Lecture No. 1 **UNIT I–** WATER SUPPLY

Topic(s) to be covered	ESTIMATION OF SURFACE AND SUBSURFACE WATER RESOURCES

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	importance and necessity for planned water supplies, firming of water supply	Understand.

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

- Water is a chemical compound and may occur in a liquid form or in a solid form or in a gaseous form.
- All these three forms of water are extremely useful to man, providing him the basic necessities of life.
- No life can exist without water, since water is as essential for life as air is. It has been estimated that two-third of human body is constituted of water.
- Huge amounts of money is required for planning, designing and executing a city water supply.

RAW WATER SOURCE:

The various sources of water can be classified into two categories.

1. Surface sources, such as
   a. ponds and lakes.

b. Streams Reservoirs
c. Storage Reservoirs
d. Oceans, generally not used for water supplies at present.

2. Sub surface sources or underground sources, such as.
a. Springs,
b. Infiltration wells
c. wells and tube wells.

Water Quality Estimation:

- The quantity of water required for municipal uses for which the water supply has to be designed requires following data:

1. Water consumption rate (per capita demand in liter/d/head)
2. Population to be served

Quantity = per capita demand × population

Water Consumption Rate:

- It is very difficult to precisely assess the quantity of water demanded by public.

Types of Consumption	Normal Range (Lit/capita/day)	Average	%
• Domestic Consumption	65-300	160	35
• Industrial and Commercial demands	45-450	185	30
• Public uses including fire demand	20-90	45	10

Losses and waste A5-150 62 25

Pricing of Municipal water supplies:

- The water supplied by municipalities to urban and rural areas for domestic, commercial or industrial uses has to be priced in such a way that the RMO (Running, Maintenance and operation).

- The rates of commercial uses should be lower than the rates for industrial uses. The fixation of such differential rates for various uses is permissible, yet the rate for water supplied should not be too low, as not to offer any incentive for saving and conserving water.

- Low water rates, thus, bring water management on a low priority area, and leads to abound wastage and mismanagment of water supply.

GROUND WATER AS A SOURCE OF WATER SUPPLY:

The part of rainfall that percolates through soil pores, contributes to ground water and appears as springs, wells and infiltration galleries.

Characteristics of water table:

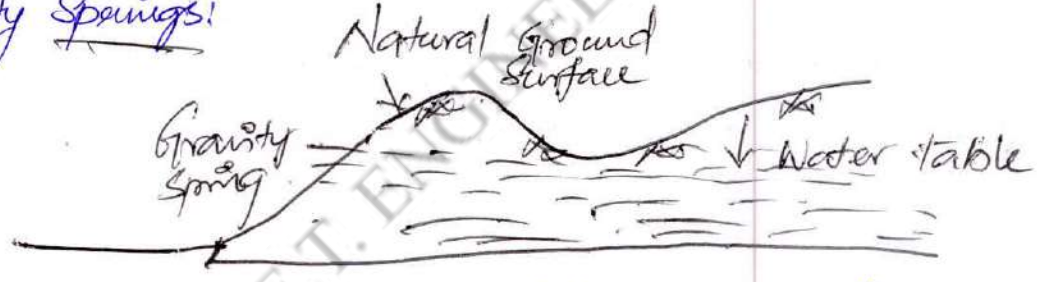
- It follows profile of ground surface
- It is not static, fluctuates, rises during wet season and falls in dry season.
- where the water table level and ground level meets springs or streams may appear.

1. Springs:

Springs are outcrops of ground water at foot of hills and river bank.

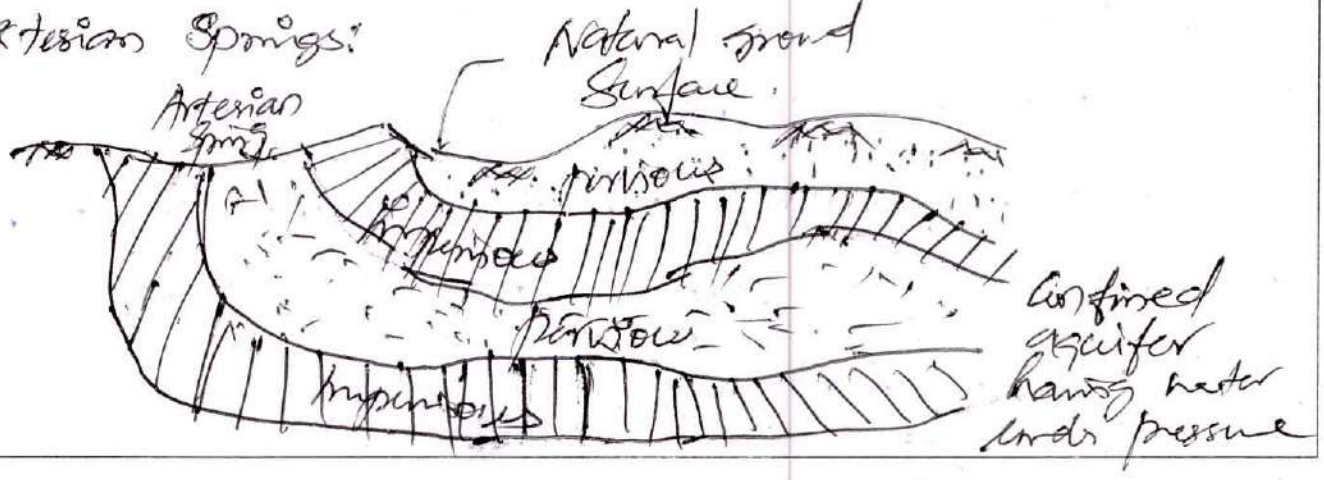
- Gravity springs
- Artesian springs
- Surface springs

- Gravity Springs:



- The ground water table rises high and water overflows through sides of natural valley, a gravity spring is formed.

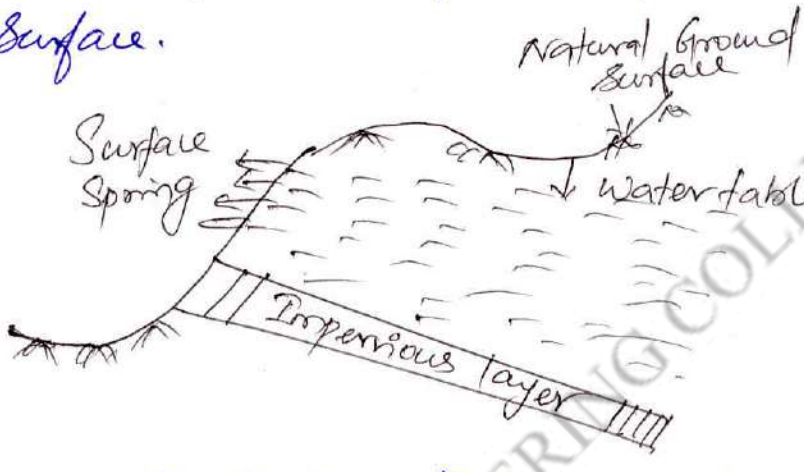
2. Artesian Springs:



When the water bearing strata between two impervious strata is under pressure, the water flows through weaker section (fault), called artesian spring (crevice).

- Surface Springs:

Surface springs are formed when an impervious stratum supporting underground storage becomes inclined causing the water table to rise up and get exposed to the ground surface.



Wells:

- Wells are vertical cylindrical opening from surface to a water bearing formation (aquifer).

(a) Based on type of Aquifer tapped.

Shallow well: Tapping of uppermost water bearing strata

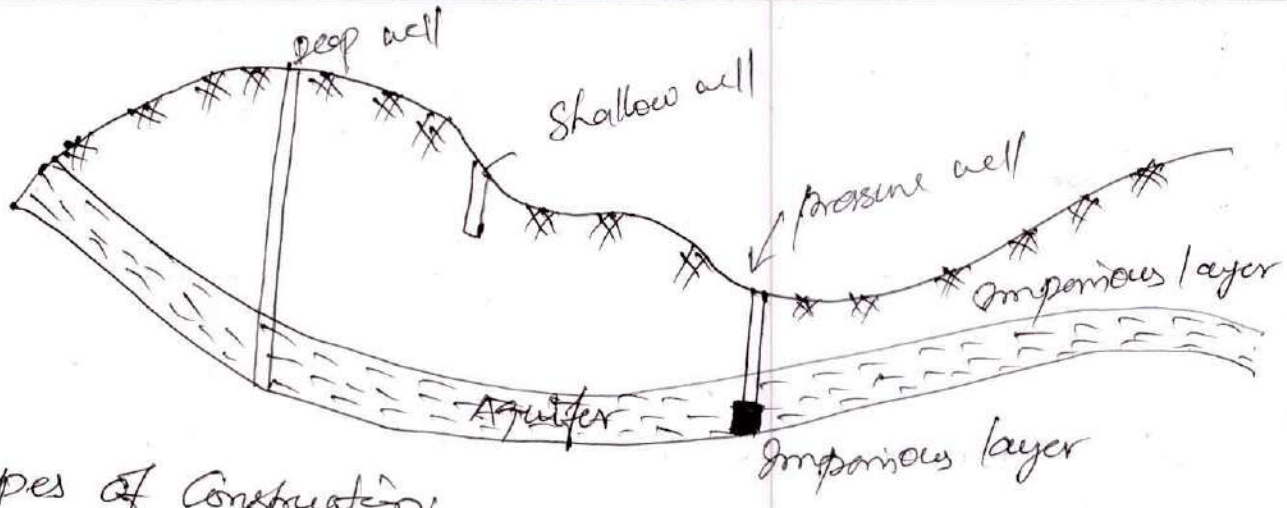
Drawback : • Large fluctuations in yield.
• Quality of water is poor.

Deep well: Tapping of deeper and larger aquifers.

(b) Based on condition of flow:

Gravity well: Water flow under gravity into the well under atmospheric pressure.

Pressure well: Aquifer is confined between two impervious strata. Water flows under pressure greater than atmospheric pressure.



Types of Construction:

(i) Dug well or percolation well (open wells)

(ii) Sunk wells

(iii) Driven well

(iv) Tube well

Suggested Questions / Assignments /Home works / any other
1. Explain in detailed about the Estimation of Surface & Subsurface Water Resources.

Text Books/ Reference Books			
S.No.	**Title**	**Author**	**Publisher**
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 2 **UNIT I–**

Topic(s) to be covered	PREDICTING DEMAND FOR WATER

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
Lo1	Objectives of a water supply, domestic, industrial, water demand, per capita demand.	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen.

Lecture Notes

DEMAND FOR WATER:

- The various types of water demand which a city may have is classified as:

1. Domestic water demand.
2. Industrial water demand.
3. Institutional and Commercial water demand.
4. Demand for public uses.
5. Fire demand.
6. Water required to compensate losses in waste and thefts.

Domestic water demand:

- The domestic water demand is 50 to 60% of the total water consumption for drinking, cooking, bathing etc.
- Total per capita demand per person is 135/l/day Bathing - 55, Washing - 20, Flushing - 30, Washing hous - 10, Cooking - 5.

Industrial water demand:

- The demand varies according to number and type of industries.
- Average per capita for industrial needs is 50 lpcd.
- In industrial cities, per capita water requirement is 450 lpcd. (Litre per capita per day)
  - → Automobile - 40 kilo liter / vehicle produced
  - → Leather - 40 kilo litre / tonne processed.
  - → Textile - 80 to 140 litre / tonne produced.

Institutional and Commercial water demand.

- Water requirement of institutions such as Hotels, Hospitals, Schools, Colleges, offices, Railway stations etc.
- Water demand depends on nature of city and number of commercial establishment.

Institution	Water Requirement (lpcd)
Offices	45 to 90
Schools	45 to 90
Hotels	135 to 180
Hostels	180
Hospitals	450
Railway station	70

Demand for public or civic use:

- The quantity of water required for public utility purpose such as watering of public parks, gardening.

washing and sprinkling on road. public fountains etc.

- It accounts to 5% of total water consumption
- On an average, it is 10 lpcd.

Fire demand:

- In dense populated and industrial areas, fire outbreaks may cause serious damages.
- The quantity of water required, fire fighting is called fire demand and it is stored in storage Reservoirs
- The minimum water pressure available in fire hydrant should be 100 to 150 kN/m² (10 to 15m)

For cities having population > 50,000, water required for fire fighting in Lilo litre.

$= 100\sqrt{P}$, P = population in thousand.

Rate of Fire demand:

Empirical formula are used to calculate fire demand.

(i) Kuichling's Formula:

$$Q = 3182\sqrt{P}$$

Q - water required in liter/minute

P - population in thousands.

(ii) Freeman Formula:

$$Q = 1136\left[\frac{P}{10} + 10\right]$$

(iii) National Board of fire under ~~writers~~ writers formula:

(a) For a Central congested high valued city

(i) population $\leq$ 2,00,000

$$Q = 4637\sqrt{P}\,[1 - 0.01\sqrt{P}]$$

(ii) Population ≥ 2,00,000
provision for 54,600 l/minute is made with additional provision of 9100 to 36400 litres/minute for a second fire.

(b) For a residential city, the water required for fire fighting is as follows:

Small building – 2200 litre/minute
Larger building – 4500 litre/minute
High rise Apartments – 7650 to 13,500 litre/minute.

(i) Buston's formula:

$$Q = 5663\sqrt{P}$$

$$Q = \frac{4360\,R^{0.275}}{(t+12)^{0.757}}$$

P - probability of occurrence of fire,
t - duration of fire (minimum 30 minute)
R - period of occurrence of fire (minimum 1 year)

6. Water Required to Compensate losses (Thefts/Wastes)

(i) Leakage/overflow from service Reservoirs
(ii) Leakage from main/service pipe connections
(iii) Leakage/losses on consumers premises (unmetered)
(iv) Leakage from public taps.
(v) Defective pipe joints
(vi) Cracked pipes
(vii) Loose valves/fittings
(viii) Unauthorised water connections
(ix) Damaged meter.

PER CAPITA DEMAND:

- Per capita demand (q) in liters per day per head (annual average daily consumption per person)

$$= \frac{\text{Total yearly water Requirement of city in litres}}{365 \times \text{design population}}$$

Factors affecting per capita demand:

1. • Size of city / type of community - The fluctuations in demand depends upon the size of city.
   - Large city - fluctuations are less and demand is more.
   - Small city - demand is less.
   - Residential community - more fluctuations in demand
   - Industrial community - Fluctuations is less.

2. Standard living / habits of people.
   - higher the standard of living - demand for water is more.

3. Climatic conditions:
   - hot climate - Usage of water will increase (bathing lawn sprinkling etc.)
   - Cold climate - water is wasted to prevent freezing of pipes.

4. Quality of water:
   - Good quality water - usage is more
   - poor quality water - usage is less.

5. Pressure in the supply:
   - High pressure - increased usage.
   - Low pressure - decreased usage.

6. System of supply - water supply may be continuous (24 hrs) or intermittent. Intermittent supply reduces the demand.

7. Sewerage - Flushing system increases water demand

8. Policy of metering - Use of water decreases when the supplies are metered.

9. Water rates - increases in water rate reduces the Consumption.

10. Age of Community - Older communities use less water. Developing new communities require large quantity of water for construction works.

11. Lawn sprinkling - Enforcement of lawn sprinkling regulation can reduce peak demands.

Suggested Questions / Assignments /Home works / any other
1. Describe per capita demand?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 3 **UNIT I–**

Topic(s) to be covered	OBJECTIVES of WATER SUPPLY.

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	water supply objectives, variations in demand	understand.

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

OBJECTIVES OF WATER SUPPLY:

- To supply safe and wholesome water to consumers.
- To supply water in adequate quantity.
- To make water easily available to consumers so as to encourage personal and household cleanliness.

(Wholesome means unpolluted water free from toxic substances, organic matter, minerals and pathogens).

Components of a water supply system:

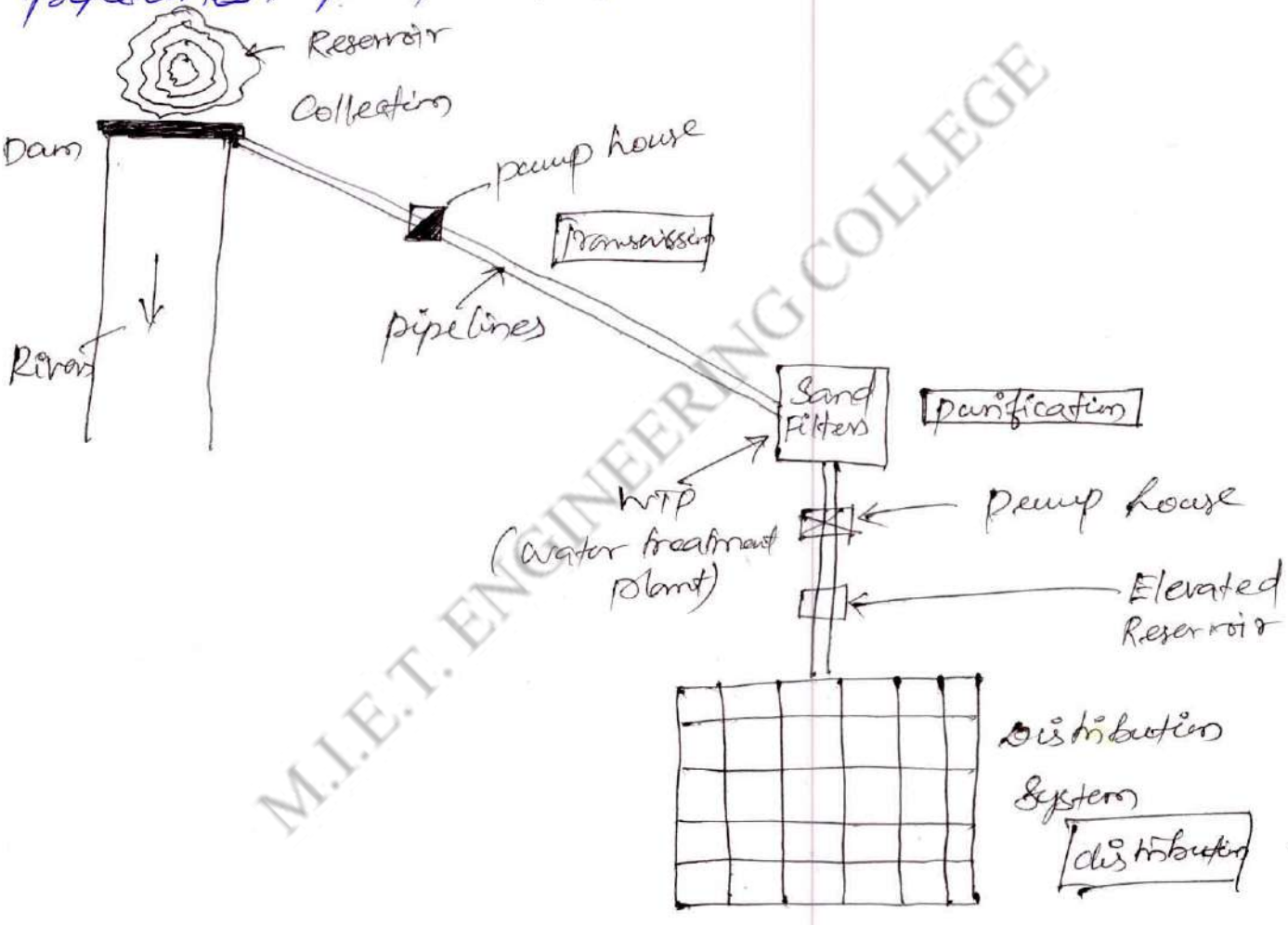
(i) Collection - • Surface water and ground water sources.
• (perennial river, dams, intake structures).

(ii) Transmission - • Conveyance of water from the source to the treatment plants.

• (pipelines/ conduits, canals, aqueducts, pumps etc).

(iii) Purification: To remove physical, chemical and biological impurities from water and make it safe for consumption water treatment plant (filter beds, softening units etc).

(iv) Distribution :- To distribute treated purified water to the consumers under pressure (Elevated Reservoirs, pipelines, pumps etc).



Components of a water supply system:

Variations in demand:

• The per capita consumption of water varies seasonally monthly, daily and hourly.

(i) Seasonal variations:

Summer Season - large use of water

Winter season - lesser use of water

Rainy season - much lesser use of water

Daily variations:

Sundays/Holidays - more usage of water

Weekdays - less usage of water

Hourly Variations:

Early morning (0 to 6 hours) - less consumption of water

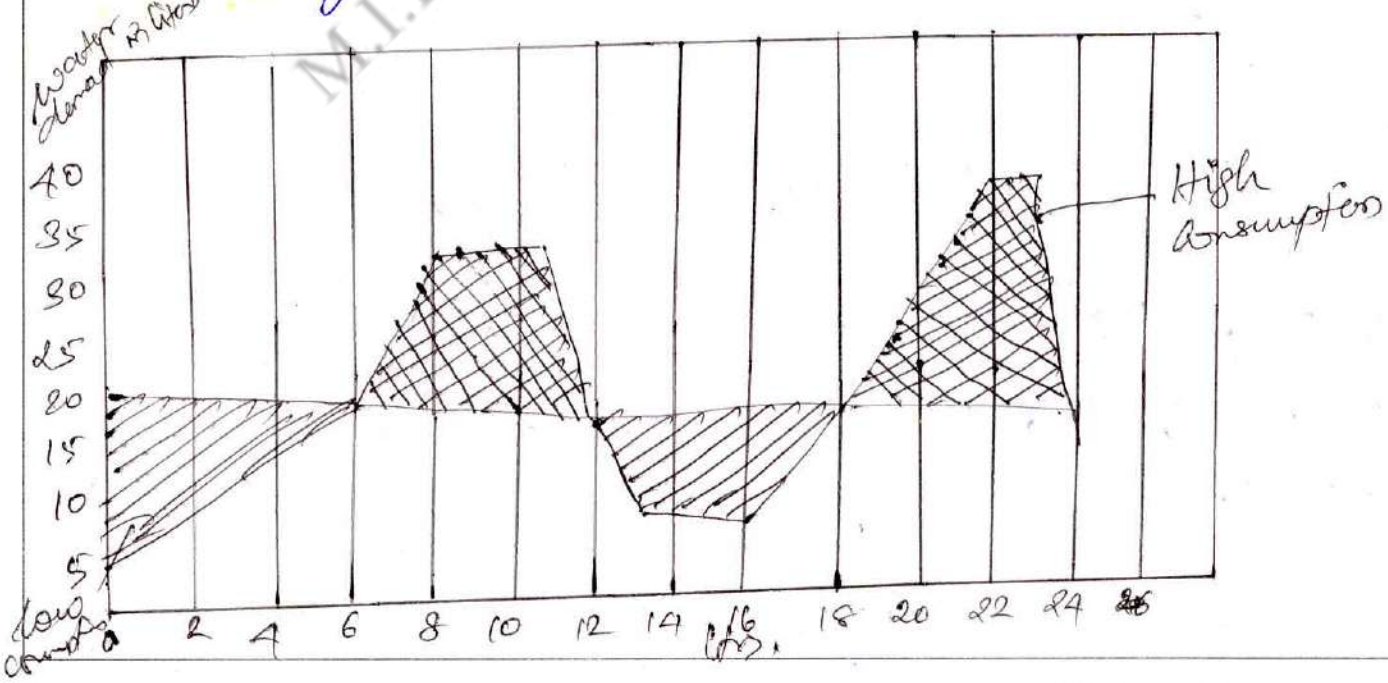
Between 8 to 11 am - peak consumption of water

Between 1 to 4 pm - Water consumption is less

Between 7 to 9 pm - High or peak consumption of water

Late night hours - Minimum consumption of water.

The hourly variation in water demand is



Assessment of Variations in demand:

(i) Maximum daily consumption = 180% of average daily demand

= 1.8q

q = average daily demand.

(ii) Maximum hourly Consumption (peak demand)

= 150% of its average hourly consumption

= 1.5 × Average hourly consumption of maximum day

(iii) Maximum hourly consumption of maximum day

$$= 1.5 \times \left[\frac{\text{Maximum daily demand}}{24}\right]$$

$$= 1.5 \times \left[\frac{1.8q}{24}\right]$$

$$= 2.7\left(q/24\right)$$

= 2.7 × (Annual average hourly demand)

Effect of Variation in demand on the design capacities of different components of a water supply schemes.

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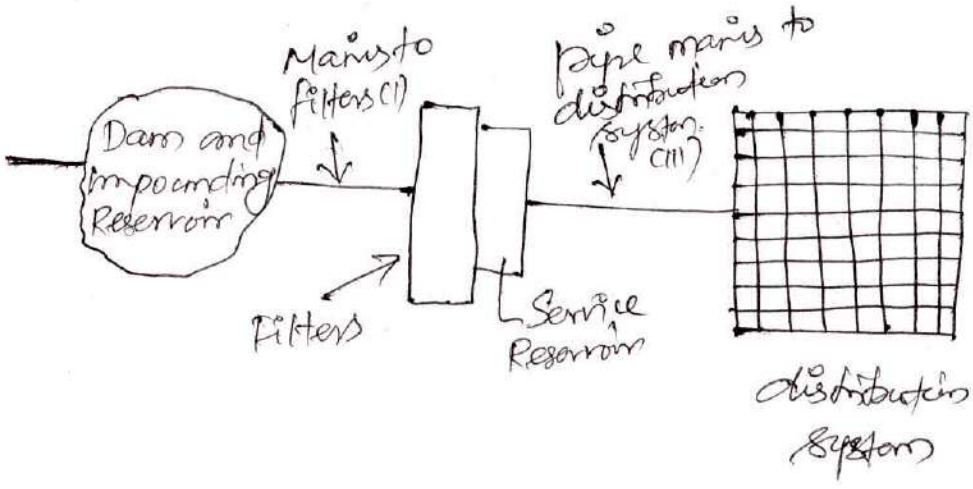

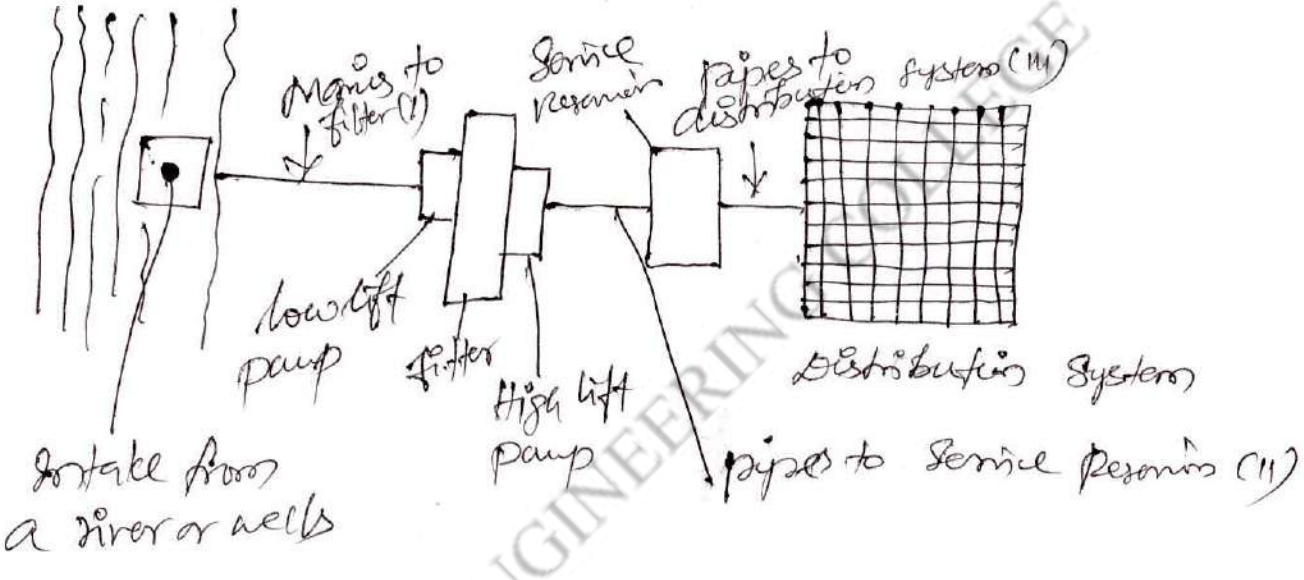

Layouts of water supply schemes

1. Source of supply - Designed for maximum daily or average daily consumption.

2. Pipe mains (Type I & II) - Designed for maximum daily Consumption.

3. Filter and other units of water treatment plant - Designed for maximum daily consumption or twice the average daily consumption (including reserve for repairs)

4. Pumps - Same as filters and WTP units

5. Distribution System - Designed for maximum hourly demand of maximum day

Type (III) - plus reserve for fire.

6. Service reservoir - Designed for hourly fluctuations, fire demand, emergency reserve etc.

Suggested Questions / Assignments /Home works / any other
1. What are the objectives ~~and~~ of water supply and Variations in demand?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 4. **UNIT I–**

Topic(s) to be covered	Impurities of water and their significance.

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Impurities in water, physical, chemical and Bacteriological impurities.	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

IMPURITIES OF WATER AND THEIR SIGNIFICANCE:

- Impurities in water can also be classified as:
  1. physical impurities
  2. Chemical impurities
  3. Bacteriological impurities

⇒ physical Impurities: Impart taste, odour, colour, and turbidity to water.

- Presence of organic matter or industrial wastes or microorganism (algae) imparts taste and odour to water.
- Presence of Suspended and colloidal matter imparts turbidity of water.
- Presence of Minerals (iron oxide) in water imparts colour.
- These impurities have no direct effect on health but have indirect consequences.

• Turbid waters protect microorganism from chlorination (disinfection) and cause health effects.

⇒ Chemical Impurities:

Impurities	Causes	Effects
A. Inorganic/mineral		
a) Suspended	Silt + clay	Turbidity
b) Dissolved	Ca + Mg (Carbonate + bicarbonate)	Hardness and Alkalinity
	Ca + Mg (Sulphate + Chloride)	Hardness and corrosion of boilers.
	Sodium (Na) (Carbonate + bicarbonate)	Alkalinity and softness
	Nitrates	> 45 mg/l cause Methaemoglobinemia "Blue babies"
	Chlorides of Na	Brakish taste
	Fluorides of Na	> 1.5 mg/l cause teeth staining
	Iron oxide	Taste, Color, Hardness
	Magarese	Taste, brown color.
B. Organic		
(i) Suspended		
(a) Vegetable	Decayed leaves, algae, fungi	Acidity, taste, color change, water suspicious
(b) Animal	Dead animals, hair, insects	Bacteria, water becomes contaminated, dangerous for health.

(ii) Dissolved (a) Vegetable	large quantity of Albuminoid nitrogen + free ammonia + chlorides	Bacteria water Suspicious
(b) Animal	large quantity of albuminoid nitrogen + free ammonia + chlorides	disease producing bacteria, Sewage-pollution water dangerous.

Physical characteristics:

- Color.
- Taste and odour.
- Temperature.
- Turbidity.

Color:

- Color in water is not harmful from health point of view but it may cause staining / discolouration of clothes and is also objectionable from aesthetic point of view.
- Presence of dissolved organic matter, inorganic materials, algal, aquatic microbes impart colour to water.
- Color is detected by naked eye or measured against hazen or platinic chloride or cobalt scale (Standard Color Scale) using tintometer.
- Tintometer has an eye piece with two holes, one for standard Color and other one is for water sample. The Color of water sample is matched with standard Color.

• For public water supplies, the color of water on Cobalt scale should be less than 20.

Significance of Color:

Color of water indicates the type of impurity present in water.

Eg: Brown color of water indicates the presence of manganese.

(ii) Taste and odour:

• Taste and odour is due to the presence of mineral salt, industrial waste, domestic sewage, organic matter and microorganism.

• It is difficult to measure taste and odour.

• It is measured in terms of "threshold odour number" which is the volume of sample (in cm3) required to be added to 100 cc of odour free fresh water, where the mixture just starts giving smell in diluted sample.

• For public water supplies, the threshold number >3.

• Odour intensity (PO value) - The number of dilutions of fresh water is known as PO value or odour intensity.

PO Value (PO) -	Meaning
0	No perceptible odour
1	very faint odour
2	Faint odour, detectable
3	Distinct odour, readily detectable
4	very distinct odour
5	Strong, intense odour
6	Extremely strong odour

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(iii) Temperature:

- The preferable temperature is 10° to 20°c.
- Temperature higher than 25°c is objectionable.
- Measured using Thermometers, Thermocouples.

Significance:

- Dissolution of gases (dissolved oxygen) depends on temperature.
- Bod and biological (bacterial) activities in water are temperature dependant.

(iv) Turbidity (Optical property)

- It is the resistance of water to passage of light. It is caused due to suspended and colloidal solids in water.

The permissible turbidity for domestic water 5 to 10 ppm (NTU)

Methods of Measuring turbidity of water:

- Turbidity rod
- Jackson's turbidimeter
- Baylis turbidimeter
- Nephelometers

(a) Turbidity rod:

- It is a graduated aluminium rod attached to platinum needle and nickel ring at bottom, graduated tape at top with position of eye marked.
- The rod is inserted in turbid water. Reading is taken when the needle just disappears.
- It is expressed in ppm (NTU)

(b) Jacksons Turbidimeter:

- Used when turbidity > 100 ppm
- It Consist of a metal stand holding a metal container and graduated glass tube.
- A Candele is placed below the stand.
- Water level is increased till flame is disappear.

(c) Baylis turbidimeter:

- Very accurate instrument used turbidity < 5 mils.
- The standard solution matches with water sample gives turbidity.

(d) Nephelometer (Photometer)

- Modern Commercial turbidimeter
- A photometer measures intensity of light passing through turbid water after it scatters at right angles
- Expressed in NTU.

Suggested Questions / Assignments /Home works / any other
1. Explain impurities of water and their significance?

Text Books/ Reference Books			
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 5. **UNIT I–**

Topic(s) to be covered	Chemical characteristics

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Total solids, chlorides, Hardness, pH, and its significance.	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

Chemical characteristics:

(i) Total solids
(ii) Chlorides
(iii) Hardness
(iv) pH - Value

Total Solids:

Total solids = Suspended solids + Colloidal solids + Dissolved solids

Suspended solids = Fixed solids (Inorganic) + Volatile solids (organic)

Total solids should be less than 500 ppm.

Significance:

- High solids content indicates contamination and presence of excessive minerals.
- Suspended solids cause turbidity and imparts color.
- Dissolved solids impart color, taste and make it salty.

(ii) Chlorides:

- Presence of sodium chloride (NaCl) in water.
- Source of chloride in water are from sewage effluents, mineral deposits and ingression of salt water.
- Chloride is determined by titration with standard silver nitrate ~~deposits~~ using potassium chromate as indicator.
- The permissible level of chloride is 200mg/l.

Significance:

Presence of chloride in water indicates sewage contamination.

(iii) Hardness:

- Due to presence of salts such as carbonates, bicarbonates, chlorides, sulphates of calcium and magnesium.
- Total hardness = Temporary (carbonate) Hardness + permanent (Non carbonate) Hardness

Temporary hardness (Carbonate hardness)

- It is due to the presence of carbonates and bicarbonates of calcium and magnesium.
- It can be easily removed by boiling or adding lime.

Permanent hardness (Non carbonate hardness)

- Presence of sulphates, chlorides and nitrates of calcium and magnesium.
- Special water softening methods are required to remove permanent hardness.
- Hardness is expressed in 1 degree = 1 ppm

Degree of hardness	Nature of water
1	Extremely Soft water
2	very Soft water
3	Soft water
6	Reasonably Soft water
7	Reasonably hard water
9	Hard water
11	very Hard water
15	Excessive hard water
17	Too hard to use

Methods of to determine Hardness:

(a) Clark's Method:

Hardness is found by determining the standard soap solution required to obtain permanent lather with water sample, volume at constant shaking.

(b) Hehner's Method:

(a) Temporary hardness: determined by titration with Std. Sol. H_2SO_4 using methyl orange as indicator.

(b) Permanent hardness: Standard sodium carbonate is added to water sample and evaporated. The amount of sodium carbonate required in excess to convert sulphate/ chloride into carbonate gives the permanent hardness.

(IV) pH (Hydrogen ion Concentration)

To determine the water is the degree of acidity or alkalinity.

$$pH = -\log(H^+) \quad / \quad H^+ = OH^- = 10^{-7}$$

Significance of pH:

- Causes incrustation / tuberculation in pipes.
- Corrosiveness of water is pH dependent.
- Biological activities are pH dependent.
- Water softening process depends on pH.
- Coagulation process depends on pH.

Methods to determine pH:

(a) Colourimetric method:

- Indicator is added to water sample.
- Colour of water is compared to standard colour of known pH.
- Acidic range indicator - methyl red.
- Alkaline range indicator - phenolphthalein red.

(b) Electrometric method:

- pH meter is used. The electrode is dipped in water sample and can read directly on the dial.

Suggested Questions / Assignments /Home works / any other
1. Define chemical characteristics?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 6. UNIT I–

Topic(s) to be covered	Chemical Characteristics

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
L01	Metals and other chemical substances, Nitrogen and its Compounds	Understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

Metals and other chemical substances:

(a) Iron and maggarese:

- Iron causes hardness, bad taste, discoloration of clothes and plumbing fixtures, heavy growth of crenothrix which leads to pipe clogging.
- Iron can be found by simple calorimetric procedure using thiocynate and thioglycollic acid.
- Manganese imparts brownish / purplish colour to water and stains plumbing fixtures.

(b) Lead and Arsenic:

- Lead is a cumulative poison. prolonged exposure can cause death.
- Concentration of lead should be less than 0.05mg/l
- Lead is added 6 drops of Sulphuric acid in water sample, white precipitate formed, indicates lead.
- Arsenic causes Chronic poisoning and is difficult to diagnose. Arsenic is removed by ion exchange equipment

using activated alumina. determined by Heteropoly blue colorimetric method by comparing stains on paper strips

Fluorides and Iodides:

- Small concentrations of fluorides and iodides are useful to human.
- Iodide < 1 ppm - prevent goitre
- Fluoride < 1.2 ppm - prevent dental caries in children
- Excess concentration > 3 ppm - causes dental fluorosis or mottled enamel.
- Fluorides is estimated by colourimetric method. ie. by developing a colour with zirconium - alizarin reagent.
- Iodide is determined by its ability to catalyze reduction of ceric ions by arsenious acid.

Barium and Boron:

- Barium is toxic to heart, blood vessels and nerves (central nervous system). It may cause 'baristn'.
- Determined by colorimetric and titrimetric methods.
- Solution of carmine acid in concentrated sulphuric acid changes colour from bright red to bluish red or blue depending on the concentration of boron.

Cadmium and Hexavalent Chromium:

Cadmium: toxic, discharged from electroplating plants. it forms compound with di-phenyl thiocarbazone and this is used for colourimetric determination of cadmium

Chromium, cause cancer, discharged from chromium plating plants. It is determined colourimetrically by reaction with diphenyl-carbazide in acid solution.

Sodium and pottasium:

- Human body maintains constant sodium content.
- Excess quantities of sodium causes edema. (இரத்த சோகை)
- Sodium and pottasium is determined by using flame photometer.

Nitrogen and its compounds:

- Ammonical nitrogen (free ammonia)
- Albuminoid nitrogen
- Nitrite Nitrogen
- Nitrate

(a) Ammonical Nitrogen:

⇒ Free ammonia in water indicates presence of organic matter particularly human and animal excreta and discharge from gas industries.

⇒ Free ammonia is estimated by distillation method using Nessler's Reagent.

Albuminoid Nitrogen:

- Its presence indicates organic pollution in water
- It is derived from aquatic plant and animal life.
- Determined by adding pottasium permanganate or sulphuric acid to water sample and boiling to liberate ammonia gas.

Nitrite:

- It is an intermediate in the oxidation - reduction process of the nitrogen cycle.
- Its presence indicates pollution.
- Determined by treating with sulphanilic acid and matching the colour with standard nitrite solution.

Nitrate:

- This is final stage of oxidation of nitrogen compound
- The source of nitrate in water is from cultivation, manure and biological activity in soil.
- Excessive nitrate in water causes infant poisoning blue baby syndrome - methae maglobinemia.
- It is determined by matching the colour produced with phenol - disulphonic acid.

Suggested Questions / Assignments /Home works / any other
1. Explain in detail about chemical characteristics?

	Text Books/ Reference Books		
S.No.	**Title**	**Author**	**Publisher**
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 7 **UNIT I–**

Topic(s) to be covered	Biological Characteristics

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Biological Characteristics, Aquatic plants, animals, fungi, Bacteria and Viruses.	Understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

Biological Characteristics:

- A contaminated water is a host for micro organisms that may spread water-borne diseases.

(a) Aquatic plants:

- Water weeds and algae are of great concern in water supply sources.
- Excess growth of algae and weeds causes the following problems.

(i) They infect the lakes and prevent entry of sunlight and oxygen into water.

(ii) They impart objectionable taste, odour and colour.

(iii) Cause turbidity.

(iv) Clog the filter beds.

(v) Reduces the capacity of canals and pipes.

(b) Aquatic Animals:

- Fishes, amphibians, insects, spiders, snails, earthworms protozoans etc.
- Some are resistant to chlorination.
- They cause intestinal infections, dysentry etc.
- They also cause clogging of supply pipes.

(C) Fungi, Bacteria and Viruses:

Fungi:

- It modify pH of water and produce organic acids and ammonia.
- Decomposition or death of fungi imparts disagreeable taste and odour to water.
- It controlled by chlorine or copper sulphate treatment.

Viruses:

- They are infections agents and cause waterborne diseases.
- Bacteriophages Viruses cause respiratory infection in children, Hepatitis, polio etc.

Bacteria:

Classification

Oxygen Requirement

- Aerobic - need oxygen to survive
- Anaerobic - Survives in the absence of oxygen
- Facultative - Survives both in presence/absence of oxygen

Temperature

- Psychrophilic - Survives at 10 to 20°C
- Mesophilic - 20 to 40°C
- Thermophilic - 40 to 65°C

It cause typhoid, Cholera, dysentry and it is necessary to detect their presence in water.

Purpose of Microbiological Examination of water:

- To detect the degree of pollution in water bodies.
- To asses the amount of treatment required to render the water safe.
- To ascertain the efficiency of treatment at various stages.
- To locate the cause of any sudden deterioration in water quality.

Coliform Index or E-coli Index:

- Number of Coliform bacterias present in water sample is found by following procedure.
- Fermentation tubes are inoculated with varying portions of water sample.

$$\text{Coliform index} = \frac{1}{0.01} = 100/\text{ml}.$$

Most probable Number (MPN)

- MPN is defined as bacterial density which if it had been actually present in sample under examination would more frequently than any other.
- It is based on probabilities. standard tables are available to determine MPN for various combination of test results.

Total count or Agar plate count (Colony count)

- Colony count in nutrient agar after 3 day incubation at 20°c
- Colony count in nutrient agar after 24 hrs @ 37°c.
- Colony count after confirmation of 37°c incubation. further 24 hrs.

Water sample after suitable dilution is taken in petridish. Molten nutrient agar is added and incubated at 37°c in an incubator for 24 hrs.

- Bacterial colonies are counted using magnifying glass.
- portable water, Total count should not exceed 100/ml.

Coliform test:

- Coliform group includes all aerobic and facultative anaerobic bacteria.
- Ferment lactose with gas formation within 48 hrs at 35°c.

Suggested Questions / Assignments /Home works / any other
1. Describe the biological characteristics?

Text Books/ Reference Books			
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications. 2010
Any other suggested Materials			

Lecture No. 8. **UNIT I–**

Topic(s) to be covered	Water Borne diseases:

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Typhoid fever, Cholera, dysentry, Escherichia coli (E-coli)	understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

Water Borne diseases:

- It is illness caused by microscopic organism, like viruses and bacteria which are ingested through contaminated water or by coming in contact with feces.
- caused by pathogenic microbes via contaminated water.
- These pathogens occurs while using infected water for drinking, food preparation, washing clothes, among others.
- Majority of water-borne diseases worldwide mainly affect children due to poor hygiene and weak immunity.
- Several pathogenic microorganism which were previously unknown have become the focus of major research in this field.

Typhoid Fever:

- It spread through contaminated food, unsafe water, and poor sanitation and it is highly contagious.
  - Fever increases gradually.
  - Muscle aches
  - Fatigue
  - Sweating
  - Diarrhea

To prevent it, refrain from drinking any water that isn't bottled and sealed.

Cholera:

- The disease is spread through contamination water and cause severe dehydration and diarrhea.
- It can be fatal within days or even hours of exposure to the bacteria, but only 1 in 10 people will develop life-threatening symptoms.
  - Nausea
  - Vomiting
  - Diarrhea
  - muscle cramps.

Dysentery:

- An intestinal infection, dysentry is a waterborne disease.
- It can be caused by bacteria, viruses, parasites in unsafe food, in contact with fecal matter.
  - Stomach cramps & pain
  - diarrhea
  - Fever
  - Nausea

- Vomiting
- Dehydration.

- Mild dysentry usually clears up with rest and fluids, but over the counter medications such as pepto-Bismol can help with stomach cramping.
- More severe cause can be treated with antibodies, although some strains of the disease are resistant.

Escherichia Coli (E. Coli)

E. Coli is a bacteria with various strains, some dangerous and some beneficial.

eg: It is important in creating a healthy intestinal tract.

- If animal waste has found its way into farmland where produce is grown or if strains of E. coli are spread through the process of making ground, those who consume these foods could experience symptoms of the waterborn illness.
- Bacteria are also found in unsafe water sources around the globe where human water sources and cattle coexist.

Symptoms:

- Dangerous strains of E. Coli are similar to that of dysentery and other waterborne disease.
- Most bouts of E. coli pass within a week, but older people

and young children have a greater chance of developing life-threatening symptoms.

Prevention and treatment:

- As always, avoid water possibly contaminated by human and animal feces (like ponds, river, swamps)
- If you are going to eat ground, cook thoroughly
- To treat the disease, drink plenty of safe water rest, take over the counter diarrheal medicated.
- While there are simple prevention and treatment tips, there are many remote villages in the world who have no choice but to drink from swam.

Suggested Questions / Assignments /Home works / any other
What is water borne disease and how to treat it?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 09 **UNIT I–**

Topic(s) to be covered	Intake Structures

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
Lo1	Different parts of an intake	understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

Intake Structures:

- Intake are the structures built in surface water water sources (such as rivers, lakes, reservoirs) for the

(i) Entry ports or inlets or penstock:

- ports are provided at different elevations to ensure water flow during all seasons. ie. to take care of fluctuation during summer.
- The lowest entry port is placed below the lowest water level (LWL) of the river so that water is available during dry season also.

(ii) Screens:

- The entry ports are protected with screens

to prevent entry of any debris or floating materials into the intakes.

(iii) Intake well:

• It is built of masonry or concrete which may be rectangular or circular in shape. Water drawn from the sources through entry ports is stored in these wells which is then discharged through conduits for water supply.

(iv) Conduits:

• They are the pipelines through which water is conveyed from the intake well to nearby treatment plant or water supply system.

(v) Gate valves and control room:

• The water flow is regulated by gate valves provided on top at the control tower.

(vi) Foot bridge:

• A foot bridge is provided on top of intake tower for access.

Factors Governing the location of site for intakes:

The site chosen for intakes should be preferably.

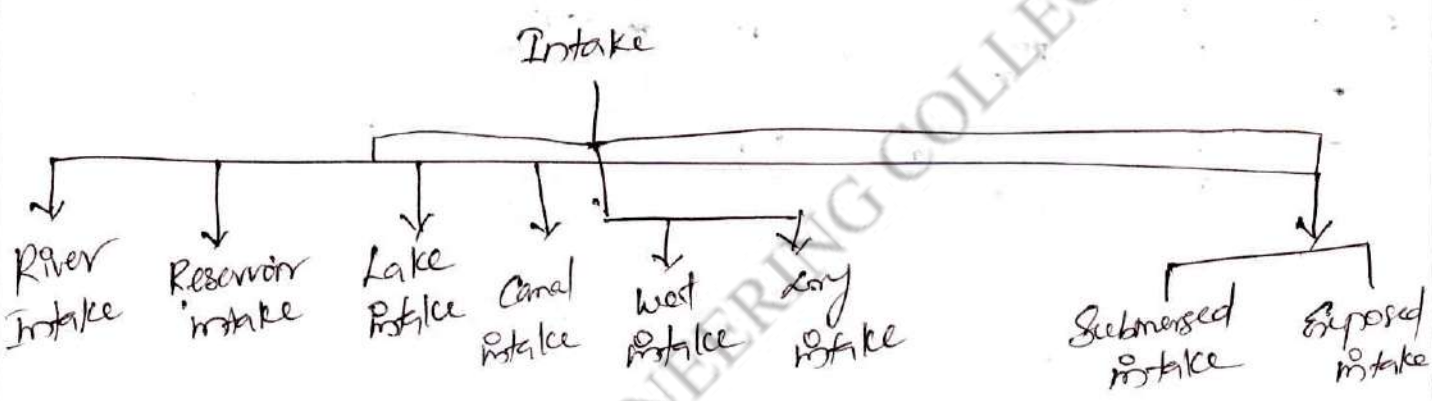
(i) Near the treatment plant
(To reduce the cost of pipelines)

(ii) At the pure zone of surface source
(To reduce the water treatment cost)

(iii) ~~At the~~ At the upstream side of source

(iv) not near any waste water or sewage disposal points
(v) provide greater withdrawal of water including expansion in future.
(vi) provide water even during dry seasons.
(vii) not near any navigation channel.
(viii) should not get flooded.

Types of Intakes:

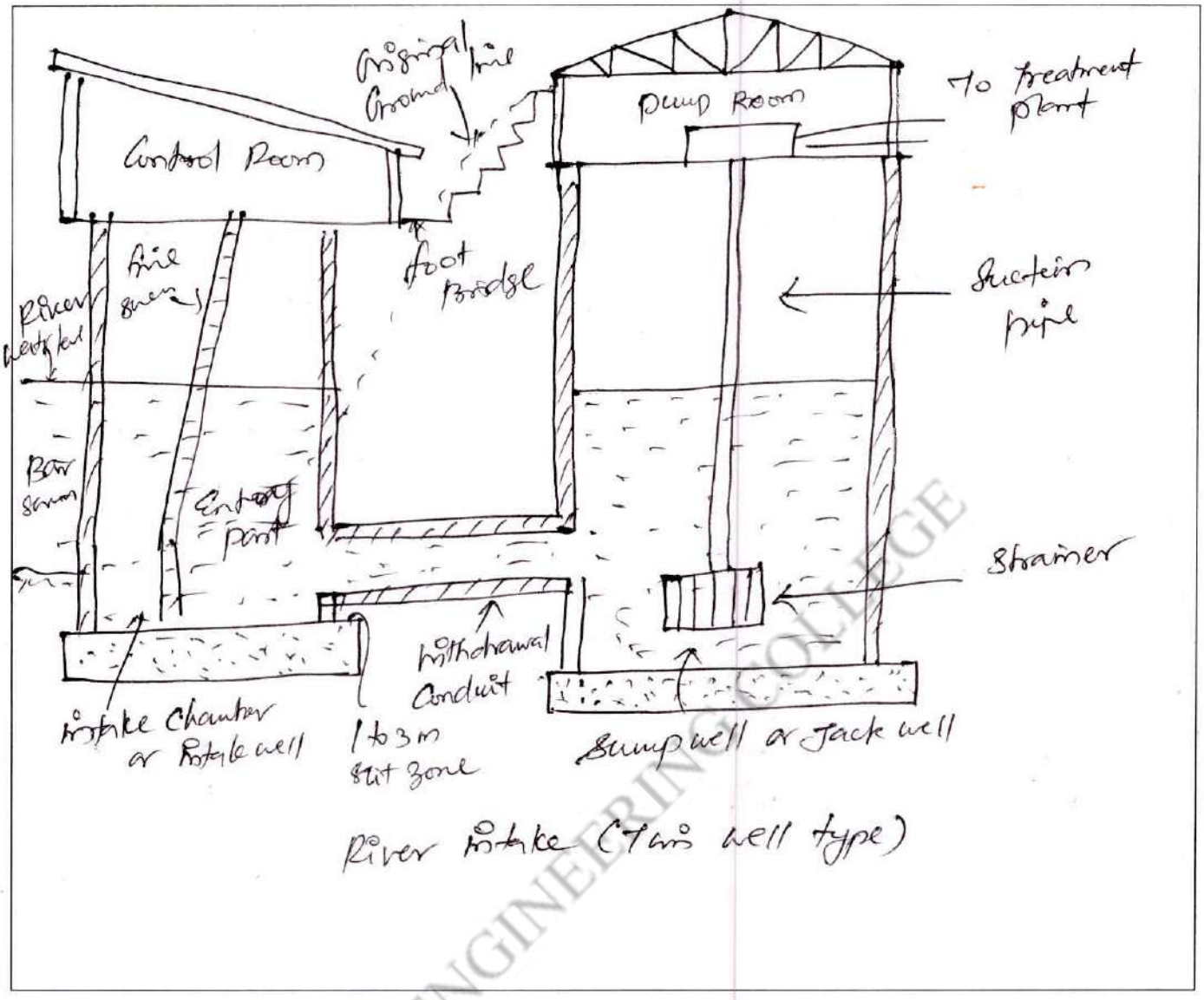


River intakes

- Located on the upstream side of rivers where pollution is minimum.
- Located inside the river or on river bank such that sufficient water depth is available to meet the demand during dry season also.
- Sometimes, weirs are constructed across the rivers to increase the water level.

Classification of River intakes:

(a) Jack well type
(b) Single well type



River intake (Tower well type)

Suggested Questions / Assignments /Home works / any other
1. Listout the types of intake structures?

Text Books/ Reference Books			
S.No.	**Title**	**Author**	**Publisher**
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 10 **UNIT I–**

Topic(s) to be covered	Types of intakes

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Tamil well type of River intake structures	understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

- Inlet well or intake collector well is circular built of concrete or masonry located on river bed such that water is available during low flows.
- A foot bridge is provided for access from the river bank. River water enters the inlet well through openings or ports provided at various levels and protected by screens to exclude entry of floating debris.
- The flow into the entry ports is regulated from the control tower using gate valves. The intake well is connected to jack well (sump well) constructed on river bank, by a RCC intake pipe.
- Bottom portion of intake well below the level of intake pipe is used for accumulation of silt and sediment.

• The deposited silt is periodically removed either manually or mechanically and it is ensured that the silt does not enter the intake conduits.

• Pipe is provided at a gentle slope and the flow through the pipe is under gravity at atmospheric pressure.

• Pipe diameter is chosen based on discharge capacity. Water entering the jack well is lifted by pumps and fed into the main lines of water supply system.

Twin well type of river intake structure:

This is the common type of river intake constructed in non-alluvial rivers.

The structure consists of

(i) An inlet well
(ii) An inlet pipe
(iii) A jack well

(ii) Single well type of river intake:

• This type of intake is constructed in alluvial rivers - weirs or approach channels constructed to increase the water level.

• In this intake, there is no separate inlet well or inlet pipe (as in Twin intake). The openings provided with bar screens are provided in jack well itself.

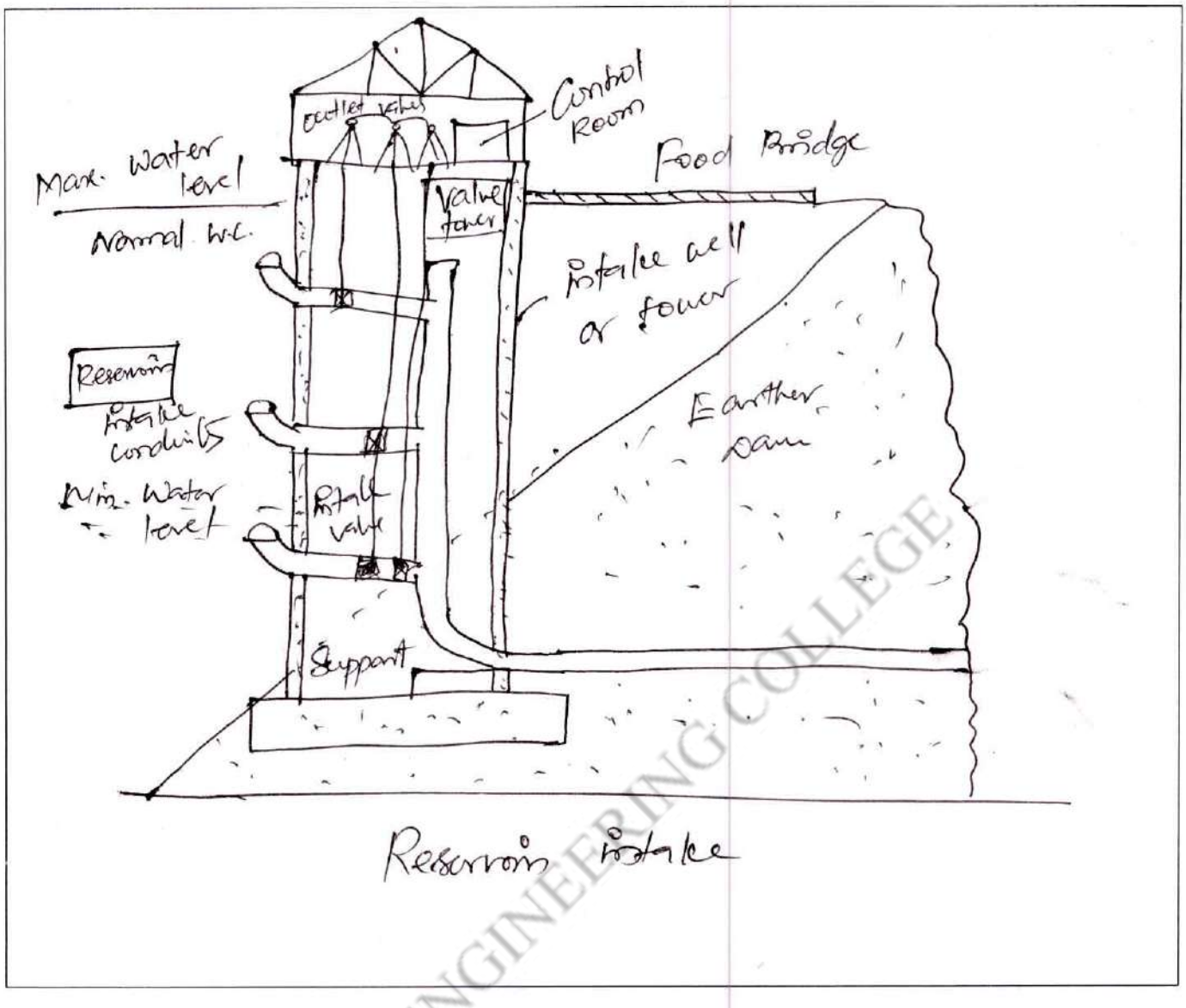
• Water entering the jack well is more clear.

• Sediments, if any gets deposited in bottom of jack well

which is periodically cleared manually by stopping the flow.

Reservoir intake:

- Located on the upstream side of earthern or masonry dams where maximum depth of water is available.
- It is similar to a river intake, except that the entry parts of river intakes are replaced here with intake conduits.
- The intake conduits which are installed at different levels withdraw the water from reservoir and let it into a common conduit (inside the intake well or tower) which conveys the water to Sluiceway funnel downstream.
- The flow of water into the intake conduits is regulated by valves operated from control room.
- The access to intake is provided through a foot bridge.
- Arrangement is similar to a dry intake tower.
- As intake well remains dry, it facilitates easy operation and inspections.



Suggested Questions / Assignments /Home works / any other
1. Write short note on intake structures

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 11 **UNIT I–**

Topic(s) to be covered	Types of intakes

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Lake intake and canal intake Submerged intake	understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

Lake intake:

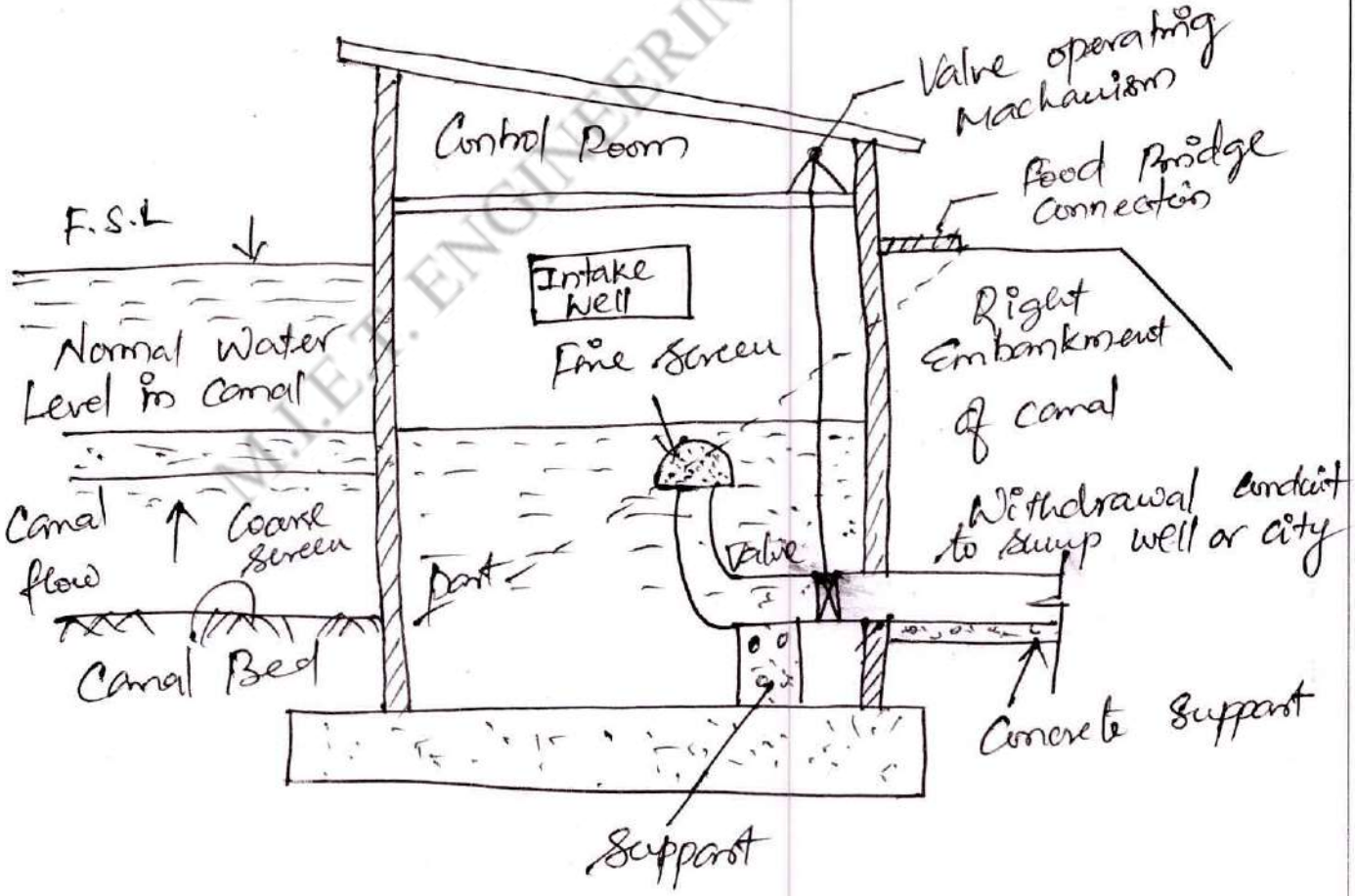
- Similar to reservoir intakes if the water depth is reasonable.
- At shallow waters, lake intakes are provided as submerged intakes.
- Submerged intake are constructed as cribs or bell mouths.
- The cribs ~~of~~ are made of heavy timber framework with cast iron or mesh grating on top. It protects the intake conduit from damage.

Canal intake:

- The intake well is located in the bank of canal.
- The water enters the intake well through a port protected with coarse screen, provided at

minimum water level in the canal.

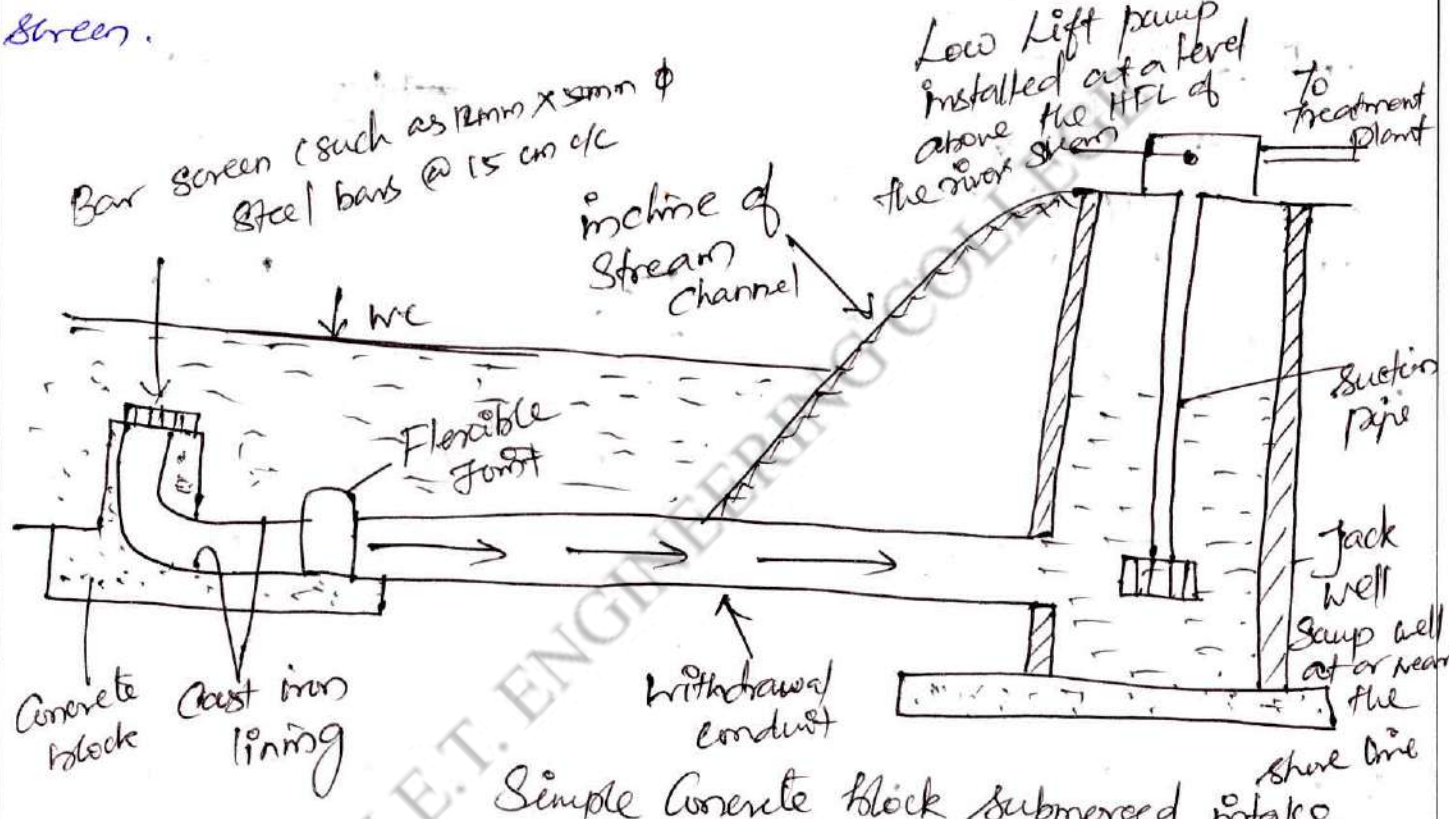
- The water from the chamber is then conveyed through a outlet (withdrawal) conduit to the distribution system.
- The inlet end of the outlet conduit is of bell mouth shape protected with a fine screen.
- An outlet valve is provided to control the flow which is operated from top.
- The flow through the outlet ~~pipe~~ may be under gravity or by pumping.



Canal Intake.

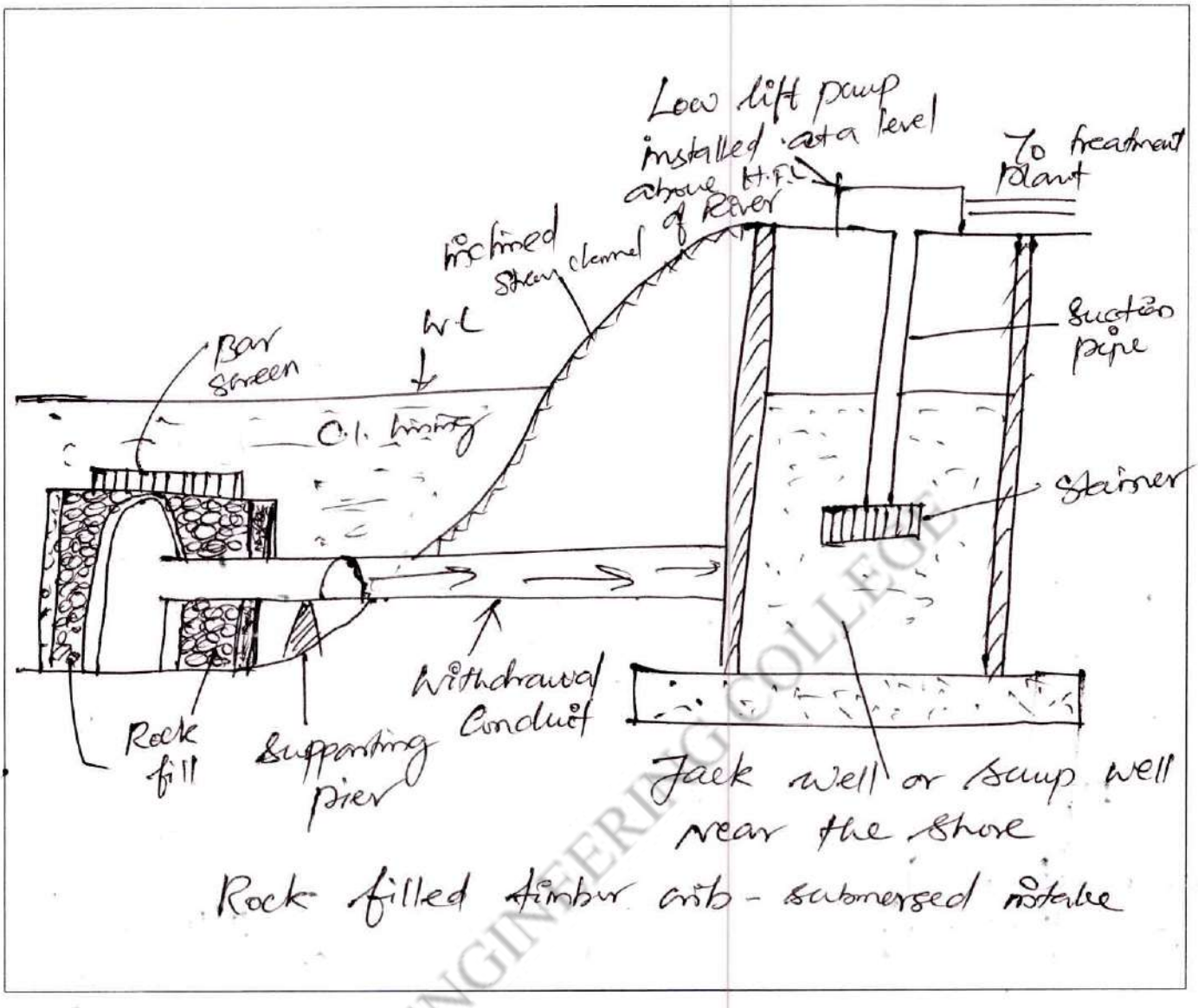
Submerged intake:

- Such intakes are placed in streams or lakes where there are deep waters and very less sediments.
- This consists of a simple concrete block or a rock filled timber crib supporting the starting end of the withdrawal pipe. The intake opening is protected by screen.



Simple Concrete block submerged intake

- The intake opening is kept about 2m above the bottom of lakes to avoid entry of sediments.
- These intakes are cheap and do not obstruct navigation. They are widely used for small water supply projects.
- The disadvantage of these intakes is that they are not accessible for cleaning, repairing etc.



Suggested Questions / Assignments /Home works / any other
1. Describe types of intakes?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 12. **UNIT I–**

Topic(s) to be covered	INTAKE TOWERS.

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
L01	Wet intake towers and dry intake towers	understand.

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

INTAKE TOWERS:

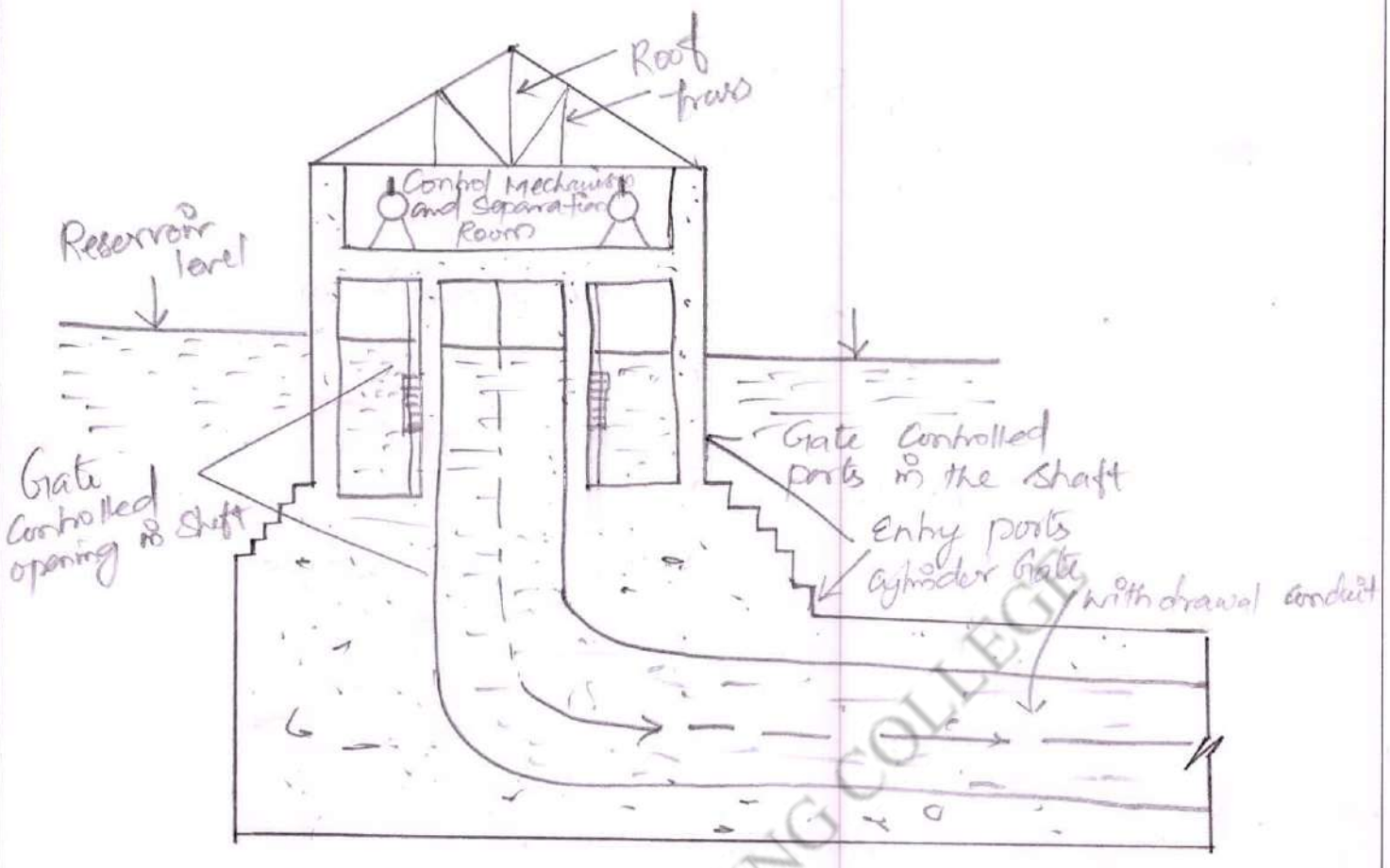
Types of intake towers:

(i) Wet intake tower

(ii) Dry intake tower.

i) Wet intake tower:

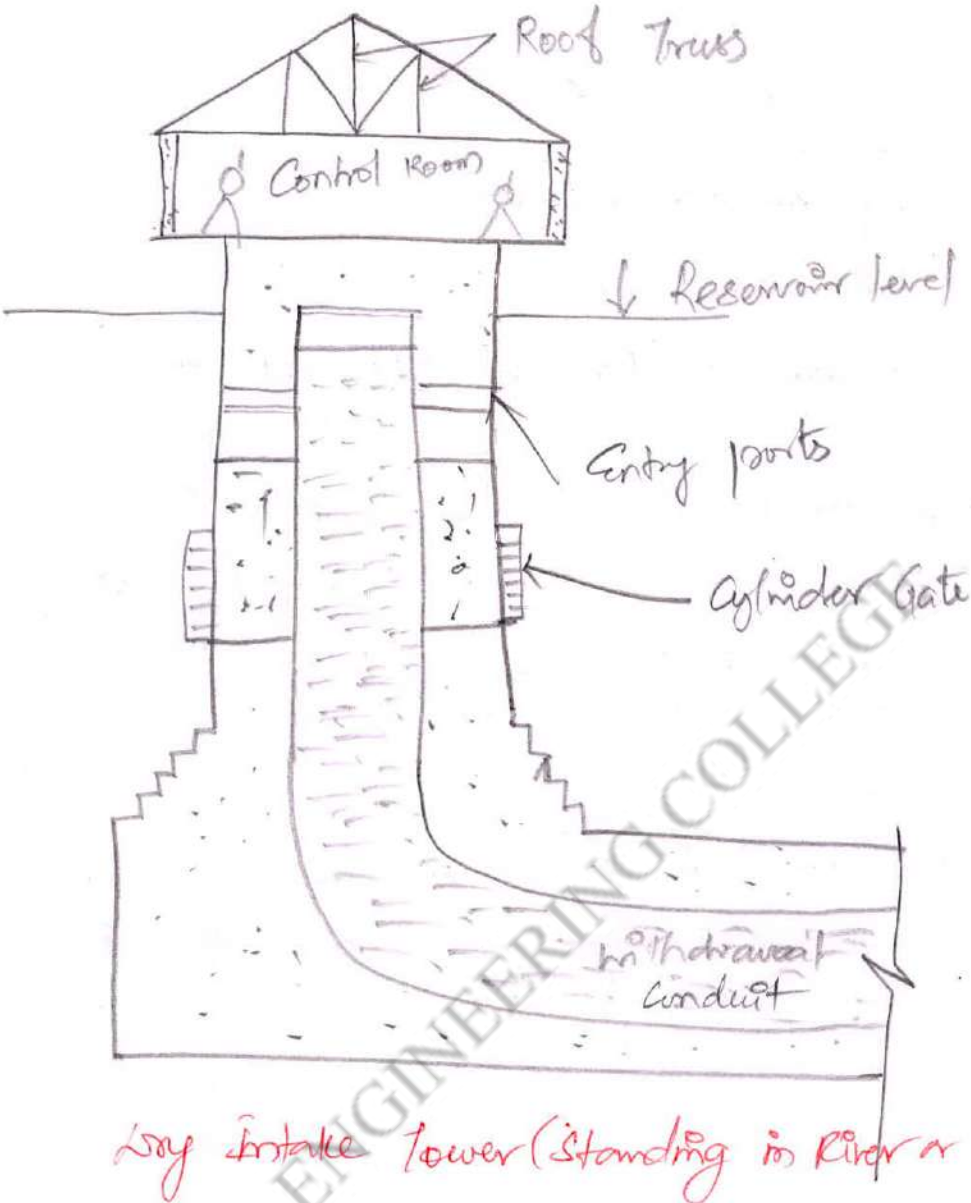
- In wet intake towers, water is filled in both the intake well (chamber) and the conduits.
- It consists of concrete circular shell filled with water and vertical inside shaft connected to the withdrawal pipe.
- Openings (ports) are provided in concrete shell as well as vertical shaft for the entry of water. The flow is regulated by gate valves.
- Water from the withdrawal pipe flows to the nearby water treatment plant either under gravity or by pumping.



Wet intake tower (Standing in River or Reservoir)

Dry intake towers:

- In dry intake towers, water is directly drawn into withdrawal conduits through gated entry ports.
- There will be no water in towers.
- Heavier construction is required than the wet intake towers.
- It facilities easy operations and maintenance.



Dry Intake Tower (Standing in River or Reservoir)

Comparison of Intake towers:

Wet Intake tower	Dry Intake Tower.
• Water is filled in both Intake tower as well as Conduits	• Water directly enters the conduits
• There will be water in Intake tower even when the valves are closed.	• There will not be any water in the intake tower when the valves are closed.
• Lighter Construction	• Heavier Construction.
• Operation and maintenance is difficult.	• Easy operation and maintenance.

Types of conduits:

- Depending upon the flow conditions, the conduits are categorised as.
  - Gravity conduits, - pressure conduits.

Gravity Conduit / open channels:

- Water flows under gravity at atmospheric pressure.
- Hydraulic gradient line will coincide with the water surface and will be parallel to bed of conduits.
- Conduits are provided at gradual slope. They cannot follow the natural surface level.

Pressure Conduit:

- closed conduits in which air entry is restricted. Water flow is under pressure above the atmospheric pressure. The bed conduit is independent of Hydraulic gradient line (HGL).
- the pipes can follow natural surface level (NSL) of ground.

Suggested Questions / Assignments /Home works / any other
1. Explain in detailed about Intake towers

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 13. **UNIT II** - WATER TREATMENT

Topic(s) to be covered	Objectives of water treatment.

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	objectives, unit operation and unit process.	understand.

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

Objectives of Water Treatment:

- To Remove objectionable colour of water.
- To Remove unpleasant taste and odour.
- To Remove dissolved gases in water.
- To Remove suspended, colloidal and dissolved impurities in water.
- To Remove hardness of water.
- To Reduce corrosiveness of water.
- To Remove the disease producing micro organism (pathogens) from water.
- To make water suitable for domestic and industrial purpose.

UNIT OPERATIONS AND UNIT PROCESS:

Unit operation: Treatment done by physical or mechanical methods are called as unit operations.

Eg: Screening, Filteration, Sedimentation etc.

Unit processes: Treatment done by employing chemical or biological methods are called as unit processes.

Eg: Coagulation, Chlorination etc.

Gas Transfer: Aeration: Water is exposed to oxygen, to remove dissolved harmful gases (CO_2, H_2S) and iron-Manganese from water. Aerators may be gravity aerators, spray aerators, diffusers. etc.

Ion Transfer:

(i) Chemical coagulation: Removal of colloidal particles - Coagulant is added to water to form clusters which settle rapidly.

(ii) Chemical precipitation: Chemicals are added to precipitate out the dissolved impurities.

Eg: Precipitation of Carbonate hardness by adding lime.

(iii) Ion Exchange: Interchange of ions between water and solid ion exchange media.

Eg: Water Softening process.

(iv) Adsorption: Ions are removed from solution and concentrated at surfaces of adsorbent.

Eg: Activated Carbon adsorption.

Solute Stabilization:

Water is stabilised and objectionable solutes are converted into unobjectionable forms.

(i) Chlorination - H_2S is oxidised into sulfate.

(ii) Liming - CO_2 is converted to soluble bicarbonate by passing through limestone.

Solids Transfer:

Removal of solids from water.

(i) Straining - Removes floating and suspended impurities using screens.

(ii) Sedimentation - Removal of suspended solids in settling tanks under gravity.

(iii) Floatation - suspended solids gets attached to floation agents that lift the particles to surface - removed by floatation devices.

(iv) Filtration - Suspended solids are trapped on the grains of filter media (sand, coal, granular materials)

Nutrient or molecular Transfer

Interfacial Contact

Miscellaneous operations

(i) Disinfection - Removal of pathogenes from water.

(ii) Desalination - Conversion of salt water into fresh water.

(iii) Fluoridation - Adding fluoride to water.

Solids Concentration and Stabilization - used in waste water (sludge) treatment to increase the

Solids Concentration of Sludge.

(i) Thickening
(ii) Centrifuging
(iii) Sludge digesters

Suggested Questions / Assignments /Home works / any other
1. Explain the objectives of water treatment?

	Text Books/ Reference Books		
S.No.	**Title**	**Author**	**Publisher**
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 14 **UNIT I–**

Topic(s) to be covered	AERATORS OF FLASH MIXERS

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	objectives, types of aerators, Spray nozzle, Cascade aerators, Air diffusion Trickling beds, inclined apron aerator and riffle plates.	understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

- It is an unit operation of gas transfer.
- In this process, water is brought in intimate contact with air, so as to absorb oxygen and to remove carbon dioxide gas.

Objectives of aeration are:

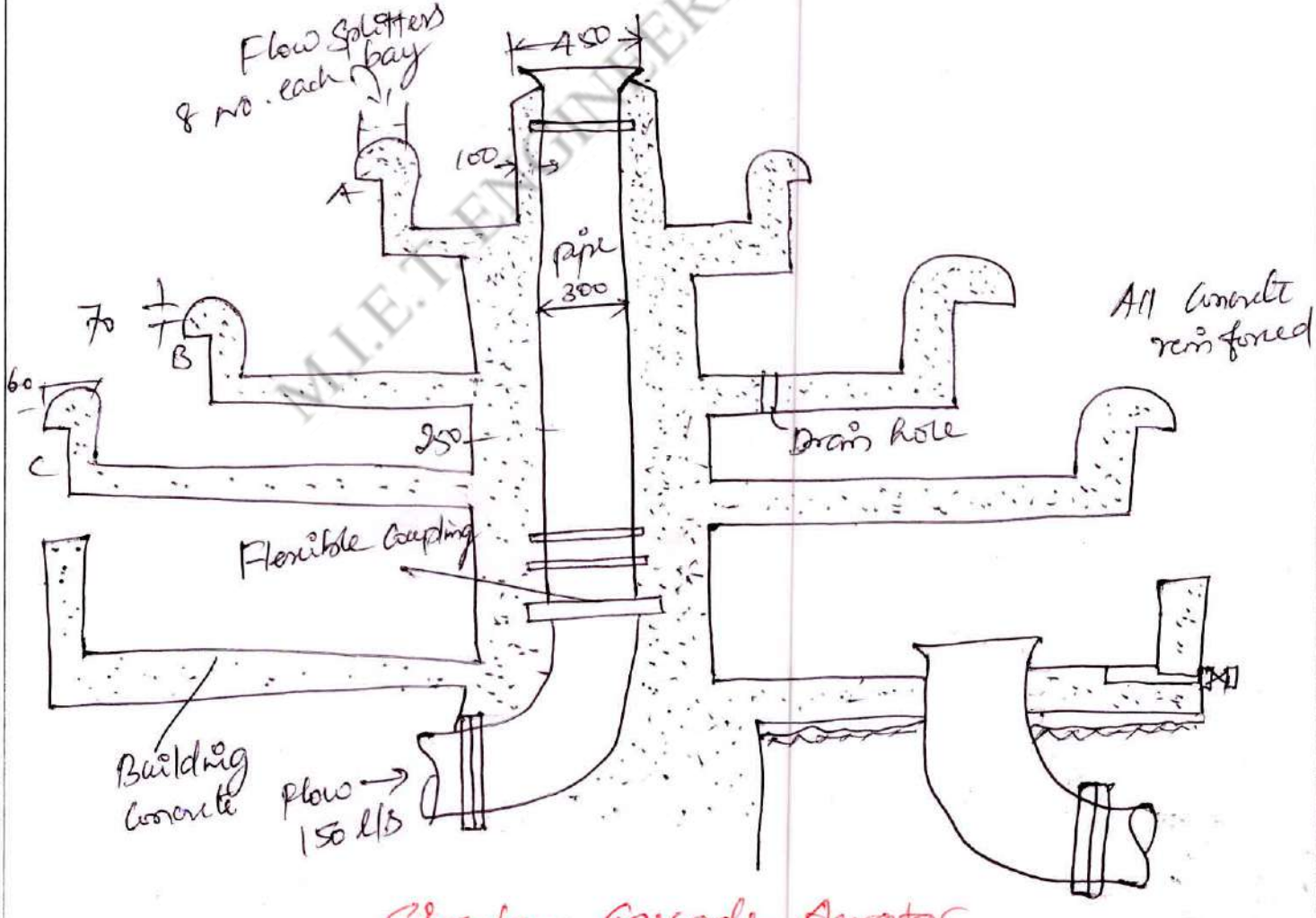
- Due to organic decomposition it removes taste and odour.
- It increases the dissolved oxygen in water.
- It removes the hydrogen sulphide and odour produced.
- It decreases carbon-di-oxide of water thereby reduces its corrosiveness and raises its pH value.
- It converts iron and manganese, from soluble and insoluble state so that these can be precipitated and removed.
- It kills bacteria to some extent.

- It helps in mixing of chemicals.

Types of Aerators:

1. Spray Nozzles: Water is sprinkled in air or atmosphere through special nozzle which breaks the water into droplets. It requires considerable head of water (0.15 to 1.5 kg/cm²) It efficiently at a pressure of 10 to 14 m Head of water. the carbon dioxide gas is removed upto 90%.

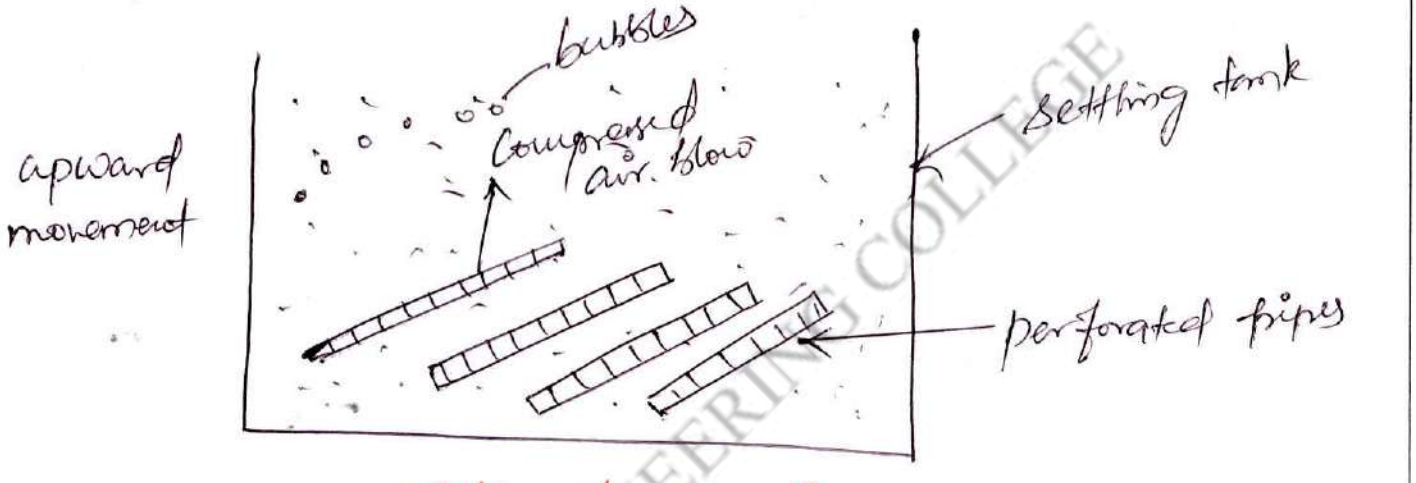
2. Cascade aerators: It is simplest form of gravity or free fall aerator. Weirs and waterfalls of any kind are cascade aerators. Water is made to fall through a certain height (1 to 3m) over a series of steps. due to this it comes into close contact with air. They are made of robust and durable materials with a long life.



Circular Cascade Aerator

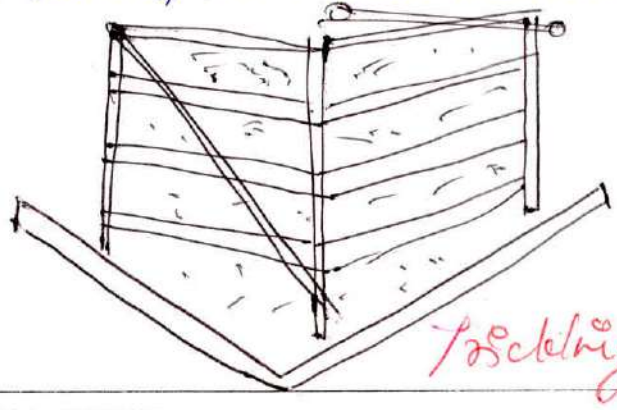
3. Air diffusion: In this method perforated pipe network is installed at the bottom of aeration tank, and compressed air is blown through these pipes. The air bubbles travel upward, it gets thoroughly mixed up with the water in the tank, causing aeration.

• Air diffuser basins have a retention period of about 15 minutes and a depth of 3 to 5 meters.



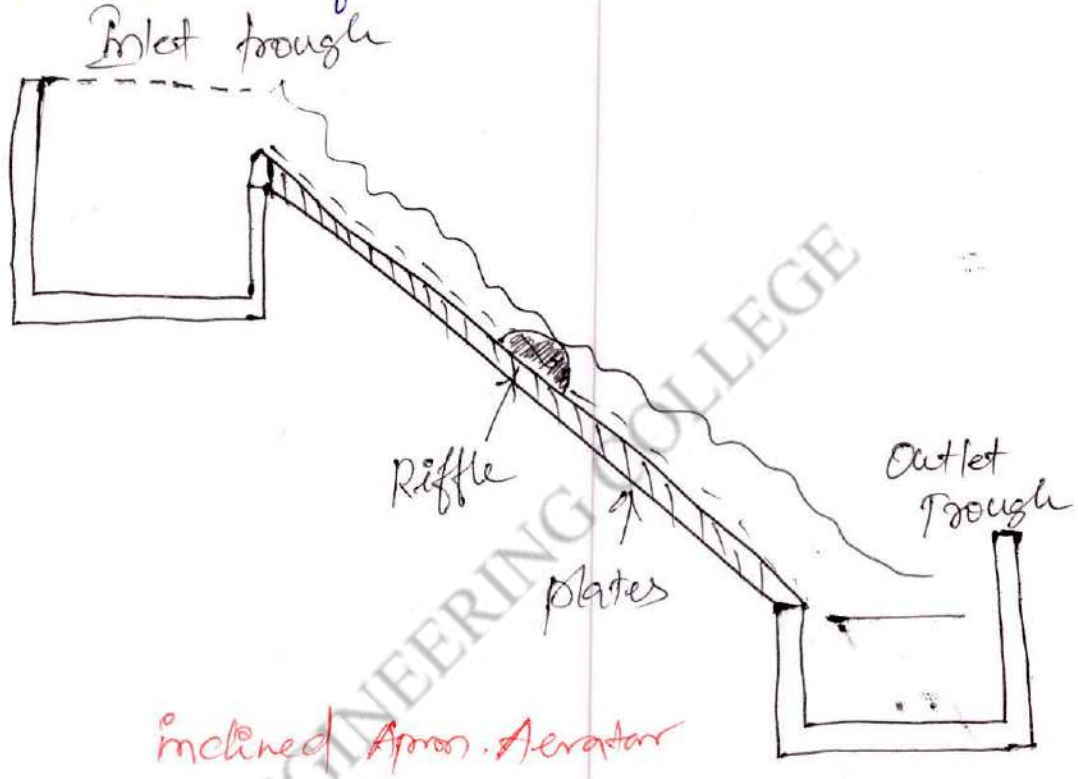
Diffused Aeration

4. Trickling beds (Gravel bed aerators): The water is allowed to trickle down the beds of coke, limestone or anthracite supported over the perforated bottomed trays, arranged vertically in series. The water is applied from the top through perforated distribution pipes and allowed to trickle down, up to the bottom bed. This method is better than cascades, but less effective than spray nozzles. Efficient in CO_2 removal than other methods.



Trickling bed Aeration

5. Inclined Apron aerator with riffle plates: The water allowed to fall along an inclined plane or apron which is usually studded with riffle plate in staring bone fashion. The breaking up of the sheet of water will cause agitation of water and consequent aeration.



Inclined Apron Aerator

Suggested Questions / Assignments /Home works / any other
1. Describe the types of aerators and its uses?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 15. **UNIT I–**

Topic(s) to be covered	Coagulation and Flocculation

	Lecture Outcome (LO)	
	At the end of this lecture, students will be able to	**Bloom's Level**
LO1	Coagulation, Flocculation, Factors affecting Coagulation.	Understand & Apply

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen & Apply

Lecture Notes

- Fine suspended and colloidal particles in water do not settle under gravity in plain sedimentation tanks.
- Most of the colloidal particles in water are negatively charged.
- Coagulants neutralize the negatively charged colloidal particles and allow them to coagulate (agglomerate) and form a gelatinous precipitate called 'floc'.
- The flocculated particles due to increase in size and mass readily settles in sedimentation tanks.

(i) Addition of measured quantities of chemicals (coagulants) to water and thorough mixing is done in a flash mixer.

(ii) Formation of precipitation which coagulates and forms floc which happens in a flocculator.

(iii) Settling of flocs in a sedimentation tank.

Coagulation:

The first stage which refers to formation of precipitate and destabilisation of charged colloidal particles.

Flocculation:

The second stage which refers to slow mixing technique promoting agglomeration of stabilised particles.

Factors affecting Coagulation:

Type of coagulant.

Quantity or dose of coagulant

Characteristics of water

- Type and quantity of suspended matter.
- Temperature of water.
- pH of water

Time and method of mixing - Short period of violent agitation (chemical mixing) followed by gentle stirring (floc formation)

Common Coagulants:

- Alum or Aluminium sulphate
- chlorinated copperas
- Ferrous sulphate and lime
- Magnesium carbonate
- polyelectrolytes
- Sodium aluminate

I

Determine the quantity of alum required in order to treat 13 million litres of water per day at a treatment plant, where 12 ppm of alum dose is required. Also determine the amount of CO_2 gas which will be released per liter of water treated.

Sol:

Quantity of water to be treated = 13×10^6 litres/day

Alum dose required = 12 ppm = 12 mg/l

Amount of alum required per day = $(13 \times 10^6) \times 12$ mg

= 156 kg.

Chemical Reaction involved is given by:

$$Al_2(SO_4)_3 \cdot 18H_2O + Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 \downarrow + 3CaSO_4 + 18H_2O + 6CO_2 \uparrow$$

Molecular wt. of alum $(Al_2(SO_4)_3 \cdot 18H_2O$

$= 2(26.97) + 3(32.066 + 4 \times 16) + 18(2 \times 1.008 + 16)$

= 666.

Molecular wt. of Carbondioxide $(CO_2) = (12.01) + 2 \times 16$

$= 44.01 = 44$

666 mg of alum → Release 6×44 mg of CO_2

Since 1 mg of alum releases 6 mg CO_2

12 mg of alum will release = $\frac{6 \times 44}{666} \times 12$ mg of CO_2

= 4.76 mg

Quantity of alum required per day = 158 kg

Quantity of CO_2 released per liter = 4.76 mg.

Suggested Questions / Assignments /Home works / any other
1. What is Coagulation?

	Text Books/ Reference Books		
S.No.	**Title**	**Author**	**Publisher**
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 16 **UNIT I–**

Topic(s) to be covered	Clariflocculator

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Feeding device, Basin, methods of feeding coagulants / feeding devices	Understand &

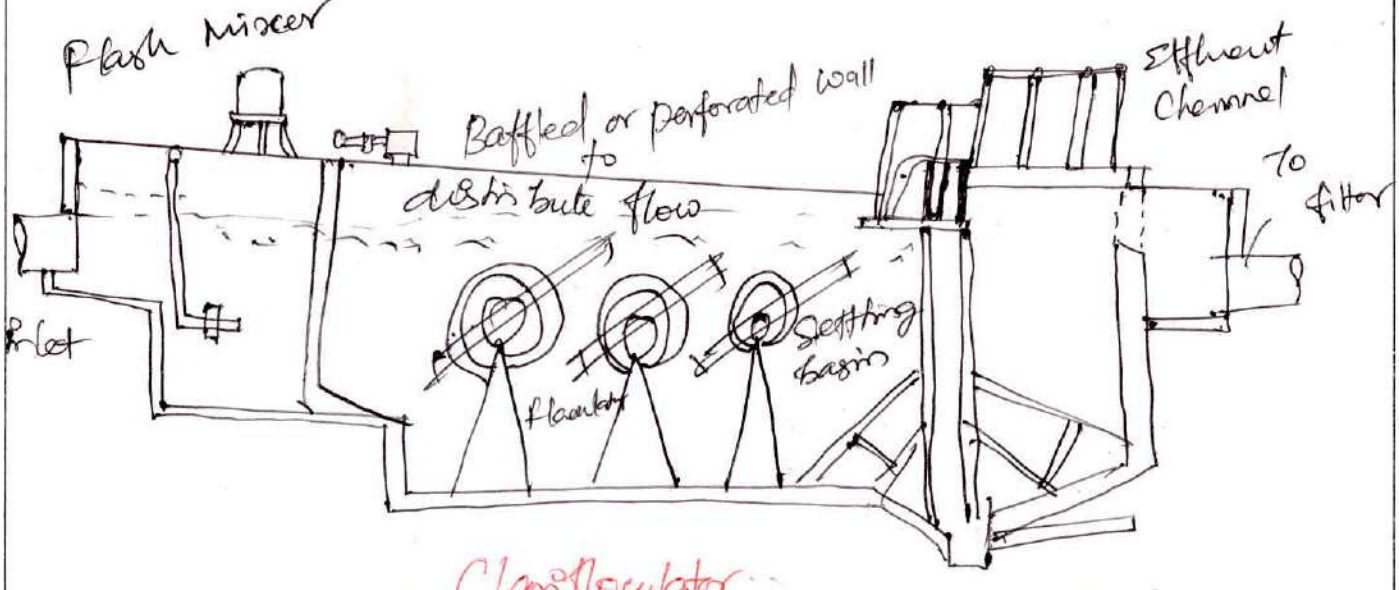
Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

The Constituents of a coagulation sedimentation plant or clariflocculator are:

- Feeding device
- Mixing device or mixing basin
- Flocculation tank or flocculator
- Settling or sedimentation tank

A clariflocculator containing all these four units.



Clariflocculator

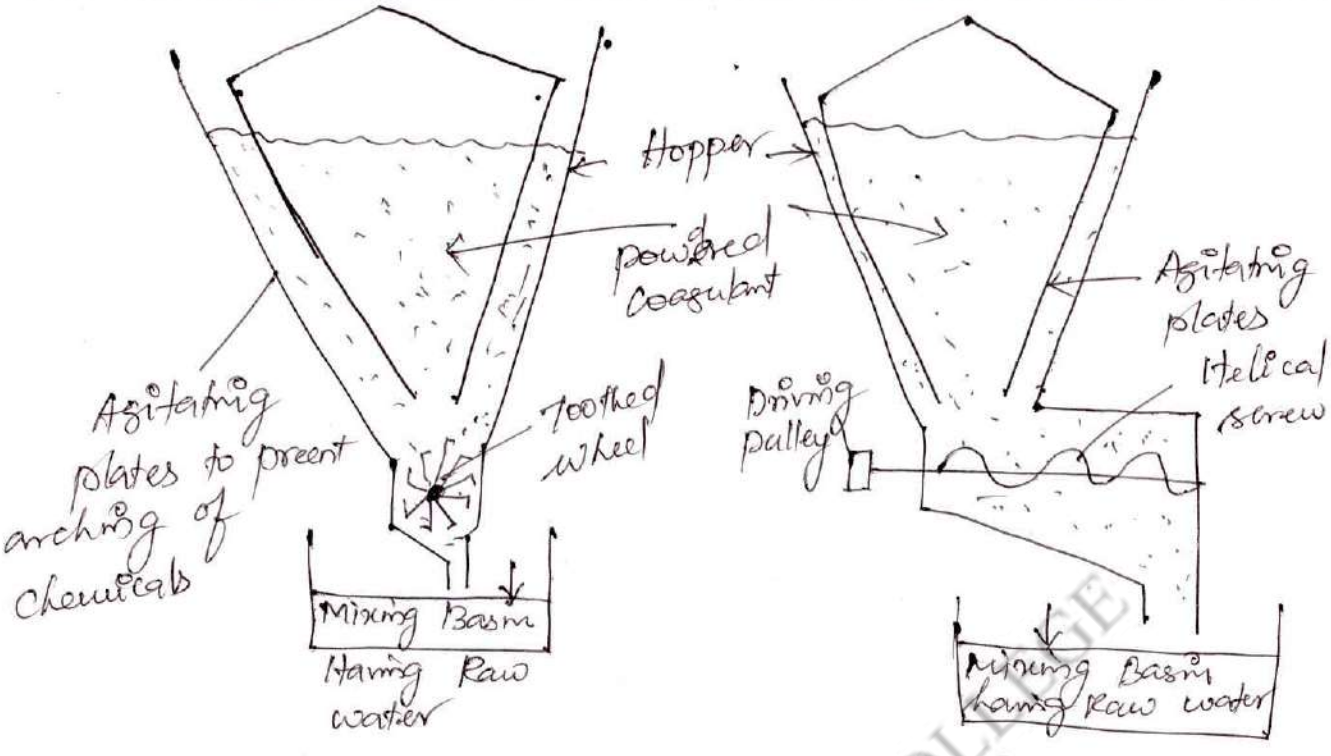
- The Chemical coagulant is fed into raw water through the feeding device.
- The mixture is thoroughly mixed and agitated in the mixing basin.
- It causes the very fine suspended and colloidal particles to agglomerate and form 'floc' which happens in the flocculation tank.
- Flocculated water is finally passed into the sedimentation tank where these flocculated particles settle and are removed.
- Each of these four units is are

Methods of feeding coagulant / Feeding devices:

(a) Dry feeding, (b) Wet feeding

Dry Feeding:

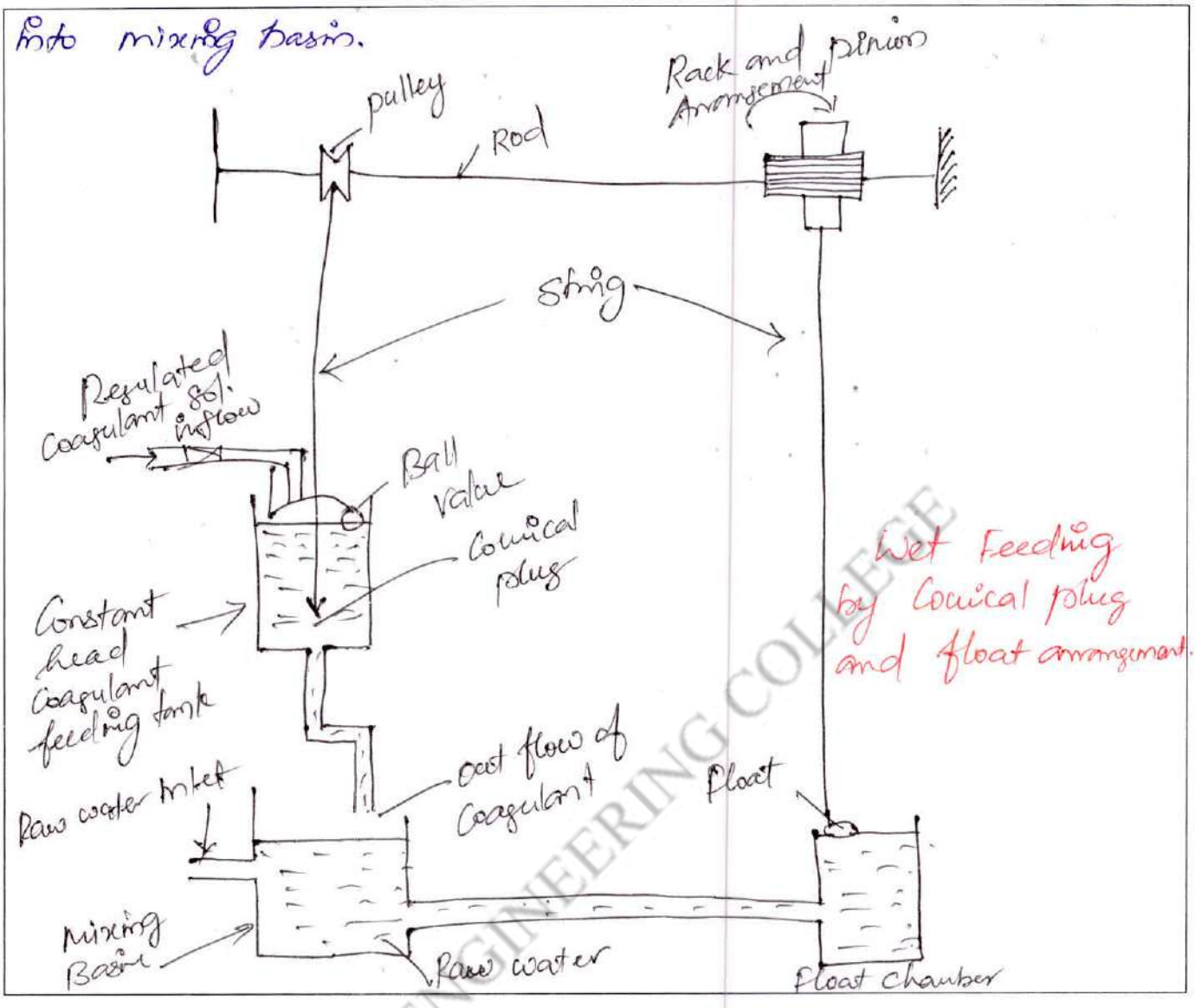
- The Chemical coagulant is fed into raw water in powdered form.
- Simple in operation, requires less space and cheaper.
- Coagulant is kept Hopper bottom of tank.
- Agitating plates prevent arching of coagulant.
- Dosage is regulated by speed of toothed wheel / helical screw which in turn is controlled by venturi device installed in the raw water pipes.
- The quantity of coagulant released is in proportion to the quantity of raw water entering the mixing tank.



Methods of dry feeding:

Wet Feeding:

- The chemical coagulant is fed into raw water in solution form.
- It is costlier, easily controlled and adjusted.
- A conical plug type arrangement is used to regulate the rate of coagulant discharge proportionate to the rate of raw water flow.
- The mixing basin and float chamber are interconnected for same water level.
- As the flow of water increases, the depth of water in mixing basin as well as float chamber increases and thereby lifting the float.
- As float rises, the pinion and pulley lifts the conical plug allowing more flow of coagulation solution



Suggested Questions / Assignments /Home works / any other
1. Define clariflaculator?

Text Books/ Reference Books			
S.No.	**Title**	**Author**	**Publisher**
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 17. **UNIT I–**

Topic(s) to be covered	Floculation and Sedimentation tank.

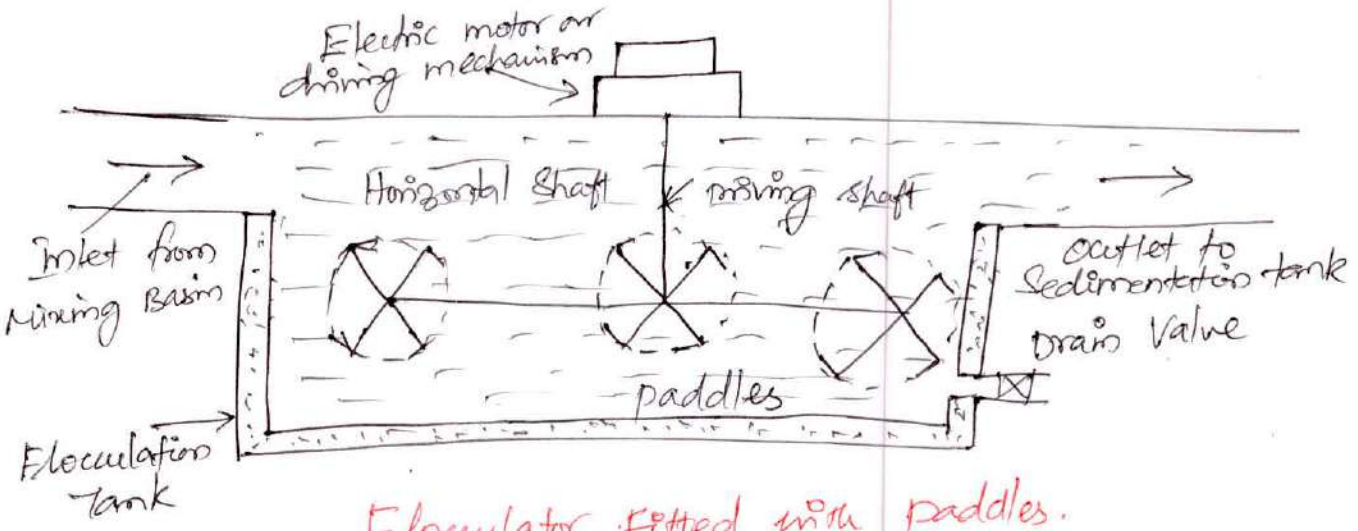
	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
Lo1	Floculator and clarifier	understand & Apply

Teaching Learning Material	**Student Activity**
Chalk and Talk.	Listen & Apply

Lecture Notes

Floculation Tank or Floculator:

- The violent agitation in a flash mixer should be followed by a slow and gentle stirring to permit agglomeration of floc particles.
- From the mixing basin, water is taken to the floculator where it is given slow and gentle stirring motion.
- They are rectangular tanks with paddles operated by electric motors.
- The water from the floculator is taken to the Sedimentation tank.
- The paddles rotate at 2 to 3 rpm speed. The detention time is 20 to 60 min (30 min normally).
- The velocity gradient is 20 to 80 s^{-1}. The clear distance between paddles and wall or floor is 15 to 30 cm.



Flocculator Fitted with paddles.

- Purpose of the flocculator is to facilitate floc formation. The floc so formed should not be allowed to settle in flocculator.
- The velocity of flow is not important in the design of flocculators, because the rolling motion created by the paddles prevents settling of floc.

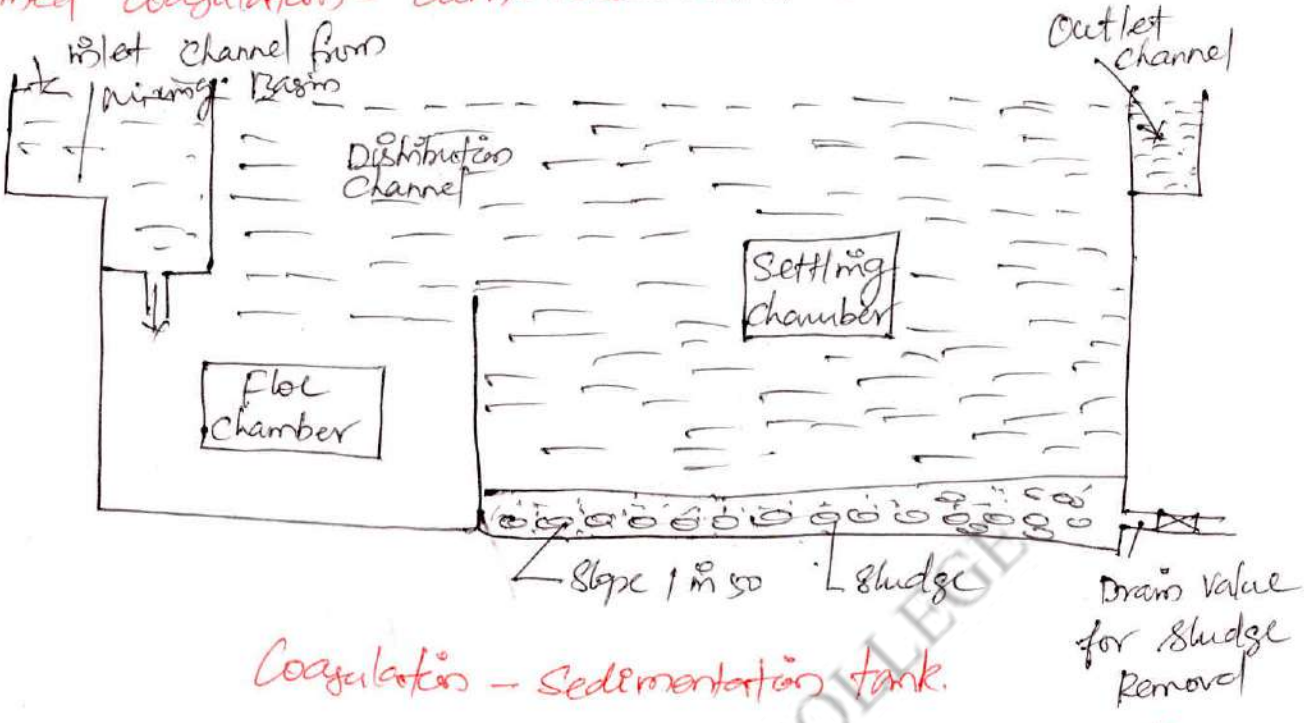
Design criteria for flocculator:

(i) Depth of tank – 3 to 4.5m
(ii) Detention time – 10 to 40 (30 min normal)
(iii) Velocity of flow – 0.2 to 0.8 m/s (0.4 m/s) normal.
(iv) Area of paddles – 10 to 25% of cross-sectional area of tank.
(v) Outlet flow velocity – 0.15 to 0.75 m/s
(vi) Power Consumption – 10 to 30 kW/mld.
(vii) Velocity Gradient (G): 10 to 75 s^{-1}.

Sedimentation tank (clarifier)

- Similar to plain sedimentation tanks, except that the detention period is less (2 to 4 hrs) and has a higher surface loading (overflow) rate of 1000 to 1250 kl/hr/m^2 or 24 to 30 m^3/day/m^2 of plan area.

Combined Coagulation - Cum - Sedimentation tanks:



Coagulation - Sedimentation tank.

Design a Coagulation - Cum - Sedimentation tank with continuous flow for a population of 60,000 persons with a daily per capita water allowance of 120 litres. Make suitable assumptions where needed.

Sol: Design of Settling tank:

Average daily consumption = population × per capita demand
= 60,000 × 120 = 7.2×10^6 litres

Maximum daily demand = 1.8 × Average daily demand
= $1.8 \times (7.2 \times 10^6) = 12.96 \times 10^6$ litres

Assuming detention time of 4 hrs (b/w 2 to 4 hrs)

Capacity or Vol. of tank = discharge × detention time

$$\text{Vol.} = \frac{12.96 \times 10^6}{24} \times 4 = 2.16 \times 10^6 = 2.16 \times 10^3 m^3$$

Assuming surface overflow rate as 1000 litres/hr/m^2 (b/w 1000 to 1250 l/hr/m^2)

$$Q = 12.96 \times 10^6 \text{ l/d} = 540 \times 10^3 \text{ l/hr}$$

$$SOR = \frac{Q}{\text{Surface area}} = \frac{Q}{B \cdot L} = 1000 \text{ l/hr/m}^2 = \frac{540 \times 10^3}{B \cdot L} \times 1000$$

$$B \cdot L = 540 m^2$$

Assuming width of tank as 12m, $12 \times L = 540 m^2$

Assuming Width of tank as 12m, $12 \times L = 540 m^2$

$12 \times L = 540 m^2$, $L = 45m$

Vol. $= L \times B \times Ht = 2.16 \times 10^3 m^3$, $45 \times 12 \times H = 2.16 \times 10^3$, $Ht = 4m$

Extra depth for Sludge storage (1 in 50 slope) $= 45/50 = 0.9m$

Assume Free Board $= 0.5m$.

Overall depth = water depth + sludge storage + free board

$= 4m + 0.9m + 0.5m, = 5.4m$

Provide settling tank of dimension $45m \times 12m \times 4m$

Design of the floc chamber

Depth of floc chamber $= \frac{1}{2} \times$ depth of settling tank

$= 1/2 \times 4.5 = 2.25m$

Assuming period of flocculation (detension period) as 20 minutes b/w 15 to 40 min).

Vol. or capacity of Chamber, $= Q \times$ detention time

$= \frac{12.96 \times 10^3}{24 \times 60} \times 2 = 180 m^3$

Area required $= \frac{Vol.}{depth} = \frac{180}{2.25} = 80 m^2$

Using same width $= 12m$

Length of flocculation Chamber $= 80/12 = 6.67m$, The dimension of floc Chamber $= 6.7m \times 12m \times 2.25m$

Suggested Questions / Assignments /Home works / any other
1. Explain in detailed about Clarifier.

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 18. **UNIT I–**

Topic(s) to be covered	plate and tube settlers

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
Lo1	plate and tube settlers, Advantage disadvantages. tube and plate settlers	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

Plate and Tube Settlers:

- It is an alternative to shallow basins and are used in conjunction with both existing and specially designed sedimentation basins.
- It is a shallow settling devices consisting of stacked offset trays or bundles of small plastic tubes of various geometries.
- The shape, hydraulic radii, angle of inclination and length of plate and tube settlers will vary according to particular installation.
- The flow within the basin passes upward through the plate or tube modules and exits from the basin above the modules.
- To be self-cleaning, plate or tube settlers are usually set at an angle btw 45° and 60° above the horizontal.

• When the angle of inclination of plate or tube is more than 60° the efficiency of the setting basin decrease.

• The need for flushing poses a problem with the use of plate and tube settlers where the characteristics of the solids to be removed vary from day to day.

• Tube settlers are a light weight structure composed of closely spaced tubes on an incline (usually b/w 45° and 60°)

• Clarifier up flow is passed through these tubes. Settling within these tubes and contact clarification of fine floc results in a build-up of particles on the tube surfaces. particles combine to form agglomerates which become heavy enough to slough against the upward flow and slide down the tube slope to join the sludge blanket below.

• Tubes are supplied in module form - each being 1 meter wide by 1 meter long by 0.67 metes high. The modules are arranged on a supporting framework to form a layer within the clarifier. The tube settlers are suspended at a ht 700mm below the top water level.

• The framework is held up by a number of 'hooks' over the top rim of clarifier tank. This was done to minimize the installation time.

• The entire installation may be completed in three days in an existing water treatment plant. The clear water

storage was filled to capacity prior to installation of the tube settlers to allow for the three days the plant was off line.

Advantages of tube settlers are:

- Solid removal efficiency will be higher leading to clarified water turbidity as less than 10NTU.
- Hence the load on filter will be less.
- Treatment plant capacity of existing water treatment plant could be increased by 50 to 60%.

Advantages of plate settlers are:

- Compact design: Spacing saving: Cost saving
- No moving parts: Low maintenance, no spare parts
- Simple installation: Saves money, immediate start up at full capacity.
- Ease of access: Individual removal of each lamella plate, easily available for inspection
- Sludge handling benefits: High underflow sludge concentration, low cost for sludge withdrawal.
- Flexible system: Retrofitting of existing tanks, custom design.

Disadvantages of tube settlers / plate settlers are:

- Algae growth in tubes and plates may cause

maintenance and odor problems.

- Easy to clean in Lambella but not in tubular module.
- Careful attention is necessary for the design of inlet and outlet structure to avoid turbulance and uneven flow.
- Sometimes high pressure hose water is injected to flush out the solids.

Suggested Questions / Assignments /Home works / any other
1. What is settlers?

Text Books/ Reference Books			
S.No.	**Title**	**Author**	**Publisher**
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 19. **UNIT I–**

Topic(s) to be covered	pulsator clarifier

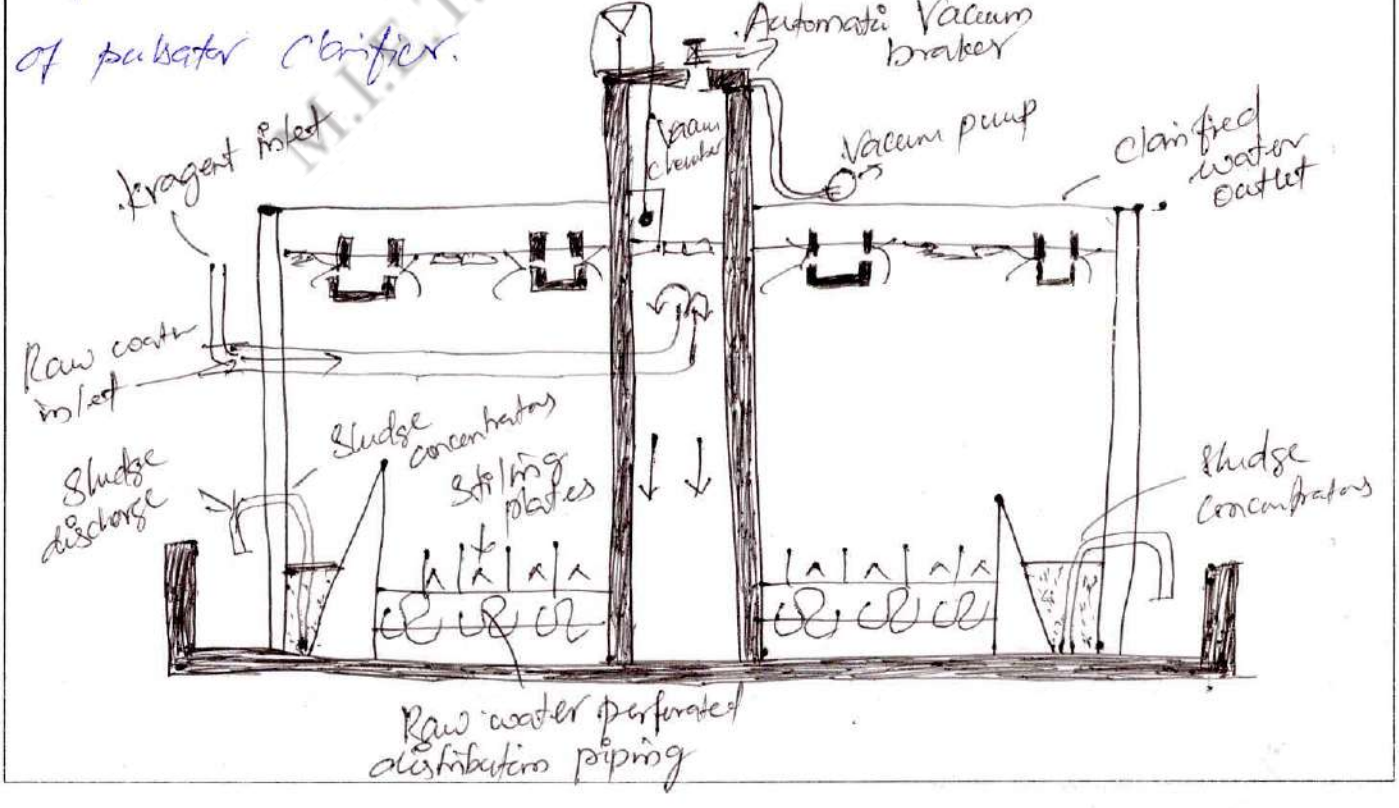
	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Components of pulsator clarifier, working principles of pulsator clarifier	understand

Teaching Learning Material	**Student Activity**
chalk & talk	Listen.

Lecture Notes

Vacuum chamber, Vacuum pump, Vent valve

1. Raw water distribution channel and perforated distribution pipes.
2. Lamellar plates and or tubes for clarification.
3. Clarified water collection laterals and channels.
4. Sludge collection and Concentrator schematic and view of pulsator clarifier.



Working Principles of pulsator clarifier:

- It consist of a flat-bottom tank with a series of perforated pipe at its base to distribute the raw water uniformly over the entire bottom.
- Coagulated water to pulsator flow intermittently through perforated pipes.
- Coagulant water is stored in the upper part of the vacuum chamber for a given period by creating vacuum.
- The hydraulic force is then released, and the coagulant water is pulsed at a high velocity through distribution pipes into the pulsator.
- Sludge blanket in pulsator flocculates and remove the particles.
- A set of channels (launders) is provided at the top of the pulsator to collect the clarified water evenly.
- By removing the air by suction from the vacuum chamber. The water level rises gradually inside the vacuum chamber. When it reaches a set level between 0.35m and 0.45m above the pulsator water level, a contact suddenly opens an air inlet valve.
- Atmospheric pressure is immediately applied to the water stored in the vacuum chamber which pushes the water into the perforated distribution pipes

at high speed.

- When the water level inside the vacuum chamber reaches the low level approximately 10-20 cm above that in pulsator, the air valve is closed and the cycle begins once again with creation of vacuum.

- The sludge blanket in the bottom part of the pulsator is subjected to alternating vertical motion. It expands when the water rushes from vacuum chamber during drop, for a short time (5-20 sec). and then shrinks (packs) during vacuum creation which lasts 25-50 seconds.

- Thus once in about 60 sec the water is pushed into pulsator through sludge blanket and the sludge blanket expands and shrinks once during that time.

- Frequency of pulsing is adjusted according to turbidity in raw water. For high turbidity shorter pulse interval (30 to 40 sec) and for low turbidity longer pulse interval (45 to 60 sec) is provided.

- The sludge blanket gradually increases in volume due to entrapping the impurities contained in the feed water. When the level of sludge blanket rises above a specified level (weir level) and sludge grid

into the concentrators.

• Sludge concentrator contains number of hopper bottomed tanks; The sludge is extracted from the concentrators at regular intervals.

Suggested Questions / Assignments /Home works / any other
1. List out the types of clarifier?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 20 **UNIT I–**

Topic(s) to be covered	SAND FILTRATION

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Purpose of filtration, theory of filtration, filter media	understand ↔ Apply

Teaching Learning Material	Student Activity
Chalk & Talk	Listen. / Apply

Lecture Notes

The process of passing the water through the beds of granular materials (filters) is known as filtration.

Purpose of filtration:

- To Remove very fine suspended and colloidal particles that do not settle in the sedimentation process.
- To Remove dissolved impurities in water.
- To Remove pathogenic bacteria from water.
- To Remove colour, odour, turbidity in water.

Theory of filtration:

- During filtration, the following actions take place:
  - (i) Mechanical straining
  - (ii) Sedimentation
  - (iii) Biological action
  - (iv) Electrolytic action

(i) Mechanical straining (for coarser particles):

- Water passes through filter media (sand), suspended particles larger than pore-space of filter media get trapped. The trapped particles form a mat on filter media, in straining impurities

(ii) Sedimentation (for finer particles):

- The voids of filter media acts as small sedimentation tanks, fine particles are removed by settling.

(iii) Biological action:

- Certain microorganisms & bacteria present in voids of filters form coatings over the sand grains.
- These organisms convert organic impurities into harmless compounds.
- It forms dirty skin layer to assisting straining out the impurities in water.

(iv) Electrolytic charge (Ionisation)

- Sand grains of filter media and impurities in water are oppositely charged. If (impurity) contact with sand grains get neutralised, making water pure.

Filter Media:

Sand (fine or coarse) is generally used as filter media and supported on gravel.

Sand:

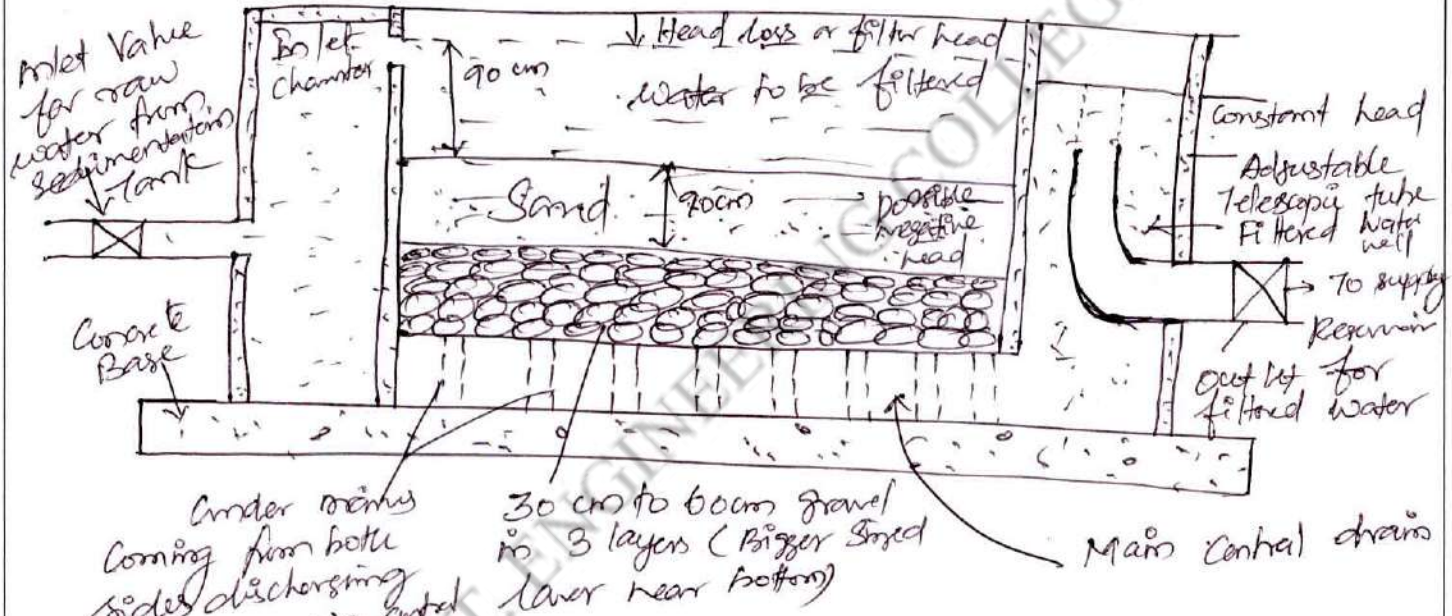
- Obtained from hard and resistant quartz or quartzite.
- Uniform in nature and size.
- It should not loose more than 5%, its wt. in HCl for 24 hrs
- D_{10} size of sieve in mm, D_{60} size, 60% particles are finer.
- Uniform coefficient (C_u) is measure of particle range

$C_u = \frac{D_{60}}{D_{10}}$, $C_u = 1$ for uniformly graded sand.

Anthracite: Crushed anthracite can be used as filter media separately or combined with sand (mixed media). It is costly than sand.

Garnet sand: Specific gravity (4.2). dense material, due to high cost, used in mixed media filter.

Other materials: Locally available materials such as shredded coconut husks, burned rice husks, crushed glass, slag, metallic ores etc. can be used as filter material.



Section of a slow sand filter.

Design of slow sand filter:

Design six slow sand filter beds

Population to be served : 50,000 persons

per capita demand : 150 litres/head/day

Rate of filtration : 180 litres/hr./sq.m

Length of each bed : Twice the breadth

Assume max. demand as 1.8 times the average daily demand.

Also assume that one unit, out of six, will be kept as stand by

Sol:

Average daily demand = pop. x per capita demand.
= 50,000 x 150 litres/day.
= 7.5×10^6 litres/day.

Max. daily demand = 1.8 x Average daily demand
= $1.8 \times 7.5 \times 10^6 = 13.5 \times 10^6$ litres/day

Rate of filtration = 180 litres/hr/sq.m = (180 x 24) litres/d/sq.m

Total surface area of filters required = $\frac{\text{Max. daily demand}}{\text{Rate of filtration/day}}$

$= \frac{13.5 \times 10^6}{180 \times 24}$ sq.m = 3125 m^2

6 units are used with 1 unit, 5 units for filtration

Area of each filter unit = $\frac{3125}{5} = 625\ m^2$

Area = 625 m^2

$L \times B = 625$

$L = 2B$

$(2B)B = 625$, $B^2 = 312.5$, $B = 17.7 \simeq 18$ m

Now, $L = 2B = 2 \times 18 = 36$m

Hence, use 6 filter units with one unit as standby, each unit of size 36m x 18m, arranged in series with 3 units on either side.

Suggested Questions / Assignments /Home works / any other
1. Explain in detailed about Sand filters.

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 21. **UNIT I–**

Topic(s) to be covered	RAPID SAND FILTER

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Gravity type, pressure type, Enclosure tank, filter media (sand), Base material (Gravel), Underdrainage system.	understand.

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

Rapid Sand filter: Gravity Type:

Rapid Sand filters are of two types:

(i) Gravity type - It uses larger and coarser sand as filter media to increase the rate of filtration.

(ii) Pressure type - Water is filtered under pressure, thereby increasing the rate of filtration.

A gravity type rapid sand filter consists of following parts:

1. Enclosure Tank: Smaller in size, generally rectangular in shape, constructed of masonry or concrete coated with water proof material. Depth of tank is 2.5 to 3.5 m.

· Surface area of each unit 20 to 50 m² and are arranged in series.

· The L/B ratio is 1.25 to 1.35. RCC or CI troughs are provided in the tank to distribute water during

operation and for collection of wash water during cleaning (backwashing).

Filter Media (Sand): Sand, free from dirt, organic and suspended matters; hard and resistant preferably quartzite, depth of sand 0.6 to 0.9m, effective size 0.35 to 0.6mm. Coefficient 1.2 to 1.7, due to increased effective size and decreased uniformity co-efficient, the void space is more which increases the rate of filtration.

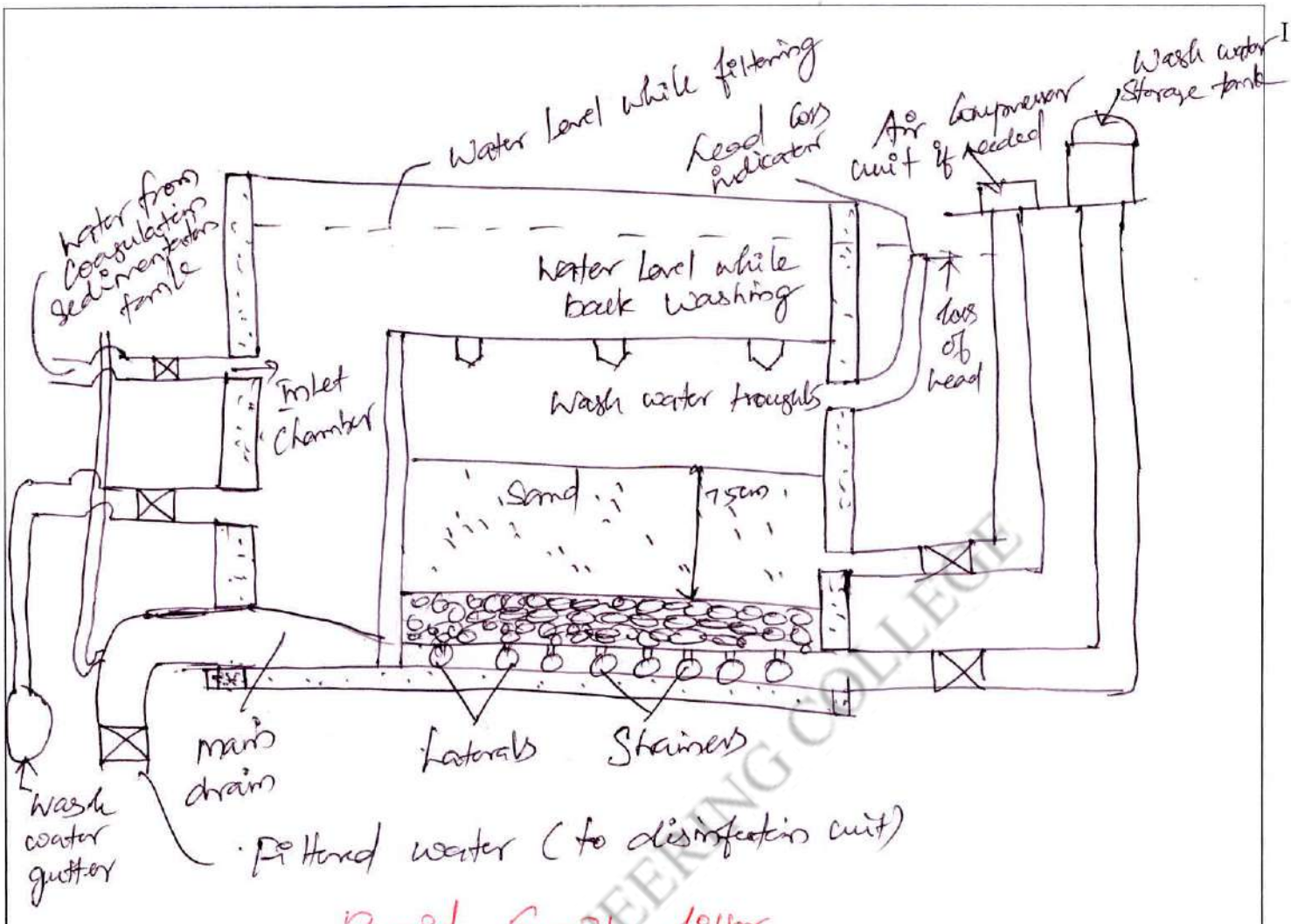
Base Material (Gravel): Sand media is supported on graded gravel layers. Gravel should be free from clay, dirt and organic matter and should be hard, durable and round. Its depth is 45 to 60 cm and normally laid in layers.

Layer	depth	Grade size
Top most	15 cm	2mm to 6mm
Intermediate	15 cm	6mm to 12 mm
Intermediate	15 cm	12mm to 20 mm
Bottom most	15 cm	20mm to 50 mm

Underdrainage system: It serves two purposes

(i) Collects the filtered water;

(ii) Distribute wash water uniformly upward during cleaning (back washing)



Rapid Gravity filter

Perforated pipe type: The lateral drains are provided with holes at bottom side.

Pipe and Strainer type: Strainers are placed on laterals, is small brass pipe closed at its top by a perforated cap.

Design of Rapid sand Filters:

Design a set of rapid gravity filters for treating water required for a population of 50,000, the rate of supply being 180 litres per day per person. The filters are rated to work 5000 liters per hour per sq.m. Assume whatever data are necessary.

Sol:

Average demand = population × per capita demand

$= 50,000 \times 180 = 9 \times 10^6$ l/d

Maximum demand = 1.8 × Avg. daily demand

$= 1.8 \times 9 \times 10^6$ l/d

$= 16.2 \times 10^6$ l/d

Water demand per hour = $\frac{16.2 \times 10^6}{24}$ l/hr

$= 0.675 \times 10^6$ l/hr

Rate of filtration = 5000 l/hr/sq.m

Area of filter beds required = $\frac{\text{Water demand}}{\text{Rate of filtration}} = \frac{0.675 \times 10^6 \text{ l/h}}{5000 \text{ l/hr/m}^2}$

$= 135 \text{ m}^2$

Since two units are designed.

Area of each unit = $\frac{135}{2} = 67.5 \text{ m}^2$

Assuming $\frac{L}{B} = 1.5$, $L \times B = 67.5$

$(1.5B)\,B = 67.5$

$B = 6.75$ m

$L = 1.5 \times 6.75 = 10$ m

Hence, two units of size 10m × 6.75m are provided with one additional unit as stand-by.

Design a rapid sand filter for 4 MLD of supply with all its Principal Components.

Sol:

Water Required per day = 4 million litres

Assuming 4% of filtered water is used for backwashing

Total filtered water required per day

$= 1.04 \times 4 \text{ ML} = 4.16$ MLD

Assuming 0.5 hr (30 min) is lost in backwashing everyday

Filtered water required per hour = $\frac{4.16}{23.5}$ ML/hr (∵ operating time 23.5 hrs)

= 0.177 ML/hr

Assuming rate of filtration = 5000 l/hr/sq.m

Area of filter required = $\frac{0.177 \times 10^6 \text{ l/hr}}{5000 \text{ l/hr/m}^2} = 35.4 m^2$

Assuming that 2 units are provided

Area of each unit = $\frac{35.4}{2} = 17.7 m^2$

Assuming L/B = 1.5, Area = L × B = $17.7 m^2$

(1.5 B) B = 17.7

B = 3.43 m/L = 1.5 × 3.43 = 5.14m

Hence, adopt 2 filter units with dimensions 5.2 m × 3.4m

Design of under drainage system (manifold & Lateral system)

Total area of perforations = 0.2% of total filter area

= $\frac{0.2}{100} \times (5.2 \times 3.4) = 0.035 m^2$

Total area of laterals = 2 × total area of perforations

= 2 × 0.035 = $0.070 m^2$

Area of manifold = 2 × area of laterals

= 2 × 0.07 = $0.14 m^2$

Diameter of manifold (Circular pipe) = $\pi/4 \, d^2 = 0.14 m^2$

$d = \sqrt{\frac{0.14 \times 4}{\pi}} = 0.42m$

Use 45 cm dia manifold pipe laid lengthwise along the center of filter bottom. Laterals are laid perpendicular to manifold width wise at spacing of 15cm.

No. of laterals = $\frac{\text{Length of filter}}{\text{spacing of laterals}} = \frac{5.2m \times 100}{15cm} = 34.6 \, (35)$

35 laterals on either side, hence total 70 laterals

Lateral length = $\frac{\text{width} - \text{manifold diameter}}{2} = \frac{3.4 - 0.45}{2} = 1.475m$

Adopt 13 mm perforations in laterals

Total area of perforations = 0.035 m² = 350 cm²

$N \times \pi/4 (1.3)^2 = 350$

where N = Total no. of perforations in all the 70 laterals

$$N = \frac{350 \times 4}{\pi (1.3)^2} = 264$$

No. of perforations in each lateral, $\frac{264}{70} = 3.8$ say 4

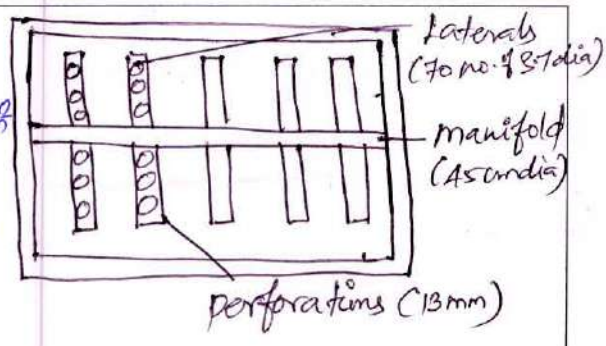
Area of perforation per lateral $= 4 \times \pi/4 \times (1.3)^2 = 5.3 \text{ cm}^2$

Area of each lateral = 2 × Area of perforations

$= 2 \times 5.3 = 10.6 \text{ cm}^2$

Dia of each lateral $= \sqrt{10.6 \times 4/\pi} = 3.7$ cm

Hence, use 70 laterals each of 3.7 cm dia at 1 cm c/c each having 4 perforations of 13 mm size, with 45 cm dia manifold.



Suggested Questions / Assignments /Home works / any other
1. Describe Rapid Sand filter.

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 22 **UNIT I–**

Topic(s) to be covered	Disinfection

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Boiling of water (Sterilization), Treatment with excess lime, with Ozone, with iodine and bromine, UV-rays.	Understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

- The filtered water from the Slow or Rapid sand filters, normally contains some harmful pathogenic (disease causing) bacteria.
- The process of killing these harmful bacteria is called disinfection and the chemicals used in this process are called disinfectants.
- The disinfectant chemicals used should therefore be able to give residual sterlizing effect for a long period.

Minor Methods of disinfection:

- Boiling of water (Sterilization):
  - Most effective method since boiling of water kills all the bacteria and micro-organism.
  - This method is not feasible for large scale public water supplies.

- During epidemics, the consumers are advised to boil the water before drinking.

- Treatment with excess lime:
  - Excess lime added increases the pH of water to greater than 9.5, when E-coli present in water will die
  - The bacterial removal efficiency is upto 99 to 100%.
  - The Excess lime added has to be removed by re-carbonation or other suitable methods, before supplying it to the consumers.
  - Dosage of lime is between 10 to 20 ppm of Calcium oxide.

- Treatment with Ozone:
  - It is faintly blue gas of pungent odour and is an excellent disinfectant.
  - It is produced by passing a high tension electric current through a stream of air in a closed chamber.

$$3O_2 \rightarrow 2O_3 \rightarrow O_2 + O$$

  - The Nascent Oxygen is a powerful oxidizing agent and removes the bacteria as well as organic matter from water.
  - Ozone removes the colour, taste and odour from water, and it is very costly.

- Treatment with iodine and bromine:
  - Addition of iodine and bromine to water kills the pathogenic bacteria. The dosage is 8 ppm and contact period is 5 minutes.
  - Not used for treating large scale public supplies, but may be used for small water supplies for army troops, private plants, swimming pools etc.
- Treatment with ultra-violet rays:
  - Uv-rays are effective in killing both the active bacteria as well as spores.
  - Uv-rays are generated by mercury vapours lamps enclosed in a quartz globe.
  - This method is costly and hence not commonly used except in private buildings, office buildings, institutions and swimming pools.
- Treatment with potassium permanganate:
  - Common method in rural areas potassium permanganate ($KMnO_4$) is dissolved in a bucket of water and is mixed with the well water.
  - The dosage is 1 to 2 mg/L with contact period of 4 to 6 hours.
  - Addition of potassium permanganate imparts pink colour to water and the water should not be used during the first 48 hours.

- Treatment with silver, called Electro-katadyn process:

. Silver when immersed in water exerts an inhibiting action on bacterial life. Silver ions, with or without activators (palladium or gold) are deposited on particles of granular activated carbon. Bacteria laden water contacting the silver impregnated carbon release minute quantities of silver - 25 to 40 ppb which acts as disinfectant.

- The contact time varies from 10 to 60 minutes. Since silver is costly, this method is suitable for small installations or for private individual houses.

Suggested Questions / Assignments /Home works / any other
1. Explain disinfection of water in detail.

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 28. **UNIT I–**

Topic(s) to be covered	Defluoridation.

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Methods of defluoridation, Adsorption by activated ammonia, ion exchange, Reverse osmosis.	Understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

- The optimum concentration of fluride in drinking water should be 1 to 1.5 mg/l.
- Fluride in water causes dental caries.
- It also believed that fluoride stimulates bone formation, reduce hardening of arteries and also helps in treatment of osteoporosis.
- Fluoride compounds are added to water in the form of sodium fluoride (NaF), sodium silico fluoride (Na_2SiF_6) and hydro-fluorisilicic acid (H_2SiF_6) and this process is called "Fluoridation".

(1) Dental Fluorosis :-

Discoloured, blackened, mottled or chalky white teeth and pitting of enamel.

(ii) Skeletal Fluorosis:

Severe and permanent bone and joint deformations.

(iii) Non-skeletal Fluorosis:

- Gastro-intestinal problems (abdominal pain, diarrhoea, constipation).
- Neurological disorders (nervousness, excessive thirst, frequent urination).

Methods of defluoridation:

- Absorption by activated alumina.
- Ion Exchange Adsorption method.
- Reverse Osmosis process.

Adsorption by activated alumina:

- Raw water containing high contents of fluoride, passed through the insoluable granular beds of substance like activated alumina or activated carbon, serpentinite, which adsorbs fluoride from the percolating water, out defluoridated water.
- Activated alumina, is found to be an excellent medium for removal of excess fluoride. It is highly selective to fluoride in the presence of sulphates and chlorides, when compared to synthetic ion exchange resins.
- The activated alumina, after becoming saturated with absorbed fluoride, can be cleaned and regenerated by back washing with 1% caustic soda sol. (NaOH).

Ion Exchange Adsorption Method:

- Ion exchange process is similar to the zeolite process for removing hardness from water.
- This process, uses a strong base anion exchange resin (zeolite) in the chloride form.
- The water passes through the bed of the resin contained in a pressure vessel, fluorides and other anions like arsenic, nitrates, etc. present in the water are exchanged with the chloride ions of the resin, thus releasing chlorides into water and adsorbing fluoride ions into the resin.
- During regeneration, the process gets reversed, as the anions absorbed on the resin get replaced by chloride ions and discharged into wastewater.
- The capacity of plant based on this technology may range from 500l/h to 5000 l/h.
- This method ensure high efficiency of fluoride removal (besides removing nitrates, arsenic etc).
- But it requires regular replacement of resin, and large amount of salt (NaCl) for regeneration of resin.
- The safe disposal of waste water from regeneration containing high concentration of ferric fluoride, nitrate and arsenic ions etc. again poses serious problems.

Reverse Osmosis process:

- The raw water is passed through a semi-permeable membrane barrier, which permits the flow of clear water through itself and blocks the flow of salts including fluorides.
- This method is generally adopted for desalination for removing salt from water and has been thoroughly explained under "desalination"

Suggested Questions / Assignments /Home works / any other
Define defluoridation.

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 24 **UNIT I–**

Topic(s) to be covered	Residual Management

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Residue, Construction, Operation and Maintenance aspect	understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

- Water treatment plants produce a wide variety of waste products as well as safe drinking water.
- These residuals may be organic and inorganic compounds in liquid, solid and gaseous form depending on the source of raw water and the type of treatment process, Commonly, coagulation/filtration, precipitative softening plant, membrane separation, ion exchange, granular activated carbon.
- Characterize form, quantity and quality of residuals.
- Determine appropriate regulatory requirements.
- Identify feasible disposal options.

- Select appropriate residuals processing / treatment technologies.
- Develop a residuals management strategy that meets both the economic and non economic goals established for a water treatment facility.

Residuals Categories:

- Sludges (i.e. water contains suspended solids from the source water & reaction products of chemicals added in treatment process.
- pre-sedimentation, coagulation, filter backwashing operations, lime softening, iron and manganese removal, and slow and diatomaceous earth filtration all produce sludge.
- Concentrate from ion exchange regeneration and salt water conversion membrane reject water and spent backwash, and activated alumina waste regenerate.
- Ion exchange resins, spent granular activated carbon and spent filters media (including sand, coal, diatomaceous earth from filtration plants)
- Air emissions (off gases from air stripping, odor control units, or ozone destruction).

Maintenance scheduling:

- Maintain each equipment is done as the recommendations of manufacturer.
- History card maintain for equipment performance.
- Housekeeping is essential for plant operation.

Pumping Machinery:

- To locate machinery in a way so as to have free fall from invert of sewer.
- Minimum one pump to be operated during night hours so that sewers are empty in morning.
- Wire / Rail should be in good condition Guide
- Wire / Rail should be in good condition

Screening Chamber & wet well:

- Regular cleaning
- Disposal of Screenings
- Washing of Bar Screens
- Washing Sludge layer from walls using Waterjet.
- Desilting of wet well once a year.

Grit Channel:

- Grit channels for peak flow.
- Should be used one at a time, alternatively everyday.
- Should cleared everyday.
- Proper & efficient removal of silt in Grit Channel will improve the functioning of treatment.

Proportional Weir:

- It is provided to maintain uniform flow on upstream and downstream of grit channel.
- Must be calibrated so as to show the quantity of flow.
- Flow be recorded every hour. In SBR plants the flow recording graphs are recorded in SCADA.

Distribution channel:

- Must be cleared every day.

Suggested Questions / Assignments /Home works / any other
1. Explain Residual management?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 25. UNIT IV WATER STORAGE AND DISTRIBUTION:

Topic(s) to be covered	Distribution systems and Storage

	Lecture Outcome (LO) At the end of this lecture, students will be able to	Bloom's Level
LO1	Requirements of a good distribution system, Storage and Balancing Reservoirs	understand.

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

Requirements of a Good distribution system:

(•) To supply water at sufficient pressure head.

• To supply requisite quantity of water for fire fighting.

• Cheap with least capital (construction) cost.

• The cost of installation of distribution system is about 70% cost of water supply projects.

• Simple, easy operation and repair. R&M cost and troubles should be minimum.

• Safe against future pollution of water. water lines should be laid away from drainage and sewerage line.

• Safe and should not cause failure of pipeline by bursting.

• water should be available even during breakdown parts.

- Water-tight and leakage losses should be minimum
- No obstruction of traffic during repairs.

Storage and Balancing Reservoirs:

Storage Reservoirs:

- Store the treated water until it is pumped into the service reservoir or distribution reservoir.
- Capacity of storage reservoirs should be 14 to 16 hours of average daily flow.

Distribution Reservoirs:

- Provide storage to meet the widely fluctuating demands, for fire-fighting and during emergencies.

Distribution Reservoirs serve the following purposes:

(i) They absorb the hourly variations in demand.

(ii) The pumps can be run at constant rate.

(iii) Reduction in pipe size, pumps and treatment units.

(iv) They serve as storage for emergencies such as fire / failure of pumps / bursting mains etc.

(v) They maintain desired pressure even in remote areas.

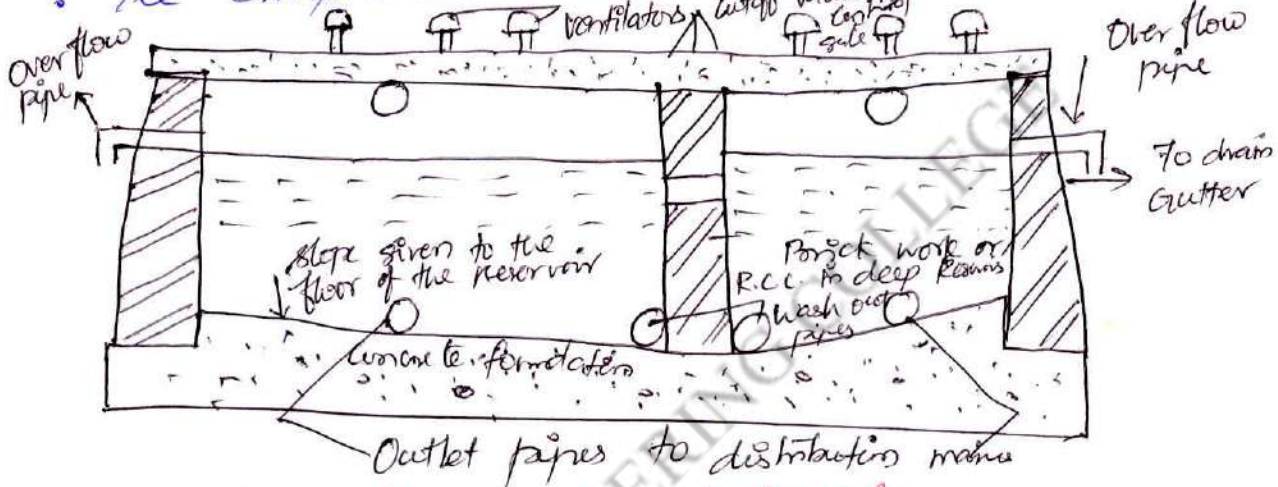
(vi) Operation of distribution system become very easy.

Types of Storage and Distribution Reservoirs:

1. Surface Reservoirs, 2. Elevated Reservoirs, 3. Stand pipes.

Surface Reservoir (Ground Reservoirs)

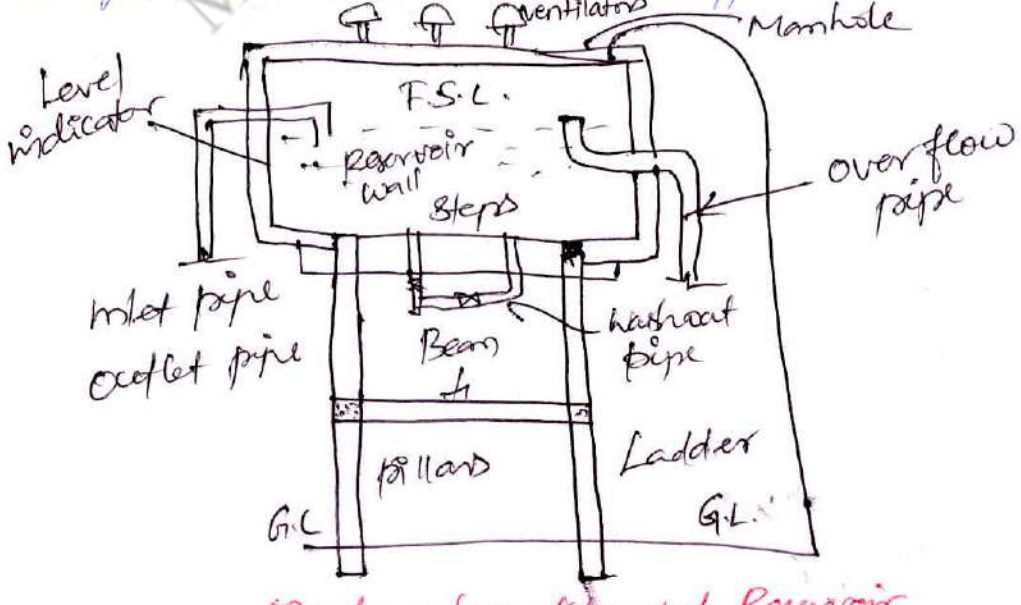
- Made of masonry or concrete, circular or rectangular constructed at ground level or below the ground level.
- Lining is provided with concrete or asphalt to check leakage of water.
- They are constructed at high points in the city to achieve gravity flow.
- The compartments are connected by sluice valves.



Surface Ground Reservoir

Elevated Reservoirs (Overhead Tanks)

- Rectangular, circular or elliptical tanks.
- Supported on towers at suitable elevation above ground level.
- Water is pumped first to these elevated reservoirs from surface reservoirs and then supplied to consumers.



Rectangular Elevated Reservoir

Stand pipes:

- They are elevated tanks without towers.
- They are tall cylindrical shells resting on ground.
- They are 15 to 30m high and 10 to 15m in diameter.
- RCC stand pipes are not used for heights above 15m as it cannot bear the high stresses.
- Stand pipes provided where high heads are required.
- The entire capacity of tank can be used during fire-fighting or by locating the stand pipes on hills or high grounds.

Suggested Questions / Assignments /Home works / any other
1. Write short notes on distribution system?

Text Books/ Reference Books			
S.No.	**Title**	**Author**	**Publisher**
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 26 . **UNIT I–**

Topic(s) to be covered	Storage capacity of distribution Reservoirs

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Balancing or Equalising storage, Hydrograph method, Mass curve method.	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

• The total storage capacity of a distribution Reservoir is the total of

1. Balancing storage (or equalising or operating storage).
2. Breakdown storage.
3. Fire storage.

Balancing or Equalising storage:

• The primary function of distribution is meet the fluctuating demand.

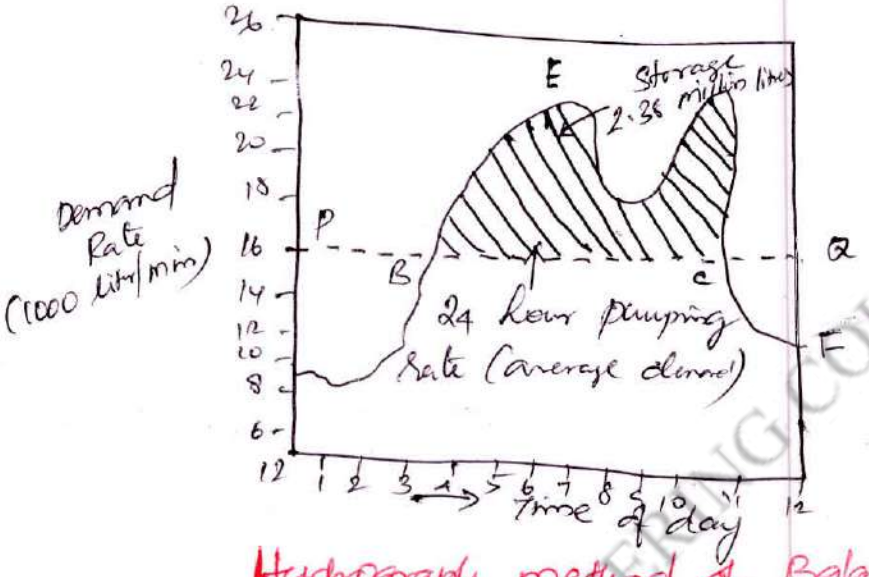
• The quantity of water required to be stored in the reservoir for balancing the variable demand is called balancing storage of distribution reservoir.

• This can be found by following methods:

(a) Hydrograph method, (b) Mass curve method (c) Analytical methods.

Hydrograph Method:

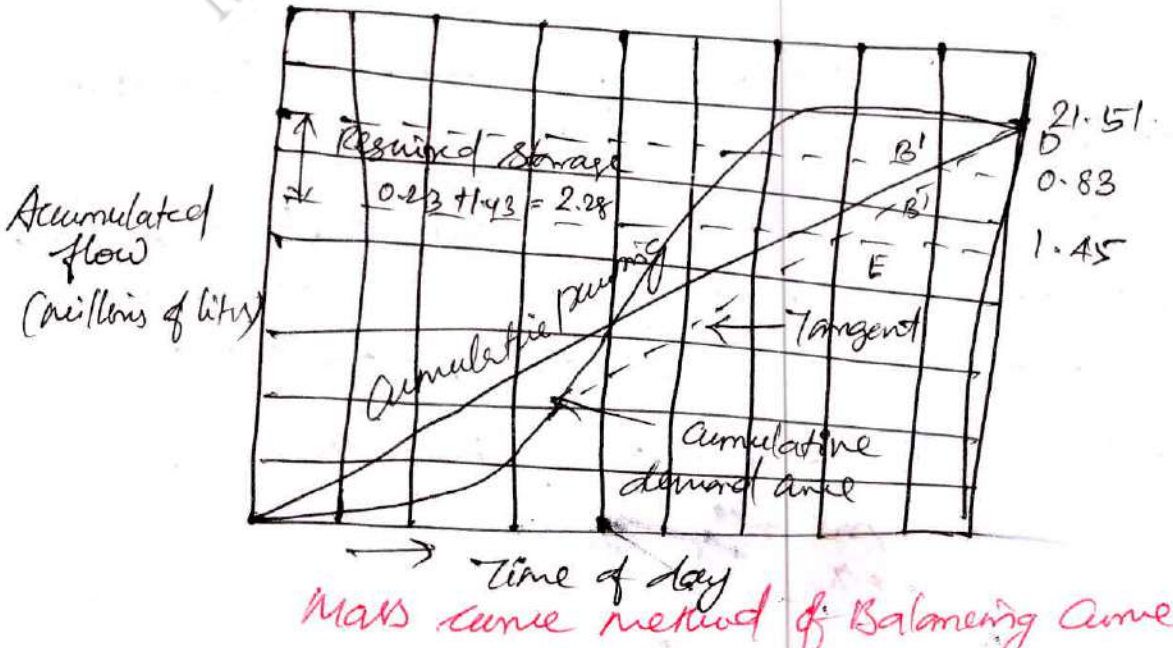
- The water demand is not constant and varies hourly.
- Demand is more during peak hours in the morning and evening.
- Hydrograph of hourly demand for maximum day.
- The pumping rate i.e. mean of hourly demand (PQ).



Hydrograph method of Balancing storage.

Mass Curve method:

- Mass curve is cumulative demand curve which is obtained by continuously adding the hourly demands of max. day and plotted against time.



Mass curve method of Balancing Curve.

- Steepness of curve indicates high rate demand.
- Draw tangents through the lowest point A and highest point B parallel to line CD.

$$S = Ep + Ed$$

Analytical method:

The cumulative hourly demand and cumulative hourly supplies are tabulated for 24 hrs. The summation of more excess demand and the more excess supply gives the balancing storage.

Breakdown Storage (Emergency Storage)

- Storage for emergencies due to pump failure, power failure and during repair works.
- Difficult to determine this storage as it depends upon the frequency and extent of failure.

Fire Storage:

- Storage is required for fire fighting, depends on chances of fire and duration of fire.
- For 10 hrs of fire fighting per day, vol. of water required to stored should be 2 million litres

Fire reserve is determined from formula:

$$R = [F - P]T$$

R – reserve storage
F – Fire demand, litres/min.

P = Reserve fire pumping capacity, litres/min

T = duration of fire, minutes.

McDonand has suggested the following expression

$$R = aD + bD + \frac{10}{24}(D + F - P)$$

Where,

R - Total storage capacity

D - Average domestic demand for maxi. month

F - Fire demand (MLD)

P = Pump capacity (MLD)

a, b - Coefficients; 0.2 and 0.1 respectively.

Suggested Questions / Assignments /Home works / any other
1. Define Storage Capacity?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 27 **UNIT I–**

Topic(s) to be covered	Distribution System - Layout.

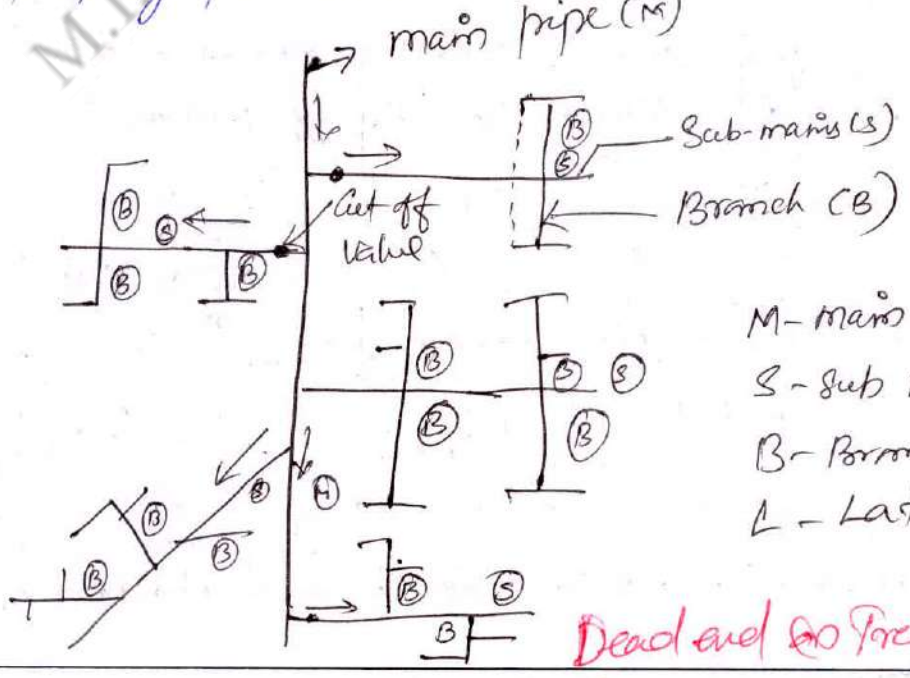
	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Dead end system, Grid iron System, Ring system (Circular), Radial System	understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

Dead - end system (Tree System)

- One main supply pipe, number of submain pipes take off a right angles.
- Each submain divides into several branch pipe (laterals)
- From laterals, service connection given to consumers.
- Used for older towns with irregular expansion, without properly planned roads.



Advantages:

- Distribution network can be easily solved. Discharges and pressure at different points can be easily and accurately calculated.
- Requires lesser number of cut-off values (sluice valves
- Shorter pipe length is need, cheap & simple.

Disadvantage:

- Damage in any pipe completely stop water supply.
- Supply is only in one direction. supplies for fire fighting cannot be increased by diverting supplies from other side.

Grid-iron System/ interlaced/ Reticulation system:

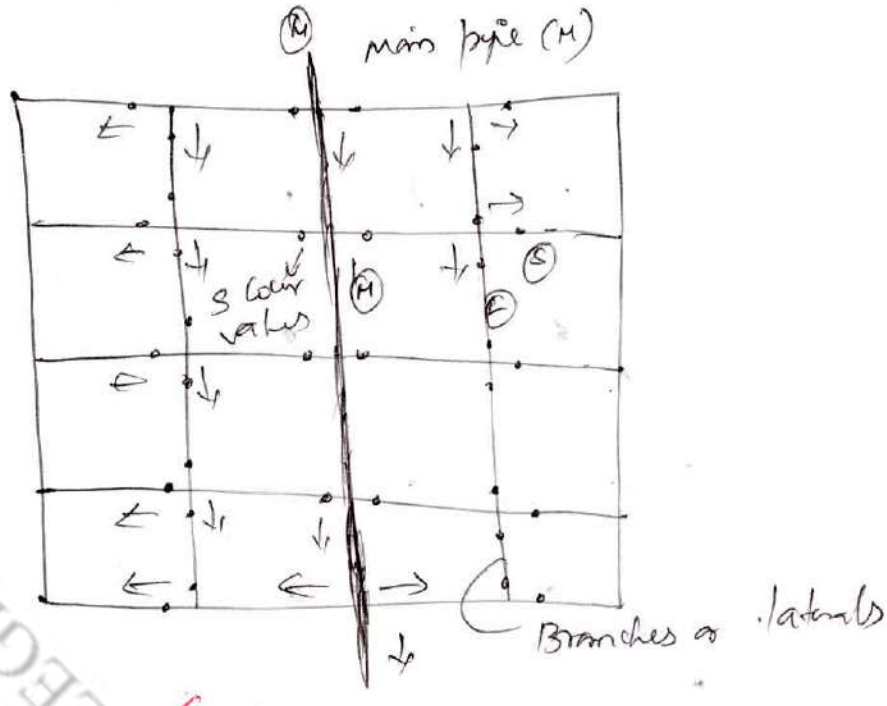
- Mains, sub-mains and branches are all inter-connected with each other. for well planned city. like Chandigarh.
- No dead end and water remains in continuous circulation.

Advantages:

- Since water reaches different place from routes, discharge friction loss, pipe size are reduced.
- During fire, more water can be diverted towards the affected area by closing the cut off valves.

Disadvantages:

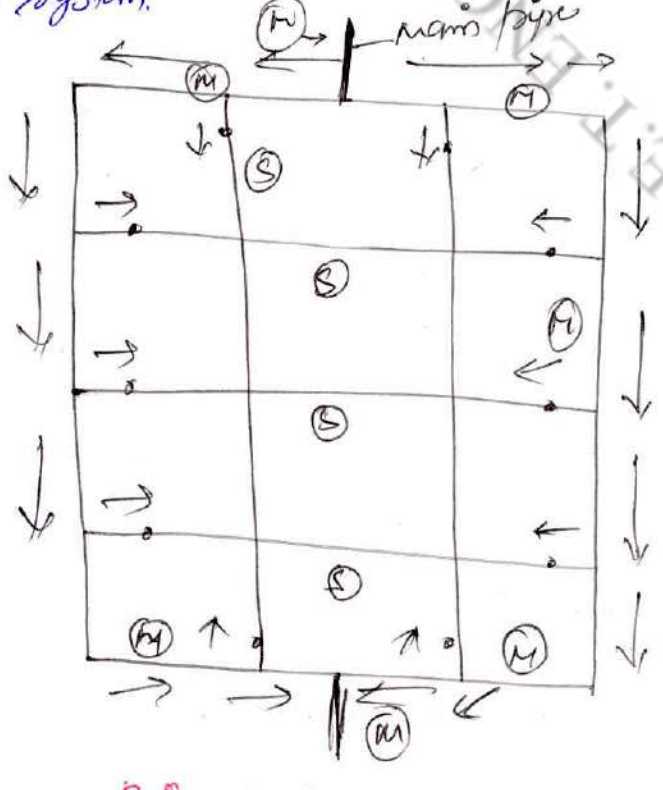
- Requires more pipe length and large no. of sluice value (cut off valves), costlier construction.
- Design is difficult and costlier, calculations for determining the pipe size discharge, velocities and pressure are tedious and may require design experts and computers.



Grid iron - System

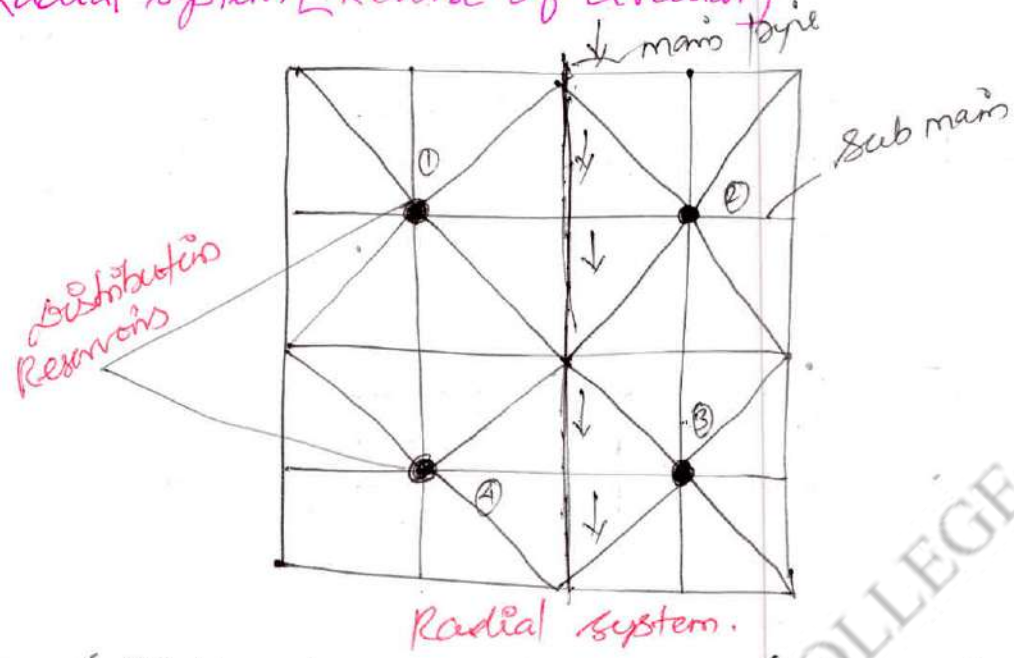
Ring System / circular System:

- Closed ring either circular or rectangular, of main pipe is formed around the area to be served.
- Suitable for towns and cities having well planned roads.
- Advantages and disadvantages of this system are same as grid iron system.



Ring System

Radial system [Reverse of circular]



Radial system.

- Suitable for city or town having radial roads emerging from different centres.
- This method ensures high pressure and efficient water distribution.
- The calculations for design of pipe size are also simple.

Suggested Questions / Assignments /Home works / any other
1. Explain in detailed about distribution network and its types?

Text Books/ Reference Books			
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 28. **UNIT I–**

Topic(s) to be covered	Hydraulics of pipe Lines:

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Darcy - weisbach formula, Manning's formula, Hazen - William's formula, Limitations of Hazen - William's formula.	Understand. & Apply.

Teaching Learning Material	Student Activity
Chalk & Talk	Listen / Apply.

Lecture Notes

- Bed of pressure conduits should be as far as possible near HGL (Hydraulic Gradient Line)
- HGL should generate sufficient velocities. The velocity should be non silting/non-scouring. (0.9 m/s to 1.5 m/s)
- Structural stability.
- Economic construction
- Head loss due to pipe friction
- Loss due to changes in flow geometry (i.e). Change in pipe size, bends, valves etc.

Head loss formula:

1) Darcy - weisbach formula (friction flow)

$$H_L = h_f = \frac{f' V L^2}{2gD}$$

$H_L = h_f$ = Head loss due to pipe friction in meters (m)

L = Length of pipe in m.

D = Diameter of pipe in m.

V = Velocity of flow in m/s.

f' = dimensionless friction factor

g = Acceleration due to gravity (9.81 m²/s).

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left[\frac{K}{3.7D} + \frac{2.51}{Re\sqrt{f}}\right]$$

K = Roughness projection (mm)

Re = Reynolds number.

(ii) Mannings formula:

• For gravity conduits and turbulent flow in pressure conduits.

$$h_f = H_L = \frac{n^2 V^2 L}{R^{4/3}}$$

For circular pipe with full flow

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

n = mannings rugosity coefficient

L = Length of pipe in (m)

V = Flow velocity (m/s)

R = Hydraulic mean depth of pipe.

(iii) Hazen-williams formula:

$$V = 0.85\, C_H R^{0.63} S^{0.54}$$

C_H = Coefficient of hydraulic capacity &
For smoother pipe C_H is greater

R = Hydraulic mean depth of pipe in m.

For circular pipe, $R = d/4$

S = Slope of energy line

V = Flow velocity through pipe in m/s.

Pipe Material	C_H (Smoothness of pipe.
Concrete	130
Cast iron (new)	150
Welded Steel (new)	120
Reveted Steel (new)	110
Brick	100
Asbestos- Cement	140

Limitations of Hazen - Williams Formula:

(i) The co-efficient C_H is not dimensionless. Its value varies.

(ii) C_H is independent of friction conditions (pipe diameter, Viscosity, velocity, Roughness and Reynolds number etc.

Hence, Hazen Williams gave a modified formula.

$$V = 143.534\ C_R R^{0.6575} S^{0.5525}$$

Suggested Questions / Assignments /Home works / any other
1. What is hydraulic pipe line?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 29. **UNIT I–**

Topic(s) to be covered	Design of Conduit.

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Determine size of Supply Conduit	Understand & Apply

Teaching Learning Material	Student Activity
Chalk & Talk	Listen & Apply

Lecture Notes

Determine the size of a supply conduit for serving a small town of population 25,000. Also find the hydraulic gradient at which the pipeline is proposed to be laid. Assume datas wherever required.

Sol:

Population = 25,000

Assume, average daily consumption of water (per capita demand) as = 120 lpcd.

Average quantity of water required

= Population × per capita demand

= 25,000 × 120 lpcd.

= 3×10^6 l/d = 3 MLD.

Maximum daily demand:

= 1.8 × Average daily demand

= 1.8 × 3 MLD, = 5.4 MLD.

$$= \frac{5.4 \times 10^6}{10^3 \times 24 \times 60 \times 60} = 0.063 \text{ m}^3/\text{s}.$$

(a) To find the diameter of pipe:

Assume flow velocity in pipe as 1.2 m/s. Consider the conduit as circular.

$Q = AV.$

Where,

Q - Discharge (m^3/s)

A - Area of cross-section (m^2)

V - Flow velocity (m/s)

$0.063 \text{ m}^3/\text{s} = A \times 1.2 \text{ m/s}$

$A = \frac{0.063}{1.2}$, $\boxed{A = 0.0525 \text{ m}^2}$

For circular conduit,

$A = \frac{\pi}{4} d^2$, $\frac{\pi}{4} d^2 = 0.0525$

$d = 0.249 \text{ m} = 24.9 \text{ cm}$

Provide 25 cm diameter for pipe.

(b) To find Hydraulic Gradient:

Use Hazen-Williams formula

Assume $C_H = 110$

$V = 0.85 C_H R^{0.63} S^{0.54}$

$= 0.85 \times 110 \times (d/4)^{0.63} S^{0.54}$ $\quad \because [R = d/4]$

$V = 93.5 (d/4)^{0.63} S^{0.54}$

$1.2 = 93.5 \left(\frac{0.25}{4}\right)^{0.63} S^{0.54}$

$\therefore$ Velocity R0 assumed as 1.2 m/s & diameter of pipe = 25cm

Hydraulic gradient is $S = 1/128$ (1m fall for 128 m length)

In a water supply system to be designed for serving a population of 4 lakhs, the storage reservoir is situated at 8 km away from city and the loss of head from source to city is 16 meters. Calculate the size of supply main by using Weisbach formula as well as by using Hazen's formula assuming maximum daily demand of 200 litres per day per person and half of daily supply to be pumped in 8 hours. Assume coefficient of friction for the pipe material as 0.012 in Weisbach formula and $C_H = 130$ in Hazen's formula.

Sol:

Maximum daily per capita demand = 200 lpcd

Pop. = 4,00,000

Maximum daily water demand = Pop. × per capita demand

$= 4,00,000 \times 200$ lpcd

$= 80 \times 10^6$ lld

$= 80$ MLD

Maximum water demand for which supply main is to be designed

$= \frac{80 \times 24}{2} \times \frac{1}{8} = \frac{80 \times 12}{8}$ MLD $= 120$ MLD

(since half the daily supply is pumped in 8 hrs)

$$Q = 120 \text{ MLD} = \frac{120 \times 10^6}{10^3 \times 24 \times 60 \times 60} \text{ m}^3/\text{s} = 1.39 \text{ m}^3/\text{s}$$

Now, $Q = 1.39$ m³/s, $L = 8$ km $= 8000$ m, $H_L = 16$ m

(a) Using Darcy-Weisbach formula:

$$H_L = \frac{f'LV^2}{2gd} = \frac{f'L}{2gd}\left(\frac{Q}{A}\right)^2 = \frac{f'L\left(\frac{Q}{\pi/4 d^2}\right)^2}{2gd} \quad \left[V = \frac{Q}{A}\right]$$

$$= \frac{f'L}{2gD} \times \frac{16Q^2}{\pi^2 d^2} = \frac{8f'LQ^2}{g\pi^2 d^2} \quad \left[A = \pi/4\, d^2\right]$$

$16 = \frac{8 \times (0.012)(8000)(1.39)^2}{9.81 \times (3.14)^2 \times d^5}$, Solving, $d^5 = 0.957$,

$d = 1.092\,m \simeq 1.25\,m$

Use the nearest Standard available pipe diameter (1.25m)

(b) Using Hazen-Williams's formula:

$$V = 0.85\, C_H R^{0.63} S^{0.54}$$

Where $C_H = 120$, $R = d/4$, $V = \frac{Q}{A} = \frac{1.39}{\pi/4 d^2}$

$$\frac{1.39}{\pi/4 d^2} = 0.85 \times 130 \left(\frac{d}{4}\right)^{0.63} \left(\frac{H_L}{L}\right)^{0.54}$$

$$= 0.85 \times 130 \frac{d^{0.63}}{2.4} \left(\frac{16}{8000}\right)^{0.54}$$

$$\frac{1.77}{d^2} = 46\, d^{0.63} \frac{1}{28.7}, \quad d^{2.63} = 1.104$$

$d = 1.038\,m, \simeq 1.25\,m$

Use the nearest Standard available pipe diameter (1.25 metre diameter)

Suggested Questions / Assignments /Home works / any other
1. Determine Sing and Supply Ondwit.

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 30 **UNIT I–**

Topic(s) to be covered	Pipe Fittings

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Different types of joints, Spigot and Socket joint, Flanged joint, mechanical joint(s) Dresser Coupling	Understand.

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

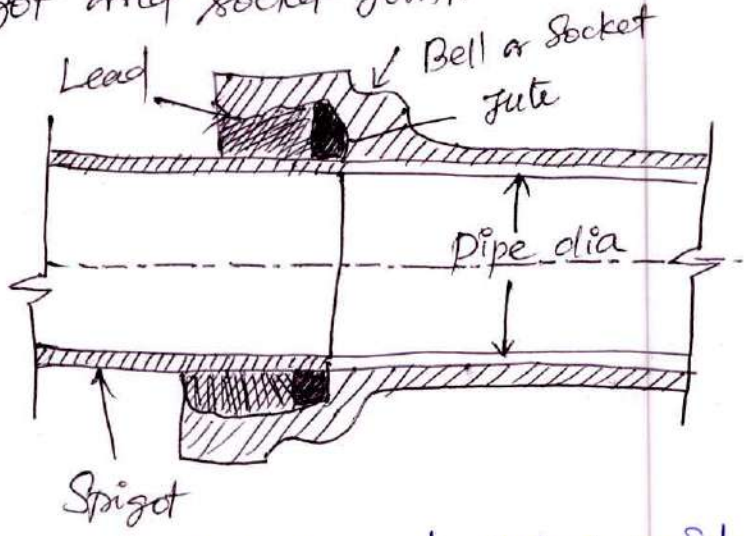
Requirements of jointing material:

(i) Imperviousness
(ii) Elasticity
(iii) Strength
(iv) Durability
(v) Adhesiveness
(vi) Workability
(vii) Economy
(viii) Availability.

Different types of joints are:

(i) Spigot and socket joint
(ii) Flanged joint
(iii) Mechanical joint (or) Dresser coupling
(vi) Flexible joint
(v) Expansion joint.
(vi) Simplex joint.

(1) Spigot and socket joint:

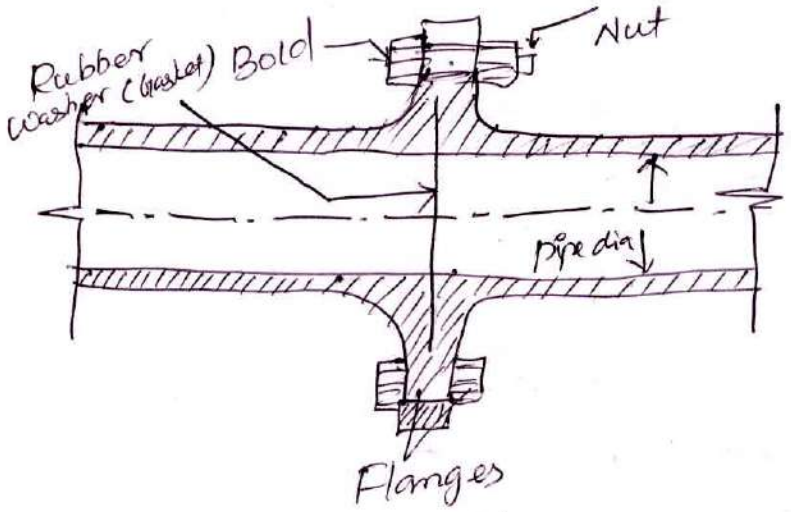


Socket and spigot joint

- Used in cast iron pipes.
- The C.I. pipes are made with one end normal and other end enlarged.
- Enlarged end is called socket.
- Normal end is called the spigot end.
- Socket accomodates the spigot end.
- The spigot is fitted into the socket
- This joint is flexible but requires skilled labour.

Flanged joint:

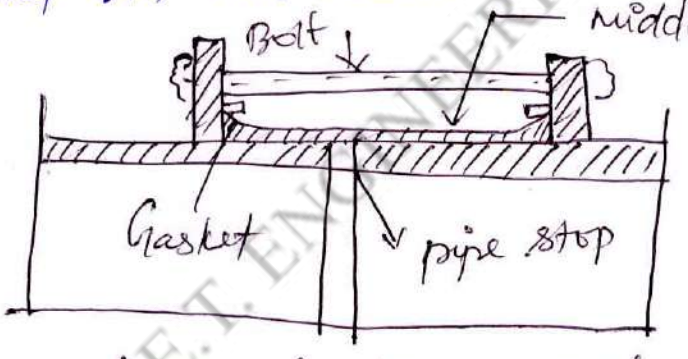
- Used in C.I pipes cast with flanges at both ends.
- Used in pumping stations and filter plants where dismantling of pipe may require occasionally.
- Two flanges are joined with rubber washer (gasket) and fixed by nuts & bolts.
- The joints are strong but rigid.
- Expensive.
- Cannot withstand vibrations



Flanged joint

(iii) Mechanical joint or Dresser coupling:

- A metallic collar is fitted and tightened over the pipe ends, to form mechanical joint.
- An iron ring and gasket are slipped over the pipe ends and an iron sleeve is inserted blw the gasket.

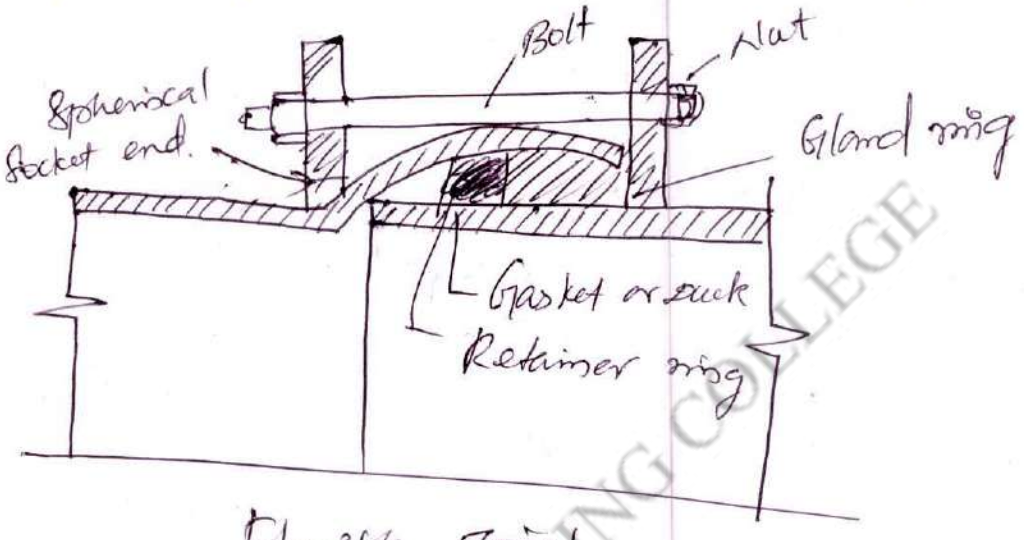


Dresser Coupling or Mechanical joint.

(iv) Flexible joint.

- Used where greater flexibility is required
- Used when pipes are laid in rivers with uneven beds, where large scale settlements may break ordinary joints
- Used while laying pipes on curves
- The CI pipes are casted such that socket is spherical and spigot has bead at the end.

- A retainer ring is placed over bead which keeps gasket in position.
- A split cast iron gland ring is then placed and tightened by bolts and nuts.



Flexible Joint

Suggested Questions / Assignments /Home works / any other
1. what is pipe fittings

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 31. **UNIT I–**

Topic(s) to be covered	Appurtenances in distribution system

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
L01	Valve, pipe appurtenances, Sluice value or gate Valve, Air Valve (Air relief valve) (Air inlet valve)	understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

Appurtenances in distribution system:

The following appurtenances are required for the efficient functioning of distribution network.

1. Valves
2. Fire hydrants
3. Water meters
4. Water taps
5. Stop cocks
6. Pipe Bends etc.

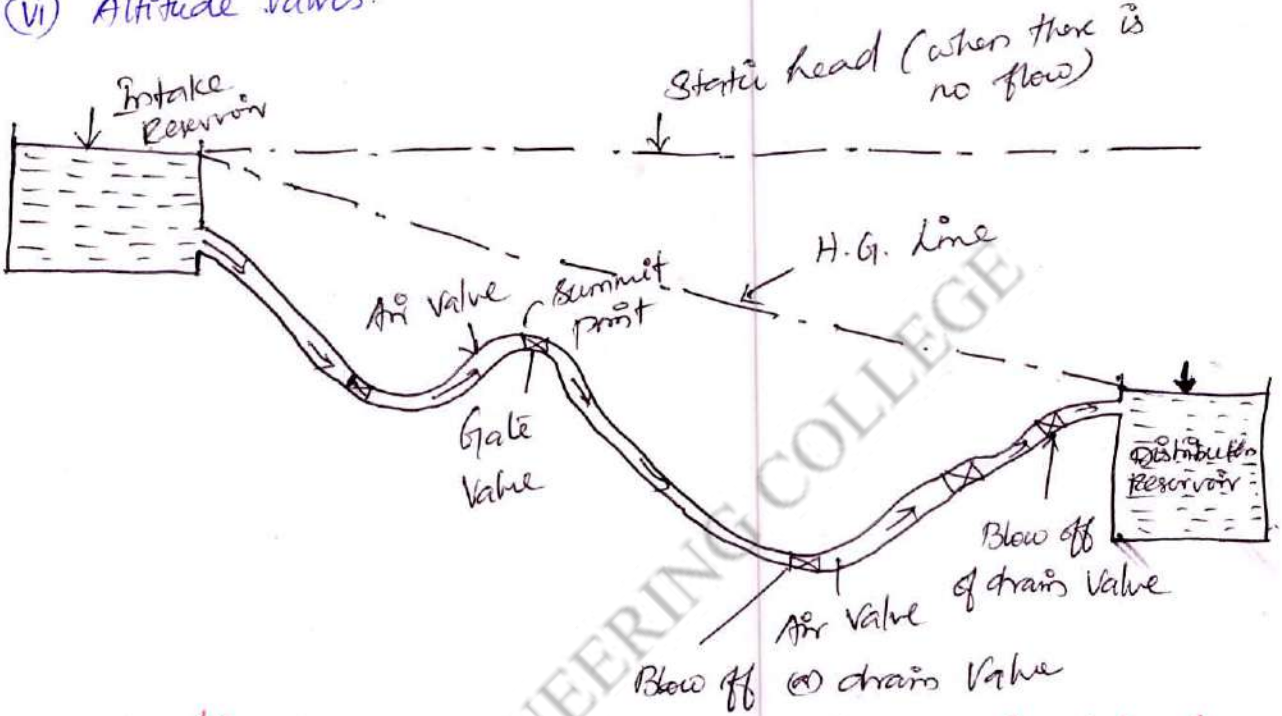
Valves:

(i) Sluice Valves (or) Gate Valves
(ii) Check Valves
(iii) Air Valves
(iv) Drain or Scour Valves.

Pipe Appurtenances:

Appurtenances in water distribution system.

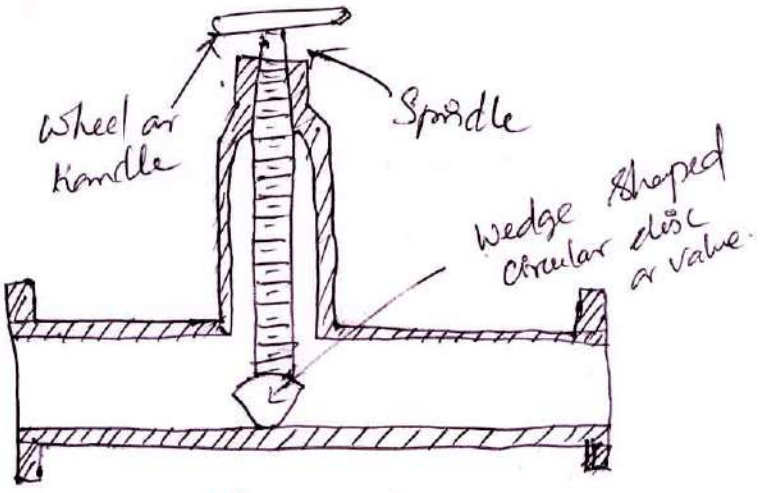
(i) Sluice Valve (or) Gate Valves
(ii) Air Valves
(iii) Scour Valves.
(iv) Relief Valves
(v) Reflux Valves
(vi) Altitude Valves.



profile of water pressure pipe showing location of gates and valves.

(i) Sluice Valve or Gate Valve:

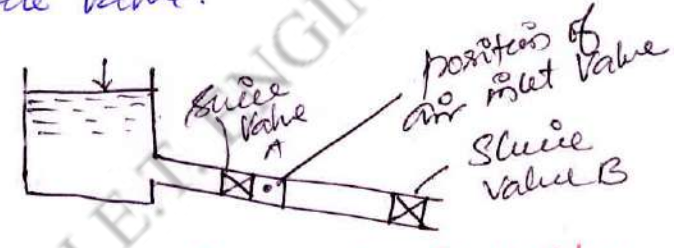
- Used to regulate the flow of water.
- For carrying out the repair works in pipeline.
- Provided at 150 to 300m spacing and on street corners, intersections of pipeline low cost and offer no resistance of flow. Placed at summits.
- (i) Solid-wedge type, (ii) Double-disk type.
- The Valve has a wedge shaped circular disk connected to a wheel (handle) by threaded spindle.
- Head loss through the valve increases when size of Valve is less.



Sluice valve

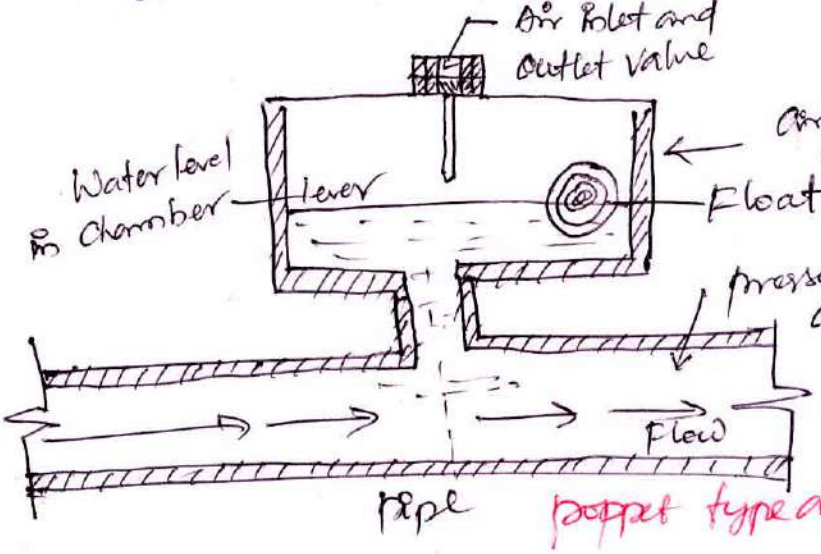
(iii) Air Valve (Air relief Valve) (Air inlet Valve):

- The water flowing through the pipe lines always contains air.
- This air accumulates at high points and may interfere with the flow.
- They ensure safety of pipe against collapse (water hammer) and negative pressure developed during sudden close of gate valve.



position of air inlet Valve.

- Single orifice air valve is commonly used air Valve which acts both as an air-inlet Valve as well as an air-relief Valve.

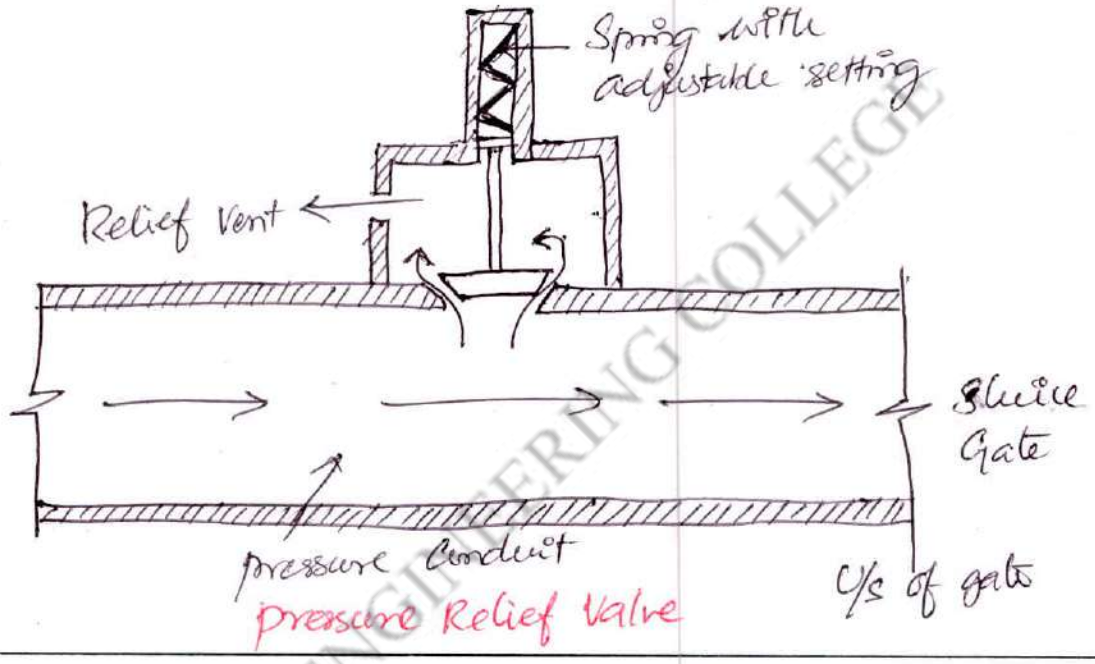


→ It is automatic Valve and can function both ways.

poppet type air Valve

(iv) pressure relief valves (Safety valve) (cut off valves):

- Reduces the water hammer pressure in pressure pipes
- Located at upstream of sluice valves.
- When pressure in pipes exceeds a certain value, the valves automatically opens out and small quantity of water flows out pipe reducing the pressure. when the pressure drops to the desired value, the value automatically closes



Pressure Relief Valve

Suggested Questions / Assignments /Home works / any other
1. Define appurtenances and its uses?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 32. **UNIT I–**

Topic(s) to be covered	Types of Fire hydrants and water meter.

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Flush fire hydrant, post fire hydrant water meters.	understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

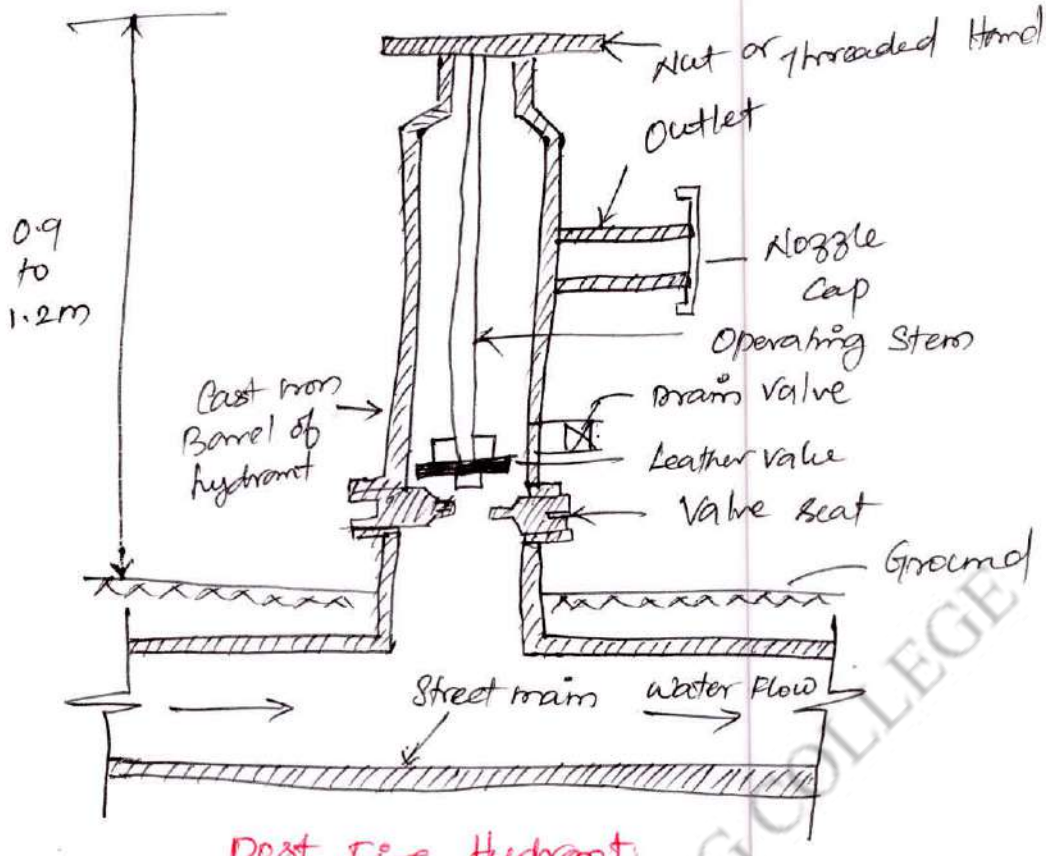
Lecture Notes

(i) Flush Fire Hydrant:

- Installed underground in brick or CI chamber with top cover above the street level. They are less prone to damage.
- But they are not easily detectable during fire. This type of hydrant is widely used in India.

(ii) post fire hydrant:

- Its like post standing 0.9 to 1.2m above ground and can be easily detected but is liable to damage.
- It consists of a barrel of cast iron, connected to water mains.
- A valve stem; with leather valve at lower end and handle on upper end is provided, to regulate the flow. when closed, leather valve rest against the valve seat.

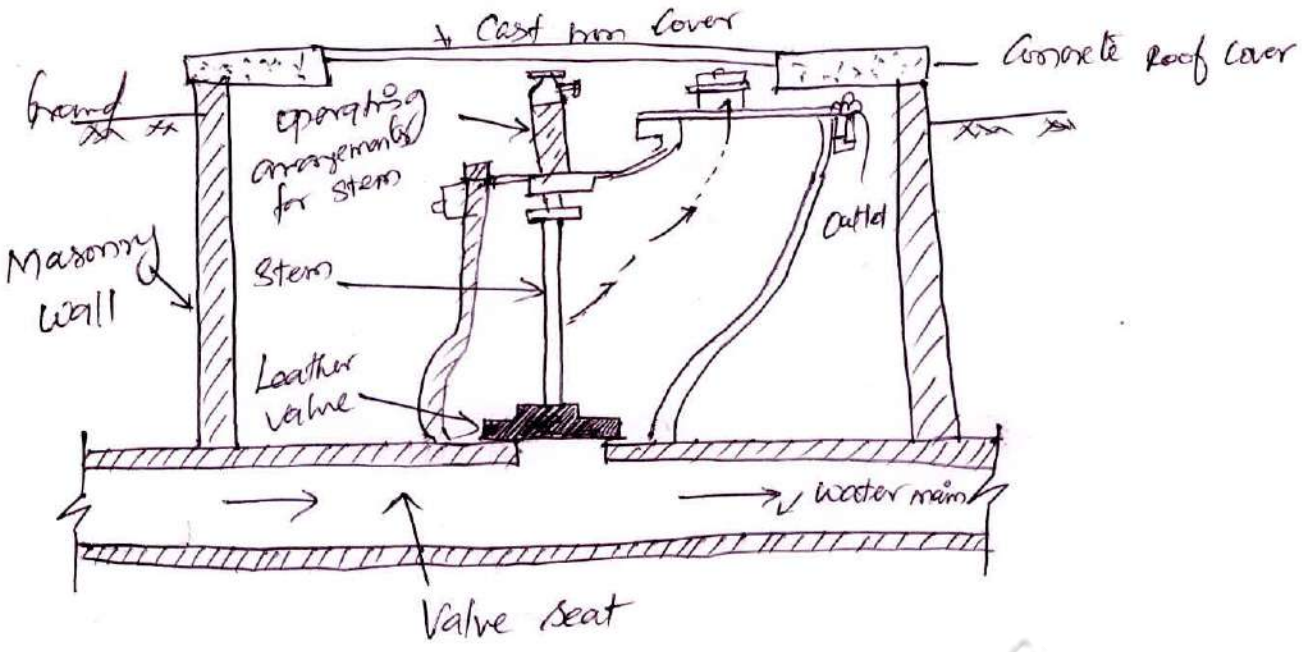


Post Fire Hydrant

- For opening the hydrant, the nut / handle is rotated so as to raise leather valve thereby allowing water inside the barrel.
- Based on the number of outlet openings, classified as one-way, two-way, three way or four-way hydrants.
- Usually 2 outlets are provided. one connected to hose, when pressure boosting is not required. other connected to fire engine or pumps; when boosting is required.

Water meters:

- Measure the quantity of water flowing under pressure through pressure conduits in order to charge the consumers.



Flush Fire Hydrant.

Requirements of good water meter:

- It should record all discharges.
- Maintenance and repair should be easy.
- Minimum error in measuring discharges (less than 2%.
- Work efficiently at all pressures.
- Minimum hindrance to flow (min. head loss)
- parts should not be damaged by chemicals present in water.
- Prevent backflow and should not be liable to clogging.

Types:

(i) Velocity / inferential meters
(ii) positive / displacement meters.

(i) Velocity / Inferential meters:

- It measures horizontal flow velocity (v)

- Discharge through the meter is computed by

$$Q = A \times V$$

Types of velocity meters:

a) Rotary meters
b) Turbine meters
c) Venturi meters.

(ii) Positive or displacement meters:

- More accurate and they measure the quantity of passing water by counting the number of times the meter chamber is filled and emptied.

Types:

(i) Reciprocating
(ii) Oscillating
(iii) Disc (Common)

Suggested Questions / Assignments /Home works / any other
1. Describe the types of fire hydrant and its uses?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 33. **UNIT I–**

Topic(s) to be covered	ANALYSIS OF DISTRIBUTION SYSTEMS.

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
Lo1	Hardy- Cross method, Equevalent pipe method.	Understand / Apply.

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen & Apply.

Lecture Notes

Conditions to be satisfied in pipe networks:

- The Algebraic sum of pressure drops around a closed loop must be zero (i.e. no discountinuity in pressure).
- The flow entering a function must be equal to the flow leaving the same function.

(i.e) law of continuity must be satisfied.

Pipe networks are solved by the following methods:

(i) Hardy cross Method.
(ii) Equivalent pipe method.

Hardy- Cross Method:

- This method is based on the principle of "Law of continuity" at any function, inflow = Outflow.
- The flow in each pipe is assumed.

• A correction to the assumed flow is computed successively for each pipe loop in the network. until the correction is reduced to an acceptable magnitude.

Q_a = assumed flow, Q = actual flow,

Correction $\Delta = Q - Q_a$

$$Q = Q_a + \Delta$$

Head loss in the pipe is given by

$$H_L = k \cdot Q^x = k(Q_a + \Delta)^x$$

$$= k\left[Q_a^x + x Q_a^{x-1} \Delta + \ldots\right]$$ Negligible terms containing higher powers of Δ)

$$= k\left[Q_a^x + x Q_a^{x-1} \Delta\right]$$

Around a closed loop, summation of head loss is zero.

$$\Sigma k\left[Q_a^x + x Q_a^{x-1} \Delta\right] = 0$$

$$\Sigma k Q_a^x = -\Sigma k x Q_a^{x-1} \cdot \Delta$$

Δ is same for all pipes of considered loop.

Hence, Δ is taken out of summation

$$\Sigma k Q_a^x = -\Delta \cdot \Sigma k x Q_a^{x-1}$$

$$\Delta = \frac{-\Sigma k Q_a^x}{\Sigma k x Q_a^{x-1}} = \frac{-\Sigma k \cdot Q_a^x}{\Sigma \left| x \cdot k Q_a^{x-1} \right|}$$

$$\Delta = \frac{-\Sigma H_L}{x \Sigma \left| \frac{H_L}{Q_a} \right|} \qquad \because H_L = k Q^x$$

Where, H_L = head loss for the assumed flow Q_a.

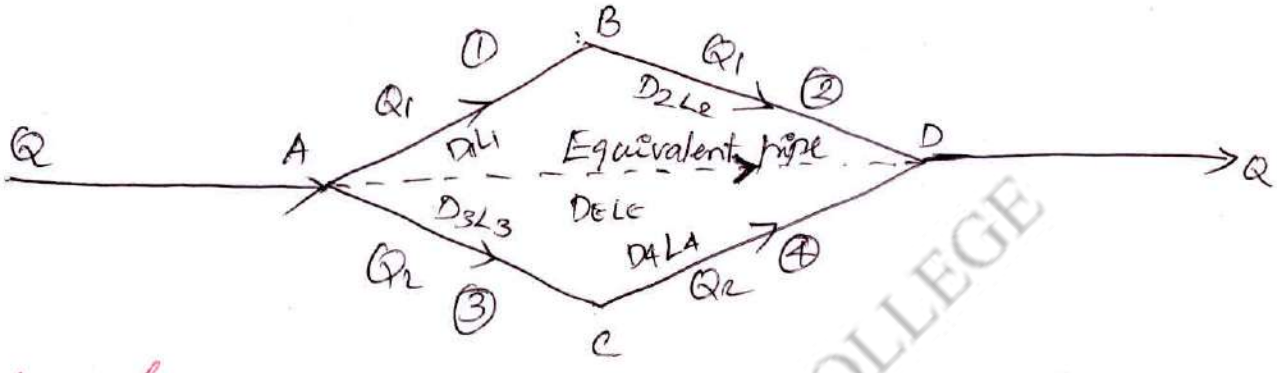
x is constant, $x = 1.85$ (for Hazen Williams's formula)

$x = 2$ (for Darcy-Weisbach formula)

• The distribution system is divided into 2 or more loops, such that each pipe in network is included in atleast one loop.

Equivalent pipe method:

- In this method, a complex network of pipes is replaced by a single hydraulically equivalent pipe.
- Equivalent pipe is one which will replace a system of pipe with equal head loss for a given flow.



Two hydraulic principles used in this method are:

(i) Head loss through the pipe connected in series (AB-BD) is additive.

(ii) The flow (discharge) through the pipes connected in parallel (ABD - ACD) is distributed such that the head losses are identical.

pipe Network, any head loss formula can be used.

$$h_f = \frac{KLQ^n}{D^x} \quad (or) \quad Q = K \cdot D^a S^b$$

Length and diameter of equivalent pipe:

	Diameter of equivalent pipe (cm)	Length of equivalent pipe (m)
System in series	$D_E = x\sqrt{L_t \Sigma \frac{D^x}{L}}$ L_t - total length of system	$L_E = D_E^x \Sigma \frac{L}{D^x}$
System in parallel	$D_E = a\sqrt{L_E^b \Sigma \frac{D^a}{L^b}}$	$L_E = b\sqrt{D_E^a \Sigma \frac{L^b}{D^a}}$

Note:

For Hazen williams formula, $x = 4.87$, $a = 2.63$, $b = 0.54$

For the flow network is

Lead loss $h_f = \frac{fLv^2}{2gD} = \frac{16fLQ^2}{2g\pi^2 D^5} = \frac{kLQ^2}{D^5}$.

$= \frac{kLQ^n}{D^x}$

Hence, $n = 2$

$x = 5$

Suggested Questions / Assignments /Home works / any other
1. Explain distribution system?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 34. **UNIT I–**

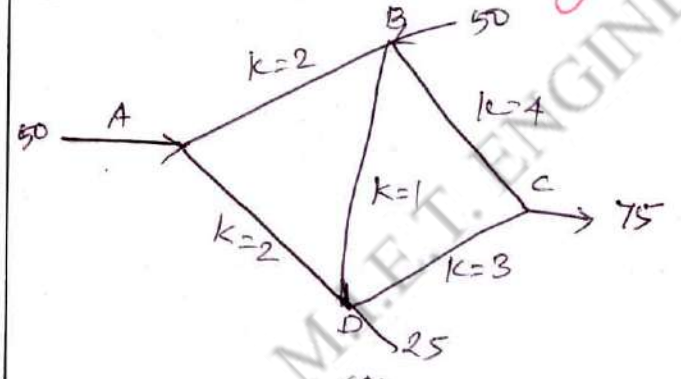
Topic(s) to be covered	Design of distribution flow

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Design of distribution flow.	understand & Apply

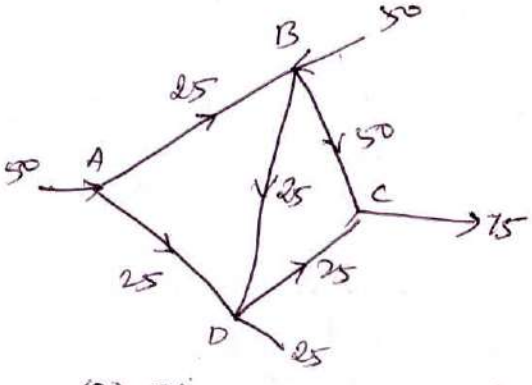
Teaching Learning Material	Student Activity
Chalk & Talk	Listen & Apply.

Lecture Notes

Determine the distribution of flow in pipe network. The head loss H_L may be assumed as KQ^2. The flow is turbulent and pipes are rough. The values of K for each pipe is shown in figure. Use Hardy cross method.



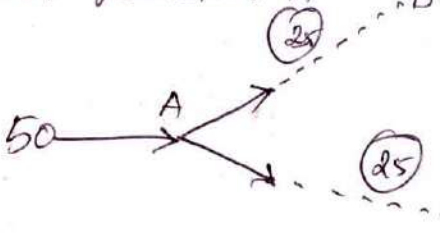
(A)



(B) Flows are assumed.

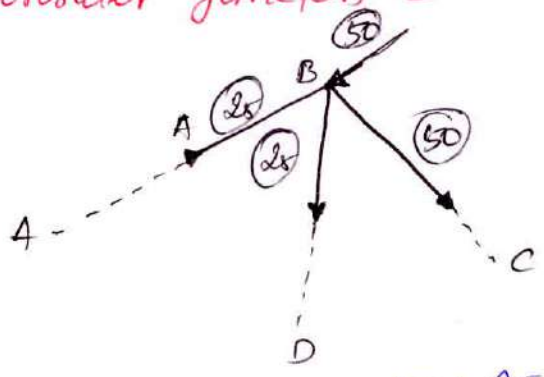
Flow is assumed based on "Law of continuity" at junction

Consider junction A



Inflow is 50 at A; as it branches out into two pipes, the flow in each pipe AB & AD is assumed as 25.

Consider Junction B

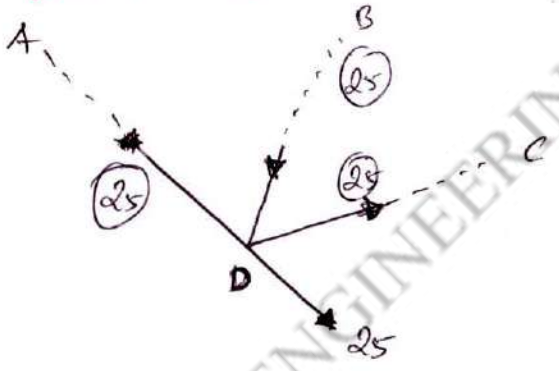


Inflow at B = 50 + 25 = 75

The flow in BC and BD are assumed as 50 and 25. direction away from junction.

• Hence, out flow = 50 + 25 = 75

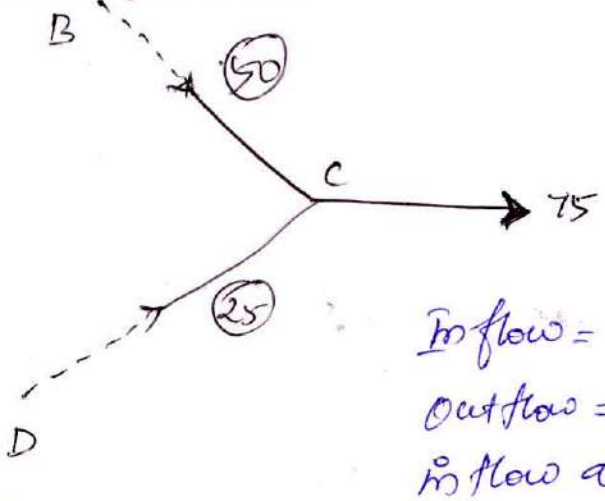
Consider Junction D



Inflow at D = 25 + 25 = 50

Since out flow should be 50, flow in DC is assumed as 25.

Consider Junction C



Inflow = 50 + 25 = 75

Outflow = 75

Inflow at C = outflow

Hence, the flows assumed in magnitude and direction are Correct.

- Network is divided into two loops, loop ABDA and loop BCDB. These loops are analysed by Hardy-cross Method.
- The flow in clockwise direction is considered positive and anticlockwise direction is negative.

Formula for correction:

$$\Delta = \frac{-\Sigma H_L}{x \Sigma \left| \frac{H_L}{Q_a} \right|}$$

Assume. $x = 2$ [Darcy - Weisbach Formula]

Head loss in each pipe is calculated

$$H_L = KQ^n$$

Assume $n = 2$ [Manning's formula or Darcy weisbach formula, for turbulent flow rough pipes]

$$\therefore H_L = KQ^2$$

Hardy cross procedure for 1st Correction:

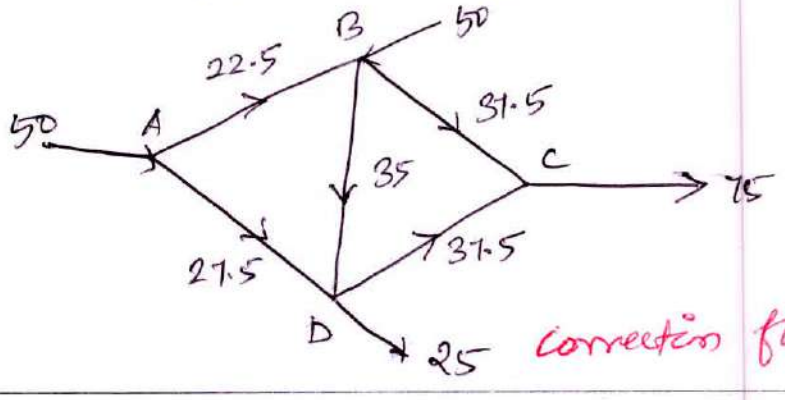
Pipe	Assumed Flow	K (given)	$H_L = KQ_a^2$	$\left\|\frac{H_L}{Q_a}\right\|$	Corrected Q after first correction $Q_{a1} = Q_a + \Delta_1$ (1/3)
For loop ABDA (loop 1)					
AB	25	2	1250	50	25 - 2.5 = +22.5
BD [Common pipe]	25	1	625	25	25 - 2.5 + 12.5 = +35 (2)
DA	-25	2	(-) 1250	50	-25 - 2.5 = (-27.5)
		Σ	+ 625	125	

Δ_1 for 1st loop $= \frac{-625}{2 \times 125} = -2.5$

For loop BCBD (loop 2)					
BC	50	4	10000	200	50 - 12.5 = 37.5
CD	-25	3	(-) 1875	75	-25 - 12.5 = -37.5
DB	-25	1	(-) 625	25	-25 - 12.5 - 2.5 = -35 (2)
		Σ	7,500	300	

Δ_1 for 2nd loop $= \frac{-7500}{2 \times 300} = -12.5$

Note: Common pipe BD (or) DB will receive corrections of both loops.

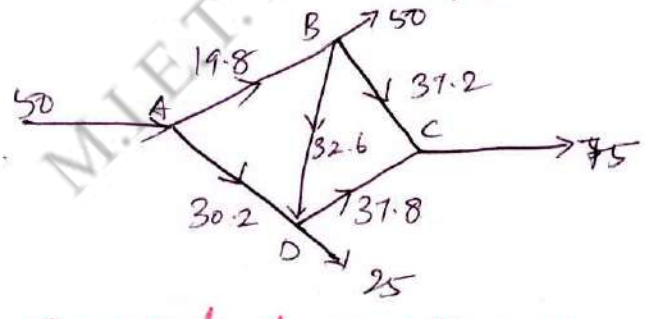


Correction flows after first corrections.

Second Correction

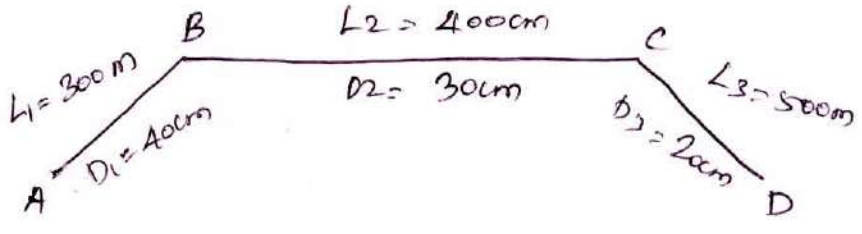
Pipe	Assumed Flow Q_a (l/s)	k (given)	$H_L = kQ_a^2$	$\left\|\frac{H_L}{Q_a}\right\|$	Corrected Q after Second Correction $Q_{a2} = Q_{a1} + \Delta_2$
For loop ABDA (Loop 1)					
AB	22.5	2	1012.5	45	19.8
BD Common Pipe	35.0	1	1225.0	35	32.6 (*)
DA	-27.5	2	-1512.5	55	-30.2
		Σ	725	135	
For loop BCDB (Loop 2)			(For loop 1) $\Delta_2 = \frac{-725}{2\times135} = (-)2.7$		
BC	37.5	4	5625	150	37.2
CD	-37.5	3	-4218.75	112.5	-37.8
DB Common pipe	-35.0	1	-1225	35	-32.6 (*)
		Σ	181.25	297.5	

(For loop 2) $\Delta_2 = \frac{-181.25}{2\times297.5} = -0.3$



Corrected flows after second Correction

2. Find the equivalent length of 30cm dia pipe for the network shown in fig. using (a) Darcy's (b) Hazen Williams formula



(a) Darcy's Formula:

$$h_f = \frac{16 f L Q^2}{2g\pi^2 D^5} = \frac{kLQ^2}{D^5}$$

$$L_E = D_E^5 \sum \frac{1}{D^5} = (D_E)^5 \left[\frac{L_1}{D_1^5} + \frac{L_2}{D_2^5} + \frac{L_3}{D_3^5}\right]$$

$$L_E = (0.3)^5 \left[\frac{300}{(0.4)^5} + \frac{400}{(0.3)^5} + \frac{500}{(0.2)^5}\right] = 4268\,m //$$

(b) Hazen williams formula:

$$h_f = \frac{kLQ^{1.85}}{D^{4.87}}$$

$$\frac{L_E}{D_E^{4.87}} = \sum \frac{L}{D^{4.87}} = \frac{L_1}{D_1^{4.87}} + \frac{L_2}{D_2^{4.87}} + \frac{L_3}{D_3^{4.87}}$$

$$L_E = (0.3)^{4.87} \left[\frac{300}{(0.4)^{4.87}} + \frac{400}{(0.2)^{4.87}} + \frac{500}{(0.2)^{4.87}}\right]$$

$$L_E = 4080.5\,m //$$

Suggested Questions / Assignments /Home works / any other
1. Determine the design of distribution flow.

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 35 **UNIT I–**

Topic(s) to be covered	Distribution systems and their maintenance.

	Lecture Outcome (LO)	
	At the end of this lecture, students will be able to	**Bloom's Level**
Lo1	Introduction, delivery of water, common issue & Hazards, Residency time, Bio film growth, operation & maintance.	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

Introduction:

- Even if the water source for your small water system is of pristine quality, if the distribution System is not maintained or is in state of disrepair, the quality of water may deteriorate before it reaches the customer.

The focus on this section is on the Safe delivery of water. we will discuss the following.

- Delevery of water.
- Some common issue and hazard that must be avoided.
- Sampling and monitoring.
- Operations and maintenance
- Easements
- Leak detection and water loss.

- Water metering
- Importance of a cross connection control program.

Delivery of water:

- Transportation of water to consumer is a primary function.
- It was originate from a well, River, lake or spring.
- As the water flow through the distribution system, three are a number of components that keep the system operations.
- The reservoir stores water for higher demand flows, such as for fire emergencies and peak domestic flows.
- The reservoir also acts as a buffer in maintaining constant flow and pressure of water in distribution system.
- Pumping stations are added to the distribution system to maintain pressure and delivery of water to uphill areas and reservoirs.
- Air valves are devices that allow air to be introduced into the distribution pipe when a vacuum may be created.
- Gate valves are added throughout the distribution systems. So sections can be isolated for water main work and the water flow can be throttled for

pipeline repair. They are a type of valve that uses a flow control element shaped like a sliding gate to block flow, often used as isolation valves.

Common Issues & Hazards:

- The greatest concern for the safe delivery of water are loss of pressure, loss of chlorine residual and cross contamination.
- Loss of pressure may result from a water main break, fire flow or inoperable pumping stations, due to power failure.
- Loss of chlorine residual can be caused by a number of factors.

Source water quality:

- Water that is high in organic or inorganic matter will use up the chlorine residual faster than water that is lower in organic matter.

Residency time:

- The more time the water spends in storage and distribution, the more chlorine residual is used up. Long residency time can result from low water usage, dead ends in the distribution system and poor turnover in the reservoir.

Biofilm growth:

- Biofilm is a large colony of microorganism that grows on pipe walls within the distribution system that will use up the chlorine residual.
- Bacteriological contamination and microbiological growth is also a concern.

Operations and maintenance:

- It is essential that all equipment for operating and maintaining the distribution system is exercised (tested or used).
- For eg. in the event of water main leak, valves can be easily operated if they were previously located and exercised.

Suggested Questions / Assignments /Home works / any other
1. Explain distribution system and their maintence?

Text Books/ Reference Books			
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 36. **UNIT I–**

Topic(s) to be covered	HOUSE SERVICE CONNECTION.

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Ferrule, Goose neek, Service pipe Stop cock, water meter.	understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen.

Lecture Notes

The water connection consists of:

(a) Ferrule:

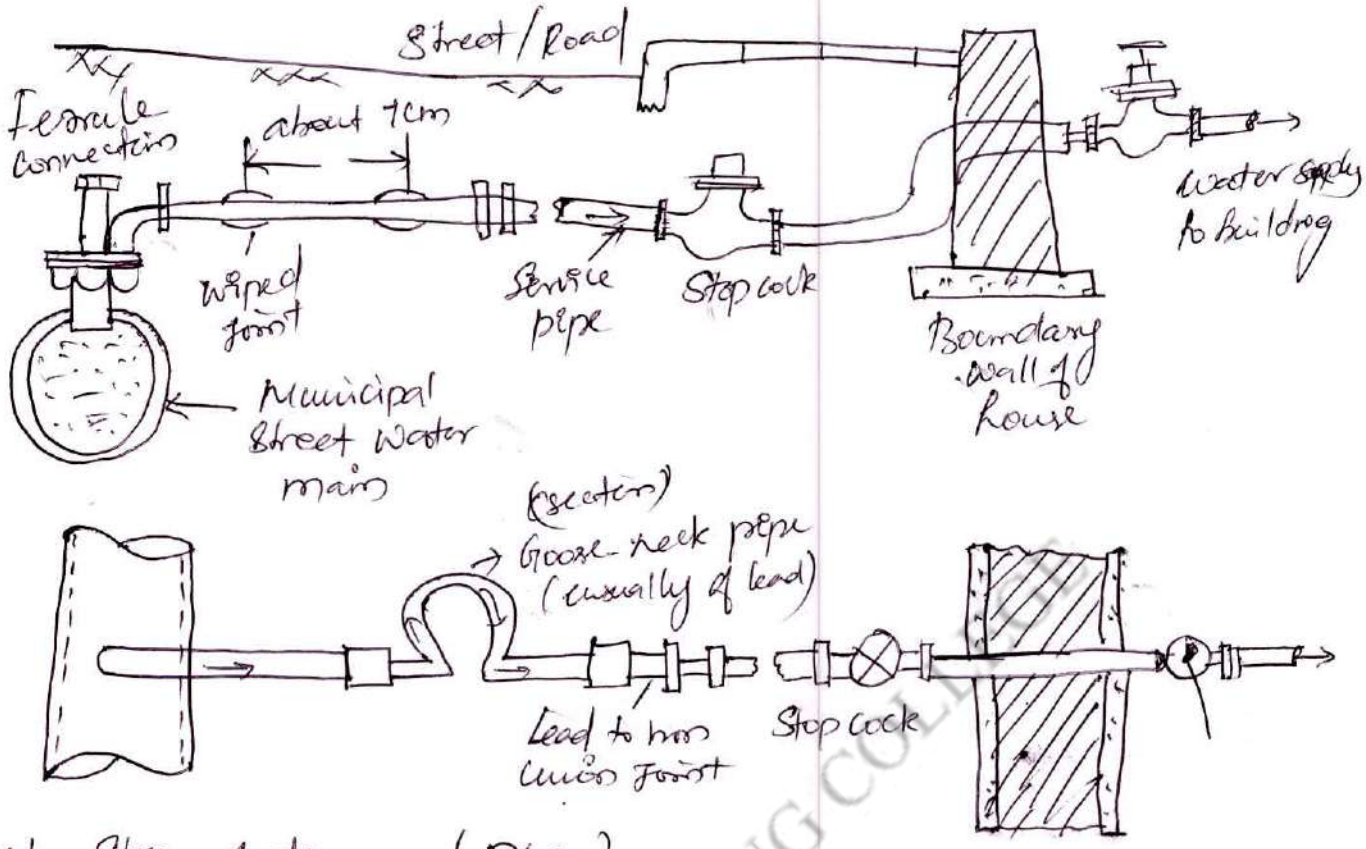
- It is a right angle sleeve made of brass or gun metal and is ~~joining~~ ed to a hole drilled in the water main and is screwed down with a plug.
- Its size varies between 10 to 50mm dia.

(b) Goose Neek:

- A small size curve pipe made of flexible material usually lead, about 75cm length forming a flexible connection between the water main and the service pipe.

(c) Service pipe:

- Galvanised iron pipe < 50mm dia laid underground in a trench. The service pipe is connected to the municipal main through the goose neek and ferrule.



(d) Stop cock:

- provided before the water meter in house. It is housed in a masonry chamber with removable cover and fixed in street close to the boundary wall.

(e) Water Meter:

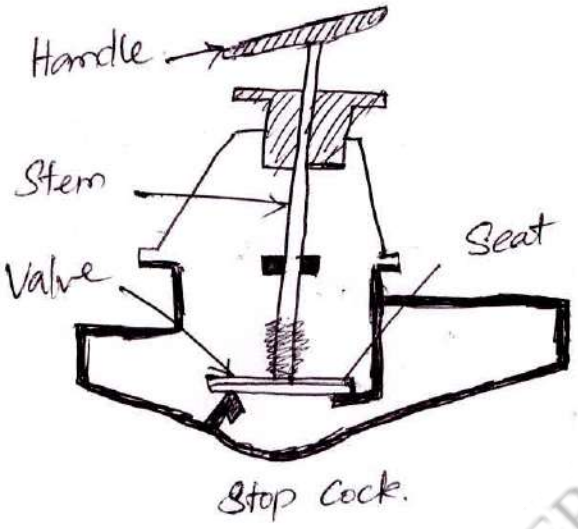
- Measures/records the quantity of water consumed in the house. It is connected to service pipe by union joint. It is fixed inside iron box fitted in cavity made in boundary wall of house and covered with movable iron cover.

Stop Cocks:

- It is a screw down type sluice valve fitted to small sized (< 50mm) pipes for opening or stopping the supply.

• They are provided at water entrance of each building or within the building.

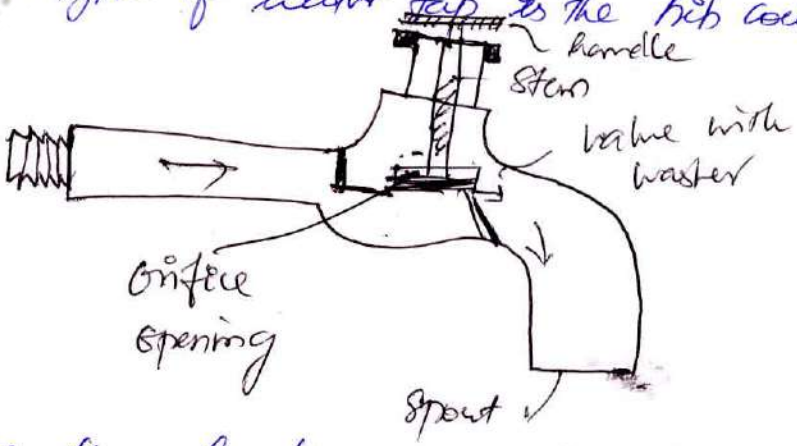
• They should be enclosed in cast iron box having a hinged cover. water passes through an orifice when the valve is raised



Water taps / Bib Cocks:

• They are provided at the end of service pipes through which water is withdrawn by consumers.

• The common type of water tap is the bib cock.



• By rotating the handle, the orifice opens and water passes out through the spout.

• They can be fitted in pipe size from 10 to 15mm dia.

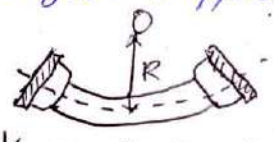
• Bib cocks may also be of push type.

• Bib cocks should be water tight and not leak.

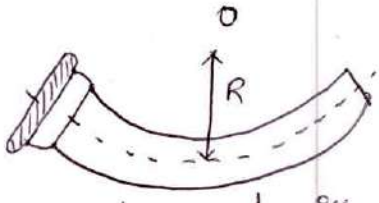
Pipe fittings:

Fittings are used in making service connections.

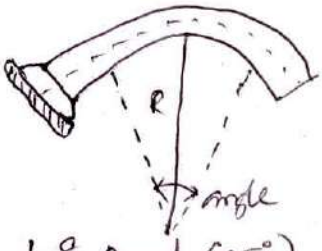
• Bends, crosses, Tees, Elbows, Unions, Caps, plugs, Flanges, nipples etc.



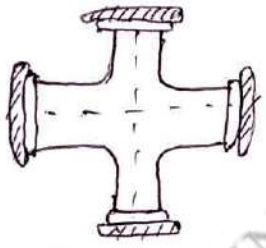
1/4 Bend with double hub



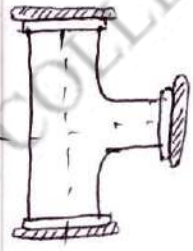
1/4 Bend with single hub.



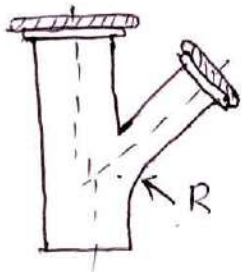
1.8 Bend (45°)



Cross

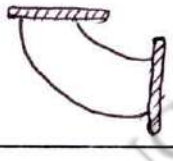


Tee

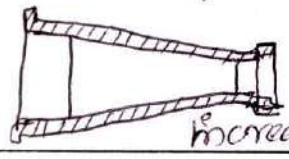


Wye

Saddle flange



Reducing elbow or bend



Increaser

Suggested Questions / Assignments /Home works / any other
1. Describe house service connections?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 37. **UNIT IV** PLANNING AND DESIGN OF SEWERAGE SYSTEM

Topic(s) to be covered	SOURCES OF WASTEWATER GENERATION.

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	definitions, wastewater generation, effects of waste water.	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen.

Lecture Notes

Definitions:

- Sanitary Sewage is wastewater generated from a community [residential, Commercial building and industries] ∴ Domestic Sewage + Industrial Sewage.
- Domestic sewage = wastewater from animals, water closets from residential and office buildings.
- Industrial Sewage – Wastewater discharged from industrial and commercial establishment.
- Night Soil = Human and Animal excreta.
- Refuse = Solid, liquid and semi - solid waste that includes Garbages, Rubbish, Sullage, Sewage, Subsoil water and Storm water.
- Garbage – Dry refuse paper, decayed vegetables, Street sweepings, organic and infected putrifying organic matter etc.

- Rubbish - Solid waste like Building material, furniture rags, papers etc.
- Sullage - Wastewater from bathroom and kitchen.
- Sewage - Liquid waste from community that includes sullage, discharge from urinals, latrines, industrial waste, ground and storm waters.
- Sewerage - Structures, devices, Equipments, Appurtenances intended for collection transportation, pumping of sewage and liquid waste but excluding treatment of sewage.
- Sewer - It is an under-ground conduit or drain through which sewage is carried to a point of discharge or disposal.

Sources of Wastewater Generation:

Domestic sources:

- Human waste from lavatories (feces, urine, flush) called Black water.
- Washing water (personal, clothes, floors, dishes) called as Greywater or sullage.
- Discharge from septic tank.

Industrial sources:

- Industrial process waters (Dyeing, tanneries etc).
- Organic or Biodegradable waste.
- Extreme pH waste (from acid/alkali manufacturing, metal plating).
- Toxic waste (metal plating, cyanide production, pesticide manufacturing etc.).

• Solids and emulsion (paper manufacturing, food stuffs, lubricating and hydraulic oil manufacturing etc).

Discharge from sewage treatment plant (STP)

• Ground water infiltration into sewers
  → Seawater ingress (Salt and microbes)
  → Agricultural drainage.

Effects of waste water:

• In developing countries like India, waste water is directly disposed into water bodies or on land with or without proper treatment.

⇒ Odour nuisance - Gases released from sewage cause foul smell.

⇒ Nuisance of Mosquito breeding, flies, rodents, insects.

⇒ Out break of diseases / Epidemic:

• Waste water contains numerous pathogens and improper disposal may cause serious diseases and illness to urban and rural population.

⇒ Water pollution:

• Waste water is discharged into fresh water bodies numerous pollutants are released into it and the oxygen level of water depletes.

• The water becomes unfit for human use. This water may even become fatal, to infants (Blue baby syndrome).

Land pollution: caused due to the harmful and toxic chemicals in wastewater.

Ground water contamination: Waste water discharged on land, percolates through the soil and pollutes underground water sources and renders it unsuitable for use.

- Contamination of drinking water supplies
- Ecological imbalance: Wastewater is discharged into water bodies, the aquatic plants and animals are affected which may alter the ecosystem.

Suggested Questions / Assignments /Home works / any other
1. define sources of wastewater?

Text Books/ Reference Books			
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 38 **UNIT I–**

Topic(s) to be covered	Characteristics and Composition of Sewage

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Physical – colour, odour, temperature, Turbidity. Chemical – Total solids, pH, Chloride contents.	Understand.

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

Physical Characteristics of Sewage:

- Colour, odour, temperature, Turbidity.

(i) Colour:

- It detected by naked eye, it indicates the freshness of sewage.
- If the colour is yellowish, grey (or) light brown indicates fresh sewage.
- If the colour is black (or) dark brown, indicates ~~fresh~~ stale and septic sewage.
- Industrial waste water imparts colour to sewage and the color depends on the chemical process in industries.

(ii) odour:

- Fresh sewage is practically odourless.
- After 3 to 4 hrs, becomes stale when all the oxygen present in sewage gets exhausted.

• It starts omitting offensive odours, especially (H_2S) hydrogen sulphide gas, due to decomposition of sewage.

(iii) Temperature:

• Affects the biological activity of bacteria present in sewage.

• Temperature is high, the solubility of gases in sewage reduces.

• Dissolved oxygen content (D.O) of sewage also gets reduced with high temperature.

• Temperature affects the viscosity of sewage, which inturn affects the sedimentation process in sewage treatment.

• Normal temperature of sewage is generally slightly higher than the temperature of water.

• Average temperature of sewage in india is 20°c which is ideal for biological activities.

(iv) Turbidity:

• Solids in suspension cause turbidity.

• Turbidity increases as sewage becomes stronger.

• Optical light emitting property.

• Degree of turbidity can be measured and tested by turbidity rods (or) by turbidity meters (Jackson's turbidity meter, Nephlometric turbidity meters etc).

Chemical characteristics of sewage:

(i) Total solids:

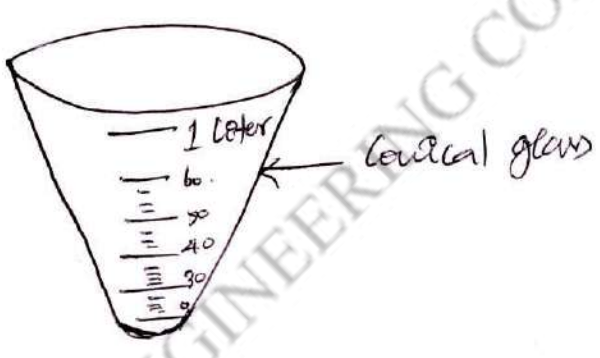
• Sewage normally contains very small amount of solids (0.05 to 0.1 %) in relation to huge quantity of water (99.9%)

• It contains about 0.05 to 0.1 %. (500 to 1000 mg/L) of total solids.

Suspended solids, which remains floating in sewage.
Dissolved solids, remain dissolved in sewage.

Colloidal solids: are finely divided solids remaining either in solution (or) in suspension.

Settleable solids: solids which settle out, if sewage is allowed to remain undisturbed for a period of 2 hours.



Imhoff Cone

(ii) pH - Value:

• pH value indicates negative log of hydrogen ion concentration

$$pH = -\log H^+ \text{ (or) } H^+ = (10)^{-pH}$$

pH < 7 - acidic range
pH > 7 - alkaline range.

• Fresh sewage is generally alkaline in nature (pH more than 7)
• Sewage turns acidic due to ~~aci~~ bacterial action.
• The efficiency of sewage treatment depends on pH.
• If pH of sewage is low, lime is added to create alkaline condition.

(iii) Chloride Contents.

- Chlorides are generally formed in domestic sewage, and are derived from the kitchen waste, urinary discharges, fees. etc.
- Large amount of chlorides may enter from industries like ice cream plants, meat salting industries.
- Chloride in sewage may also be due to infiltration sea water (NaCl).
- The normal chloride content of domestic sewage is 120 mg/l.

Suggested Questions / Assignments /Home works / any other
1. What is the characteristics of sewage and its composition.

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 39. **UNIT I–**

Topic(s) to be covered	Population Equivalent

	Lecture Outcome (LO)	
	At the end of this lecture, students will be able to	**Bloom's Level**
LO1	Strength of industrial sewage, sanitary sewage flow estimation, sewer materials	Understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

- Population equivalent is used to calculate the quantity of industrial sewage. The industrial sewage is compared with the rate of generation of domestic waste water.
- It is used to charge the industries for causing pollution (or) discharging waste water against the discharge norms and also to choose appropriate treatment methods.

Strength of industrial sewage (BOD_5 days) =

= Standard BOD_5 days of domestic sewage per person per day × population Equivalent.

BOD_5 of domestic Sewage = 0.08 kg/day/person.

Eg: If BOD_5 of industrial sewage = 300 kg/day, then

$$\text{population equivalent} = \frac{300}{0.08} = 3750.$$

Sanitary Sewage flow estimation:

Sanitary Sewage is spent water of community that drains into sewers.

Sanitary Sewage = Domestic sewage + Industrial Sewage

Quantity of sewage = Quantity of water supplied.

(i) plus evacuated private water supply.
(ii) plus ground water infiltration
(iii) Minus water losses (leakage, seepage in ground)
(iv) Minus water lost in evaporation.

Net quality of Sewage produced = Quantity of water supplied + (i) + (ii) − (iii) − (iv)

* Usually 80% of water supply may be expected to reach the sewers.

Quantity of Sewage = Per capita Sewage contributed per day × population.

Factors affecting dry weather flow (DWF):

• Dry weather flow (DWF) is the flow of sanitary sewage alone in the absence of storm water (during dry season).

(i) Rate of water supply.
(ii) population growth
(iii) Type of area served (Residential / Commercial / Industrial)
(iv) Infiltration of sub soil water.

Sewer materials:

a. Resistance to Corrosion:

- Sewer carries wastewater that releases gases such as H_2S. This gas in contact with moisture can be converted into sulfuric acid.
- The formation of acids can lead to corrosion of sewer pipe. Hence, selection of corrosion resistance material is must for long life of pipe.

b. Resistance to Abrasion:

- Sewage contain considerable amount of suspended solids part of which are inorganic solids such as sand or grit.

c. Strength and durability:

- Sewer pipe should have sufficient strength to withstand all the forces that are likely to come on them.
- Sewers are subjected to considerable external loads of backfill material and traffic load, if any.
- In addition, the material selected should be durable and should have sufficient resistance against natural weathering action to provide longer life to the pipe.

d. Weight of material:

- The material selected for sewer should have less specific weight, which will make pipe light in weight. The light weight pipe are easy for handling and transport.

e. Imperviousness:

• To eliminate chances of sewage seepage from sewer to surrounding, the material selected for pipe should be impervious.

f. Economy and cost:

• Sewer should be less costly to make the sewerage scheme economical.

g. Hydraulically efficient:

• The sewer shall have smooth interior surface to have less frictional co-efficient.

Suggested Questions / Assignments /Home works / any other
1. Define Population Equivalent?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 40 **UNIT I–**

Topic(s) to be covered	Hydraulics of flow in sewers

	Lecture Outcome (LO)	
	At the end of this lecture, students will be able to	**Bloom's Level**
LO1	Factors that influence flow, Hydraulic formula, Chezy's formula, kutter's formula Bazin's formula, Manning's formula.	Understand & Apply.

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen & Apply

Lecture Notes

Factors that influence flow of sewage in sewers:

- Slope of sewer.
- Geometry of sewer.
- Roughness of interior surface of water
- Bends, transitions, obstructions
- Flow condition
- Characteristics of sewage.

Hydraulic formula:

(i) Chezy's Formula:

$$V = C\sqrt{R \cdot S}$$

V - velocity of flow (m/s)

S - Hydraulic gradient of sewer

R - Hydraulic mean radius (m) = A/P

C - Chezy's constant

A - Area of cross section (m^2)

P - Wetted perimeter (m)

(ii) Kutter's Formula:

$$\text{Chezy's Coefficient, } C = \frac{23 + \frac{0.00155}{S} + \frac{1}{N}}{1 + \left(23 + \frac{0.00155}{S}\right)\frac{N}{\sqrt{R}}}$$

R - Hydraulic mean radius

S - Slope

N - Rugosity Co-efficient (depends on nature of inner surface of sewer)

when d decreases, diameter increases.

Eg: Cement Concrete sewer of ϕ 600 mm, $N = 0.013$.

(iii) Bazin's Formula:

$$\text{Chezy's Constant, } C = \frac{157.6}{1.81 + \frac{k}{\sqrt{R}}}$$

k - Bazin's Constant (depends on nature of inner surface of sewers)

(iv) Mannings's Formula:

$$\text{Velocity of flow, } V = \frac{1}{N} R^{2/3} S^{1/2}.$$

Where N, R, S, have same meaning as given by kutters formula.

(v) Crimp and Burgels formula:

$$V = 83.5\, R^{2/3} S^{1/2}$$

(similar to manning's formula where $1/N = 83.5$ or $N = 0.012$

Eg: For a circular pipe,

$$R = \frac{A}{P} = \frac{\pi/4 D^2}{\pi D} = \frac{D}{4}$$

$$V = 83.5 (D/4)^{2/3} \cdot S^{1/2}$$

$$Q = A * V = \left(\frac{\pi}{4} D^2\right) 83.5 \left(\frac{D}{4}\right)^{2/3} S^{1/2}$$

$$Q = 26.02 D^{8/3} S^{1/2}$$

(vi) William - Hazen Formula:

For flow under pressure for designing water pipes.

$$V = 0.85 C R^{0.63} S^{0.54}$$

C - Value depends on the type of pipe material.

Note: Apart from the above formulae, nomograms, Tables, charts are also available for designing sewers.

Sewer design:

- Hydraulic elements of circular sewers:

Easy manufacture, efficient section. A circular section gives the highest (hydraulic mean depth) when running full (or) half full.

- When depth is more, velocity and discharge will be high.

- It is most economical section since it utilizes minimum quantities of material.

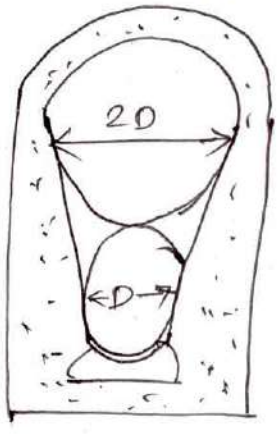
Egg-shaped Sewers (Ovoid sewers):

- Used in combined sewerage system where discharge (flow) highly varies.
- There will be heavy flows during rainy season only only 5 to 10% flow (dry weather flow) during summers

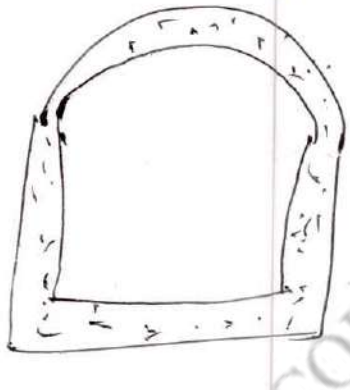
• Egg-shaped sewer provide greater depth (than circular) during low flow conditions.

Other Sewer Sections:

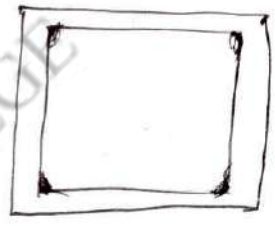
• Soft soils with difficulty of providing foundations for circular/ovoid sections, following shapes are used.



Standard Egg Shaped Sewer



Horse Shoe sewer Section



Rectangular Sewer

Suggested Questions / Assignments /Home works / any other
1. Explain hydraulic flow in Sewers?

Text Books/ Reference Books			
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 41 **UNIT I–**

Topic(s) to be covered	Storm drainage

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
L01	Combined sewers, surface drains / Storm shapes, drainage system.	Understand

Teaching Learning Material	Student Activity
Chalk & talk	Listen

Lecture Notes

Combined sewers:

- Large size of sewer section
- Hydraulic performance is unsatisfactory during dry weather flow (DWF).

Surface drains / storm water drains:

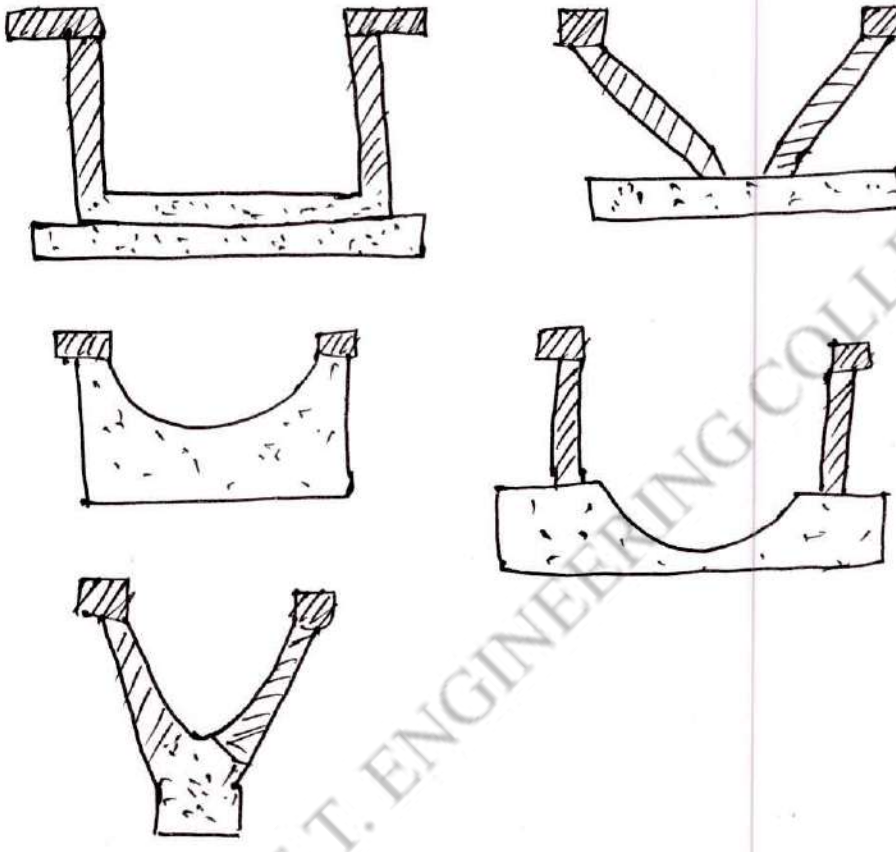
- It is used to carry sludge and rain water.
- It is less hygienic since they are open and exposed to atmosphere.
- Surface drains are normally laid along either sides of street facing boundary walls of houses and buildings.
- Surface drains flow under gravity.

Requirements for efficient surface drains:

- The inner surface of drain should be smooth
- Sufficient carrying capacity and should have reasonable free board.
- All the joints should be properly and neatly finished

Shapes of surface drains:

(i) Rectangular
(ii) Trapezoidal
(iii) Semi-circular
(iv) U-section
(v) V-section



Design of Drainage System:

(i) Contour maps of area is collected.

(ii) Alignment of drains - laterals, branches, mains is done.

(iii) Catchment area of each drain is marked.

(iv) Based on population of catchment area, the peak discharge expected in each drain is calculated.

(v) Information on underground structures (water lines, existing, sewer lines, electric and telephone cables, gas lines etc. location of streets, subsoil condition, strata type, ground water level.

• Longitudinal section of the entire drain line. The natural surface level of catchment area is checked with drain.

• The bed level (depth) of drain is fixed based on following criteria:

→ Bed of drain should be higher than bed of discharge source at outfall point.

→ Depth should be less than man's height to prevent drowning.

→ The drain so designed should be economical section and the velocity achieved should be non-silting / non scouring.

Empirical Formula - Width / depth of drains.

(i) Drains upto 15 cumecs

$$Y = 0.5\sqrt{B}$$

B - width of drain

Y - depth of drain

(ii) Drains with discharge b/w 15 to 30 cumecs.

Discharge (cumecs)	depth (Y(m))
15	1.7
30	1.8
75	2.3
150	2.6
300	3.0

Type of soil / Type of surface	Maximum permissible velocity (m/s)
a) Unlined drains	
(i) Rock and gravel	1.5
(ii) Murram, hard soil etc	1.0 to 1.1

3. Sandy loam, Black cotton soil 0.6 to 0.9
4. Very light loose sand to average Sandy soil 0.3 to 0.6
5. Ordinary soil 0.6 to 0.9

b. Lined drains.

(i) Stone pitched 1.5
(ii) Burnt clay tile lined 1.8
(iii) Cement concrete lined 2 to 2.5

Suggested Questions / Assignments /Home works / any other
1. Define Storm drainage

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 42. **UNIT I–**

Topic(s) to be covered	Storm Runoff Estimation

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Peak run-off rate depends on, Rational formula, Empirical formula	Understand & Apply

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen & apply.

Lecture Notes

Peak run-off rate depends on:

- Type of precipitation
- Intensity and duration of rainfall
- Rainfall distribution
- Soil moisture
- Direction of storm / duration / Storm frequency
- Climatic Conditions.

a) Rational Formula:

- Rain falls on an impervious surface at a constant rate the resultant runoff from the surface would be equal to the rainfall

Runoff rate = Rate of rainfall

Time of Concentration:

- Period after which the entire catchment area starts contributing to the runoff in drains.

Critical rainfall duration:

. Maximum runoff obtained from rain having duration equal to the time of the Concentration.

$$Q_p = \left(\frac{1}{36}\right) k \cdot P_c \cdot A$$

Q_p - Peak rate of runoff

k - Co-efficient of runoff

A - Catchment area in hec.

P_c - Critical rainfall intensity (cm/hr).

Average Impermeability factor (I) (K):

$$K = I_{av} = \frac{A_1 I_1 + A_2 I_2 + \cdots A_n I_n}{A_1 + A_2 + \cdots + A_n} = \frac{\Sigma AI}{\Sigma A}$$

A - area of different surfaces of catchment

I - Corresponding impermability factors for different surfaces.

Intensity of Rainfall:

• The value of intensity obtained is the rainfall at the rainfall gauge station and is called as point rainfall intensity.

• Intensity at any point on catchment area
= point rainfall intensity × Areal distributing factor

• Rains with frequency of 10 years

$$P = \frac{38}{\sqrt{T}}$$

• Rains with frequency of 1 year

$$P = \frac{15}{T^{0.62}}$$

- Kuichling's formula:

$$P = \frac{267}{T+20} \quad \text{(Storms of 10 year frequency)}$$

$$P = \frac{305}{T+20} \quad \text{(Storms of 15 years frequency)}$$

- Empirical formula for computing the peak discharge for larger catchment areas.

(i) Burkli – Ziegler formula:

$$Q_p = \left[\frac{1}{455}\right] k' \cdot P \cdot A \sqrt{\frac{S_0}{A}}$$

Q_p - Peak runoff in cumecs

k' → Runoff co-efficient = 0.7.

P → Maximum rainfall intensity
= 2.5 to 7.5 cm/hr.

A → Drainage area in hectares

S_0 → Slope of ground surface in metres per thousand metres.

Dicken's formula:

$$Q_p = CM^{3/4}.$$

M → Catchment area in sq.km.

C → Constant depends on runoff factors (11.5 generally)

Ryve's formula:

$$Q_p = CM^{2/3}$$

C = 6.8 (less for flat catchment and more value for hilly area)

- Inglis formula: (Fan-Shaped Catchment Bombay)

$$Q_P = \frac{123M}{\sqrt{M+10.4}} = 123\sqrt{M}$$

- Nawab Jung Bahadur formula: (Hydrabad Deccan Catchment)

$$Q_P = C_2 M' \left[0.93 - \left(\frac{1}{14}\right) \log M'\right]$$

C_2 Varies b/w 48 to 60

$M' \rightarrow$ Catchment area in acres.

- Lredgc(or) Burgd's formula:

$$Q_P = 19.6 \frac{M}{L^{2/3}}$$

$L \rightarrow$ length of drainage basin in kilometers.

Suggested Questions / Assignments /Home works / any other
1. What is Storm runoff?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 43. **UNIT I–**

Topic(s) to be covered	Surface on which rain fall occurs.

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Total Runoff, Runoff ratio for entire area.	Understand & Apply

Teaching Learning Material	Student Activity
Chalk & Talk	listen & apply

Lecture Notes

Area %	Surface	Runoff Ratio
20	Roof	0.90
20	pavements	0.85
5	paved yards	0.80
15	Macadam Roads	0.40
25	Lawn, gardens	0.10
5	Wooden	0.05

Total area of district is 36 hectares and the max. rainfall intensity is 5cm/hr.

Determine: (i) Co-efficient of runoff
(ii) Total runoff for district.

Sol:

Runoff Ratio for entire area:

$$K = \frac{\Sigma kA}{\Sigma A} = \frac{k_1A_1 + k_2A_2 + k_3A_3 + \cdots k_nA_n}{A_1 + A_2 + A_3 + \cdots A_n}$$

$$k_1 A_1 = \left[\frac{20}{100} \times 0.9\right] A = 0.18A$$

$$k_2 A_2 = \left[\frac{20}{100} \times 0.85\right] A = 0.17A$$

$$k_3 A_3 = \left[\frac{5}{100} \times 0.80\right] A = 0.04A$$

$$k_4 A_4 = \left[\frac{15}{100} \times 0.4\right] A = 0.06A$$

$$k_5 A_5 = \left[\frac{35}{100} \times 0.1\right] A = 0.035A$$

$$k_6 A_6 = \left[\frac{5}{100} \times 0.05\right] A = 0.025A$$

$$K = \frac{k_1 A_1 + k_2 A_2 + k_3 A_3 + k_4 A_4 + k_5 A_5 + k_6 A_6}{A}$$

$$= \frac{(0.18 + 0.17 + 0.04 + 0.06 + 0.035 + 0.025)A}{A}$$

$$\boxed{K = 0.4875}$$

Rational formula:

$$Q_p = \frac{1}{36} k \cdot P_c \cdot A$$

$P_c = 5$ cm/hr; $A = 36$ hectares

$$= \frac{1}{36} \times 0.4875 \times 5 \times 36$$

$Q_p = 2.44$ cumecs.

• A population of 30,000 is residing in a town having an area of 60 hectares. If the average co-efficient of runoff for this area is 0.60 and time of concentration of the design rain is 30 min. calculate the sewage discharge for the sewers in a combined sewerage system. Assume suitable data.

Sol:

Assume avg. per capita demand = 120 litres/day/person.

Water supply will reaching sewers as Sanitary Sewage } = 80% of water supplied × population

∴ Quantity of Sanitary Sewage produced per day = $\left[\frac{80}{100}\right]$ × 120 lpcd × 30,000

= 2880 × 10^3 l/d

Average flow = 2880 m^3/d.

Quantity of sewage produced per second = $\frac{2880}{24 \times 60 \times 60}$ = 0.033 m^3/s

Assuming the maximum sewage discharge as 3 times of average sewage discharge.

Maximum sewage discharge = 3 × Average flow

= 3 × 0.033 m^3/s

= 0.1 m^3/s

Storm water discharge $Q_p = \frac{1}{36}$ k. pc. A

$$P_c = \frac{100}{T+20} = \frac{100}{30+20} = 2\text{cm/hr} \quad (\because T \text{ b/w } 20 \text{ to } 100\text{min.})$$

$$Q_p = \frac{1}{36} \times 0.60 \times 2 \times 60 = 2\text{m}^3/\text{s}$$

∴ Total peak discharge in sewers.

= maximum sewage discharge + Max. Storm runoff

= 0.1 + 2

= 2.1 m^3/s

= 2.1 cumecs.

Suggested Questions / Assignments /Home works / any other
1. Determine total runoff, runoff ratio and entire area?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 44. **UNIT I–**

Topic(s) to be covered	Sewer Appurtences

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
Lo1	Manholes, classifications of man holes, component parts of manhole.	understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

Sewer appurtenances are those structures which are constructed at suitable intervals along a sewerage system, which helps in efficient operation and maintenance.

- Man holes, drop manholes, Lampholes, Clean-outs, Street inlets, Catch basins, flushing tanks, Grease and oil traps, Inverted Siphons, Storm Regulators

- purpose - provide access into sewers for inspection, cleaning and maintenance works.

- Location - provided at every bend, junction, change of gradient (or) change of sewer diameter at suitable intervals along sewer line.

Spacing - depends on sewer size (larger diameter - greater spacing)

Classification of manholes: [Based on Depth]

(i) Shallow manhole:

- Used as inspection chamber
- Depth = 0.7m to 0.9m
- Constructed at start of branch sewer and at places of minimum traffic.
- Light cover is provided at top.

(ii) Normal (or) Medium manholes:

- Depth = 1.5m
- Square (1m x 1m)/Rectangular (1.2m x 1m) shape.
- Heavy cover is provided at top.
- Unlike shallow manholes, the section does not change with depth.

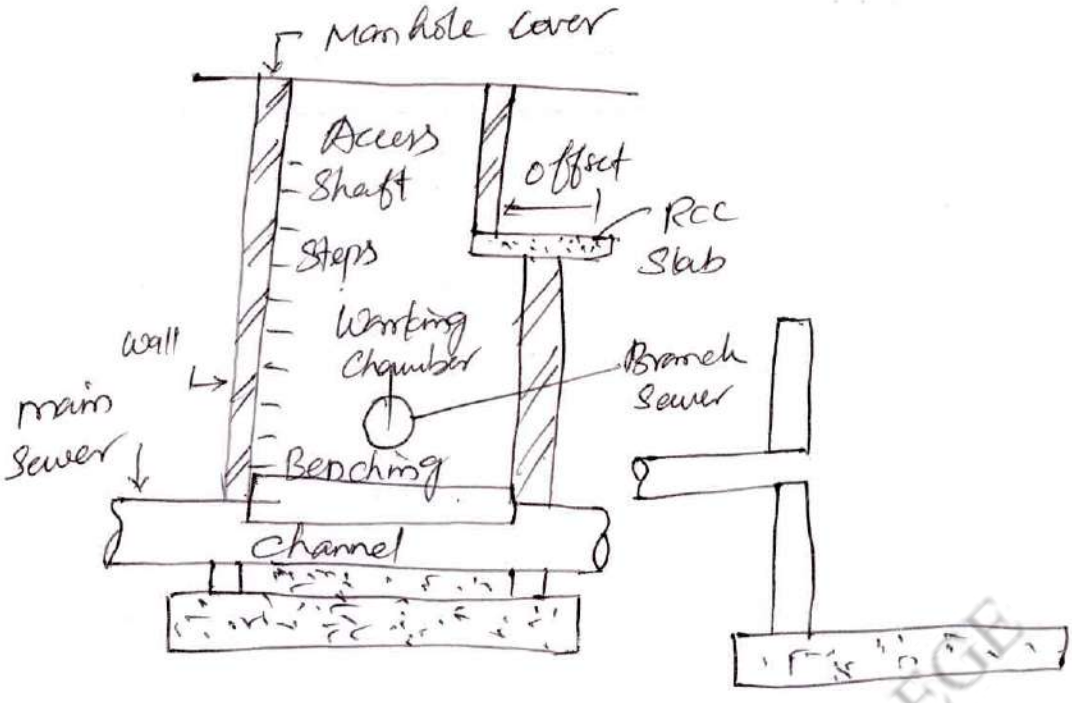
(iii) Deep manhole:

- Depth > 1.5m
- Section normally varies, the upper portion is reduced
- Steps are provided to enable workers entry to bottom.
- Heavy cover is provided at the top.

Component parts of manhole:

Access Shaft:

- It is the upper portion of deep manhole.
- Rectangular manhole - Size of access shaft is 0.75m x 0.6m
- Circular manhole - Size is 0.6m to 0.7m
- Depth of access shaft depends on manhole depth



Working Chamber:

- It is lower portion of manhole.
- Provide working space for inspection and cleaning apratus
- Rectangular manhole - working size 1.2 m × 0.9 m
- Circular manhole - size of working chamber is 1.2 m dia.
- Height of this chamber must not be less than 1.8 m.

Benching:

- Bottom portion of manhole is constructed in cement concrete
- Semicircular (or) U-shaped channel is generally constructed and the sides are made to slope towards it.
- Arranging is known as benching and facilitate the entry of sewage from branch sewers into the main sewer.

Side walls:

- The side walls are made of brick / Stone masonry / R.C.C.
- The minimum thickness of brick walls should be 22.5 cm (9")

• The thickness of R.C.C. walls will however be much less as compared to that of brick wall, but RCC walls are costly than brick.

Steps or Ladders:

• Steps are generally provided for descending into deep manholes.

• Steps are made of cast iron and are placed at a horizontal distance of about 20cm and a vertical distance.

Cover and Frame:

• Cover is generally made of cast iron material and are fixed at the top of the manhole embedded in pavements.

• Thickness of frame is 20 to 25 cm about 10cm wide

• Weight of cover and frame varies b/w 90 to 270 kg which depends on traffic volume.

Suggested Questions / Assignments /Home works / any other
1. Explain Sewer appurtenances?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 45. **UNIT I–**

Topic(s) to be covered	Sewer Appurtenances

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Grease and oil traps, inverted siphons storm water Regulator/ storm relief works.	understand

Teaching Learning Material	Student Activity
Chalk & talk	Listen.

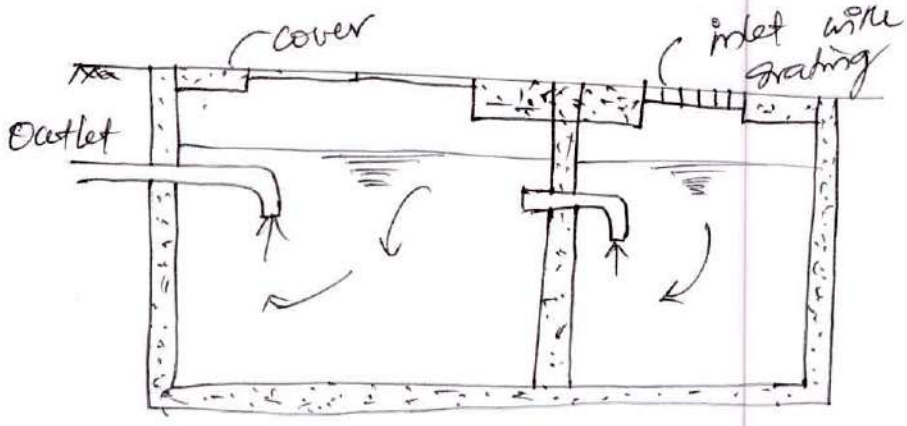
Lecture Notes

Grease and oil traps:

- Trap chambers are used to remove oil / grease from sewage, before entering sewer line.
- These are located near sources which generate grease and oil (automobile repair workshops, garages, kitchens of hotels, oil/grease industries etc.)

principle:

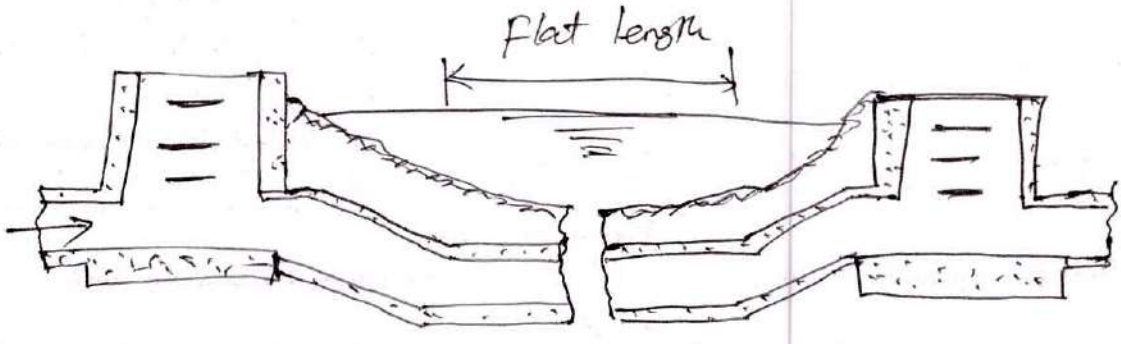
- Grease and oil traps consists of two chambers inter connected through a pipe.
- Inlet is provided with a grating on the top.
- Oil and grease float on surface. the outlet is provided submerged to exclude oil and grease.
- Combined sand, grease and oil trap is also available.



Oil and grease trap

Inverted Siphons:

- Inverted siphons are sewer sections that are provided lower than the adjacent sewers (or) that drops below the hydraulic gradient line (HGL).
- They are provided under the obstructions such as roadway, railway, stream, valley etc.
- Inverted siphons should be provided only in areas where other means of passing the obstructions are not feasible.
- They are siphon tubes or pipes made of cast iron or Concrete.



Demerits of Siphons:

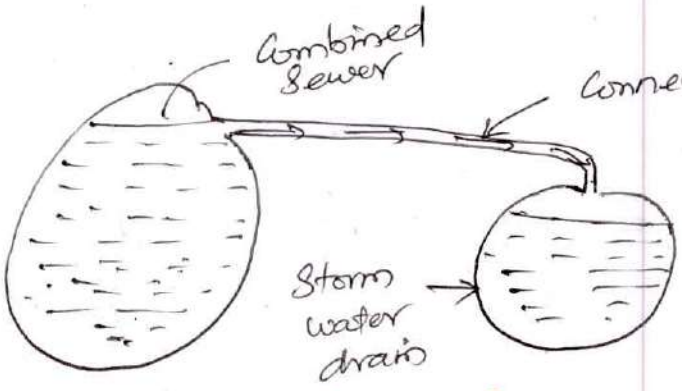
- Silting occurs because the down gradient pipe is not continuous and is difficult to cleaning.
- Improper design of inlet chamber cause accumulation of floating matter and reduce efficiency.

Storm water Regulator / storm relief works:

- Storm water regulators are provided in combined sewerage system to divert excess storm water into stream.
- These are overflow devices to prevent overloading of sewers, pumping stations, treatment plants.

Overflow weirs (side flow weirs):

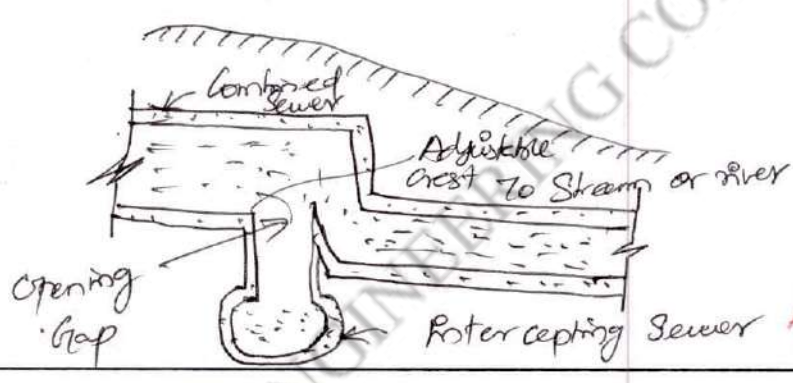
- Masonary chamber with overflow weir is common type
- Overflow weirs are located where sewer approaches a water course.
- Single acting (single side) or double acting (double side) overflow weirs can be provided.
- Openings are provided at suitable height of combined sewer and joined to storm drains.
- Excess sewage overflows the combined sewer and enters channel, carrying storm water drain or into a stream.



Overflow weirs

Leaping weir:

- Opening is provided at invert of storm drain. (Combined Sewer)
- Normal storm water flows in Intercepting Sewer.
- Excess flows are diverted to nearby stream by the leap over combined sewers.



Leaping Weir

Suggested Questions / Assignments /Home works / any other
1. Describe sewer Appurtenances and its types?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 46. **UNIT I–**

Topic(s) to be covered	Corrosion in Sewers

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Chemical Corrosion, Neutrophilic Colonisation, Sound Concrete, Impact of Sewer Lead space temperature.	understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen.

Lecture Notes

Corrosion in Sewers:

- Bacteria in slime under flowing sewage convert sulphates in sewage into sulphides.
- Sulphides in liquid make their way to surface of sewage and released into sewer atmosphere as hydrogen sulphide (H_2S) gas.

$$H_2S + O_2 = H_2SO_4$$

Chemical Corrosion during the initial months:

- When a Concrete sewer pipe is first manufactured and installed the interior surface of the pipe is too alkaline (pH > 10.5) for bacterial or fungal colonisation to take place.
- Under these circumstances only the chemical corrosion of the pipe is possible.
- H_2S and CO_2 dissolve in concrete pore water to form weak acids $H_2SA\cdot HS^- + H^+$

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \rightleftharpoons CO_3^{2-} + 2H^+$$

• This attack is limited to the outer exposed skin of the pipe (< 0.5mm deep)

• Purely chemical attack on sewer pipe only last for no. a month.

• By the end of this stage of corrosion cycle the surface pH has dropped to the point where biological processes dominate the corrosion process.

Neutrophilic Colonisation of pipe surface:

• When the pH of surface of pipe has fallen to pH = 9 fungal and bacterial colonies begin to appear on the pipe surface.

• As the surface of pipe becomes more acidic successive waves of bacteria more suited to lower pH conditions will dominate the pipe surface.

• The production of these acids acts to further lower the pH of sewer pipe surface but no measurable loss of mass has as yet occured.

Second Concrete loss begins

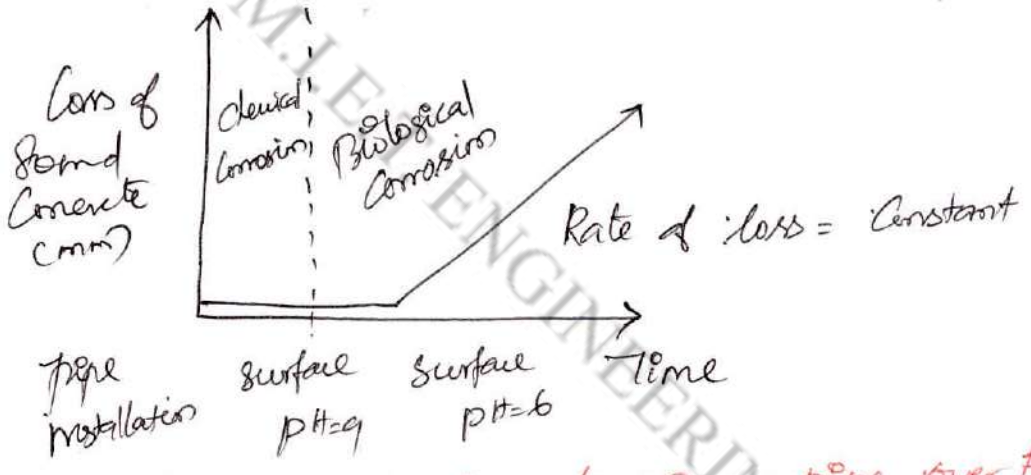
• When the pH of surface of sewer pipe falls to pH = 6, significant conversion of second concrete to corroded product begins.

• Once mass loss begins the rate at which concrete is lost per year remains constant for the remainder of pipe service.

• Rate at which concrete is lost however varies from site to site and ~~it~~ is dependent on chemistry & environmental factors.

• As sound concrete loss continues a layer of corroded product builds on the pipe surface however this layer does not affect level of corrosion activity and rate of corrosion remains constant.

• When the amount of concrete lost over time is plotted the corrosion function takes the following general form.



Corrosion of Concrete sewer pipe over time.

Factors affecting the rate of concrete sewer pipe corrosion:

• Rate at which sound concrete is corroded varies from site to site depending on nature of local sewer environment.

Impact of H_2S concentration in sewer headspace:

• As the H_2S concentration in sewer headspace increases so does the rate of corrosion.

• Field studies and literature data suggested that the rate of corrosion increases with the square root of H_2S concentration

Rate of Corrosion $\propto ([H_2S]_{gas})^{0.5}$

Impact of sewer headspace temperature:

- The sewer temperature increases the rate of biological activity increases as well as the rates of reaction b/w the acids produced and concrete.
- Impact of sewer gas temperature (averaged over time) on the rate of corrosion can be described by.

Rate of Corrosion $\propto e(-30,000 / R \times (T + 273))$

Suggested Questions / Assignments /Home works / any other
1. Write short note on Corrosion in sewer?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 47. **UNIT I–**

Topic(s) to be covered	Sewage pumping

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Pumping Sewage, types of pumps, advantages and disadvantages of pumps.	Understanding

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

Pumping Sewage:

- For lifting sewage from low lying areas (sewers run at higher elevation than the sources of sewage generation.
- In flat terrains, laying of sewers at designed gradient requires large excavation and is expensive. To reduce the excavation cost, pumping is done at suitable intervals.
- Pumping is resorted to when outfall sewer is lower than the entrance of treatment works or receiving water bodies.
- For lifting sewage from basements of commercial buildings (since street sewers are higher than basement level of buildings).
- Instead of driving tunnel through ridges for sewer line, it is economical to pump sewage into sewers laid across the slope of ridges.

Sewage lifting pumps:

- Pump capacity: Must be able to handle peak flows
  - Two or more pumps and power sources are required.
- Clogging Aspects:
  - Special pumps which do not clog due to floating and suspended solids in sewage are used.
  - pumps should be accessible for cleaning and removal of obstructions.

Types of pumps:

- Centrifugal pumps
- Reciprocating pumps.
- Pneumatic ejectors or air pressure pumps.

Centrifugal pumps:

Advantages:

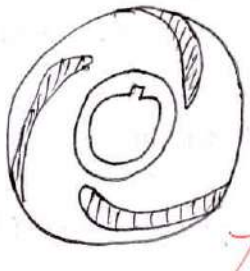
(a) Widely used for lifting sewage.

(b) Easily installed in pits and sumps.

(c) pre-treatment (Grit removal) of sewage is not required before pumping.

Disadvantages:

(a) Low efficiency (30 to 60%)



Three vane type impeller.

Reciprocating pumps:

(i) High initial cost
(ii) Difficulty in maintenance
(iii) Greater wear and tear
(iv) Not used nowadays.
(v) Used for pumping sludges and where large quantity is required to be pumped against low heads.

Ram type:

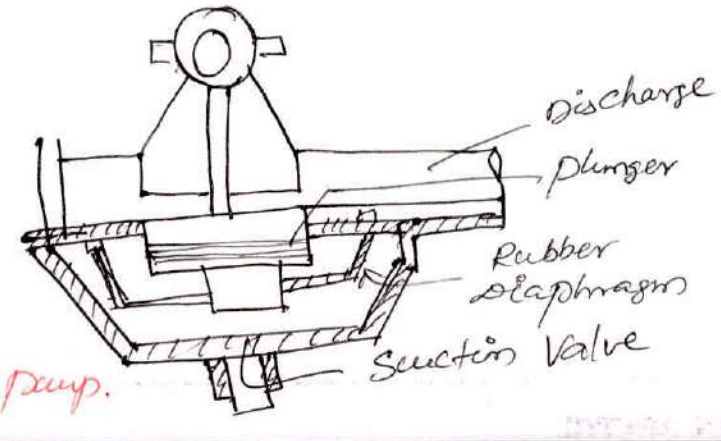
- A piston or plunger moves inside a closed cylinder.
- On intake stroke, the liquid enters the cylinder through suction valve.
- On discharge stroke, suction valve closes and liquid is forced into the delivery pipe through the delivery valve, which opens during discharge stroke.

Eg: Diaphragm pump.

Propeller type:

- In this pump, a multiple blade screw rotor or propeller moves vertically inside a pump casing, causing the sewage to lift up.
- The propeller draws water through the inlet guide vanes and discharges through the outlet guide vanes.

Eg: Axial flow screw pump.



Diaphragm pump.

Pneumatic Ejectors:

- Used for pumping smaller quantities of waste waters.
- Works under the action of compressed air.
- Consists of an air-tight tank into which waste water flows by gravity.
- The waste water is forced out automatically whenever sufficient waste water has accumulated to raise a float, which opens the compressed air inlet valve.

Advantages:

- Automatic operation & Require least supervision.
- only few parts come in contact with sewage.
- Ejectors do not get clogged.
- Economical where smaller quantities of sewage are required to be lifted.

Disadvantages:

- Low efficiency - 15%.

Suggested Questions / Assignments /Home works / any other
1. Explain in detail about sewage pumping?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 48. **UNIT I–**

Topic(s) to be covered	Pumping system for drainage

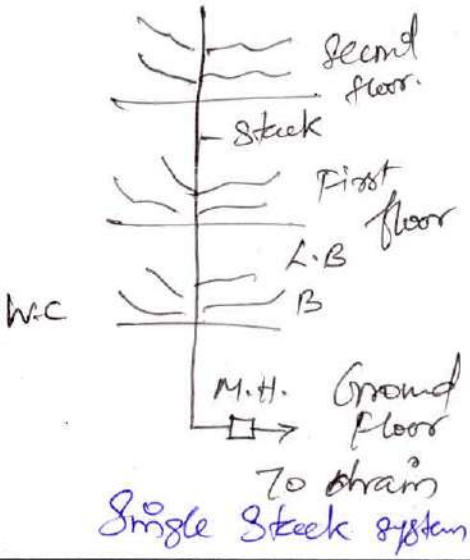
	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Single stack system, one pipe system partially ventilated single stack system Two pipe system.	Understand.

Teaching Learning Material	Student Activity
Chalk talk	Listen.

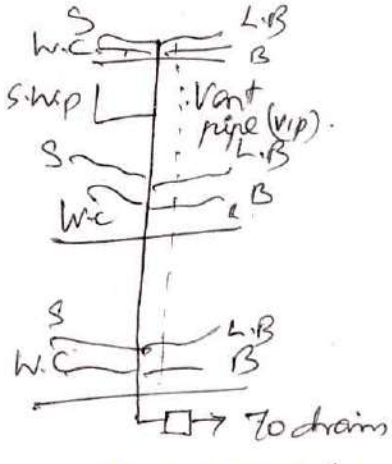
Lecture Notes

Single Stack System:

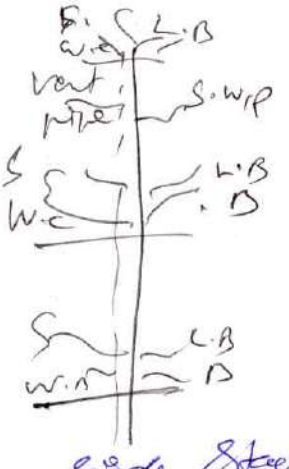
- Systems in which the waste matter from bathrooms, sinks etc. as well as foul matter from water closets are discharged in one single pipe called the soil and waste pipe (SWP)
- No separate vent pipe is provided.
- Effective only if the traps are filled with water seal of depth not less than 75mm.
- Simple and economical since one pipe is used.



Single Stack system



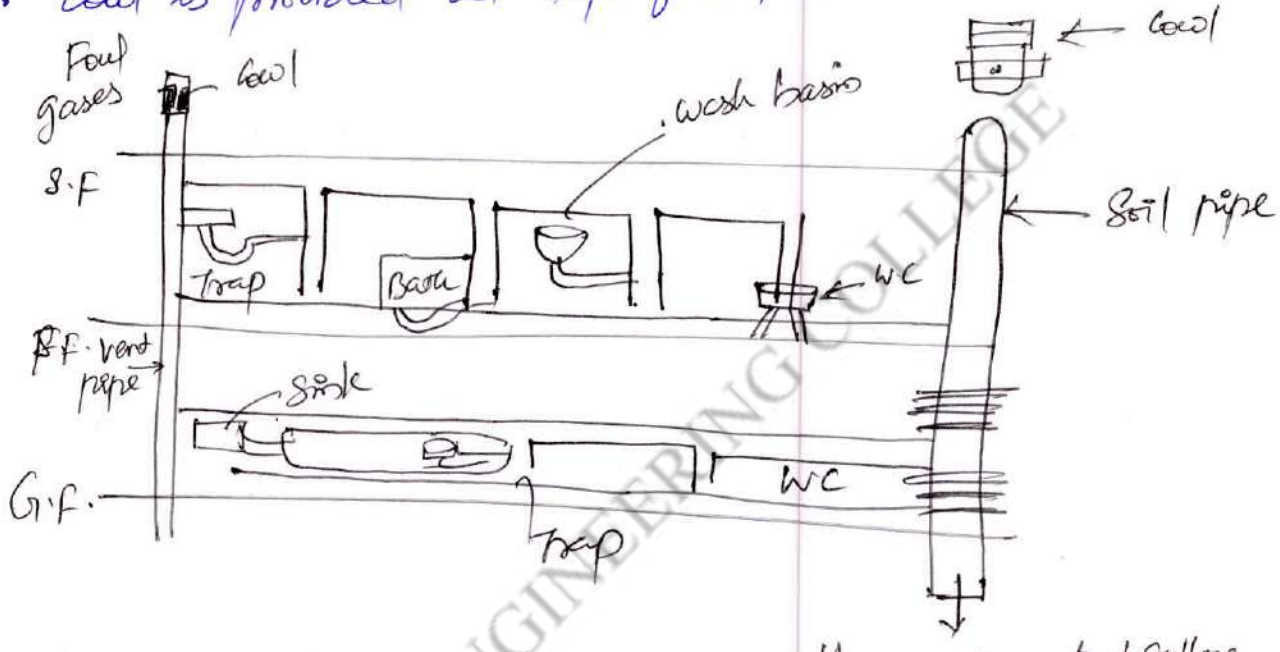
One pipe system



Single Stack partially ventilated

One pipe system: (costilier than single Stack system):

- Common Soil and Waste pipe (SWP) connects different floor and carries both human excreta and Sullage.
- Separate vent pipe is also provided.
- Traps of all water closets, basins etc. are completely ventilated.
- Cowl is provided at top of SWP for Ventilation.



Single Stack system partially Ventilated:

- This is modified form single stack system and one pipe system.
- Waste water from W.C. basins; sinks is discharged into one common Soil and waste pipe (S.W.P).
- A relief vent pipe is also provided which provides ventilation to traps of water closets.
- Traps of basins are not directly connected to vent pipe.

Two pipe - System:

- This is improved but costly system, which requires large number of pipes.
- Separate soil pipe (SP) and waste pipe (WP) are provided which carry human excreta and sullage respectively.
- Water closet is connected to soil pipe (S.P)
- Bathroom sinks, Lavatory basins are connected to waste pipes (WP) which are connected to drain.
- All the traps are ventilated by separate ventilation pipes.
- One ventilation pipe provided along with soil pipe and another ventilation pipe for waste pipe. A total of 4 pipes, one soil pipe, one waste pipe and two ventilation pipes are provided.

Plumbing systems:

- Efficient for multi-storeyed buildings
- Requires minimum use of traps.
- But, large number of pipe makes the system costly.
- Difficulty in accomodating pipe in buildings.

One pipe system:

- Economical.
- Easy to accomodate.
- But require ventilation, water seals and proper connections.
- On multi Storyed buildings, it requires lavatory blocks to be placed one above the other.

Suggested Questions / Assignments /Home works / any other
1. Brief the pumping system of drainage?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 49. **UNIT-V** SEWAGE TREATMENT AND DISPOSAL

Topic(s) to be covered	Objectives and Selection of treatment process.

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
L01	Objectives, Selection of treatment process, activated sludge process and extended aeration systems.	Understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

Objectives:

- To remove solids in wastewater.
- To prevent water pollution
- To prevent environmental degradation
- To avoid damage to soil structure.
- To minimize the discharge of waste water into the environment.

Wastewater treatment is a combination of physical, chemical and biological processes/ operations that can be reduce the objectionable properties of waste and render it safe.

Selection of treatment process:

(i) Quantity / Volume of wastewater to be treated.
(ii) Quality / characteristics of waste water to be treated.
(iii) Effluent disposal standards.

(iv) Quality of treated wastewater desired (efficiency of treatment)

(v) Land required for installing treatment units.

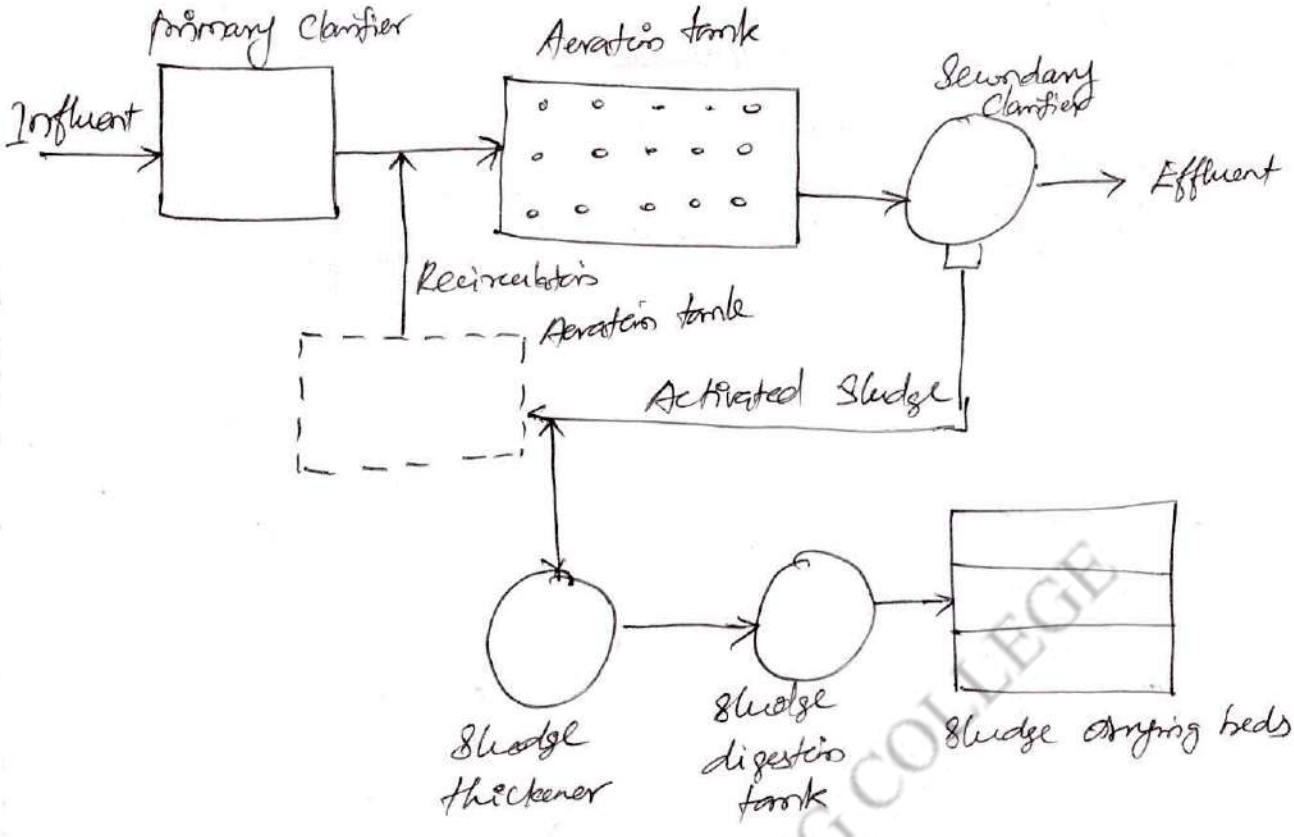
(vi) Requirement of skilled labour for operation and maintenance.

(vii) Capital, operation and maintenance cost.

(viii) Economically viable, environment friendly and sustainable technology.

Activated Sludge process and Extended Aeration systems:

- It is an aerobic process. It has two treatment units - an aeration tank followed by a secondary settling tank.
- Organic solids in sewage are stabilised by aerobic production of activated mass of aerobic microorganisms.
- Sewage after sedimentation in primary sedimentation tank enters the aeration tank where it is mixed with activated sludge and aerated for long hours.
- Aeration replenishes/increases dissolved oxygen (DO) level in sewage.
- The increase in microbial biomass helps in decomposition of organic waste in sewage.
- Later the biomass is settled in secondary settling tank. The settled sludge has active microorganism.
- The mixture of waste water and activated sludge in aeration tank is called mixed liquor.

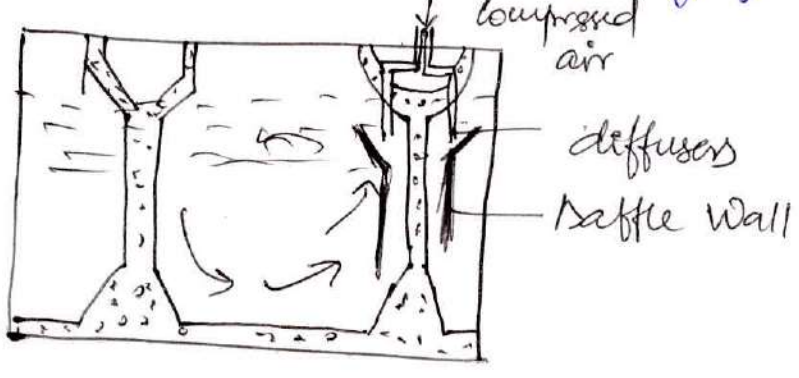


Activated Sludge process:

Methods of Aeration:

Diffused Aeration:

- Compressed air under pressure of 35 to 70 kN/m² is introduced to aeration Chamber through diffusion plates (diffusers)
- Diffusers fixed at bottom of aeration tank diffuse air in small bubbles to provide greater efficiency of aeration.



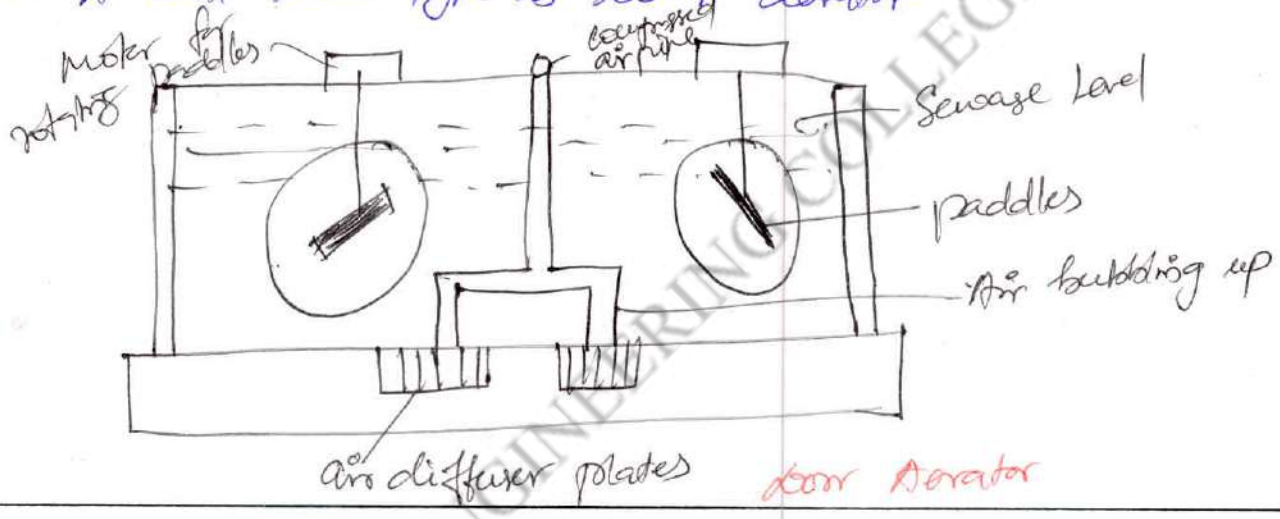
Diffused Aeration:

Mechanical aeration:

- Atmospheric air is used.
- Sewage is stirred up using mech. devices like paddles.
- Only requirement is thorough agitation.
- Aeration period is 6 to 8 hours.

Combined aeration:

- Diffused air aeration as well as mech. aeration are combined together in a single unit.
- A well know type is Door aerator



Suggested Questions / Assignments /Home works / any other
1. Describe about Activated Sludge process?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 50. **UNIT I–**

Topic(s) to be covered	Design Consideration involved in an ASP

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Hydraulic retention time, volumetric loading rate, F/M ratio.	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

Hydraulic Retention time (HRT):

Aeration period decides the loading rate of sewage in aeration tank.

$$HRT = \text{Retention time} = \theta = \frac{\text{Volume of tank}}{\text{Rate of sewage flow}}$$

$$= \frac{V}{Q} \text{ (day)}$$

$$HRT = \theta = \frac{V}{Q} \times 24 \text{ (hrs)}$$

θ - aeration period in hrs

V = Vol. of aeration tank (m^3)

Q = quantity of wastewater flow into aeration tank.

Organic loading Rate:

Volumetric loading is defined as the BOD load applied per unit volume of aeration tank.

$$V = \frac{Q \times Y_o}{V.}$$

Y_o - BOD_5 in mg/l of influent sewage
V - Aeration tank volume (m^3)
Q - Sewage flow in aeration tank (m^3).

Food to Microorganism (F/M Ratio)

. Food here means the organic waste in sewage. optimum F/M is reached, sufficient food is available for microorganism, recycling of activated sludge has to regulated by wasting excess sludge from system.

$$\frac{F}{M} = \frac{\text{Daily BOD load applied to aeration tank (g)}}{\text{Total microbial mass in system (g)}}$$

$$\frac{F}{M} = \frac{Q \cdot Y_o}{V \cdot X_t}$$

F/m ratio controls BOD removal.

Lower F/m value, indicates higher BOD removal.

F/m is varied by varying the MLSS microbial concentration.

Sludge Age / Solids Retention time

Average time for which the mass of suspended solids remain under aeration.

$$\text{Sludge Age } (\theta_c) = \frac{\text{Mass of suspended solids}}{\text{Mass of solids leaving system per day}}$$

(a) Mass of solids in reactor:

$$M = V \times MLSS$$
$$= V \times X_t$$

(b) Mass of Solids removed with wasted Sludge per day.

$= Q_w \times X_R$

(c) Mass of Solids removed with effluent per day.

$= (Q - Q_w) X_E$

(d) Total Solids removed per day

$= (1) + (2)$

$= Q_w \cdot X_R + (Q - Q_w) X_E$

(e) Sludge age:

$$\theta_c = \frac{\text{Mass of Solids in reactor}}{\text{Mass of Solids removed with wasted Sludge / day}}$$

$$= \frac{V \cdot X_t}{Q_w \cdot X_R + (Q - Q_w) \cdot X_E}$$

$$\theta_c = \frac{V \cdot X_t}{Q_w \cdot X_R}$$

(f) Recycle Ratio

$$r = \frac{Q_r}{Q}$$

(g) Total microbial mass in reactor

$$X_t \cdot V = \frac{\alpha_y \cdot Q (S_o - S) \theta_c}{1 + k_d \theta_c}$$

$$X_t = \frac{\theta_c}{\theta} \cdot \frac{Y (S_o - S)}{1 + k_d \cdot \theta_c}$$

Sludge Volume index (S.V.I) / Sludge index.

- Indicates sludge concentration in system and settlability characteristics of sludge.
- Indicates the rate of sludge recycling required to maintain MLSS and F/M ratio.

$$SVI = \frac{Vab}{Xab} \text{ ml/mg}$$

$$SVI = \frac{Vab}{Xab} \times 1000 \text{ ml/g}$$

Xab – Concentration of suspended solids in mixed liquor

SVI - adopted = 50 to 150 ml/g =

= good settling sludge.

Suggested Questions / Assignments /Home works / any other
1. Explain design of ASP?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 51. **UNIT I–**

Topic(s) to be covered	Conventional activated Sludge treatment plant

	Lecture Outcome (LO)	
	At the end of this lecture, students will be able to	**Bloom's Level**
Lo1	Design Conventional ASP	Understand & Apply

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen / Apply

Lecture Notes

An average operating data for Conventional activated Sludge treatment plant is as follows.

Wastewater flow	– 35000 m³/d
Vol. of aeration Tank	– 10900 m³
Influent BOD	– 250 mg/l
Effluent BOD	– 20 mg/l
Mixed liquor SS (MLSS)	– 2500 mg/l
Effluent Sludge SS	– 30 mg/l
Waste sludge SS	– 9700 mg/l
Quantity of waste sludge	– 220 m³/d

(i) Aeration period (hrs)

(ii) F/M kg BOD per d/kg MLSS.

(iii) Percentage efficiency of BOD removal.

(iv) Sludge age (days).

Sol:

(i) Aeration period (θ) in hours:

$$t = \frac{V}{Q} \times 24 = \frac{10900}{35000} \times 24 = 7.5 \text{ hours}$$

(ii) F/M ratio:

$$\frac{F}{M} = \frac{Q \cdot Y_0}{V \cdot X_t} = \frac{35000\ m^3 \times 250\ mg/l}{10900\ m^3 \times 2500\ mg/l}$$

$$= 0.32 \text{ kg BOD per/day 1 kg of MLSS.}$$

(iii) Percentage efficiency of BOD removal:

$$\eta = \frac{\text{Incoming BOD} - \text{Outgoing BOD}}{\text{Incoming BOD}}$$

$$= \frac{250 - 20}{250} \times 100\%$$

$$= 92\%$$

(iv) Sludge age in days (θ_c):

$$\theta_c = \frac{V \cdot X_t}{Q_w \cdot X_R + (Q - Q_w) \cdot X_E}$$

$$= \frac{10900 \times 2500}{220 \times 9700 + (35000 - 220) \times 30}$$

$$\theta_c = 8.58 \text{ days.}$$

Design a conventional activated sludge plant to treat settled domestic sewage with diffused air aeration system for the following data:

(i) population — 1,20,000

(ii) per capita sewage contribution — 160 lpcd

(iii) Settled sewage BOD_5 — 200 mg/l

(iv) Effluent BOD_5 required — 15 mg/l.

Sol:

Step 1: Influent flow = population × per capita sewage contribution

$= 120000 \times 160 = 19.2 \times 10^6$ lpd

$= 19.2$ MLD

$= 19200\ m^3/d.$

$$\text{Efficiency required} = \frac{\text{Influent BOD} - \text{Effluent BOD}}{\text{Influent BOD}} \times 100$$

$$= \frac{200 - 15}{200} \times 100 = 92.5\%$$

Step 2: Volume of Aeration tank:

Assume $F/m = 0.2$, MLSS$(X_t) = 3000$ mg/l.

$$F/m = \frac{Q \cdot Y_0}{V \cdot X_t}$$

$$0.2 = \frac{19200 \times 200}{V \times 3000} \times \frac{m^3 \times mg/l}{m^3 \times mg/l}, \quad V = 6400\ m^3$$

Step 3: Check for HRT

$$HRT = \frac{V}{Q} \times 24 = \frac{6400}{19200} \times 24 = 8 \text{ hrs}$$

Step 4: Check for volumetric loading:

$$= \frac{Q \cdot Y_0}{V} = \frac{19200\ m^3/d \times 200\ mg/l}{6400\ m^3} = 0.6 \text{ kg } BOD_5/m^3$$

Step 5: Return Sludge Ratio:

$$\frac{Q_r}{Q} = \frac{X_t}{\left(\frac{10^6}{SVI} - X_t\right)}; \quad \text{taking SVI} = 100$$

$$\frac{Q_r}{Q} = \frac{3000}{\left(\frac{10^6}{100} - 3000\right)} = 0.429 = 42.9\%$$

Step 6: Tank dimension:

Assume depth = 3m, width = 4.5 m

Length of aeration tank $= \frac{\text{Volume}}{\text{depth} \times \text{width}} = \frac{6400}{3 \times 4.5} = 474$ m.

Provide continuous channel. Six baffles; 7 sections of length = 68 m.

Total length, $L = 7 \times 68 = 476$ m

Thickness of each baffle = 0.25 m.

Step 7: Check for minimum air availability:

In second half, 760 diffuser plates = $760 \times 0.3 \times 0.3 \times 12$

$= 82.08$ m³/min.

In a length of 242 m, air available per metre length of channel = $\frac{82.08}{242} = 0.34$ m³/min/m

length > 0.25 m³/min/m length.

Hence Satisfactory.

Suggested Questions / Assignments /Home works / any other
1. Describe conventional design of ASP?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

• **Lecture No.** 52. **UNIT I–**

Topic(s) to be covered	Trickling Filters:

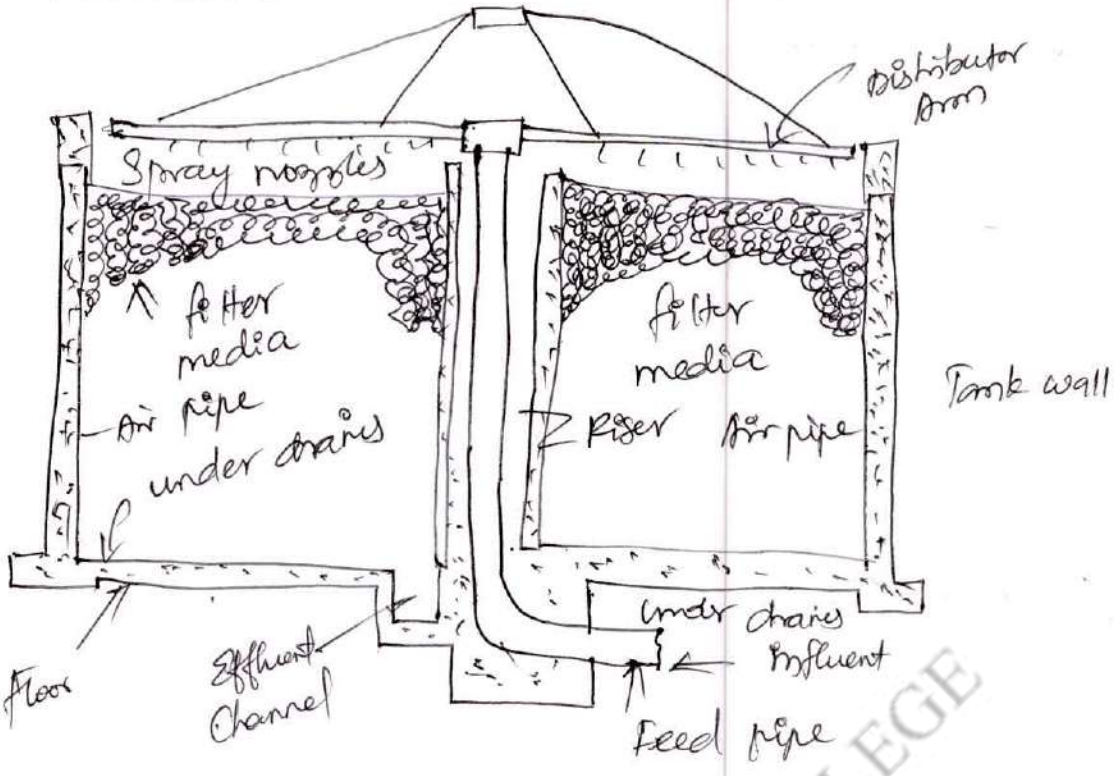
	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
Lo1	Classification of trickling filters, filter media, under drainage system	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen

Lecture Notes

Trickling filters:

- It is an aerobic and attached growth process.
- Trickling filters are also called percolating filters (or) Sprinkling filters.
- Sewage is allowed to sprinkle (or) trickle over a bed of coarse, rough, hard filter media and it is then collected in under-drainage system.
- Spray nozzles rotary distributors provided on top are used for sprinkling sewage on filter media.
- Biological purification is brought about mainly by aerobic bacteria, which form a bacterial film (biofilm) around particles of filter media.
- The color of this film is blackish, greenish and yellowish and apart from bacteria it may consist of fungi, algae, protozoa etc.



Trickling filters.

- Sufficient O_2 (oxygen) is supplied inside filter for existence of this bio-film.
- Organics are removed by absorption.
- Trickling filter is always preceded by primary sedimentation tank along with skimming devices to remove the scum. This will prevent the clogging of filter by settleable solids.

Classification of trickling filters:

(i) Low Rate trickling filters

(ii) High rate trickling filters

Filter media:

- Filter media used should have high surface area high void space, resistance to abrasion and insoluble.
- Particles of filter media should be round (or) cubical in shape. Filtering media should be free from flat elongated pieces & should not contain dirt.

Under-drainage system:

- To carry the liquid effluent and sloughed biological solids
- To distribute air throughout the bed.
- They are formed of precast vitrified clay or Concrete blocks with perforated cover.
- Slope of the under drain should be same as floor sloping towards a common collection point.

Main Collecting Channel:

- Main collecting channel is provided to carry away the flow from under drains and to admit air to filter.
- Main collecting Chanel shall have Semi-circular (or) other rounded inverts.
- Velocity shall not be less than 0.6 m/s.

Filter floor:

- Filter floor should be strong enough to support the under drainage system.
- An R.C.C. Slab of 10 to 15 cm thick is provided.

Filter walls:

- Filter walls may either be fully plastered stone or brick masonary (or) R.C.C.

Ventilation:

. Natural ventilation is ensured by providing under drain or forced ventilation is done with air flow of $1 m^3/min/m^2$ of filter area.

Suggested Questions / Assignments /Home works / any other
1. What is backwashing filter? and its types?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 53. **UNIT I–**

Topic(s) to be covered	SBR and UASB R.

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Sequential batch reactor and upflow anaerobic Sludge blanket reactor	understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen.

Lecture Notes

Sequential Batch Reactor:

- First is to make certain that all mechanical, electrical and control equipment is operating properly.
- Purpose of fill react operation is to add substrate to the reactor.
- Addition of substrate or filling is controlled by a timer to a set of time period.
- The filling operation is also controlled by level transmitter to limit filling volume upto maximum level.
- Usually SBR tanks are designed to take flows as it comes into STP with all variations from peak flow to minimum flow without requiring any equalization tank.
- The settling process is controlled by time and is usually

fixed b/w 30 min. to an hour. So that the sludge blanket remains below the withdrawal mechanism during next phase.

- Purpose of decantation is to remove the clarified, treated water from the reactor.

- The precaution needed is to make sure that power supply is available continuously. If power supply fails, immediately ~~am~~ turning the generator line.

- Daily tests shall be COD, TSS, pH, DO, Ammonia and dissolved phosphate. BOD can be a weekly test.

Upflow anaerobic sludge blanket reactor (Suspended growth):

- UASB reactor maintain a high concentration of biomass through the formation of highly settleable microbial sludge aggregates.

- Waste water flows upwards through a layer of very active sludge (sludge-Bed) to cause anaerobic digestion of organics of waste water.

- At the top of reactor, three phase separation b/w gas solid-liquid takes place.

- This process is suitable for both soluble waste water as well as waste water containing particulate matter.

- The sludge bed consists of anaerobic and facultative micro-organisms capable of flourishing in oxygen deficient environment.

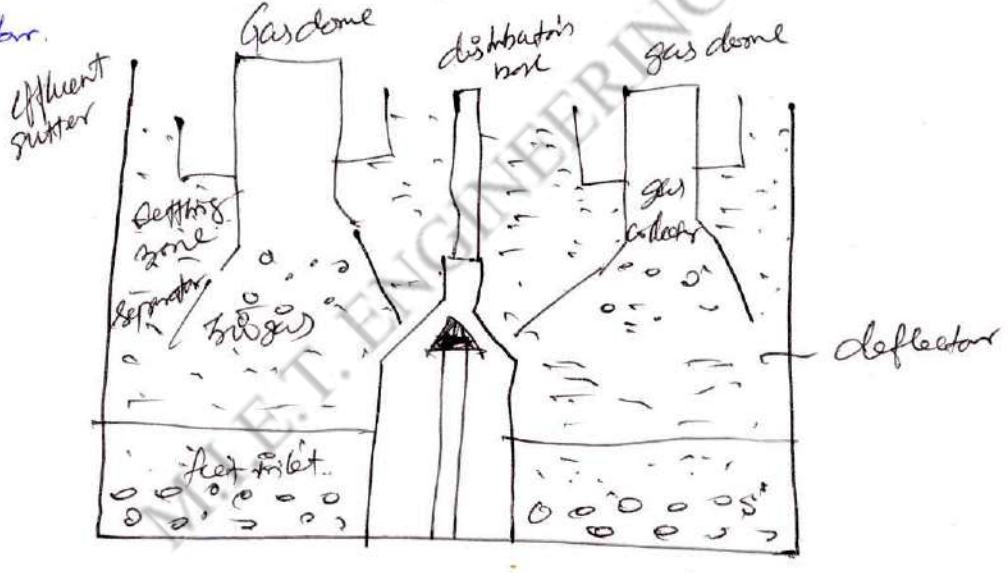
• The biogas produced helps in gentle mixing and stirring of biomass increasing efficiency of decomposition and reducing the BOD and suspended solids concentration of waste water.

• Gas produced is sufficient to keep the sludge fully mixed.

• Biogas consists of 65 to 70% CH_4 & 30 to 35% CO_2.

• Methane (CH_4) biogas is collected at top of tank in a gas collector.

• Water sludge mixture is made to enter a settling tank. Where sludge settle down and flows back into bottom of the reactor.



UASB Reactor

• Sludge has good settling properties.

• No packing material, the particles attach to each other to small particles, agglomerate, granulates to form sludge bed or blanket.

• Retention time is about 6-8 hrs with continuous atmospheric pressure.

Advantages:

- Space required less compared to ASP/ oxidation pond.
- Capital cost is less.
- System requires lesser / simple electromagnetic parts.
- Quicker sludge digestion.
- Biogas produced as by product is used for electricity generation.

Disadvantages:

- System lowers only two parameters of wastewater (a) BOD, (b) Suspended solids.
- Acids produced by breakdown of organic matter in UASB - may cause corrosion of reactor.
- Efficiency of BOD/SS removal is low.
- Pretreatment (Screening/ Grit removal) is necessary.

Suggested Questions / Assignments /Home works / any other
1. Explain in detail about UASBR?

Text Books/ Reference Books			
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 54. **UNIT I–**

Topic(s) to be covered	Waste Stabilization ponds or Basins.

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
Lo1	Aerobic, anaerobic ponds, facultative (aerobic-anaerobic ponds).	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen.

Lecture Notes

- Stabilisation ponds are open flow through earthern basins, designed and constructed to treat domestic sewage and biodegradable industrial waste waters.
- WSB have long detention period, extending to several days.
- Low cost system and is used in rural areas.
- These ponds are completely mixed biological reactors without solids return.

Advantages:

- Regulation of effluent discharge is possible.

Disadvantage:

- Requires extensive land required used in rural areas.
- Odour problems.
- Effluent quality standard of 30mg/l for suspended solids.

Oxygen transfer depends on:

Aerobic ponds:

- Stabilization ponds, oxygen is supplied by natural surface aeration and by algal photosynthesis.
- Aerobic ponds are shallow (0.5 to 1.2m depth) and functions aerobically throughout the depth.
- retention period = 7 days
- Content of pond are stirred to maintain aerobic conditions.

Lagoon surface area to volume:

Larger the ratio, better will be the O2 diffusion into lagoon.

Temperature of lagoon.

Greater solubility of O2 in water and hence greater diffusion rate at lower temperature.

Turbulence.

Generally provided by wave action.

Bacterial oxygen uptake rate:

- The faster the microbes consume D.O, greater will be the rate at which oxygen is replenished

Anaerobic ponds:

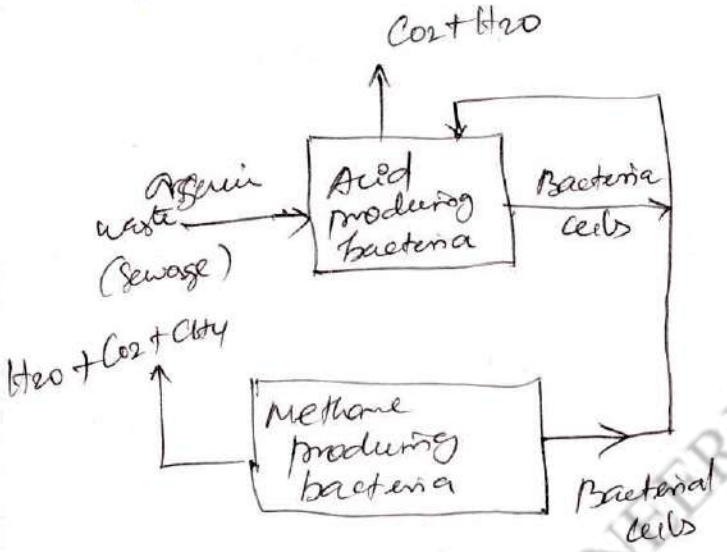
- Entire depth of pond is in anaerobic condition. The anaerobic decomposition takes place in two steps.

Step 1: Decomposition of dissolved organic waste by acid producing bacteria into organic acids.

Step2: Decomposition of these acids into end products methane CO_2 and water by methane producing bacteria.

→ Black colour of lagoon indicates that the lagoon is fermentering properly.

→ process release H_2S · Septic odours and effluent is only partially purified.



Anaerobic degredation process

Facultative ponds:

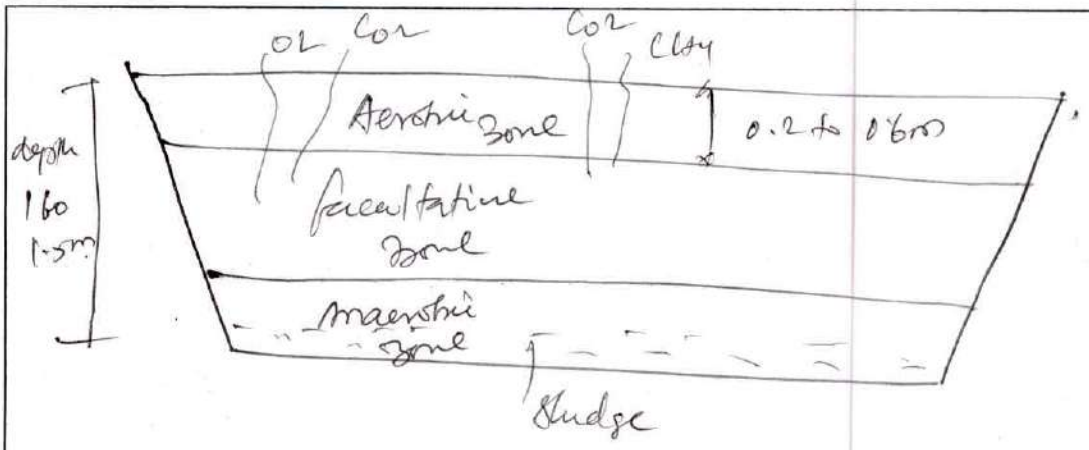
- Combination of aerobic and anaerobic ponds.
- Constructed of intermediate depth = 1 to 1.5m

Facultative ponds consists of three zones.

(i) Aerobic zone at the top.

(ii) Anaerobic zone at bottom.

(iii) Facultative zone b/w aerobic zone and anaerobic zone.



Facultative pond.

- Aerobic zone is similar to aerobic ponds.
- Top layers, algae grows and utilize CO_2 during day light for photo synthesis and liberate O_2 and maintains the aerobic conditions.
- Aerobic conditions promotes the oxidation of organic waste matter by aerobic bacteria.
- Greater depths prevent mixing and settled solids remain in bottom.

Suggested Questions / Assignments /Home works / any other
1. Describe the stabilization ponds with their significance?

Text Books/ Reference Books			
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 55. **UNIT I–**

Topic(s) to be covered	Other methods (Treatment)

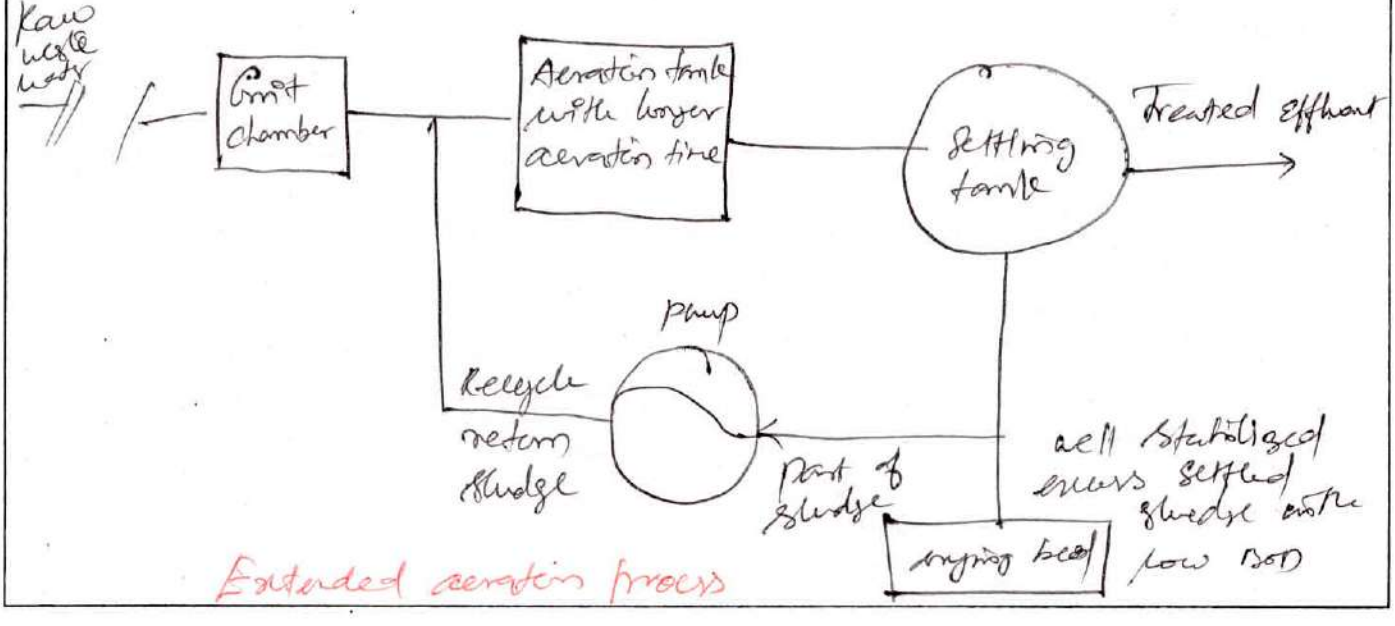
	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Oxidation ditch, types, intermittent, continuous flow type,	understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

Oxidation ditch:

- It is economical for population upto 1.5 lakh compared to Asp or trickling filters.
- Land requirement is less.
- Oxidation ditch plant involves the construction of number of ditch channels, placed side by side having depth of 1 - 1.5m, width of 1-5m based on rotors used.



• The oxidation ditches may be constructed either in earthwork with embankments (or) in trench (or) in stone masonry wall.

• Each ditch channel is equipped with a horizontal axis rotor for agitating and circulating the sewage and thereby oxygenating sewage and keeping the sewage solids in suspension.

• Velocity of sewage is 0.3 m/s.

• Aerated sewage is settled in settling tank by stopping the rotors for 2 hrs.

• When rotors are stopped, supernatant liquor is taken out.

• A part of settled sludge is recirculated where sludge is easily dried in sand beds and disposed suitably.

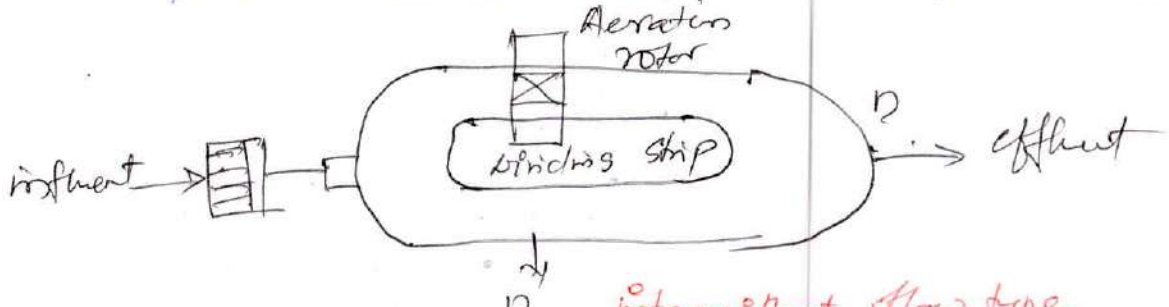
Types of oxidation ditches:

Intermittent flow type:

• No separate settling tank

• When rotor is stopped, sludge get settled and supernatant is withdrawn.

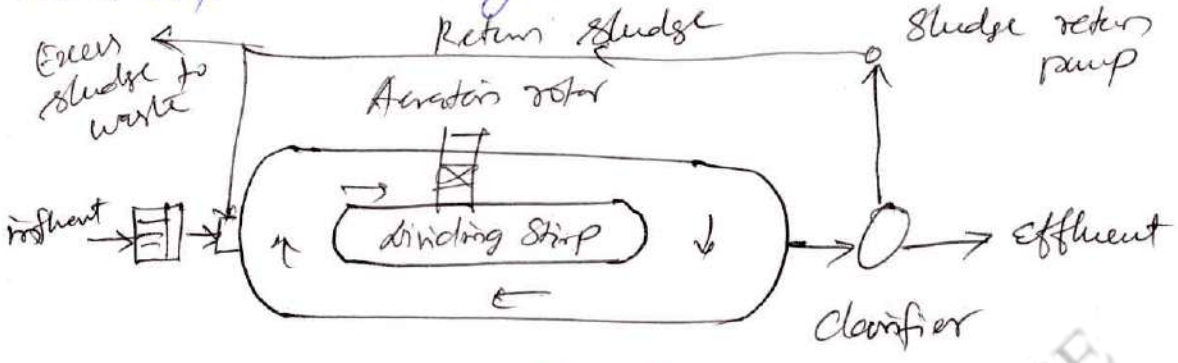
• Surplus sludge is removed and disposed after treatment.



Intermittent flow type

(ii) Continuous flow type:

• There is continuous operation. mixed liquid gets settled in a separate settling tank.



Continuous flow type

• Long aeration basin to carry MLSS conc 3000 to 8000 mg/l.

• F/M ratio (loading factor) is low - 0.03 to 0.1.

• Efficiency - 95% for suspended solids removal,

- 98% for BOD removal.

• Settled sludge is mineralised is dried without odour.

• Detention period = 12 to 15 hours.

= 0.8 to 2.5 m^3 per kg of BOD_5 load in surge

• Volume of ditch = 150 m^3 per metre length of rotor.

$$F/M = \frac{QLa}{\left(\frac{V}{1000}\right) \times Xt}$$

Sludge return ratio, $\frac{Qr}{Q} = \frac{Xt}{\frac{10^6}{SVI} - Xt}$

$$X = \frac{\theta}{V} \cdot \frac{Qc\,Y(So - S)}{1 + kd \cdot \theta c}$$

Microbial mass in excess sludge, $P_x = \frac{\chi V}{\theta c}$

Wasting of excess sludge $= \frac{V}{\theta c}$

Active microbes in return sludge,

$$\chi (Q + Q_r) = \chi_r \cdot Q_r$$

Hydraulic retention time $= \frac{V}{Q}$

Process loading $= \frac{Q(L_a - L)}{X_t \cdot V}$ kg total BOD/kg of MLSS.

Suggested Questions / Assignments /Home works / any other
1. Brief oxidation ditch with its design consideration.

Text Books/ Reference Books			
S.No.	**Title**	**Author**	**Publisher**
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 56. **UNIT I–**

Topic(s) to be covered	Design of oxidation pond.

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
LO1	Design of oxidation pond and oxidation ditch.	Understand & Apply

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen / Apply

Lecture Notes

Design an oxidation pond for treating sewage from a hot climate residential colony with 5000 persons. Contributing sewage @ 120 lpcd. BOD5 of sewage is 300 mg/l.

Sol:

Quantity of sewage treated per day = pop. × sewage contribution

= 5000 × 120 lpcd

= 6,00,000 litres

= 600 m^3/d or 0.6 MLD.

BOD Content per day.

Total BOD = discharge × BOD concentration

= 0.6 MLD × 300 mg/l

= 180 kg/d.

Assume organic loading in pond = 300 kg/ha/day

Surface area required = $\frac{\text{Total BOD of Sewage}}{\text{OLR}}$

$$= \frac{180\ kg/d}{30\ kg/ha/d} = 6000\ m^2$$

Assume $L/B = 2$

$L \times B = 6000\ m^2$

$2B \times B = 6000$

$B = 55\ m$

$L = 2 \times 55 = 110\ m.$

Assume effective depth = 1.2 m

Volume (capacity) of pond = $L \times B \times H$

$= 110 \times 55 \times 1.2 =$

$= 7260\ m^3.$

Capacity = Sewage flow per day × detention time (days)

$$D.T = \frac{\text{Capacity}}{\text{Flow}} = \frac{7260\ m^3}{600\ m^3/d} = 12.1\ days = 12\ days$$

Results:

Use oxidation ponds with

length = 110 m, width = 55 m

Overall depth = (1.2 + 1) = 2.2 m

Detention period = 12 days

Design a continuous flow type oxidation ditch to treat a domestic sewage flow of 2.5 MLD.

BOD$_5$ of raw sewage = 160 mg/l

Desired of BOD$_5$ effluent = 25 mg/l

SS in raw sewage = 240 mg/l

Desired SS in effluent = 30 mg/l.

MLSS = 4600 mg/l

Growth yield co-efficient = 0.55 → Y

Micro-organism decay co-efficient = 0.03 — kd

mean cell ~~residence~~ time = 16 days

Sol:

(i) BOD of influent and effluent

= 0.25 × 240 = 60 mg/l.

S_o = 160 − 60 = 100 mg/l.

= 0.45 × 30 = 13.5 mg/l.

= 25 − 13.5 = 11.5 mg/l.

(ii) Volume of Reactor (ditch)

$$X = \frac{Q}{V} \times \frac{\theta c \cdot Y (S_o - S)}{1 + kd \cdot \theta c}$$

MLSS (X) = 60% of MLSS = 0.6 × 4600 = 2760 mg/l.

$$V = \frac{(2.5 \times 10^3) \times 16 \times 0.55 (100 - 11.5)}{2760 (1 + 0.03 \times 16}$$

$V = 476.6 m^3$

(iii) Microbial mass in excess sludge

$$= \frac{XV}{\theta c} = \frac{2760 (476.6 \times 10^3) \times 10^6}{16} = 82.2 \text{ kg/d}.$$

(iv) Rate of Wasting of Excess Sludge

$$= \frac{V}{\theta c} = \frac{476.6}{16} = 29.79 \text{ m}^3/\text{d}$$

(v) Return Sludge Concentration

$$X_r = X \times \left(\frac{Q + Q_r}{Q_r}\right) = \frac{4600 \times 1.5Q}{1.5Q} = 13800 \text{ mg/l}.$$

(vi) Oxygen required (kg/d) = 1.2 kg of O_2 / kg BOD$_5$ removed

$$= 1.2 (160 - 25) \times 2.5 = 405 \text{ kg/d}.$$

(vii) Check for HRT:

$$HRT = \frac{V}{Q} = \frac{476.6 \times 10^3}{2.5 \times 10^6} = 0.191 \text{ d}$$

$$= 4.58 \text{ hrs}.$$

Suggested Questions / Assignments /Home works / any other
1. Design of oxidation pond and ditch?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 57. **UNIT I–**

Topic(s) to be covered	Reclamation and Reuse of Sewage Waste water.

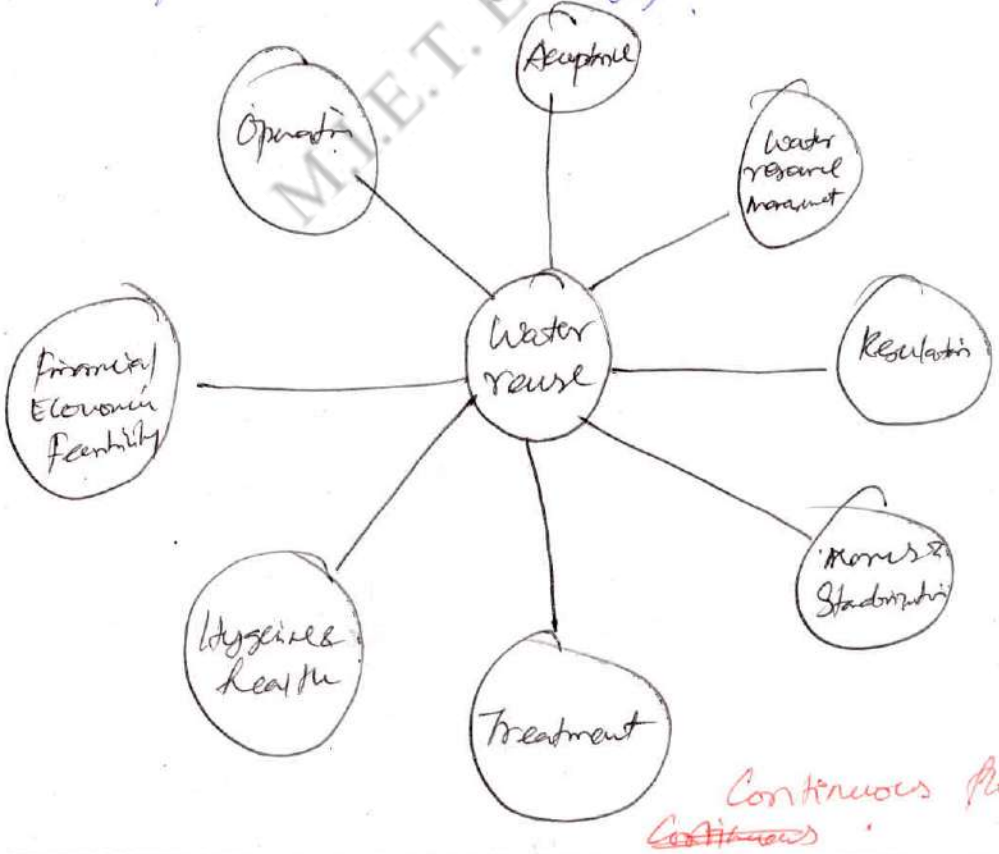
	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Wastewater reuse, types, applications technical description	Understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

Wastewater Reuse:

"Using wastewater or reclaimed water from one application for another application. A common type of recycled water is water that has been reclaimed from municipal wastewater (sewage):



Continuous flow type

~~Continuous~~

Types of Reuse.

- Urban Reuse:

⇒ Irigation of public parks, school yards, highway medias residential landscape, as well as for fire protection and toilet flushing in commercial and industrial buildings.

- Agricultural Reuse:

⇒ Irrigation of non-food crops, such as fodder and fibre commercial nurseries, pasture lands,

- Recreational impondments -

⇒ Such as pond and lakes.

- Environmental Reuse:

⇒ Creating artificial wetlands, enhancing natural wetlands, and sustaining stream flows.

- Industrial Reuse - process or makeup water and cooling tower water.

Technical description:

- One of the most critical steps in any reuse program is to protect the public health especially that of workers and consumers.

- For some reuse applications, such as irrigation of non-food crops plants, secondary treatment may be acceptable

Application of treated wastewater:

Agricultural Irrigation
- Crop Irrigation
- Commercial nurseries

Landscape Irrigation
- parks
- School yards
- Highway medians
- Golf courses
- Cemeteries
- Residential

Industrial Recycling and Reuse
- Cooling water
- Boiler feed
- process water
- Heavy Construction

Recreational / Environmental Uses
- Lakes & ponds
- Marsh enhancement
- Stream flow augmentation
- Fisheries

Non-potable urban uses
- Fire protection
- Air conditioning
- Toilet flushing

Potable Reuse:

- Blending in water supply Reservoirs
- Pipe to pipe water Supply
- Constituents to be checked in Reclaimed water

Heavy Elements:

- public health – nervous system disorders / carcinogenic
- Bio accumulation (food chain or crops & animals)

Surface water pollution:

- Environmental impact
- Nutrients (N & P)

Suggested Questions / Assignments /Home works / any other
1. Explain in detail about reclamation of water?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 28. **UNIT I–**

Topic(s) to be covered	Construction operation and maintenance Aspects

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
Lo1	Maintenance scheduling, pumping machinery, Screening Chamber & wet well Cleaning Chamber fine Screens	Understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen

Lecture Notes

Maintenance Scheduling:

- Maintenance of each equipment is done as recommendation of manufacturer.
- Maintain each equipment so that record is monitored for equipment performance.
- Good housekeeping is an important aspect of plant operation.

Pumping machinery:

- To run the machinery in a way so as to have free fall from invert of sewer.
- Mostly 2 or 3 pump sets are out of order.
- Minimum one pump be operated during night hours so that sewers are empty in morning.

Screening Chamber & wet well:

- Regular cleaning
- Disposal of screening
- Washing of bar screens
- Washing sludge layer from wall using water jet.
- Desilting of wet well once a year.

Cleaning chamber & Fine screens:

- Should be cleared minimum once in a week.
- Fine screens should be kept clean of all obstructions.

If the screen are of mat type, its operation should be adjusted such that a mat is always on screen.

Grit Channel:

- Should be used one at a time, alternatively everyday.
- Should be cleared velocity.
- Proper & efficient removal of silt in grit channel will improve the functioning of treatment.

Properties are:

- It is provided to maintain uniform flow on upstream and downstream of grit channel.
- Must be calibrated so as to show the quantity of flow.
- Flow be recorded every hour. SBR plants the flow readings graphs are recorded.

Moving Bed Biofilm Reactor (MBBR):

- The biofilm layer shall accumulate on biomedia
- Flocs should generate in clarifiers.
- Smell of sludge should not be felt.
- Starting the plant initially, air blowers should be operated for passing the air through diffusers and run continuously desired parameters will not be achieved.
- Fill both aeration tanks to the normal operating sewage depth thus allowing the aeration equipment to operate at maximum efficiency.
- Using all of aeration tank will provide the largest possible aeration time.
- The COD reduction in treated sewage, raw sewage cannot be less than BOD reduction.

DO in aeration tank:

- Presence of DO in aeration tank requires the elaborate procedure of using a motor operated electronically and keeping the probes well cleaned at all times.
- This is not always possible
- Typical plant control requires an answer to the question of whether residual DO is present or absent

in secondary clarifier overflow.

- Allow the sewage to fill the tube and overflow for a few minutes.
- Gently take the tube and pour out 2ml.
- Close the top with the thumb and invert a few times.
- If there is a white precipitate, there is no DO.

Suggested Questions / Assignments /Home works / any other
1. Describe the Construction, operation & maintenance of sewage plant?

	Text Books/ Reference Books		
S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010
Any other suggested Materials			

Lecture No. 59 **UNIT I–**

Topic(s) to be covered	Sludge Conditioning and dewatering.

	Lecture Outcome (LO)	**Bloom's Level**
	At the end of this lecture, students will be able to	
Lo1	Chemical Conditioning, sludge drying beds.	Understand

Teaching Learning Material	**Student Activity**
Chalk & Talk	Listen.

Lecture Notes

Chemical Conditioning:

- Chemical like alum, polyelectrolytes, ferric or alluminium salts, lime, ferric chloride are added.
- These Chemicals make the sludge particles agglomerate and become denser. Charge neutralisation occurs b/w particles.
- Choice of chemicals depends on pH, temperature and ash content of sludge.
- Optimum dosage of ferric chloride and alum is 1 kg/m³ of sludge.
- Elutriation is physical washing of sludge with low alkalinity water which reduces the chemical demand

• Elutriation is done before chemical conditioning.

(a) Single stage
(b) Multi - stage
(c) Counter - current washing.

• Quantity of washing water required depends on method adopted and alkalinity of sludge.

• Single stage washing requires 5 times more water than the counter - current and for small plants.

• The volume of wash water required is twice or thrice the volume of sludge elutriated.

• Physical unit operation used to reduce moisture content of sludge and thus increase the solids concentration.

• Methods:

(i) Air drying
(ii) Mechanical means.

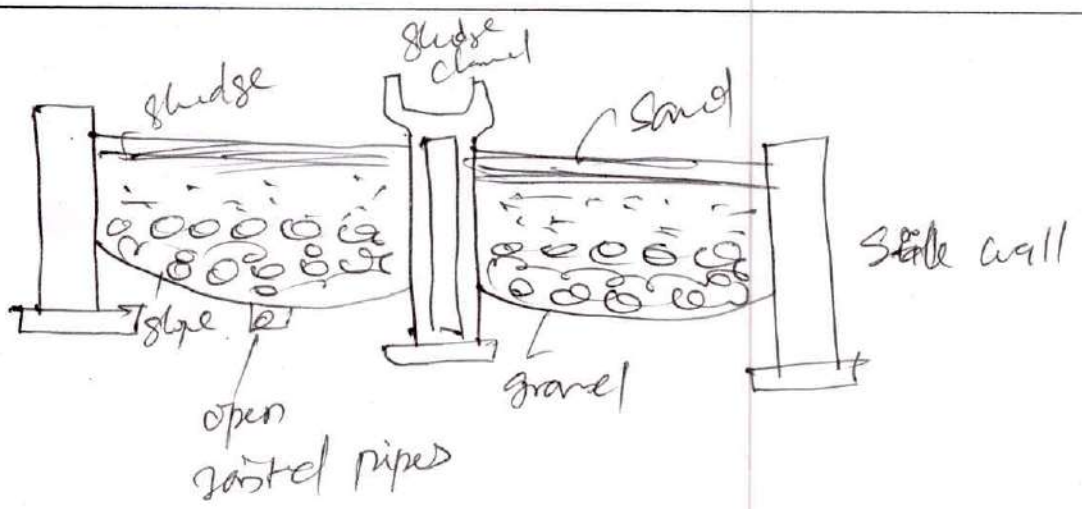
Purpose of dewatering:

• Cost of transportation of sludge to ultimate disposal site is reduced.

• Ease in handling dewatered sludge.
• Rendering sludge odourless and non - putrescible.
• Reduce leachate production when disposed in landfills.

Sludge drying Beds:

- Suitable for locations where temp. is high.
- Sludge is applied on specially prepared open beds of land.
- Sludge bed consists of bottom layer of gravel of uniform size and depth 30 cm over which is laid a bed of clean sand of depth .15 to 30cm.
- Clean sand of effective size of 0.5 to 0.75 mm and uniformity co-efficient not greater than 4 is placed over the gravel.
- Graded gravel is provided around the under drains in layers upto 30cm with a minimum of 15cm above the top of under drains.
- Drying beds adopted are 6 to 8 m wide and 30-45 m long.
- Minimum of two drying beds should be provided.
- Sludge should be deposited evenly to a depth of not greater than 20cm.
- Major portions of liquid drains off in few hours and evaporation starts. The sludge cakes shrink.
- Pick up trucks are used for hauling sludge cakes.



Mechanical methods:

- Vacuum filtration
- Filter press
- Centrifugation
- Chemical conditioning is normally done prior to mech. dewatering.
- Used to dewater raw or digested sludges.

Suggested Questions / Assignments /Home works / any other
1. Write short note on sludge conditioning & dewatering.

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials

Lecture No. 60 **UNIT I–**

Topic(s) to be covered	Ultimate Residue disposal

	Lecture Outcome (LO)	Bloom's Level
	At the end of this lecture, students will be able to	
LO1	Spreading on farm land, dumping, Land filling, sludge lagooning	Understand

Teaching Learning Material	Student Activity
Chalk & Talk	Listen.

Lecture Notes

Spreading on farm land:

- Dewatered sludge is disposed by spreading over farm lands and after drying the soil is ploughed.
- Wet dewatered sludge can be injected directly into soil by digging shallow trenches, 30 to 90 cm width 0.3 to 0.4m deep and 1 to 1.5m c/c spacing.
- The sludge is a source of nutrients, nitrogen and phosphate and improves soil fertility.
- Sludge acts as soil conditioner and reduces soil erosion.

Dumping:

- Stabilised sludge, digested sludge, clean grit, incinerator residue that will not cause pollution or nuisance can be disposed in abandoned mines or gen

• The sludge may also be dumped into sea, where cities are located near sea shores and where such wind direction prevail which will discharge the sludge deep into sea.

Land Filling:

• Sanitary landfill can be used to dispose off the sludge, grease, grit and solids both stabilised and not stabilised.

• To reduce transportation cost, it is better to dewater the residues.

• Sludge waste is deposited in designated area to landfills, compacted with tractor/roller and covered with 30 cm soil.

• Safety measures have to be taken to prevent any pollution of surface or ground waters.

Sludge Lagooning:

• A lagoon is a shallow earthern basin into which untreated or digested sludge is deposited.

• Untreated sludge undergoes anaerobic or aerobic decomposition and may release objectionable odours, so the lagoon should be located away from towns.

• Depth of lagoon is 0.5 to 1.5m detention time is 1 to 2 months.

- Under drainage system is provided at the bottom.
- It works on fill and draw basis.
- After stabilisation or evaporation, the lagoon contents are dugout to half the volume and used as manure.
- Lagoons are used for storage + digestion + dewatering + disposal in isolated locations where the soil is not porous and there is no chance of ground water contamination.
- Cost is less, but cause ugly sight, odours and mosquito breeding.
- Used as emergency storage when digesters are under repair.

Disposal by incineration:

- The dewatered waste sludge may be disposed by burning at very high temperatures inside incinerators.

Types of incinerators:

(i) multi-hearth furnace.

(ii) Flash-type of furnace.

(iii) Fluid-bed furnace.

- End product is ash which is harmless and can be disposed in low-lying areas, sea, water, abandoned mines etc.

Disposal in water or Sea:

- Not commonly adopted.
- Used where large volume of water is available for dilution
- Sludge is barged into deep sea for proper dilution and dispersion.
- Outfall / disposal end should be carefully designed to prevent coastal pollution and navigation problems.

Suggested Questions / Assignments /Home works / any other
1. Describe the disposal methods?

Text Books/ Reference Books

S.No.	Title	Author	Publisher
1.	Environmental Engineering, Vol.I	Garg, S.K.	Khanna Publishers, New Delhi, 2010
2.	Environmental Engineering Vol.II,	Garg, S.K.	Khanna Publishers, New Delhi, 2015.
3.	Environmental Engineering, Vol.II,	Punmia, B.C., Jain, A.K., and Jain.A.K.	Laxmi Publications, 2010

Any other suggested Materials