ES 200: Environmental Studies

Sewage Treatment and Sludge Disposal

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Learning Objectives

- To understand sewage generation and typical characteristics
- To understand the conventional sewage treatment methods
- To know about sewage sludge generation and disposal
- To get information on various land treatment methods
- To learn about working of on-site sewage treatment system (i.e., septic tank)

Introduction to Sewage Generation

- Sewage is the wastewater produced as a result of water use for various daily activities including cooking, drinking, bathing, flushing etc.
- Sewage is considered a mixture of grey (bathrooms, kitchen sink, laundry) and black water (toilet)
- Disposal of domestic sewage from cities and towns is the biggest source of pollution of water bodies in India
- The wastewater thus produced is contaminated with various organic and inorganic pollutants
- Proper treatment is required before discharging the sewage into surface or sub-surface water bodies
- Due to scarcity of fresh water, sewage should be recycled after adequate treatment

Sewage generation and treatment in Class I cities and Class II towns (2001 population basis) (https://cpcb.nic.in/status-of-stps/)

City category & population	Number of cities	Sewage generation, MLD	Installed sewage treatment capacity, MLD	Capacity gap in cities having STPs, MLD (A)	Sewage generation in cities having no STPs, MLD (B)	Total capacity gap, MLD (A+B)	Planned treatment capacity, MLD
Class I cities having more than 10 lac population	39	13503	4472 (In 29 cities)	6135	2896	9031	1549
Class I cities having 5 to 10 lac population	32	3836	485 (In 13 cities)	1293	2058	3351	123
Class I cities having 2 to 5 lac population	119	4807	768 (In 34 cities)	804	3235	4039	4
Class I cities having 1 to 2 lac population	224	4018	322 (In 36 cities)	373	3323	3696	32.5
All the above Class I cities together	414	26164 (100%)	6047(23.1%) (In 112 cities)	8605 (32.9%)	11512 (44%)	20117 (76.9%)	1708.5 (6.5%)
Class II towns having 0.5 to 1 lac population	489	2965 (100%)	200 (>143*) (4.8%) (In 22 towns)	Nil	2822 (95.2%)	2822 (95.2%)	34.1 (1.15%)
All Class I cities and Class II towns	893	29129 (100%)	6190 (21.3%)	8605 (29.5%)	14334 (49.2%)	22939 (78.7%)	1742.6 (6.0%)

**Estimated sewage of the cities having STPs*

Typical Characteristics of Sewage

Constituent	Concentration (mg/l)		
	Strong	Medium	Weak
Total Solids	1200	720	350
BOD_5	400	220	110
COD	1000	500	250
TOC	290	160	80
Nitrogen (as N)	85	40	20
Phosphorous	15	8	4
Alkalinity (as $CaCO_3$)	200	100	50
Chlorides	100	50	30

Sewage Treatment

- **It is assumed that 75 – 80% of the total water supplied is generated as wastewater.**

- **Various stages in a typical sewage treatment plant includes**

➢ **Preliminary treatment**

✓ **Screening, grit chamber**

➢ **Primary treatment**

✓ **Sedimentation**

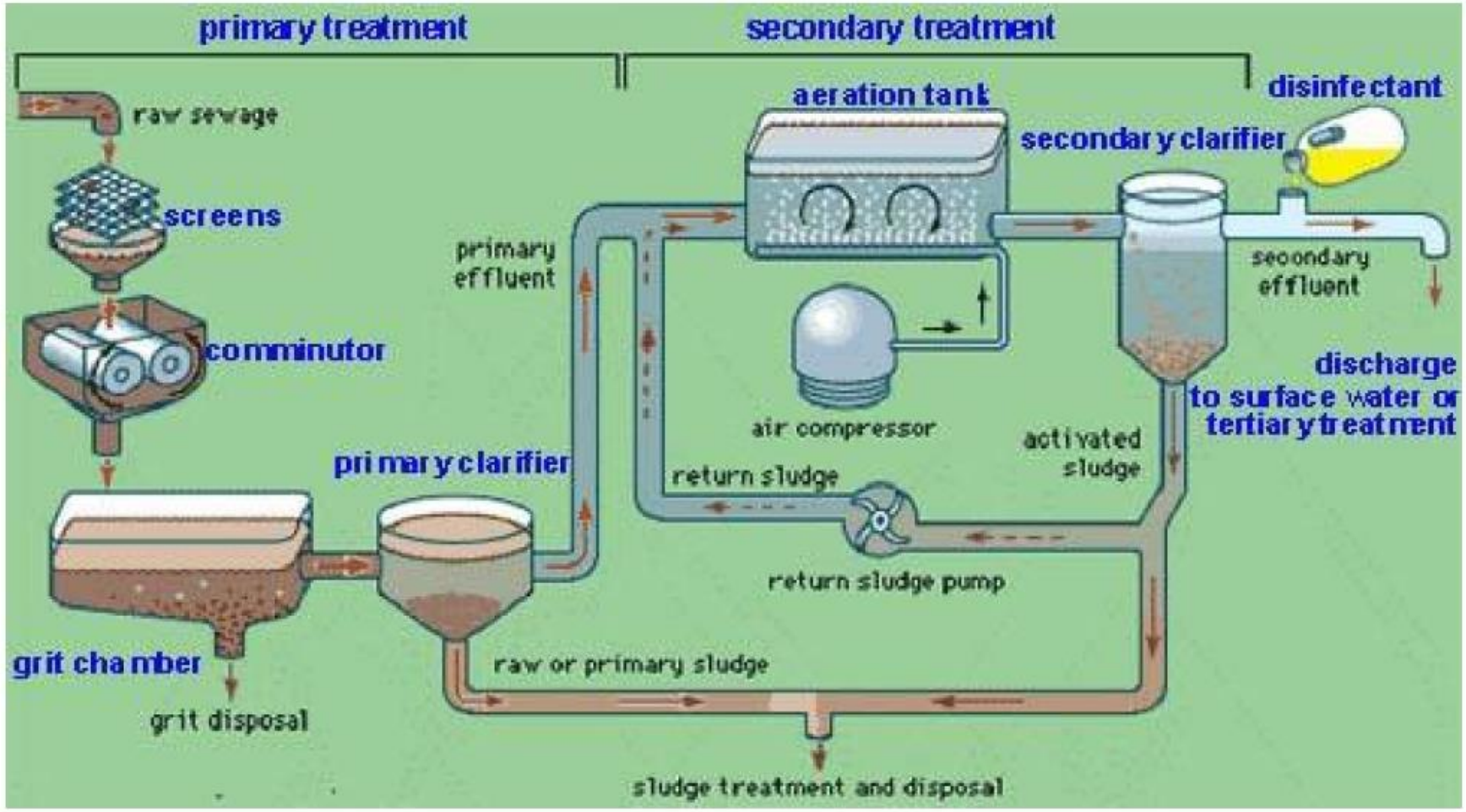
➢ **Secondary (or biological) treatment**

✓ **Biological processes**

➢ **Final or advanced treatment**

Schematic of Sewage Treatment Plant

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.thewatertreatments.com%2Fwastewater-sewage-treatment%2Fprimary-water-treatment-sewage-treatment-waste%2F&psig=AOvVaw31mNC_oJtt94oFZUv2_fqp&ust=1669012982176000&source=images&cd=vfe&ved=0CA0QjRxqFwoTCNjs14eUvPsCFQAAAAAdAAAAABAE



Biological Treatment Process

- **The major aim of secondary treatment (biological processes) is to remove at least 85% BOD and total solids from the raw sewage.**

- **Biological systems use micro-organisms to remove organic pollutants from wastewater and these organisms consume organics as food and convert them in harmless compounds.**

- **Two most common biological systems are:**

✓ **Trickling filter : Fixed or attached growth Process**

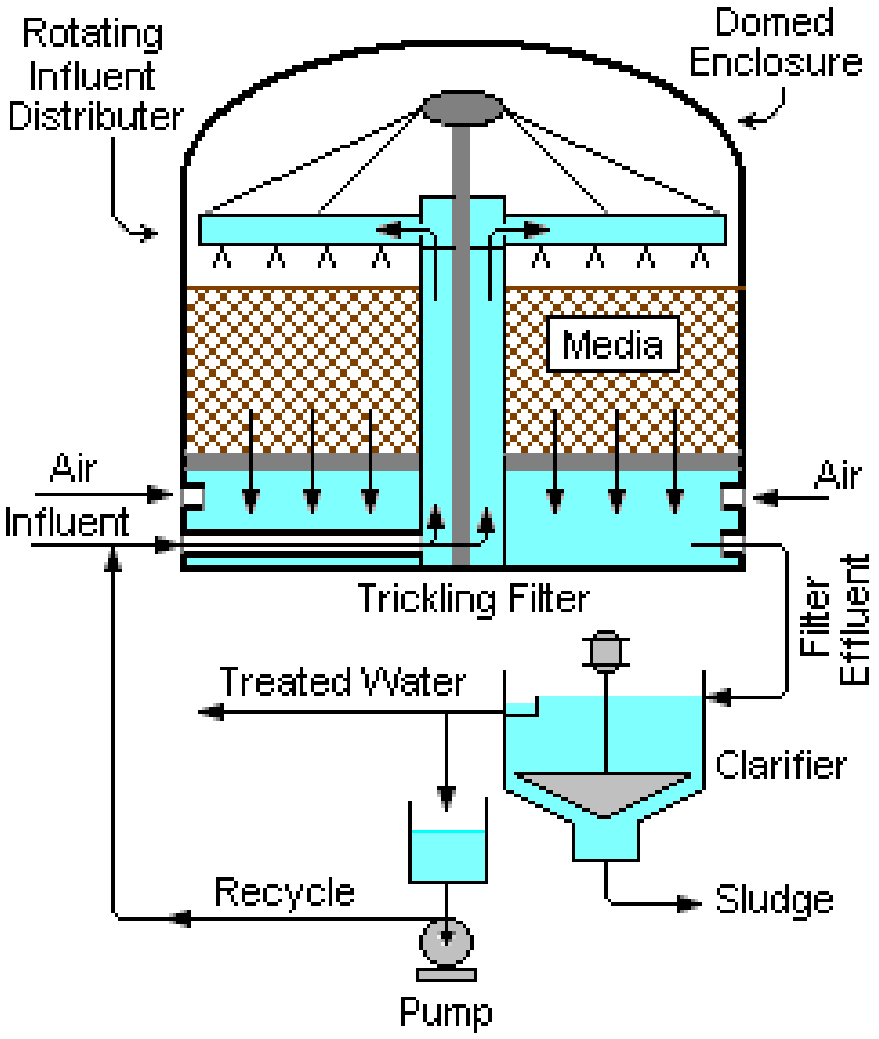
✓ **Activated sludge process: Suspended growth Process**

Trickling Filter

- **Trickling filter is a fixed-growth aerobic system.**
- **The wastewater is sprinkled over the surface by means of spray nozzles or rotary distributors.**
- **The percolating sewage is collected at the bottom of the tank through under-drainage system.**
- **The collected wastewater is conveyed to the secondary clarifier.**
- **A trickle filter are circular (diameters up to 60 m) in shape.**
- **Wastewater recirculation is suggested:**
  - **To maintain flow rate during periods of low flow,**
  - **To improve the pollutant removal efficiency**

Tricking Filter

(https://upload.wikimedia.org/wikipedia/commons/thumb/e/e0/Trickle_Filter.svg/264px-Trickle_Filter.svg.png)



Trickling Filter……

- **Recirculation**
  - ✓ Recirculation ratio (R) = Q_R/Q
    where Q_R = recirculated flow rate, Q = raw sewage flow rate
  - ✓ R is generally in the range of 0 to 3.0.

- **Hydraulic load**
  - ✓ The rate at which the wastewater flow is applied to the filter surface is called hydraulic load.
  - ✓ Hydraulic load = $(Q + Q_R)/A_s$
    A_s = trickling filter surface area (plan view)
  - ✓ A typical value for a high rate trickling filter is 20 $m^3/m^2.d$.

- **Organic (BOD) load**
  - ✓ The rate at which organic material is applied to the trickling filter is called organic load or BOD load ($kg/m^3.d$).
  - ✓ For high rate trickling filters, its value is 0.5 $kg/m^3.d$.
  - ✓ Organic load = (Q x BOD)/V, V = Volume of trickling filter bed

Problem

- **A trickling filter has a diameter of 18 m and a depth of 2 m. It is operated with a direct recirculation ratio of 1.5 and the influent sewage flow rate is 2.5 Mld. Influent BOD to the primary tank is 210 mg/L and the BOD removal efficiency in that tank is 30%. Compute both the hydraulic load and the organic load on the trickling filter.**
- **Solution: Compute surface area of tank = $A_S = \pi.d^2/4 = 254.5\ m^2$**

  Volume of trickling filter = Area*depth = 254.5*2 = 509 m^2.

  Recirculated flow rate = $Q_R = R.Q = 1.5*2.5 = 3.75$ Mld

  Total flow = $Q + Q_R = 6.25$ Mld = 6250 m^3/d

  Hydraulic load = $(Q+Q_R)/A_s = 25\ m^3/m^2.d$

  Organic load = Q.BOD/V

  BOD in trickling filter = 147 mg/l

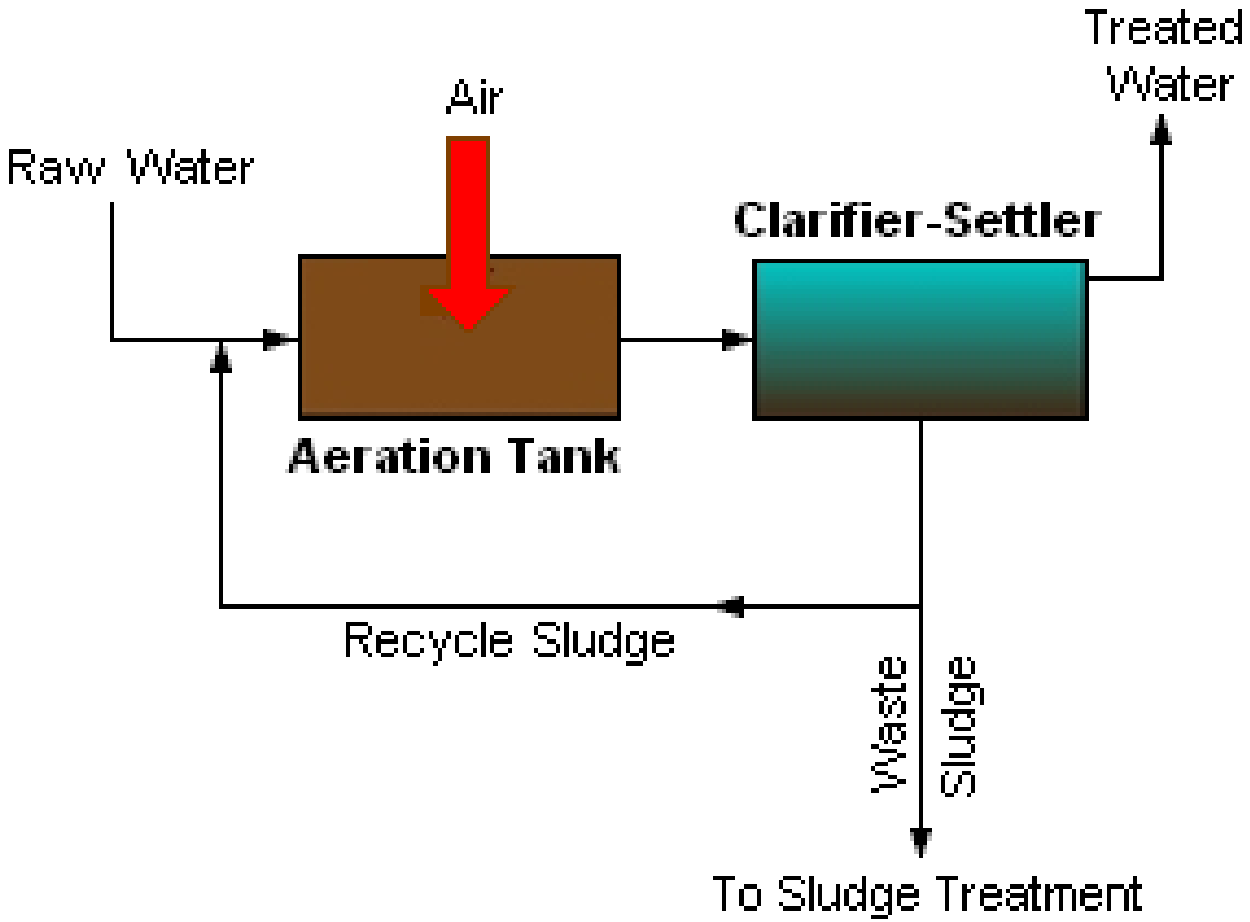
  Organic load = 2.5*147/509 = 0.72 $kg/m^3.d$

Activated Sludge Process

- **The activated sludge treatment is a suspended growth aerobic system.**
- **In this process, sewage effluent from primary sedimentation tank is mixed with activated sludge and aerated with air for 4 – 8 h.**
- **The combination of activated sludge and wastewater in the aeration tank is called the mixed liquor.**
- **Large concentration of aerobic microorganisms form an active suspension of biological solids called activated sludge.**
- **In the aeration tank, micro-organisms oxidize the organic matter.**

Schematic of Activated Sludge Process

(http://image.absoluteastronomy.com/images/encyclopediaimages/a/ac/activated_sludge_1.png)



Problem

- **Sewage is to be aerated in an activated sludge tank. The flow rate is 3 Mld and the primary effluent has a 5–day BOD of 120 mg/l. The MLSS is to be kept at 2000 mg/l and the F/M ratio is to be 0.3. If the SWD is 5.0 m and the tank is to be 20 m long, what should be its width.**
- **Solution: $F/M = (Q.BOD_5)/(V.MLSS)$**

  $V = (3000*120)/(2000*0.3) = 600\ m^3$

  $V = L*B*H = 20*B*5$

  $B = 6\ m$

Sludge Generation From Different Stages in Wastewater Treatment Plant

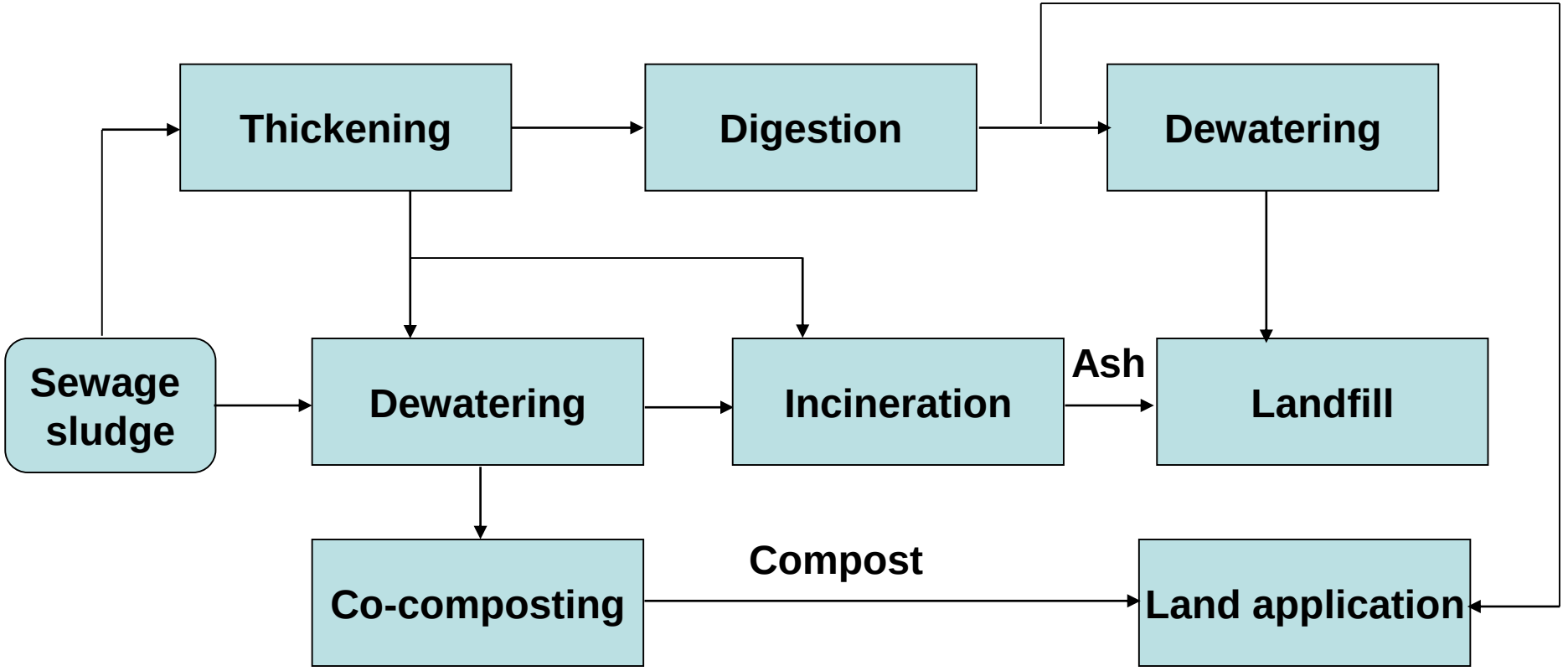
(Girovich, 1996)

Item	Primary	Secondary	Advanced
Volume generated (L)	2500 – 3500	15000 – 20000	10000
Total solids (%)	3.0-7.0	0.5-2.0	0.2-1.5
Dry biosolids quantity (t/million liters)	0.1-0.15	0.2-0.3	0.02-0.15

Goals For Processing Solids

- **Volume reduction**
- **Removal of pathogens, pollutants and odors**
- **Energy generation or recovery**
- **Production of beneficial use products**

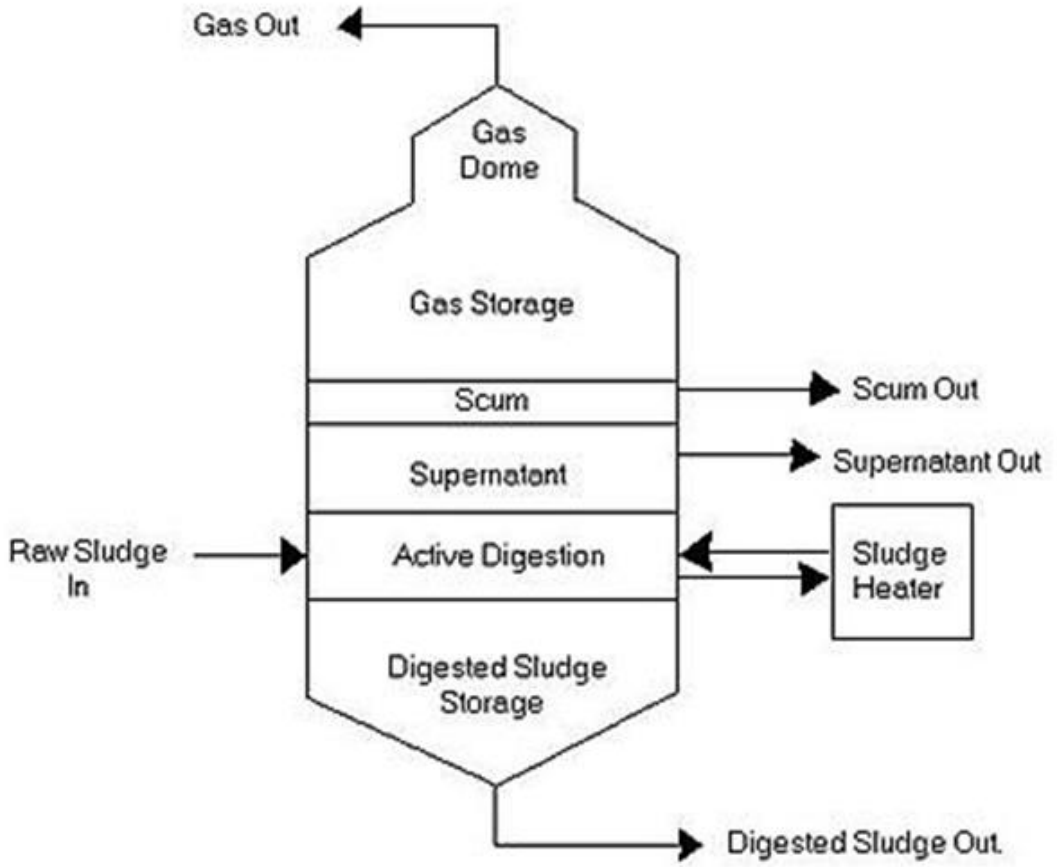
Generalized Sludge Processing Flow Diagram



Two major purpose for treatment:

- ✓ **Volume reduction**
- ✓ **Stabilization of organics**

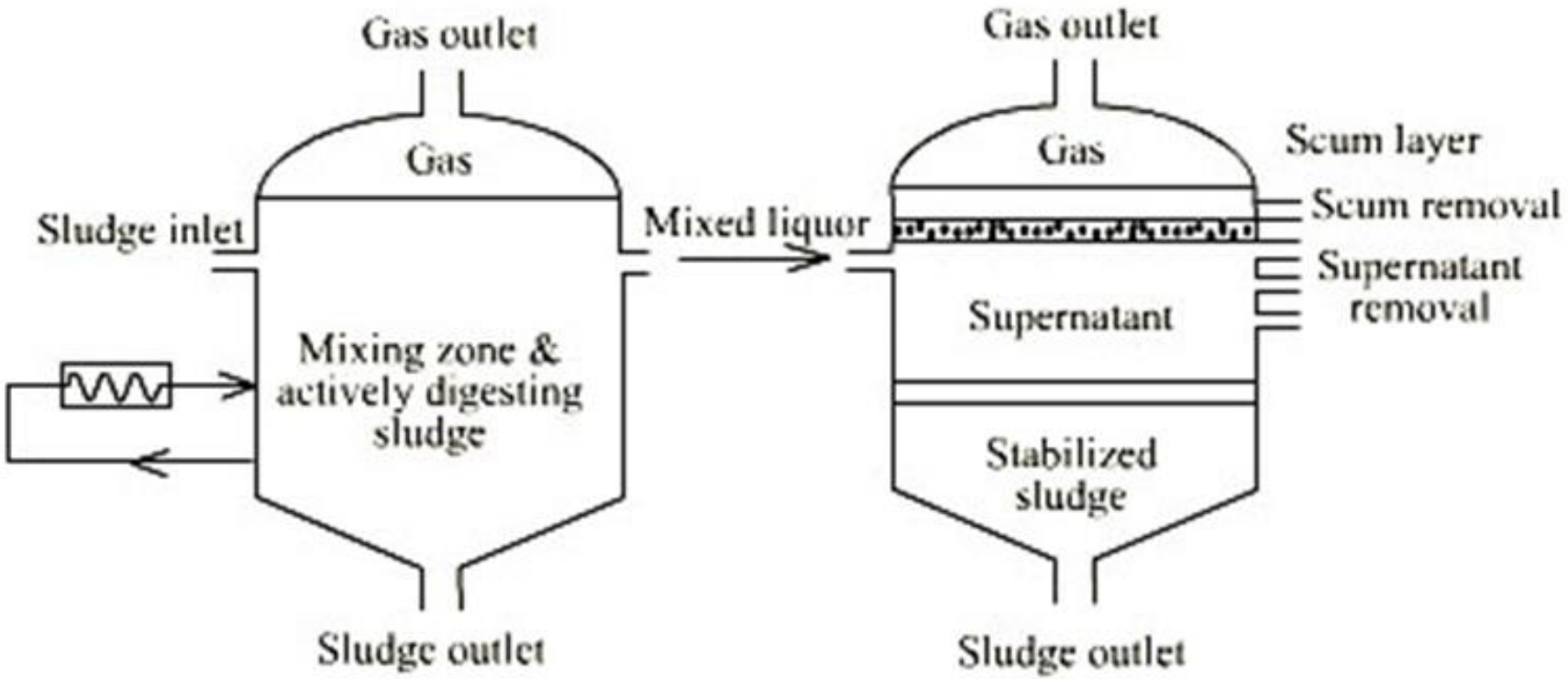
Single Stage, Standard Rate Anaerobic Digester



https://cr2014studyabroad.wordpress.com/daily-topic-updates/anaerobic-digestion-dana/

Two-Stage Anaerobic Digester

https://www.google.com/url?sa=i&url=https%3A%2F%2Fc2biotechnologies.com%2Findex.php%2Fabout%2Ffaqs%2F119-single-and-multi-stage-digesters&psig=AOvVaw0R9lEdL-kOxsivRnBM1sVj&ust=1669012369915000&source=images&cd=vfe&ved=0CA0QjRxqFwoTCNDX0uORvPsCFQAAAAAdAAAAABAE



Anaerobic Digestion Products

- **Digested sludge**

  Stable solid matter, free from pathogens, having reduced volume (~ 1/3 of the original volume)

- **Supernatant liquor**

  Liquid having high BOD (~ 3000 ppm)

- **Gas production and use**

✓ **Gas from the digester contains 65-70% (by volume) of CH_4, 25 – 30% of CO_2. and small amounts of other gases.**

✓ **Typical gas production varies from 0.75 to 1.12 m^3/kg of volatile solids destroyed.**

✓ **The digester gas has a LHV of 22400 kJ/m^3.**

✓ **Digester gas can be used:**

- **As fuel for boiler and IC engines**
- **In cogeneration**

Biosolids Treatment for Beneficial Use

- **Land Application**
- **As an energy resource**
- **As a landfill cover material**

Tertiary Treatment Processes

- **Chemical precipitation**
  - **Phosphorous removal**
- **Nitrification and denitrification process**
  - **Nitrogen removal**
- **Filtration**
  - **BOD and TSS**
- **Land treatment of water**

Land Treatment of Wastewater

- **The primary objective of land treatment can be extended beyond the removal of objectionable compounds from secondary effluent.**
- **The other objectives may include crop growth, irrigation and groundwater recharge.**
- **Three types of land treatment:**

✓ **Slow rate**

  – **Provides best results with respect to tertiary treatment**

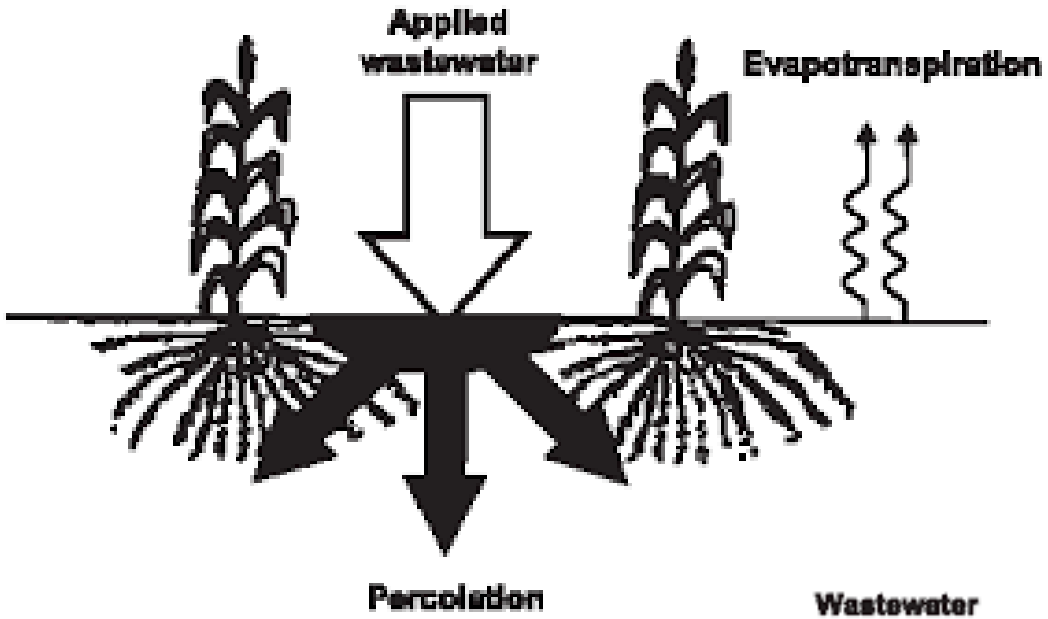
✓ **Rapid infiltration**

  – **Effective for the removal of BOD, TSS and P**

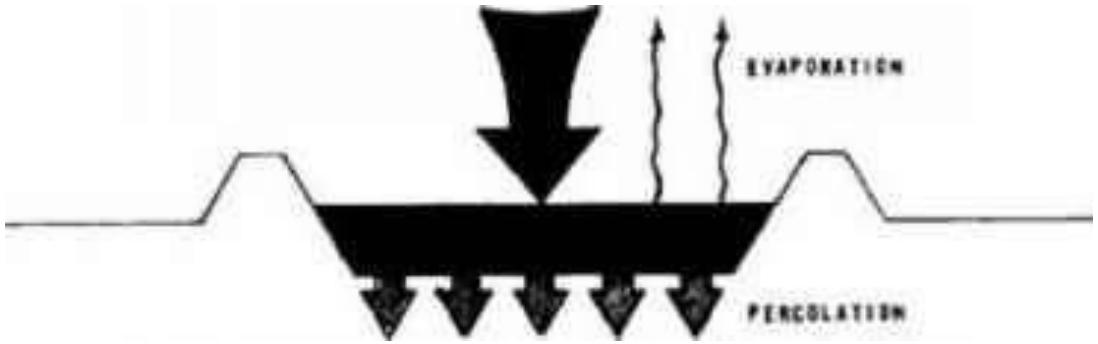
✓ **Overflow rate**

  – **Good removal of BOD and nitrogen**

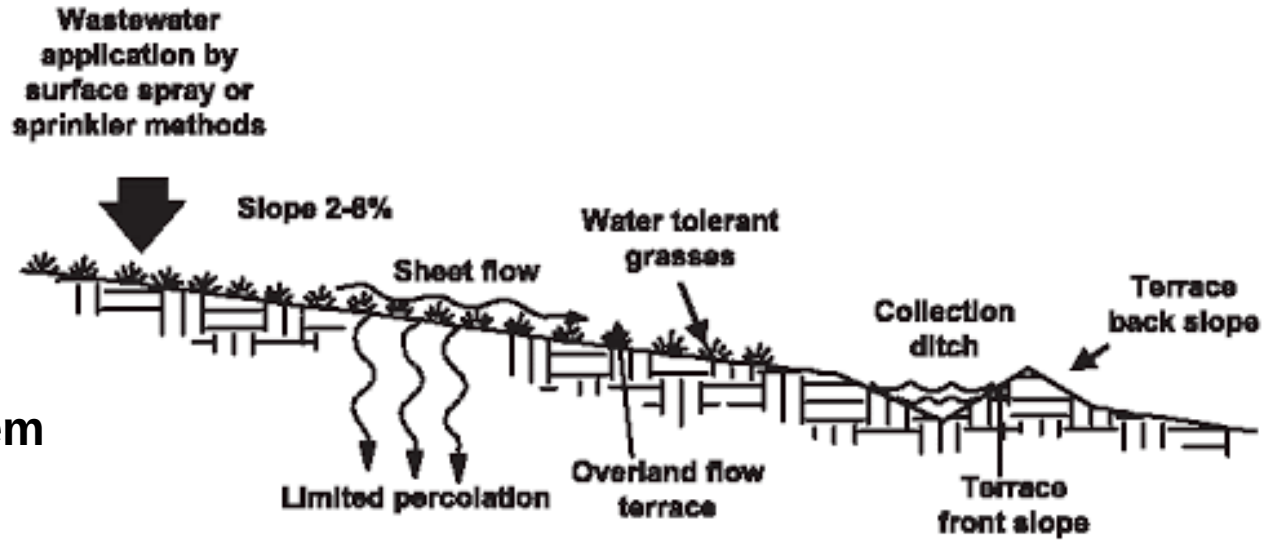
Three Types of Systems



Slow rate system



Rapid infiltration system



Overflow rate system

Favorable Conditions for Effluent Irrigation

- **Natural water body should not be located in the close vicinity.**
- **Irrigation water is scarcely available.**
- **This method of disposal is useful in areas of low rainfall.**
- **Soil is porous and sandy.**
- **Water table should not be located at shallow depths below the ground surface.**

Sewage Sickness

- **Continuous application of the sewage on land causes the clogging of soil pores or voids. This prevents the free air circulation and generate the anaerobic conditions resulting in the evolution of foul gases. This phenomenon of soil clogging is called sewage sickness.**
- **Preventive measures include primary treatment of sewage, choice of land, Under-drainage of soil, giving rest to the land, rotation of crops and applying shallow depths.**
- **A sewage sick land can be improved by ploughing and exposing it to the atmosphere.**

Merits of Land Disposal Method Over Dilution Method in India

- DO of natural waters is low due to hot climate.
- There are only few coastal cities or towns that have strong forward tidal currents and the necessary depth of water at the point of disposal.
- Most of the rivers run dry or have very small flow in summer season.

Problem

- **A town disposes sewage by land treatment. It has a sewage farm of area 150 ha. The area included an extra provision of 50% for rest and rotation. The population of the town being 50000 and rate of water supply 140 lpcd. Determine the sewage consuming capacity of the soil.**

On-Site Wastewater Disposal

- In lightly populated suburban or rural areas, a system for disposal of wastewater from individual house or a small community can be provided into the ground. This is called on-site subsurface wastewater disposal.
- For the successful operation of such systems, surface topography as well as subsurface conditions at the proposed site are important.
- Important factors are:

✓ Soil texture,

✓ Permeability of soil

✓ Depth to groundwater and bed rock

- To evaluate the ability of soil to transmit the flow of water, a percolation test, or “perc test”, is conducted.

Percolation Test

- The test gives an indirect measure of soil permeability.
- A perc test measures the rate at which water seeps into the soil in a test hole.
- It is also called falling head perc test.
- The perc test also provides data for designing the size of the leaching field.
- The steps are:

✓ Digging a test hole

- 200 mm diameter

✓ Soaking the test hole

- Soil is soaked and saturated with water before the test

✓ Measurement of perc rate

- Time required for water level to drop 150 mm is recorded or the drop of water in 30 min can also be used to determine the perc rate (especially for slow draining soils).

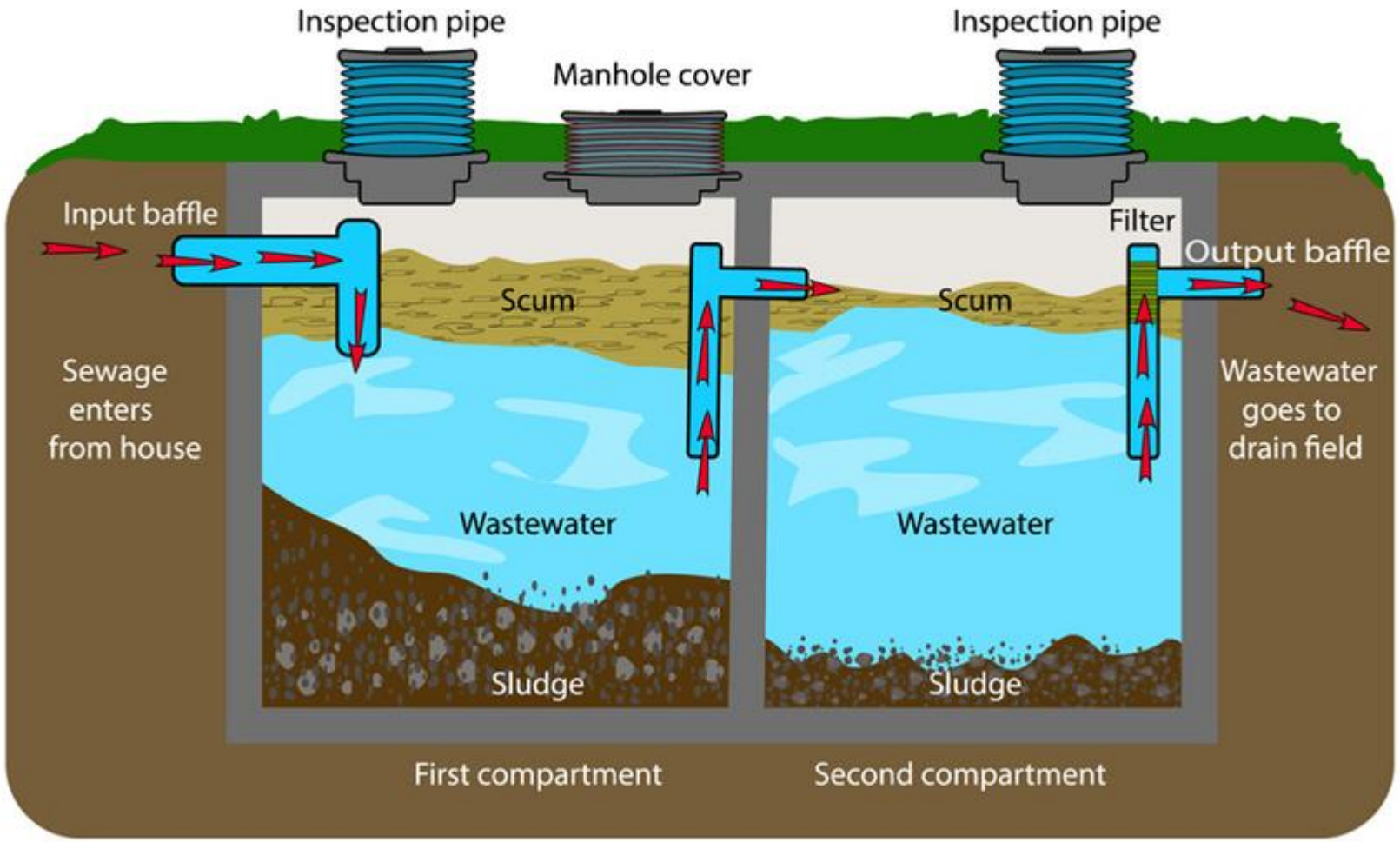
✓ Computation of perc rate

- The perc rate is represented in minutes per inch of water drop.

Septic Tank: An On-Site Sewage Disposal Method

- It is like a sedimentation tank with longer detention period.
- These are buried and watertight pits removes settleable matter and partially digest the organics by anaerobic biological process.
- A portion of organic matter is converted into CO_2, CH_4 and H_2S.
- A scum of fats and grease rises to the top.
- The partially clarified liquid is allowed to flow through an outlet structure.

Septic Tank



Taken from: https://www.vectorstock.com/royalty-free-vector/septic-tank-diagram-septic-system-vector-28836393 (10th May 2020)

Methods for Effluent Disposal from Septic Tank

- **In leaching field**

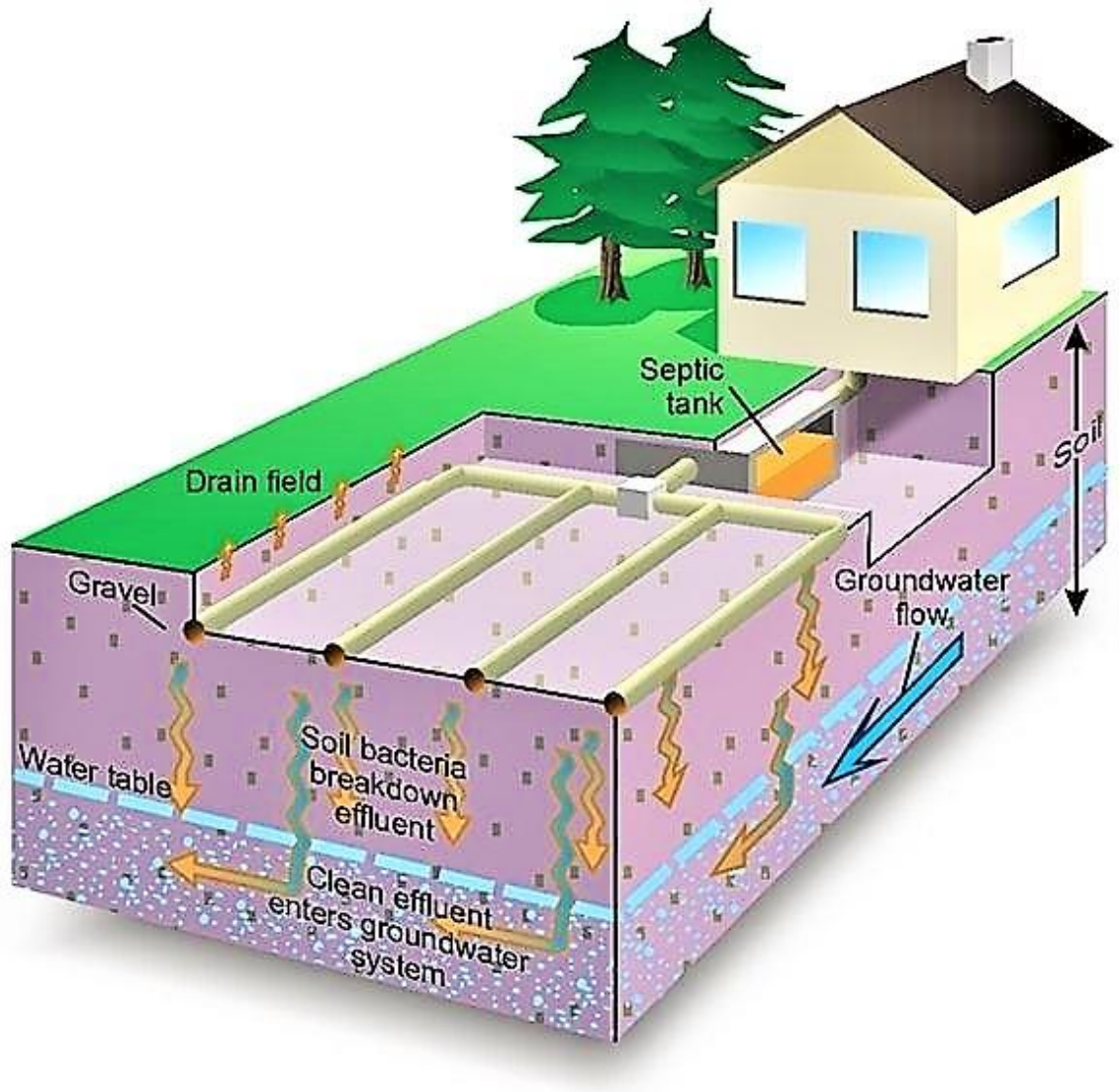
✓ **Absorption or leaching field distributes the liquid uniformly over a sizable area.**

✓ **As it flows through the soil voids, microbes and pollutants are removed from the effluent.**

✓ **A typical leaching field consists of two or more separate trenches with pipes that serve to spread the wastewater.**

✓ **The design of an absorption field requires the determination of the required number and length of laterals or trenches.**

Leaching Field



Taken from: https://sswm.info/factsheet/leach-fields (May 10, 2020)

Methods for Effluent Disposal….

- **Seepage pits**

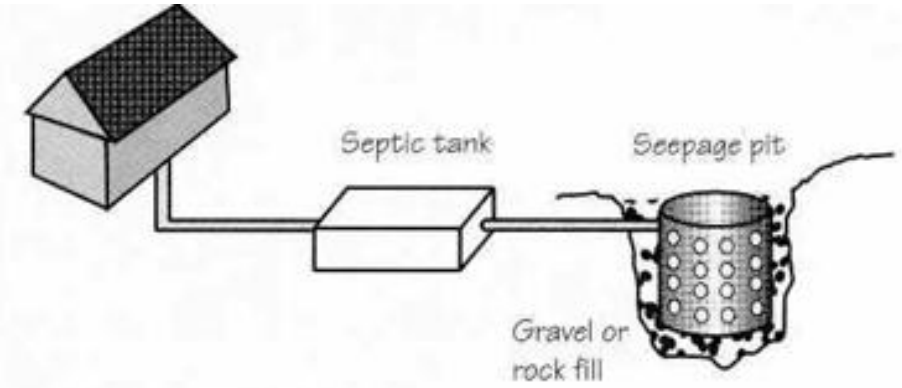
✓ **When site is too small for a conventional leaching field, deeper excavations taking up less area are used for subsurface disposal.**

✓ **The water table should be at least 1.2 m below the bottom of the pit to protect the water quality.**

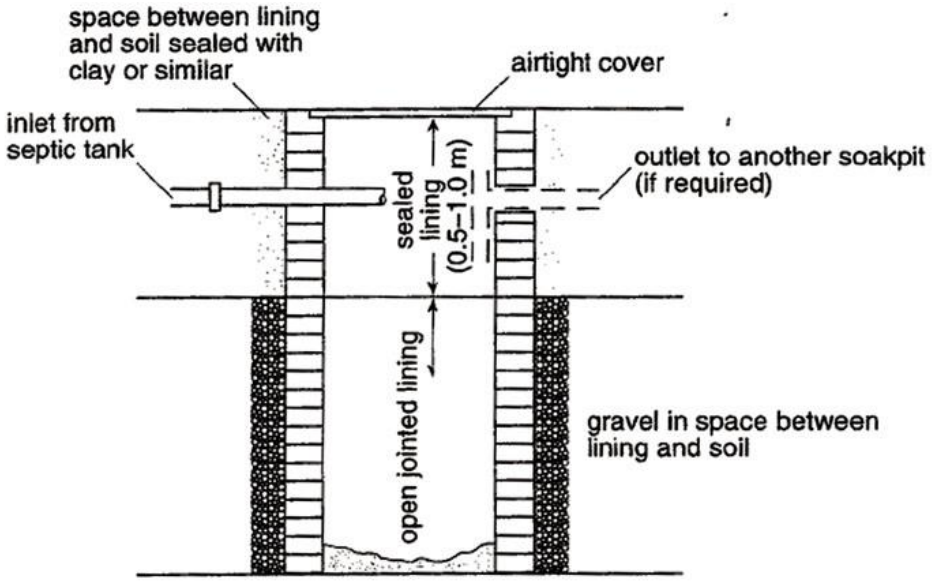
✓ **A typical seepage pit is about 3 m in diameter and 4.5 m deep.**

✓ **Perc rate should be more than 30 min/in.**

Seepage or Soak Pit



Taken from:
https://inspectapedia.com/septic/Seepage_Pits.php (May 10, 2020)



Taken from:
https://www.open.edu/openlearncreate/mod/oucontent/view.php?id=80563&section=5
(May 10, 2020)

Solid Quantity and Disposal

- The septage refers to the partially treated sludge stored in septic tank.
- The typical properties of septage are: BOD_5 = 6000; TSS = 15000; TN = 700; NH_3-N = 400; TP = 250; Oil and grease = 8000 (All are in mg/L)
- The effective method of septage disposal is by discharge into sewage treatment plant.
- Other disposal methods are co-disposal with solid wastes, and land application.

Advantages of Septic Tank

- Easy construction and don’t require skilled supervision.
- No sewerage system is needed.
- Excellent system can reduce significant BOD and suspended solids
- Sludge volume is less compared to that of a normal sedimentation tank.
- Best suited for rural areas and for isolated buildings etc.

Disadvantages

- If the tank is not properly functioning the quality of effluent would be very poor.
- Size requirement may be high for large number of people.
- Leakage of gases may cause bed smells and environmental pollution
- Periodic cleaning is a tedious process.

Thank you

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