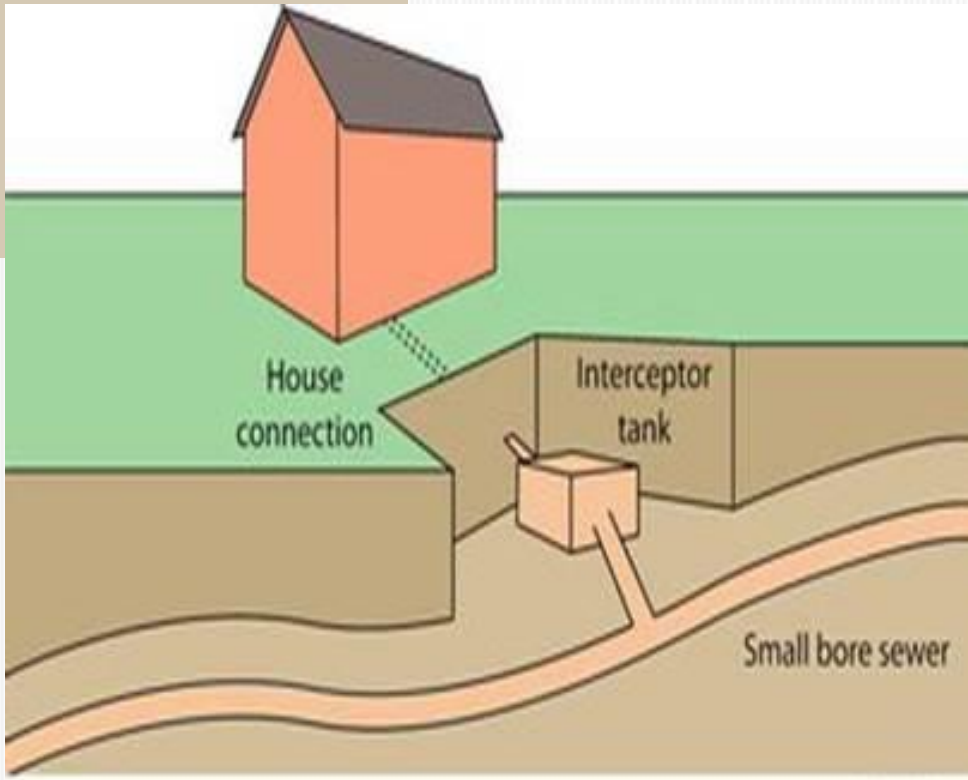
c) Small bore solid-free sewer

- 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^{o}C

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.